Understanding the Relationship between Climate Change and Poverty in Nepal

Niraj Prakash JOSHI
Assistant Professor
Graduate School for International Development and Cooperation (IDEC)
Hiroshima University
1-5-1 Kagamiyama, Higashi-Hiroshima, Japan, 739-8529
nirajpjoshi@hotmail.com

Keshav Lall MAHARJAN
Professor
IDEC, Hiroshima University
1-5-1 Kagamiyama, Higashi-Hiroshima, Japan, 739-8529
mkeshav@hiroshima-u.ac.jp

Luni PIYA
PhD Candidate
IDEC, Hiroshima University
1-5-1 Kagamiyama, Higashi-Hiroshima, Japan, 739-8529
loonypiya@hotmail.com

Abstract

Nepal has a negligible share of global Green House Gases (GHGs) emission. However, amidst sluggish economic growth rate, the emission is increasing at significantly higher rate compared to its fast growing neighboring economies like China, India and Bangladesh. This higher growth rate of emission is mainly due to the constantly increasing use of fossil fuels, emission from livestock, and use of nitrogen fertilizer. Sector-wise emission shows that agriculture and forestry are two most important sectors contributing almost ninety percent of the total emissions. Hence, any mitigation effort in Nepal should consider these two sectors, which are also the most important sectors for poor people. Consequently, intervention in these sectors will help to build rural community's resilience to Climate Change (CC). Increase in temperature and variable rainfall pattern have a negative direct influence on water resources at the highest level followed by agriculture, forest, and health sectors of the country. Increased risk of Glacial Lake Outburst Floods (GLOFs) and higher variability in run-off will adversely affect livelihood assets. Crop loss due to flooding, inundation, landslide, and drought is a common phenomenon in Nepal causing reduced production of major crops. Nepal is experiencing depletion of forest land due to landslides, floods, water erosion, and forest fires. The spread of vector-borne disease in the new regions as a consequence of CC is the major challenge in the health sector. Being signatories of major international legislations related to CC, Nepal has a prospect to generate revenue through mitigation effort, which could be used to deal with adverse impact caused by CC. Alternative energy promotion, forest management, and agricultural practice are potential areas, which can generate revenue from carbon trading. All these prospective areas have multiple functions of mitigation, adaptation as well as economic empowerment of the vulnerable section of the population. Therefore, a proactive role of Nepal in international forum with adequate research and development to incorporate these aspects in international negotiations and capacity development of its own in the field is very crucial to deal with the adverse impacts of CC and meet its overarching goal of poverty reduction as well. In addition, further research on the impact of climate variables on agriculture based on the historical evidence as well as livelihood of rural poor based on the household level data is recommended.

1. Introduction

Climate Change (CC) refers to a change in the state of climate that can be identified by changes in the mean and/or variability of its properties and that persists for an extended period, typically a decade or longer (Intergovernmental Panel on Climate Change, 2007a). Natural variability or human induced increase in Green House Gases (GHGs) are the main factors responsible for CC. Fuel-combustion, deforestation, agriculture, urbanization and industrialization are the main sources of anthropogenic GHGs emissions. Marked increase in the concentration of these GHGs compared to pre-industrial era has been reported. At present total CO_2 equivalent (CO_2-eq) of prominent GHGs is estimated to be around 455 parts per million (ppm) CO_2-eq, which if not stabilized below 550ppm CO_2-eq, would lead to the most harmful irreversible consequences of CC through a temperature rise of more than 2°C (Intergovernmental Panel on Climate Change, 2007a).

Several indications of CC on the earth have been reported. For instance, the temperature of earth surface has been rising over the last few decades. This has caused changes in weather patterns, melting of glaciers, and rise in sea level. In addition, more frequent storm events, increased events of drought, increased number of El-Nino and other adverse climatic situations can also be attributed to the global CC. Predictions show that rise in 2°C temperature is inevitable even if emissions are reduced to less than fifty percent of the current level by 2050. This increase in temperature is determined to be 'an upper limit beyond which the risks of grave damage to ecosystems, and of non-linear responses, are expected to increase rapidly' (Intergovernmental Panel on Climate Change, 2007b, p99). However, the current trend of emission, i.e., emission well above 2000 levels in 2100, would lead to 4°C increase in temperature causing unavoidable devastating losses, and excessively higher adaptation costs (Intergovernmental Panel on Climate Change, 2007b). Thus, any adverse impact of CC will put the poorest countries and the poorest people there in the most vulnerable situation as they are highly dependent on natural resources. In this decade alone, around 3.5 billion people, almost all from developing and least developed countries, are likely to be affected by climate related disasters. This figure is significantly higher compared to approximately 0.8 billion in 1970s, 1.4 billion in 1980s and 1.9 billion in 1990s. Based on this, the World Bank estimates that people in developing countries are affected at twenty times higher the rate of those in developed countries (World Bank, 2007a; World Bank, 2008).

Degree of vulnerability in Nepal is even higher due to its rugged terrain with steep topography, and fragile geological conditions, which make the country disaster prone. In addition, significant proportion of marginal population with low income, limited institutional capacity and greater reliance on climate-sensitive sectors like agriculture increase the degree of vulnerability (Regmi & Adhikari, 2007; World Bank, 2008). Hence, exposure to risks and low adaptive capacity to cope with those risks are major factors contributing to the vulnerable situation of the country. This justifies the strong need of understanding CC at national context and its relation with poverty in order to develop mitigation and adaptation programs to minimize risks at different levels. Therefore, this paper aims to analyze different aspects of CC in Nepal namely; emission scenarios, CC scenarios, impacts of CC on poverty, and initiatives taken by Nepal and their prospects to generate revenues from international CC regimes in relation to their possible impact on poverty reduction.

2. Green House Gas (GHG) emission situation in Nepal

Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the major GHGs that contribute to CC in Nepal and, therefore included in national GHG inventory of 1990/91 and 1994/95[1] (Dhakal, 2001; Ministry of Population and Environment & United Nations Environment Programme, 2004). Nepal has a very negligible share (0.025 percent) of global GHG emission (Ministry of Environment, 2011). However, if we see the trend of emission, it is increasing at a higher rate in Nepal. There was a 63.5 percent increase in CO_2 emission between the first inventory period (1990/1991) and the second inventory period (1994/95), which shows annual growth rates of 13.1 percent (Figure 1). Similarly, despite the sluggish economic growth, annual growth rate of 9.3 percent per capita CO_2 emission was reported between 1990 and 2004, which is significantly high compared to its economically fast growing neighboring countries like India (3 percent), China (4.4 percent), and Bangladesh (4.4 percent) (United Nations Development Programme, 2007; Joshi, Maharjan, & Piya, 2010). Growing consumption of fossil fuel is the main reason for such increase. Fuel consumption increased from 4,000 barrels per day to 7,258 barrels per day during 1990-1995 and reached 17,200 barrels per day in 2007, which indicates the annual growth rate of 16 percent between 1990/91 and 1994/95 (Energy Information Administration, 2009).

Mainly, rice production, livestock, and biomass burning are responsible for CH_4 emission in Nepal (Figure 1). Methane emission shows some positive signs in terms of emission reduction. This is mainly due to significant reduction in emission from rice production, and biomass burning or manure management. In addition, the promotion of minimum tillage farming in rice cultivation such as System of Rice Intensification (SRI) and visible reduction in rice production area from 1.4 million ha in 1990/91 to 1.3 million ha in 1994/95 could have contributed to the reduction of CH_4 emission. However, a rising population of ruminant livestock in the same periods resulted in an increase in CH_4 emission from livestock through enteric fermentation (Ministry of Agriculture and Cooperatives, 2005). At the same time manure management as well as replacement of fuel wood achieved through installation of 11,941 biogas plants between 1992/93 and 1994/95 could be the reason behind the significant reduction in CH_4 emission from biomass burning (Laudari, 2008).

The significant increase in consumption of nitrogen fertilizer has resulted in a drastic increase in the emission of N_2O, despite reduction in the area under rice cultivation. Annual sales of urea increased from 81 thousand tons to 121 thousand tons between 1990/91 and 1994/95 (Ministry of Agriculture and Cooperatives, 2005). Rice cultivation in Nepal is mostly done under submerged condition. Therefore, the increased use of nitrogen fertilizer (urea) triggered N_2O emission between these periods. However, thereafter there is a continuous decline in the use of nitrogen fertilizer and reached only around 7 thousand tons in 2003/04 (Ministry of Agriculture and Cooperatives, 2005). This may signify that there is a decline in N_2O emission since 1994/95 in Nepal.

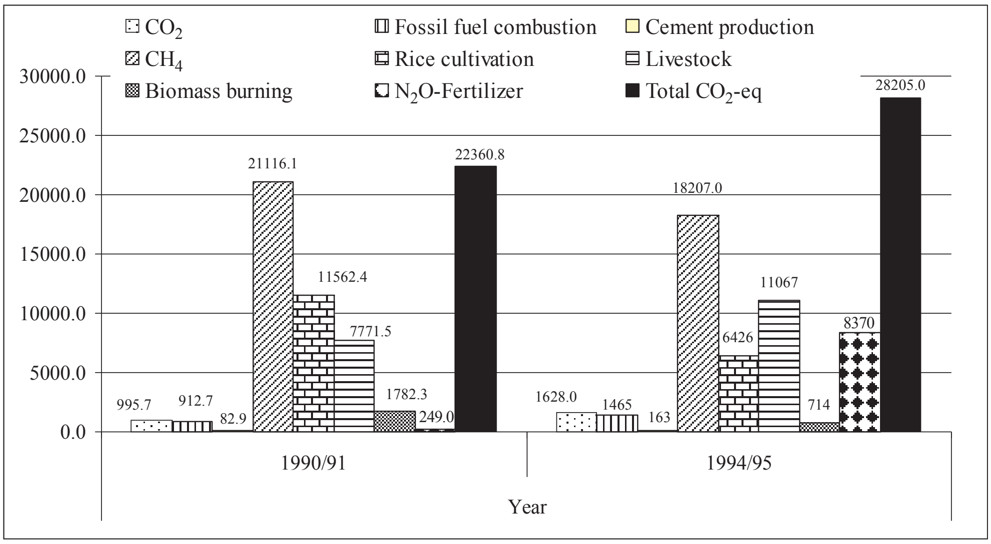

Figure 1. GHGs emission from different sectors in Nepal from 1990/91 to 1994/95 (in '000' tons)

Source: Dhakal, 2001; Ministry of Population and Environment & United Nations Environment Programme, 2004; Intergovernmental Panel on Climate Change, 2007c

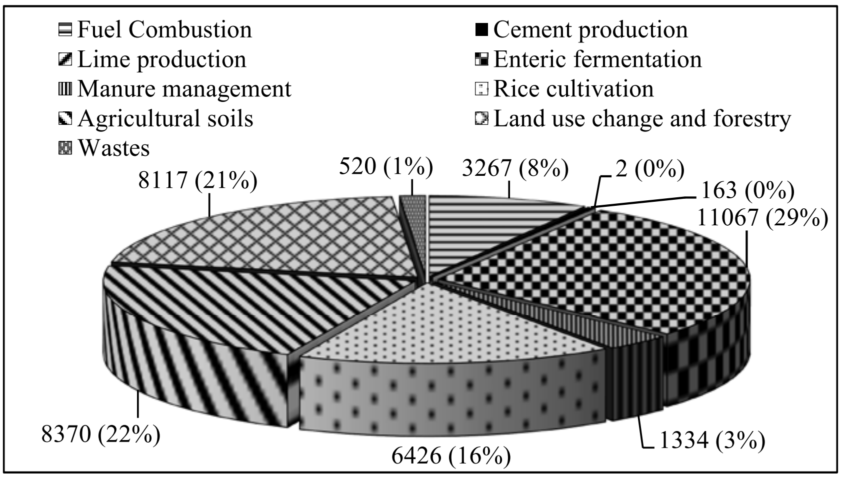

Figure 2. CO_2-eq emission from different sectors in Nepal 1994/95 (in '000' tons)

Source: Ministry of Population and Environment & United Nations Environment Programme, 2004; Intergovernmental Panel on Climate Change, 2007c

The rise in total CO_2-eq emission in Nepal can be observed between the same duration. The total CO_2-eq emission reached 28.2 million tons CO_2-eq in 1994/1995 from 22.4 million tons CO_2-eq in 1990/91. This indicates the increase in CO_2-eq emission at the annual rate of 5.8 percent. With the inclusion of important GHGs sources like land use change and forestry, wastes and lime production, GHG emissions in 1994/95 reached 39.3 million tons of CO_2-eq. Agriculture has significant bearing on the total CO_2-eq emission. Enteric fermentation in livestock (29 percent), manure management (3 percent), rice cultivation (16 percent), and agricultural soils (22 percent) as components of agriculture altogether emit around 69 percent of total CO_2-eq emission. This is followed by land use change and forestry, which contribute around 21 percent of the total CO_2-eq emission, fuel combustion (8 percent) and waste (1percent) (Figure 2). This suggests the importance of agriculture and forestry sectors in any mitigation effort to reduce GHGs emission as well as building resilience to CC among the farmers. Since agriculture and forestry are the most important sources of livelihood for the majority of the poor in the country, mitigation measures on these sectors will have a high significance in reducing emission as well as poverty. Further, adaptation measures on these sectors in the short term are very crucial to deal with vulnerability caused by CC.

3. Climate change scenario

Climate change can be assessed mainly in terms of variability in temperature, and precipitation (Shrestha et. al., 2000; Intergovernmental Panel on Climate Change, 2007b). Nepal has experienced the fastest long-term increase in temperature with 1.6°C increase between 1976 and 2005 (Figure 3), which is very high compared to global temperature increase of 0.6°C in the last three decades (Intergovernmental Panel on Climate Change, 2007b). Trend analysis shows that temperature is increasing at an annual rate of 0.054°C, which is statistically significant (Table 1). The rate is higher in winter (0.06°C) compared to summer (0.05°C). Moreover, several climate models show that the warming trend will continue in Nepal throughout the 21st century (Agrawala, et al., 2003; NCVST, 2009).

Table 1. Trend coefficient of temperature and rainfall in Nepal between 1976 and 2005

Variables	Coefficient	R^2 value	P-value
Annual temperature	0.05	0.74	0.00***
Winter temperature	0.06	0.50	0.00***
Summer temperature	0.05	0.70	0.00***
Rainfall	6.10	0.10	0.10*

Source: CBS, 1987; CBS, 1993; CBS, 1997; CBS, 2005; CBS, 2007
Note: ***, and * significant at 0.01, and 0.1 level of significance respectively.

The highest rate of increase in annual temperature is recorded in higher altitudes compared to the lower one (Maharjan et al., 2009), which is expected to continue throughout the 21st century (Agrawala, et al., 2003). Similar scenario can be observed from the seasonal breakdown of the meteorological observations. For instance, the temperature increase in winter is higher compared to that of summer (Figure 3). This trend will continue throughout the 21st century (Table 2). Therefore, people are now experiencing and expected to experience hotter summers and warm winters with increasing warm days and nights (Baidya & Karmacharya, 2007; NCVST, 2009).

Similar to the temperature, overall global precipitation has also increased by about two percent since the beginning of the twentieth century, which is statistically significant. However, such increase is neither spatially nor temporally uniform. Indian monsoonal rainfall has shown the increasing trend since 1974 (Intergovernmental Panel on Climate Change, 2001). Since Indian monsoonal rainfall is the main source of precipitation in Nepal, it also experienced an increasing trend of precipitation though it is very erratic over the years (Figure 4). Coefficient of trend value shows that annual national average rainfall is increasing. The increase is statistically significant at ten percent level of significance (Table 1). Such increase can be attributed to global warming, which results in an increase in land-ocean thermal contrast, thereby intensifying monsoon circulation (Shrestha, et al., 2000).

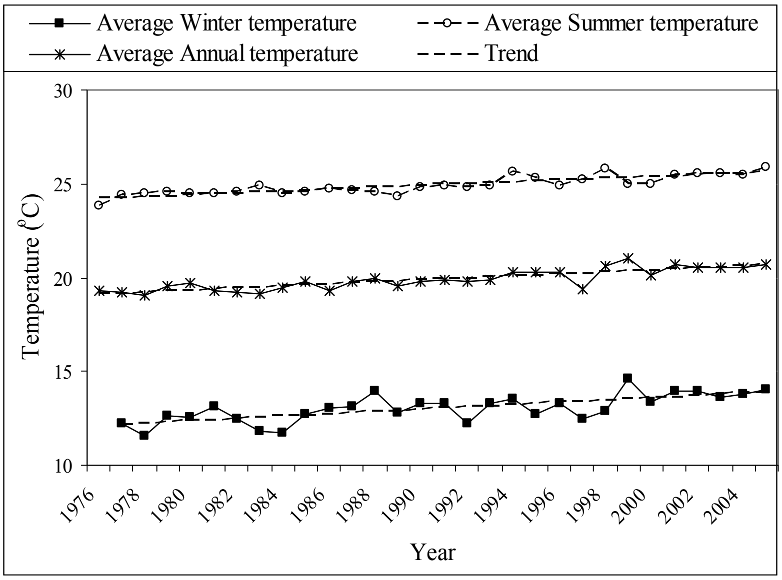

Figure 3. Temperature trends in Nepal

Source: CBS, 1987; CBS, 1993; CBS, 1997; CBS, 2005; CBS, 2007

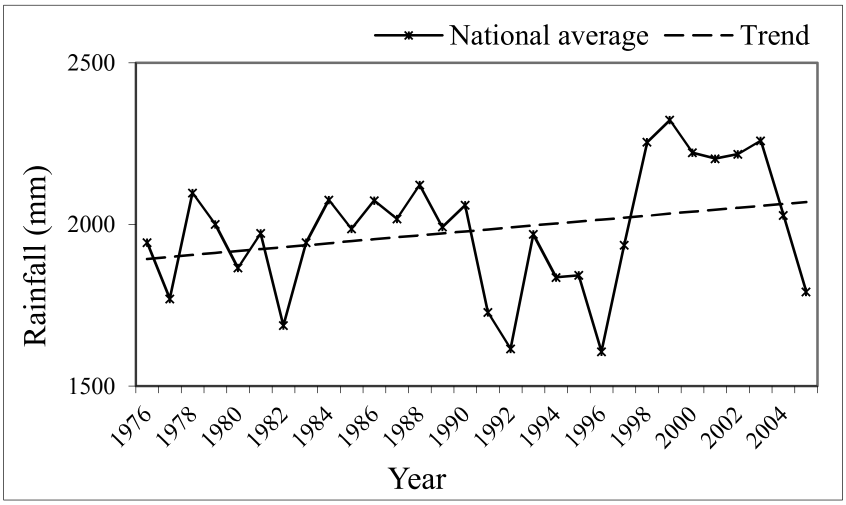

Figure 4. Annual rainfall in Nepal

Source: CBS, 1987; CBS, 1993; CBS, 1997; CBS, 2005; CBS, 2007

General Circulation Model (GCM) estimates an overall increase of precipitation in Nepal (Table 2). Seasonal breakdown of estimated precipitation shows that monsoon rain is going to be more intense whereas dry season will be drier (Agrawala, et al., 2003; NCVST, 2009). In recent days, heavy rainfall events as well as a maximum 24-hour rainfall in the country is in increasing trend and projected to increase further in the future (Baidya & Karmacharya, 2007; NCVST, 2009). Monsoon rain, which contributes around 80 percent of total rainfall, is the main source of water borne disaster in Nepal. Therefore, increase in intensity of summer monsoon can be translated into an increase in intensity of water borne disasters like flood, landslide, and sedimentation. Consequently, there will be considerable losses of settlements, infrastructure, and fertile top soil resulting in lower agricultural productivity. These are regular phenomena but have became more intense in recent years.

Table 2. Prediction of temperature and precipitation in Nepal (GCM estimates)

Year	Mean temperature increase (°C)			Mean precipitation increase (mm)		
	Annual	**Winter**	**Summer**	**Annual**	**Winter**	**Summer**
Baseline average				1433	73	894
2030	1.2 (0.27)	1.3 (0.4)	1.1 (0.2)	71.6 (3.8)	0.6 (9.9)	81.4 (7.1)
2050	1.7 (0.39)	1.8 (0.58)	1.6 (0.29)	104.6 (5.6)	0.9 (14.4)	117.1 (10.3)
2100	3.0 (0.67)	3.2 (1.00)	2.9 (0.51)	180.6 (9.7)	1.5 (25.0)	204.7 (17.9)

Source: Agrawala, et al., 2003
Note: Figures in parentheses indicate standard deviation.

Moreover, topography of the location also dictates rainfall patterns in Nepal. Some region of the country will receive more water, whereas other region will receive less (NCVST, 2009). Trend analysis shows the decreasing trend of rainfall in Dipayal from Far-Western Hills of the country. However, rainfall is continuously increasing in Kathmandu (Central Hills) at a significant rate. Similarly, rainfall is continuously increasing in Pokhara (Western Hills), Surkhet (Mid-Western Hills), and Dhankuta (Eastern Hills). Pokhara has the highest coefficient, and due to its typical topography it also receives the highest annual rainfall in Nepal (Maharjan, et al., 2009).

4. Impact of climate change on poverty

Poverty is persistent and widespread in Nepal, more specifically in the rural areas. Poverty measurements made since 1977 show no indication of poverty reduction in the country. The sign of improvement in poverty reduction was realized only in the NLSS II (2003/04) and NLSS III (2010/11) (Joshi et al., 2010; CBS, 2011). Despite such decrease in poverty, the nature of poverty however, still remains the same. Poverty is more rampant, deeper and severe in rural areas, and much worse in Mid-Western and Far-Western Hills and Mountains. Similarly, most of the poorest of the poor belong to the *dalit* (oppressed caste), and ethnic communities. Agriculture wage laboring, casual laboring and self-employments in agriculture are the main sources of livelihoods of the poor in rural areas. Thus, poverty in Nepal is complex, diverse in nature, and associated with location, gender, caste/ethnicity, land ownership, occupation and low economic growth of the country. Consequently, due to persistent poverty in the country, there is a lack of institutional capacity to adapt with any adverse impact of climate change in Nepal despite being prone to natural disaster due to its rugged terrain with steep topography and fragile geological condition.

Nepal has a very negligible contribution on the global CC as it has a negligible share on global GHG emission and also has one of the lowest per capita GHGs emissions in the world (Olivier & Peters, 2010; Ministry of Environment, 2011). But it is not free from adverse impacts of CC. Its fragile geography, predominantly natural resource based livelihoods, and low level of adaptive capacity due to higher incidence of poverty place the country among the fourth most vulnerable country to CC (Maplecroft, 2010).

Water resource, agriculture, forestry and biodiversity, and human health are some of the important sectors, which could be adversely affected by CC and consequently aggravate poverty in Nepal. Figure 5 shows how the two aspects of CC, namely; temperature and precipitation along with their extreme events, affect poverty in Nepal through water resource, agriculture, forestry and biodiversity, and health sector.

Water resource, which is the most important resource of Nepal having the highest economic potential in terms of hydroelectricity generation as well as irrigation management, is ranked as the most vulnerable sector to CC in Nepal (Agrawala, et al., 2003). This sector is affected mainly through variability in temperatures and precipitation. Rise in temperature in Nepal has an adverse impact on 3,252 glaciers covering a total area of 5,323 Square Kilometers (km^2) (International Centre for Integrated Mountain Development & United Nations Environment Programme, 2001). These glaciers are retreating at a faster rate compared to any other glaciers, and the rate is even higher compared to previous estimates (Pokhrel, 2007). For instance, The Rika Samba Glacier in the Dhaulagiri region is retreating at a rate of ten meters per year. There are 2,323 glacial lakes in Nepal that cover an area of 75.7 km^2, of which twenty are reported to be dangerously close to bursting because of global warming (International Centre for Integrated Mountain Development & United Nations Environment Programme, 2001). It is calculated that up to 70 percent of snow and glacier in the glaciated area above 5,000 meters may disappear with the temperature increase of 4°C (Ministry of Population and Environment & United Nations Environment Programme, 2004). Disappearance of glacier and snow consequently leads to the development of more glacial lakes or swelling of existing glacial lakes and increase potential GLOF hazards in Nepal.

A GLOF comes with enormous destruction. It poses threats to downstream settlements, infrastructure, natural resource, and human lives. Nepal has already experienced twenty-five GLOFs in the past (Gum et al., 2009). The Dig Tsho GLOF that occurred in 1985 was the most devastating one. It caused a ten to fifteen meter high surge of water and debris to flood down the Bhote Koshi, and Dudh Koshi River for ninety kilometers in Eastern Nepal. The flood swept the newly built Namche Small Hydel Project, fourteen bridges, wide areas of cultivated land, at least thirty houses among others including livestock and inhabitants (Rana, et al., 2000; Alam & Regmi, 2004; Regmi & Adhikari, 2007). Just recently, a collaborative anticipatory planning and management by the government, donors, and experts in GLOF mitigation is able to reduce the risk of a GLOF from the Tsho Rolpa Glacial Lake. This is the biggest glacial lake situated in the Rolwaling Valley of Eastern Nepal covering an area 1.76 km^2. Unless the mitigation effort was taken, the glacial lake would have caused significant destruction claiming more than 10,000 human lives, and huge infrastructure loss including sixty megawatts Khimti Hydropower (Rana, et al., 2000).

The higher variability of runoff is another important factor in Nepal that can lead to increased water disaster such as flood, landslide and sedimentation, and more pronounced variations in water availability throughout the year. The available surface water of Nepal is 202 Cubic Kilometers (km^3), which goes down to only 26 km^3 in dry season (Ministry of Environment, 2010).

The uneven distribution of rainfall and glacier retreat is the main reason for such variation that leads to water borne disaster. More than 80 percent rainfall occurs between June and September through monsoon rain that comes from the Bay of Bengal. The current trend shows that the monsoon period is shortening, but at the same time the amount of rainfall is increasing, which means monsoon rain is becoming more intense. This is causing the problem of flood and landslide in the wet season and severe drought in the dry season. The widespread impact of change in hydrological flows has been observed in Nepal. It has impacted many irrigation systems, water-powered grain mills, hydropower plants and drinking water supply systems throughout the country (Gum et al., 2009). People are experiencing more intensive rainfall and subsequent flood and landslide that have a direct adverse impact on livelihood assets such as physical, natural, financial, social, and human specially among the poor (Vidal, 2006; Gautam et al., 2007a; Gautam et al., 2007b; Pokhrel, 2007). Therefore, water resource has high significance on overall livelihood of the majority through a number of ways including disasters, hydropower that supplies around 91 percent of the nation's power, irrigation, transportation and other several infrastructures.

Agriculture is another important sector to be hard hit by CC as it can be linked to the impact of CC on water, forests, health, and soil temperature. Considering its importance in Nepalese economy, any adverse impact on agriculture will jeopardize the life of many people. Around 66 percent of the population (Ministry of Agriculture and Cooperatives, 2006), for whom agriculture is the mainstay, will face the risk of food insecurity due to CC. Since agriculture is heavily dependent on weather condition, this sector will be adversely affected through extreme rainfall, which results in increased runoff variability, soil fertility loss, temperature rise, as well as drought.

Nepalese agriculture is predominantly rain-fed. Therefore, any variations in rainfall patterns will have a direct impact on its agriculture. For instance, drought condition will result in decreased crop yields thereby total crop production. In 2005, food production of the country was adversely affected by drought that has caused 2 and 3.3 percent decrease in paddy and wheat production respectively. Nearly, 10 percent of agricultural land was left fallow due to rain deficit. Similarly, in 2006, drought in Eastern Tarai resulted in decrease of rice production between 27 to 39 percent (Regmi, 2007). There were 21 percent decline in rice production and 3 percent decline in millet production in the same year. This dragged the country under food self-insufficiency for the first time since it started attaining food self-sufficiency in 1999 (Joshi et al., 2010). Moreover, World Food Programme (2010) identified climate related natural disasters like drought, flood, hailstorm, late/early rain, landslide, and crop pest disease as the major causes of high or severe levels of food insecurity in a number of districts in the Far-Western Hills. These natural disasters have caused crop losses at 30 to 70 percent among over 50 percent of households (World Food Programme, 2010).

Drought became even worse in 2008/09, which is considered one of the worst in the country's history with least rainfall and widespread across Nepal. It has resulted in decline in production of major winter crops; wheat and barley by 14.5 percent and 17.3 percent respectively. The situation was even worse in some districts of the Mid- and Far-West region. They received less than 50 percent of average rainfall during the period of November 2008 to February 2009 (World Food Programme, 2010). Consequently, crop yields dropped by more than half. Thereby, many farmers are exposed to high risk of food insecurity as agriculture still remains subsistence in nature. In contrast, excessive rainfall also results in more frequent flood events that not only inundate the agriculture field and destroy the crops, but also destroy farmland and irrigation facilities. This consequently results in decreased agriculture production. Heavy rain and subsequent floods, landslides, and soil erosion are regular phenomena in the Mid-Western Tarai, and Western regions of the country. Increased variability in runoff, therefore, is the major source of soil erosion in Nepal that washes away the fertile top soil in the sloppy areas, and sedimentation in inundated land. In both cases, soil fertility loss is the major outcome that consequently leads to production loss in agriculture, which also indicates loss of livelihood for the people who predominantly depends on agriculture.

Agriculture, being part of life science, will also respond to changes in temperature. Rise in temperature will affects agriculture through an increase in incidence of pests and diseases, and decrease in physiological performance of animal and poultry, thereby reducing crop and animal productions (Intergovernmental Panel on Climate Change, 2007d). However, degree of effects will vary depending upon the altitudes. It is reported that the rise in temperature under atmospheric CO_2 doubling will initially increase the yield of rice, wheat, and maize in all three ecological regions of Nepal; Mountains, Hills, and Tarai. However, the rise in temperature at 4°C will cause loss in rice and wheat yield in Tarai, which is considered the grain basket of the country having the highest proportion of land area under cultivation. Although the continued increase in yield is reported in Hills and Mountains, it will be obtained at the cost of exhausted soil fertility and likely adverse impacts on a nutritional value of the crops. Increase in temperature under increased availability of atmospheric CO_2 leads to the vigorous growth of food-crops and reduce the level of soil organic carbon, soil micronutrient, and enhances decomposition by activating the microbial population in the soil thereby decreasing agricultural productivity in the long run (Malla, 2003). Similarly, temperature rise by 2°C would decrease the quality of meat and milk, hatchability of poultry, and increases the possibility of disease in the livestock (Intergovernmental Panel on Climate Change, 2007d). Besides, temperature rise above 4°C is detrimental to the existence of life on earth. Joshi et al., (2011a) has shown that at the national level the current trends of climate variables have suppressed the yield growth of major food crops in Nepal. Suppression of yield is more pronounced in summer food crops like maize and potato. At the regional level, Joshi et al., (2011b) has shown that the adverse impact on yield of major food crops is more prevalent in low lying Tarai.

Forestry and health are the other sectors to be adversely affected by CC. Changes in temperature and precipitation would alter vegetation patterns of forests. It may cause a forest modification through migration of plant and animal species along with other biotic species towards the Polar Regions, changes in their composition, extinction of species, etc. With the increase in temperature, shifting upward of several domestic and wild plants and animal species has been reported in Nepal (Malla, 2008). A study has shown that out of 15 types of forest categorized by Holdridge model existing in Nepal under current CO_2 condition; 3 types will disappear if CO_2 concentration is doubled. Tropical wet forest and warm temperate rain forest would disappear, and cool temperate vegetation would turn into warm temperate vegetation (Ministry of Population and Environment & United Nations Environment Programme, 2004). Such change in vegetation would affect biodiversity in forests of Nepal. In addition, landslides, floods, and water erosions have resulted in massive depletion of forest. At the same time, summer drying and drought increased the risk of forest fire that poses threat to adjacent human settlements. Forest being an integral part of livelihood, such depletion of forest as well as loss of biodiversity will hamper the livelihood of the majority of the total population who are dependent on forest based livelihoods, especially ethnic forest dwellers in rural Nepal like Chepangs (Piya et al., 2011).

Climate change has been recognized as one of the major challenges by the World Health Organization (WHO) for the health policy makers, planners, and managers and urged to address the issues before it becomes too late. Intergovernmental Panel on Climate Change (2007d) projects an increase in under-nutrition and related disorders, morbidity and mortality due to heat waves, floods, droughts, windstorms, and fire. Similarly, an incidence of vector-borne diseases such as malaria, kalaazar, Japanese encephalitis, and dengue in tropical and sub-tropical regions, diarrheal diseases, and cardio-vascular diseases due to increase in ground-level ozone is expected to increase with the higher intensity of CC. In the particular case of Nepal, the vector-borne diseases are now moving to new regions as mosquito from Tarai and Mid-Hills are being able to survive in the High-Hills as well. In 2006, 7 out of 13 Mountain districts of Nepal were classified as malaria prone districts due to the spread of the vector in these areas (World Health Organization, n.d.). Similarly, incidence of kalaazar is now reported in more than dozens of Tarai districts. In addition, people in Nepal are exposed to death threats due to heat and cold waves. These extreme temperatures claimed more than sixty lives in 2003, which then rose to more than 110 in 2004 (Figure 6). Since then, these extreme temperatures are continuously claiming lives. Given that less than one fifth of the population has access to modern health services, vulnerability to future CC in the health sector is quite high.

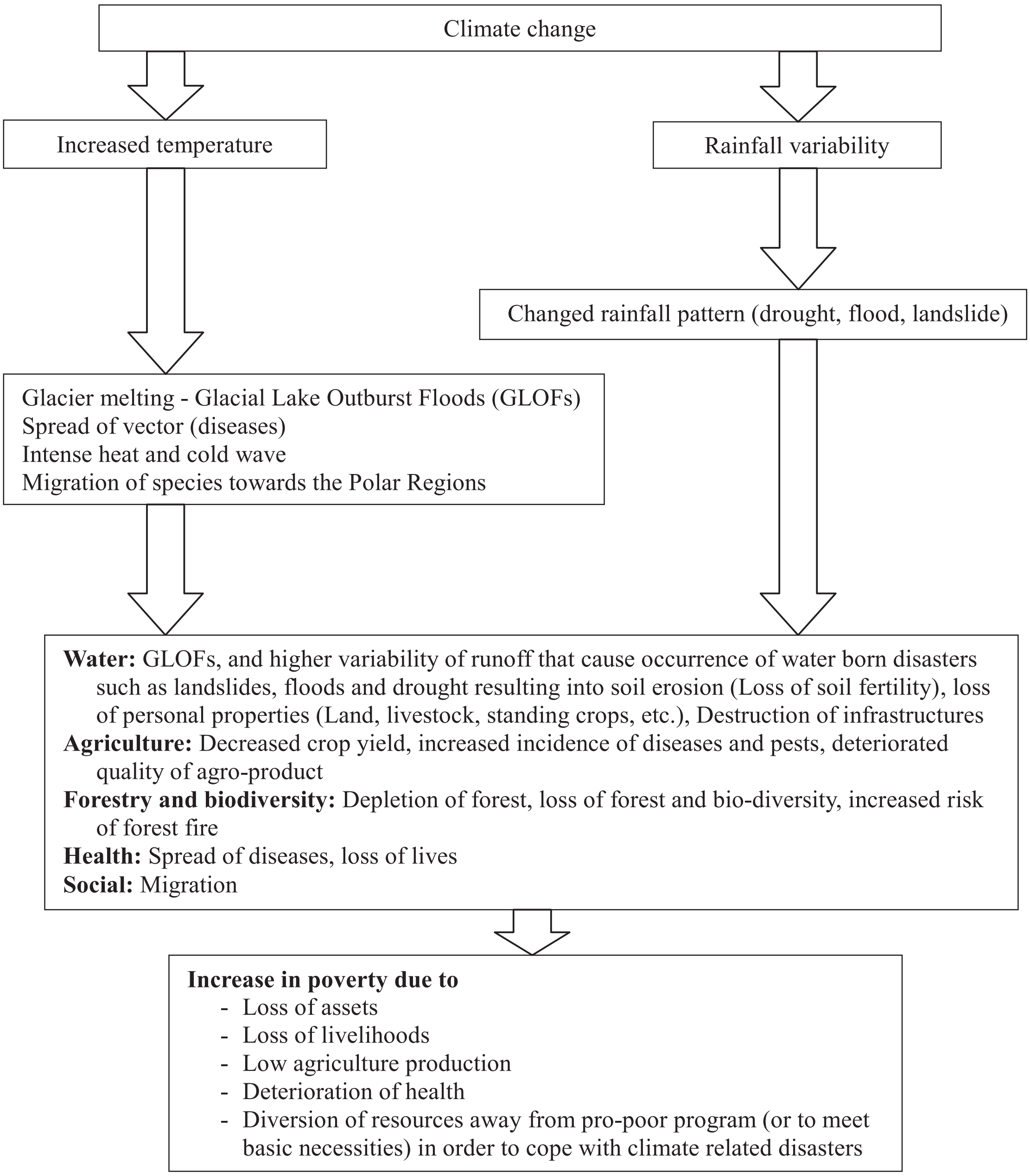

Figure 5. Climate change - poverty nexus in Nepal

Source: Joshi, 2011

Therefore, the loss of shelter and infrastructure (physical assets), spread of vector-borne diseases and loss of lives (human assets), displacement of community (social assets), loss of water sources and cultivable land (natural assets), lower saving and higher debt (financial assets) are widespread evidences of CC impact in Nepal. All of these factors are responsible for higher vulnerability to CC, which exacerbates the problem of poverty especially among the marginal populations, who have very limited resources to cope with the problem.

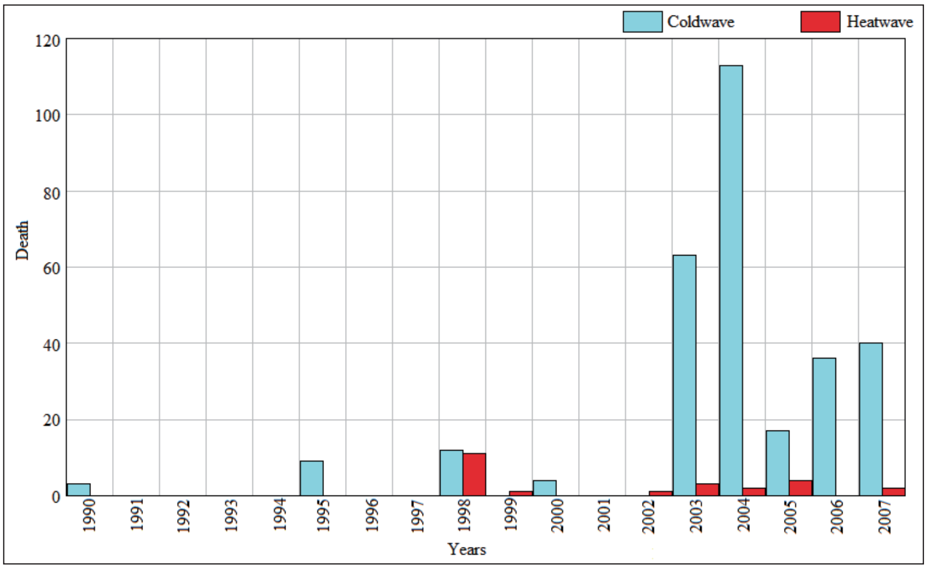

Figure 6. Death caused by cold and heat waves in Nepal

Source: http://online.desinventar.org/desinventar/index.php?r=NPL-1250695185-nepal_histo ric_inventory_of_disasters

5. Opportunities created by international climate change regimes for poverty reduction

Nepal is signatory of the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP), which are very crucial international legislations with regards to CC. However, the government of Nepal has not yet internalized aspects of CC in its policy documents. It was only in the Tenth Periodic Plan (2002-2007), that the government of Nepal committed itself to implement treaties on CC and took initiative to assess and control hazards caused by GLOFs taking CC convention as the basis (National Planning Commission, 2003). The plan also envisaged the poverty reduction by optimal use of natural resources through community participation. The Eleventh Periodic Plan (2007-2010) moves forward in this direction and identify the promotion of carbon trade to achieve benefit from Clean Development Mechanism (CDM) under the KP. The promotion of alternative energy, and management of natural resources especially forest have been identified as a means for generating financial resources in the long term through carbon trading (National Planning Commission, 2007). Similarly, possibilities of revenue generation from international CC regimes have been raised by Climate Change Policy, 2011 through low carbon and climate resilient development path (Ministry of Environment, 2011).

Household biogas, micro/mini hydropower, solar energy, Improved Water Mill (IWM) and Improved Cooking Stove (ICS) are some of the prospective alternative energy projects identified for international carbon trading. Two biogas projects that cover 19,396 biogas plants have already been registered in Clean Development Mechanism-Executive Board (CDM-EB) for carbon trading under voluntary basis in December 27, 2005, and have started generating revenue. With the estimated net emission reduction of 4.99 tons CO_2-eq/biogas-plant/year, and given US$ 7/ton CO_2-eq of carbon price (Koch-Mathian, 2010), these projects are generating annual income of approximately US$ 0.65 million until 2012, the end of the first commitment period of the KP. Such revenue generated is expected to reduce dependency on large subsidies provided by the government and external donors. Also, such revenue will help to expand biogas installation in more remote and poorer areas of Nepal.

Considering the importance of biogas in tackling poverty, such expansion of biogas in remote and poorer areas of Nepal can also help in reducing poverty to some extent. Biogas plant can help to alleviate poverty through time saving (approximately four hours/day) and cash saving. Time can be saved from a shortened time for cooking in biogas as well as saving time involved in collecting fuel-wood. Similarly, cash savings of NRs. 25,499/HH/year can be achieved through the replacement of kerosene for lighting, reduced use of fertilizer, reduced expenses in health due to better sanitation, significantly lower indoor air pollution compared to fuel-wood used for cooking and kerosene used for lighting. Until 2006/07, there are 185,585 biogas plants installed in the country of which 96.2 percent are operational. Therefore, any effort to bring 178,533 operating biogas plants under the small scale CDM project will generate around US$ 6.2 million per year. This amount can be utilized for scaling up of a biogas installation among the poor through subsidy and credit. Thus, it will further support to achieve poverty reduction goal of the country. Moreover, the existing number of biogas installation is only 10 percent of total potential (Laudari, 2008). Therefore, there is a high scope for dissemination of the installation all over the country, especially in rural areas.

The Nepal Micro-Hydro Project (MHP) is the second CDM project in Nepal to be registered under CDM-EB, and the Energy Reduction Purchase Agreement was signed on June 29, 2007 by Alternative Energy Promotion Center. Thus, there is a possibility to generate Certified Emission Reduction of 324,999 tons CO_2-eq through the promotion of 15 megawatt MHPs by the end of the project year 2012. Out of these, 191,000 tons CO_2-eq could be sold at the rate of US$ 10.25/ton of CO_2-eq (World Bank, 2007b). The price difference for CER from biogas and MHP is mainly due to the risk associated with the project as well as demand and supply situation from the particular project (Ascui & Costa, 2007; Castillo, 2007). Thus, MHPs being more mature and reliable compared to the biogas, the price offered for MHP is higher. MHPs will be developed under Rural Energy Development Programme (REDP); therefore, will operate in the poorest and geographically isolated areas serving the marginalized groups in rural Nepal through provision of off-grid electricity. This will provide a large number of rural households with electricity for lighting, milling and other needs. Thus, the project will help in poverty alleviation through employment generation as well as direct local environmental benefits through reduction in diesel and kerosene consumption (reduced CO_2 emission), and the use of dry cells (lowering chemical pollution and health hazard) and lead acid cell batteries (reducing pollution and transport cost involved in charging) (World Bank, 2007b). Similarly, Project Idea Note (PIN) for IWM has already been submitted to the Designated National Authority (DNA), and that for ICS was supposed to be submitted to DNA on July 2008. These two CDM projects are very crucial from a viewpoint of poverty reduction as they have rural orientation. Besides, the PIN is being prepared for solar energy projects, electric vehicle, landfill solid waste management, and the vertical shaft brick kiln.

Forestry is another important sector in which about two thirds of the globe's terrestrial carbon is sequestered in the form of standing forest, forest understory plant, leaf and forest debris, and in forest soils together with other non-natural stocks. Nepal has 39.6 percent of the total area covered by forest. Under the forestry sector, the CDM mechanism of the KP recognizes the afforestation and reforestation project to be eligible for carbon trading for the first commitment period. However, despite substantial plantation activities through community-based forest management and leasehold forest management programs, forestry-based CDM has not been initiated in Nepal so far. Therefore, some of the Community Forestry (CF) projects, leasehold forestry projects, private lands, and national forest have potentials to be brought under the CDM mechanism if such projects are developed to meet the necessary criteria. They should meet at least the following three criteria: plantation area equal to or greater than 0.5 hectares, the crown coverage should be less than 10 percent, and the plantation carried out in 2000 onwards in areas where there had been no forests since 1990.

Most of the forest regeneration activities are taking place in the hilly regions of the country. Therefore, carbon sequestration study done by the International Centre for Integrated Mountain Development (ICIMOD) in 2007 in the Himalayas including Nepal could be very much relevant to the Nepalese context in general. The carbon sequestration capacity of Nepalese forest is 6.89 tons CO_2/ha/year (Banskota et al., 2007). It is estimated that Nepal can negotiate the price of at least US$ 5/ton CO_2 for the carbon sequestration by Nepalese forest. Food and Agriculture Organization (2006) reported that in Nepal plantation activities were carried out in 52,000 and 53,000 ha of land on 2000 and 2005 respectively. This also means that Nepal can claim US$ 3.6 million from the plantation activities in degraded land if such plantation was carried out with due consideration to bring under the CDM mechanism. Plantation activities in Nepal basically took place on private land, community forest, leasehold forest, and government forest. Similarly, by July 2000, plantation on 8,000 ha of marginal land was done through leasehold forestry, which has reached to 17,244 ha in 2007 (Food and Agriculture Organizations, 2000; Department of Forest, 2007). This indicates that between 2000 and 2007, some 9,244 ha of degraded land was brought under plantation through the leasehold forestry program. Thus, the modest calculation shows that Nepal can generate revenue of around US$ 0.32 million per year only through leasehold forest, which could go up significantly if thorough study is made in this direction. Considering the success of the program in tackling poverty through secure right of land and employment generation (Food and Agriculture Organization, 2006; Department of Forest, 2007), such revenue could be crucial in scaling up the program in around 1.6 million ha of barren lands or grasslands with scattered trees. Thus, afforestation and reforestation project eligible for CDM have economic potential of around US$ 55 million together with its contribution on the overarching goal of poverty reduction from its extension in all potential areas.

Exclusion of projects on natural forest conservation under the category of 'avoided deforestation' hinders the possibility of bringing CF of Nepal under the CDM mechanism. However, the recognition of avoiding deforestation by the international community for its higher carbon mitigation benefits and sustainability has raised the prospects of Nepalese CF for carbon trading (Intergovernmental Panel on Climate Change, 2007b). Considering a wide coverage of CF and protected areas in Nepal, it could be an important sector for revenue generation through carbon trading. In addition, given that deforestation is being the single most important source of carbon emission, there is an unequivocal emphasis to curb deforestation in developing countries as part of future responses to CC. The international community made an agreement in this direction during the 13th Conference of Parties (COP13) of the UNFCCC in Bali in 2007. The proposed Reducing Emissions from Deforestation and Forest Degradation (REDD) policy is a new international legal framework for CC mitigation, which emerged during the COP13, and at present, it is undergoing vigorous discussions. As it recognizes forest as carbon sources, management of existing forests, and rights of indigenous people who are dependent on forest resources to meet their subsistence needs, it is appealing for carbon trading. It is also considered as a 'road map' for post-Kyoto Protocol after 2012 on the role of forests in the global climate budget. It has a provision of compensating developing countries in proportion to the amount of carbon emission that are reduced by halting its national deforestation rate below the baseline.

The World Bank launched a forest carbon fund for the REDD initiative called "Forest Carbon Partnership Fund" (FCPF). This fund has the dual objectives of building capacity for REDD in developing countries, and testing a program of performance-based incentive payments in some pilot countries. The FCPF can also be regarded as a precursor to the REDD (Karky & Banskota, 2009). Nepal is one of the 13 tropical countries whose Readiness-Project Idea Note (R-PIN) is selected under this fund. After the formulation of the full Readiness Plan and its approval, Nepal will be able to implement a prototype of REDD and gain experience and build capacity to operationalize REDD by taking on board CF in an experimental way under FCPF. In addition, Nepal has successfully started generating revenue from CF of three watersheds in Dolkha, Gorkha and Chitwan with the implementation of the first-ever pilot Forest Carbon Trust Fund. A total sum of US$ 95000 was handed over to representatives from those three watersheds as the payments for their successful effort to sequestrate additional 0.1 million tons of CO_2 in 2011 compared to that of 2010 from around 10,000 ha of CF (International Centre for Integrated Mountain Development, 2011). This shows that any successful initiative of Nepal to implement REDD would fetch as much as US$ 42.7 million from CF and US$ 82.4 million from protected areas (2.4 million ha excluding buffer zones as these areas are also covered by CF to some extent) annually. Besides, there are also several hectares of land under private ownership, which could be brought under either CDM or REDD.

Agriculture in Nepal is predominantly subsistence in nature, with the very low level of external input use such as fertilizers, irrigation, pesticides and improved seeds. Due to heavy energy required for these external inputs, especially fertilizer and irrigation, any effort to reduce the use of these resources or efficient use of these resources could significantly reduce GHG emissions from agriculture. Moreover, development and promotion of agricultural system that built on local resources for production input will be crucial in building resilience to CC. In this line, SRI with the baseline of methane emission, and Organic Agriculture (OA) with the baseline of nitrous oxide emission could be prospective projects to be brought under CDM. Steps to bring SRI under CDM are already in progress. Therefore, Nepal can claim its share from more than 1,000 ha of area under SRI, which is expanding at a higher rate in Nepal from Tarai (60 masl) to Mid-Hills (around 2,000 masl) (Upreti, 2008). Besides, considering tolerance of SRI to adverse climatic influences such as drought, storms, hot spells and cold snaps that results in reduced economic and agronomic risk, and higher yield compared to conventional practice, SRI could be an important practice of adaptation to CC (Uphoff, 2007). Organic agriculture also serves in this direction. Love Green Nepal, an NGO, has taken an initiative to incorporate OA in the carbon market (United Nations Environment Programme, n.d.). However, there is a lack of documentation for area under OA as well as their certification mechanism. Any initiative to bring these practices under CDM through research and development not only generates the carbon credit but also helps to adapt against the adverse impact of CC among the resource poor farmers.

6. Conclusion

Climate change is an unequivocal fact the earth is already experiencing, caused mainly due to the anthropological GHGs emission. CC regarded as the greatest threats posed to the humankind putting more pressure on the poorest countries and the poorest people therein. Nepal has rugged terrain with steep topography and fragile geological conditions as well as higher incidence of poverty. The country is prone to disaster amidst limited institutional capacity and greater reliance on climate-sensitive sectors like agriculture thereby quite sensitive to any adverse change in climate. Therefore, this paper dealt with different aspects of CC and its relation with poverty. Nepal has a negligible share of global GHGs emission. However, the rate of emission increase is high mainly due to the constantly increasing use of fossil fuels, emission from livestock, and use of N_2O fertilizer. Sector-wise emission shows that agriculture and forestry are two most important sectors contributing almost ninety percent of the total emissions in Nepal. Therefore, any mitigation efforts in Nepal should consider these two sectors, which are also the most important sectors for poor people to build resilience to CC. Despite such low level of emission, Nepal has already shown some indication of CC in terms of rising temperature, variability in rainfall and more frequent occurrence of climate related natural disasters.

Increase in temperature and rainfall pattern have a negative direct influence on water resources at the highest level followed by agriculture, forestry, and health sectors of the country. Increased risk of GLOFs poses threat to important infrastructures and settlements downstream claiming properties and lives of thousands. Similarly, higher variability in run-off results in increased water disasters such as flood, landslide, sedimentation, and variations in water availability throughout the year. These kinds of events adversely affect livelihood assets. Agriculture is also adversely affected by variations in temperature and rainfall. Crop loss due to flooding, inundation, landslide, and drought is a common phenomenon in Nepal these days reducing the production of major crops. The impact of CC in the forest is an alteration of forest composition and thereby loss in biodiversity. Increased temperature will cause migration of forest species towards the Polar Regions thereby loss of three forest types. Also, Nepal is experiencing depletion of forest land due to landslides, floods, water erosion, and forest fires. The spread of vector-borne disease to the new regions is the major challenge in the health sector as a consequence of CC. In addition, increased incidence of water-borne disaster and negative impact on agriculture and forest will affect the health sector adversely.

Being a signatory of major international legislations related to CC, Nepal has a prospect to generate revenue through mitigation effort, which could be used to deal with adverse impact caused by CC. Alternative energy promotion, forest management, and sustainable agricultural practice are potential areas, which can generate revenue from carbon trading. Two biogas projects and one micro-hydro project have been successfully registered and have started generating revenue through CDCF/World bank. Biogas project for CDM cover only 10 percent of installed biogas plant in the country, which itself is only ten percent of potential biogas installation. Therefore, there is huge potential to generate revenue from the biogas sector through CDM mechanism. Similar is the case from micro-hydro projects as the country is rich in water resources. In the forest sector, leasehold forest and part of community forest has the prospect to generate revenue from the CDM mechanism under afforestation and reforestation provisions. In the context that Nepal is in the process to prepare full readiness plan that enables it to implement a prototype of REDD, any successful initiative to implement REDD policy would generate more than US$ 122 million from the forest sector alone. SRI and OA are two sustainable agricultural practices that have the potential to be brought under the CDM mechanism. These agricultural practices can also be regarded as adaptive measures against the adverse impact of CC as they reduce dependency on external inputs as well as improve tolerance against adverse weather conditions. All these prospective areas have multiple functions of mitigation, adaptation as well as economic empowerment of the vulnerable section of the population. Therefore, a proactive role of Nepal in international forum with research and development to incorporate these aspects in international negotiations and capacity development of its own in the field is very crucial to deal with the adverse impacts of CC and meet its overarching goal of poverty reduction as well. In addition, further research on the impact of climate variables in agriculture based on the historical evidence as well as livelihood of rural poor based on the household level data is highly recommended.

Endnote

[1] Due to the lack of national GHGs inventory after 1994/95 the paper discussed national GHGs inventory between 1990/91 and 1994/95 only.

References

Agrawala, S., Raksakulthai, V., van Aalst, M., Larsen, P., Smith, J., & Reynolds, J. (2003), *Development and climate change in Nepal: Focus on water resources and hydropower*, Paris, Organization for Economic Co-operation and Development .

Alam, M. A., & Regmi, B. R. (2004), *Adverse impacts of climate change on development of Nepal: Integrating adaptation into policies*, Bangladesh, Capacity Strengthening in the Least Developed Countries for Adaptation to Climate Change, Bangladesh Center for Advanced Studies.

Ascui, F., & Costa, P. M. (2007), CER pricing and risk, In G. Hodes, & K. Kamel (eds.), *Equal exchange: Determining a fair price for carbon* (pp. 78-93), Denmark, UNEP RISOE Centre.

Baidya, S. K., & Karmacharya, J. (2007), Observed and future climate change in Nepal, *National workshop on climate change and human health: Potential impact, vulnerability and adaptation in Nepal*, Kathmandu, Nepal Health Research Council.

Banskota, K., Karky, B. S., & Skutsch, M. (2007), *Reducing carbon emissions through community managed forests in the Himalayas*, Kathmandu, International Centre for Integrated Mountain Development.

Biogas Support Program. (2009), *BSP Year Book 2009*, Lalitpur, Biogas Support Program.

Castillo, M. P. (2007), Market perspectives to determine for fair carbon price, In G. Hodes, & S. Kamel (eds.), *Equal exchange: Determining a fair price for carbon* (pp. 94-99), Denmark: UNEP RISOE Centre.

CBS. (1987), *Statistical year book of Nepal, 1987*, Kathmandu, Central Bureau of Statistics.

CBS. (1993), *Statistical year book of Nepal, 1993*, Kathmandu, Central Bureau of Statistics.

CBS. (1997), *Statistical year book of Nepal, 1997*, Kathmandu, Central Bureau of Statistics.

CBS. (2005), *Statistical year book of Nepal, 2005*, Kathmandu, Central Bureau of Statistics .

CBS. (2007), *Statistical year book of Nepal, 2007*, Kathmandu, Central Bureau of Statistics .

CBS. (2011), *Poverty in Nepal 2010/11*, Kathmandu, Central Bureau of Statistics.

Department of Forest. (2007), Current data on pro-poor leasehold forestry programme, *Hamro Kalpabriksha*, 18(197), 23-24.

Dhakal, S. (2001), Climate change initiatives and Nepal, *Technical Journal*, 2001(1), 24-31.

Energy Information Administration. (2009), *Nepal energy profile*, Retrieved December 1, 2010, from US Energy Information Administration (EIA), http://tonto.eia.doe.gov/countr y/country_time_series.cfm?fips=NP.

Food and Agriculture Organization. (2006), *Global forest resources assessment 2005: Progress towards sustainable forest management*, Rome, Food and Agriculture Organization.

Food and Agriculture Organization. (2000), Group promotors effectively raise awareness of poor leasehold forestry farmers in Nepal, *Poverty Alleviation Initiatives*, 10(3), 13-15.

Gautam, D., Gautam, K., & Poudel, D. (2007a), *Climate change impacts and adaptation strategies by poor and excluded communities in Western Nepal: A comparative study of Banganga river basin; Arghakhanchi and Kapilvastu, Nepal*, Kathmandu, ActionAid Nepal.

Gautam, D., Jnavaly, S., Sharma, A., & Amatya, A. (2007b), *Climate change adaptation on livelihood of women farmers: Case study of Banke and Bardiya districts of Nepal*, Kathmandu, ActionAid Nepal.

Gum, W., Singh, P. M., & Emmett, B. (2009), *Even the Himalayas have stopped smiling: Climate change, poverty and adaptation in Nepal*, Kathmandu, Oxfam International.

Intergovernmental Panel on Climate Change. (2001), *Climate change 2001: The scientific basis, Cambridge*, Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007a), *Climate change 2007: Synthesis report*, Geneva, Intergovernmental Panel on Climate Change.

Intergovernmental Panel on Climate Change. (2007b), *Climate change 2007: Mitigation of climate change*, Cambridge, Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007c), *Climate change 2007: The physical science basis*, Cambridge, Cambridge University Press.

Intergovernmental Panel on Climate Change. (2007d), *Climate change 2007: Impacts, adaptation, and vulnerability*, Cambridge, Cambridge University Press.

International Centre for Integrated Mountain Development & United Nations Environment Programme. (2001), *Inventory of glaciers, glacier lakes and glacial lake outburst floods, monitoring and early warning systems in the Hindu Kush Himalayan region*, Kathmandu, International Centre for Integrated Mountain Development & United Nations Environment Programme.

International Centre for Integrated Mountain Development. (2011), *ICIMOD pilots first Forest Carbon Trust Fund in Nepal - Helps communities benefit from forest conservation and sustainable use*, Retrieved June 16, 2011, from www.icimod.org/?q=3743.

Joshi, N. P. (2011), *Poverty and climate change in Nepal: Poverty analysis in Far-western Rural Hills*, Hiroshima, A PhD dissertation submitted to Hiroshima University.

Joshi, N. P., Maharjan, K. L., & Piya, L. (2010), Poverty and food insecurity in Nepal: A review, *Journal of International Development and Cooperation, 16*(2), 1-19.

Joshi, N. P., Maharjan, K. L., & Piya, L. (2011a), Effect of climate variables on yield of major food crops in Nepal: A time-series analysis, *Journal of Contemporary India Studies: Space and Society, 1*, 19-26.

Joshi, N. P., Maharjan, K. L., & Piya, L. (2011b), Effect of climate variables on yield of Rice in Nepal: A panel data analysis with regional disaggregation, *7th Asian Society of Agricultural Economists International Conference*, Hanoi, Asian Society of Agricultural Economist.

Karky, B. S., & Banskota, K. (2009), Reducing emissions from Nepal's community managed forests: Discussion for COP 14 in Poznan, *The Journal of Forestry and Livelihood, 8*(1), 43-47.

Koch-Mathian, S. (2010), *Case study 4: Biogas Support Programme (BSP) - Nepal*, Lyon, Sustainable Architecture and Energy Projects Scaling Up (SAESUp).

Laudari, R. (2008), Biogas support program of Nepal: Current situation and experiences/lesson learnt, *Regional forum on bio-energy sector development: Challenges, opportunities and the way forward*, Bangkok, United Nations Economic and Social Commission for Asia and the Pacific & Asian and Pacific Center for Agricultural Engineering and Machinery, Retrieved February 9, 2010, from http://www.unapcae m.org/Activities%20Files/A0801/0207.pdf.

Maharjan, K. L., Joshi, N. P., & Piya, L. (2009), Sources of climate change, its impact, and mitigation issues in Nepal, *International conference on climate change, livelihoods, and food security*, Jaipur, Institute of Development Studies and Association of Asian Scholars.

Malla, G. (2003), Impact of climate change on water and soil health, *Agriculture and Environment*, 63-71.

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 - Bangladesh, India, Philippines, Vietnam and Pakistan - most at risk from climate* *change*, Retrieved March 9, 2011, from Maplecroft: Risk, responsibility and reputation: http://maplecroft.com/about/news/ccvi.html

Ministry of Agriculture and Cooperatives. (2005), *Statistical information on Nepalese agriculture: Time-series information*, Kathmandu, Agri-business Promotion and Statistics Division, Ministry of Agriculture and Cooperatives.

Ministry of Agriculture and Cooperatives. (2006), *Statistical information on Nepalese agriculture*, Kathmandu, Agri-Business Promotion and Statistics Division, Ministry of Agriculture and Cooperatives.

Ministry of Environment. (2010), *Developing Nepal's strategic program for climate resilience: Prioritisation planning process*, Kathmandu, Ministry of Environment.

Ministry of Environment. (2011), *Climate change policy, 2011*, Kathmandu, Ministry of Environment.

Ministry of Population and Environment & United Nations Environment Programme. (2004), *Initial national communication to conference of the parties of the United Nations Framework Convention on Climate Change*, Kathmandu, Ministry of Population and Environment & United Nations Environment Programme.

National Planning Commission. (2003), *The tenth plan (Poverty Reduction Strategy Paper) 2002-2007*, Kathmandu, National Planning Commission.

National Planning Commission. (2007), *Three-year interim plan 2007/08 - 2009/10*, Kathmandu, National Planning Commission.

NCVST. (2009), *Vulnerability through the eyes of the vulnerable*, Kathmandu, Institute for Social and Environmental Transition-Nepal.

Olivier, J. G., & Peters, J. A. (2010), *No growth in the total global CO_2 emissions in 2009*, Bilthoven, Netherlands Environmental Assessment Agency.

Piya, L., Maharjan, K. L., & Joshi, N. P. (2011), Forest and food security in indigenous people: A case of Chepangs in Nepal, *Journal of International Development and Cooperation, 17*(1), 113-135.

Pokhrel, A. P. (2007), Impact of climate change on water resources in Nepal, *National workshop on Climate change and human health: Potential impact, vulnerability and adaptation in Nepal*, Kathmandu, Nepal Health Research Council.

Rana, B., Shrestha, A. B., Reynolds, J. M., Aryal, R., Pokhrel, A. P., & Budhathoki, K. P. (2000), Hazard assessment of the Tsho Rolpa glacial lake and ongoing remediation measures, *Journal of Nepal Geological Society, 22*, 563-570.

Regmi, B., & Adhikari, A. (2007), *Human development report 2007: Climate change and human development - risk and vulnerability in warming world; Country case study-Nepal*, New York, United Nations Development Programme.

Regmi, H. R. (2007), Effect of unusual weather on cereal crop production and household food security, *The Journal of Agriculture and Environment, 8*, 20-29.

Shrestha, A. B., Wake, C. P., Dibb, J. E., & Mayewski, P. A. (2000), Precipitation fluctuations in the Nepal Himalaya and its vicinity and relationship with some large scale climatological parameters, *International Journal of Climatology, 20*, 317-327.

United Nations Development Programme. (2007), *Millennium Development Goals indicators*, Retrieved March 9, 2010, from http://mdgs.un.org/unsd/mdg/Data.aspx.

United Nations Environment Programme. (n.d.), *Company profile: Love green Nepal*, Retrieved June 11, 2011, from CDM Bazaar: www.cdmbazaar.net/repo/sellers/seller-827688724

Uphoff, N. (2007), The System of Rice Intensification (SRI) as a system of agricultural innovation, *Farmer first revisited: Farmer participatory research and development twenty years on*, Sussex, Institute of Development Studies.

Upreti, R. (2008), System of Rice Intensification (SRI) experience of Nepal, *Third National Symposium on SRI*, Tamilnadu, SRI India.

Vidal, J. (2006, December 2), *Nepal's farmers on the frontline of global climate change: Himalayan communities face catastrophic floods as weather pattern alter*, Retrieved from The Guardian: http://www.guardian.co.uk/environment/2006/dec/02/christmasappeal2006.frontpagenews.

World Bank. (2007a), Climate variability, climate change, and adaptation: An emerging framework for engagement in Nepal, *Identifying priorities and opportunities of action on climate change adaptation in Nepal*, Kathmandu, Ministry of Environment, Science and Technology, World Bank, Department of Hydrology and Meteorology, and Winrock International.

World Bank. (2007b), *Nepal: Micro-hydro promotion by Alternative Energy Promotion Centre (AEPC)*, Retrieved June 2, 2011, from http://wbcarbonfinance.org/Router.cfm? Page=CDCF&FID=9709&ItemID=9709&ft=Project&ProjID=33540.

World Bank. (2008), *Towards a strategic framework on climate change and development for the World Bank group; Concept and issue paper (Consultation draft)*, Washington DC, The World Bank.

World Food Programme. (2010), *Nepal food security bulletin (Issue 26, October-December, 2009)*, Kathmandu, World Food Programme.

World Health Organization. (n.d.), *Malaria endemic districts of Nepal*, Retrieved June 1, 2010, from World Health Organization: http://www.searo.who.int/LinkFiles/Malaria_in_t he_SEAR_NEp_ende_dist.pdf.