GLOBAL EFFECT OF CLIMATE CHANGE AND FOOD SECURITY WITH RESPECT TO NEPAL

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ABSTRACT

The effect of global climate change in Nepal could be observed by glacier retreat in the Himalaya region and change in the pattern of the south west monsoon which is the only reliable source of water for farming. Climate change has been occurred in Terai, hills and mountain of Nepal resulting change in agriculture systems leading to the emergence of new insect, pest and disease of crops and animals. There are frequent losses of lives, crops and, human settlements due to occurrence of flash floods, droughts, typhoon and hurricanes in the world mainly due to climate change. Global food production and trade have been affected by the negative consequences of climate change as a result countries like Nepal are also victimized due to the negative effect of climate change. Increase in $C0_2$concentration in the atmosphere and change in precipitation are being the main cause of floods, droughts, glacier retreat, and melting of snows, hence, change in the flora and fauna globally. To address such measures of climate change, Nepal has been trying to develop some adoptive ways such as development of climate resilient technology including crop varieties, animal breeds; agronomic practices that could address vagaries of climate change and sustain food and nutritional security. In Nepal, the effect of climate change is more pronounced in hills and mountains with respect to increase in temperature than that of Terai. This paper tries to address issue of global climate change with respect to food security of Nepal by applying some of the pragmatic adoptive measures to follow in agriculture for sustaining food security in Nepal.

KEY WORDS: Adaptation and mitigation, climate change, food security, global agriculture

MATERIALS AND METHODS

This is partly a review of the effect of global climate change with respect to the food security in Nepalese perspective. To make an analogy of climate change in Nepal two cross section study areas were selected to represent mountains and Terai region of Nepal encompassing Kakani (2030-m), central high hill and Dhangadhi (210-m), far western Terai, Nepal from where ten years' meteorological data (total rainfall, number of rainy days and temperature (max and min) were interpreted. Meteorological data of these two locations were correlated to judge impact of climate change in Nepal with respect to food security. Hence, effect on agriculture systems in Nepal.

INTRODUCTION

Nepal, noted for her majestic Himalayas, the roof of the world, *Sagarmatha,* Mount Everest (8848 m) in the north and the lowest point *Kechanakal*(60-m) in the south. The Himalayas, the water towers, which supply water to the Indo-gangetic plain of Indian subcontinent,

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are the proud of the mountainous and hilly country, Nepal. Nepal is about 650 kilometers long and about 200 kilometers wide, and comprises a total of 147,181 square kilometers area. Climate of Nepal varies from cool summers and severe winters in north to subtropical summers and mild winters in south. Nepal is rich in biodiversity and so is the case of climate that are prevailed almost all the climate available in the world, hence called the micro-museum of world climate. Climatic zones range from tropical to tundra with a narrow band of altitude. Climate varies from subtropical to arctic, all within a distance of approximately 180 kilometers. The broad differentiation in climate is that there is a great variety of micro climatic conditions, resulting in a diversity of land use and farming practices within the country.

In each of broad agroclimatic zone in Nepal there is variation of land type, vegetation and cropping patterns. In general, the climate of the Terai, Dun valleys, and part of the Siwaliks (300 to 1000-m) is subtropical while the climate of the middle mountains (1000 to 3000-m) ranges from warm temperature to cool temperate, and the high mountains (2600 to 4200-m) from cool temperate to sub-alpine. Mid hills or the mountain region is pleasant and amicable for many flora and fauna. As a result, this region is densely populated by many ethnicities. The Himalayas are above 4200-m to 8848m, the roof of the world and is represented by tundra and high alpine climate.

Merlon*et al* (2013) reported that 97% of climate scientists agree that global warming is because of human cause. They further noted that fewer than half of Americans believe in human caused global warming and 15% understand the degree of consensus in scientific community. Hence, global warming and climate change are very complex phenomena and it is difficult to come into consensus even globally how actually these phenomena are happening. Likewise, Cook *et al* (2013) analyzed 12000 peer-reviewed papers in climate science literature and found that 97% of the papers that stated apposition on the reality of human caused global warming are happening at least in part. They also noted by contrast that only 41% of Americans say global warming is happening and human caused. The impact of climate change in the world has occurred. It is accepted that developed countries are primarily responsible for enhancing factors of climate change and these have resources and ways to mitigate it whereas developing countries like Nepal have suffered heavily due to the negative impact of climate change. However, there are only ways for developing world to go for adaptation mechanisms to lessen the vagaries of climate change on food security, environment conservation and sustainability despite their low or no role in bringing climate change of present situation globally. Nevertheless, there are events of powerful typhoon in coastal areas of Philippines, India, USA and other parts of the globe. It has been forecasted that in the coming decades, global agriculture faces the prospect of a changing climate (International Panel on Climate Change (IPCC), 1990a, 1992). There lies a challenge to feed the world's population, projected to double its present level of five billion by about the year 2060 (International Bank for Reconstruction and Development/World Bank, 1990). Climate change could have far-reaching effects on patterns of trade among nations, development, and food security. Above all, climate change could make it more difficult to grow crops, raise animals, and catch fish in the same ways and same places as we have done in the past.

RESULT AND DISCUSSION

GLOBAL PERSPECTIVES OF CLIMATE CHANGE AND AGRICULTURE

Changes in the constituent of climatic factors have immense effect on agriculture such as increases in temperature and carbon dioxide (CO_2) can be beneficial for some crops in some places. Changes in the frequency and severity of climatic factors could lead droughts and floods which could pose challenges for farmers. Climate change has direct effect on other stresses such as population growth may magnify their effects. For example, in developing countries, adaptation options like changes in crop-management or ranching practices or improvements to irrigation are more limited than in the developed and other industrialized nations. Hence, it is imperative that there could be heavy burden of climate change to developing world compared to developed countries in coming days ahead with respect to agriculture and livelihood of rural poor is concerned.

Natural calamities have devastating effects on human civilization. In the Philippines, there are more than a dozen typhoons in a year and in December 2013 Typhoon *Haiyan* was so devastating that nearly 6,000 people are believed to have died, and some 3.6 million are displaced and there was massive land slide that destroyed many human settlements (http://www.worldvision.org/news-stories-videos/typhoon-haiyan-response-philippines). Similarly, hurricane *Katrina* was one of the deadliest hurricanes ever to hit the United States. An estimated 1,836 people died in the hurricane and the flooding that followed in late August 2005, and millions of others were left homeless along the Gulf Coast and in New Orleans, which experienced the highest death toll (http://www.livescience.com/22522-hurricane-katrina-facts.html). There are number of climate related such events that are experienced in the recent years. All of such natural calamities could be associated with negative impacts of climate change that have local and global impacts on human civilization affecting much on poor and agro-based countries in the world.

Impact of climate trends on global crop yields has been observed for important crops of maize, rice, wheat and soybean (Don Hofstrand, 2011). As a result, maize production would have been about six percent higher and wheat production about four percent higher had the climate trends since 1980 not existed whereas the effects on rice and soybeans were observed lower and not significant (Fig. 1). The implication of climate on agriculture explains that there is a need of finding ways of adapting to these changes of climatic scenarios. It was also noted that the impact of temperature on crop yields is a larger factor than the impact of precipitation. This would indicate that adaptation strategies should focus more on temperature changes than on precipitation changes. In developed countries, increase in agricultural production over the last century was mostly as a result of yield increases rather than agricultural land area expansion. However, due to the world's rapidly growing demand for food due to negative impact of climate change on food production, there will be elevated pressure to expand the world's agricultural land area. To cope up with these challenges on agriculture there needs an increased investment in agricultural research across the world to meet the challenge of world food production.

In Figure 1, estimated changes in yields for maize, rice, wheat, and soybeans for major producing countries are shown (Don Hofstrand, 2011). The country with the largest impact was wheat production in Russia with an estimated negative yield impact of almost 15 percent while for the U.S., yield changes due to temperature and precipitation trends are negligible for maize, wheat and soybeans. Yield impacts were smaller for rice than the other crops. The confidence intervals of the yield estimates were larger for soybeans than the other crops.

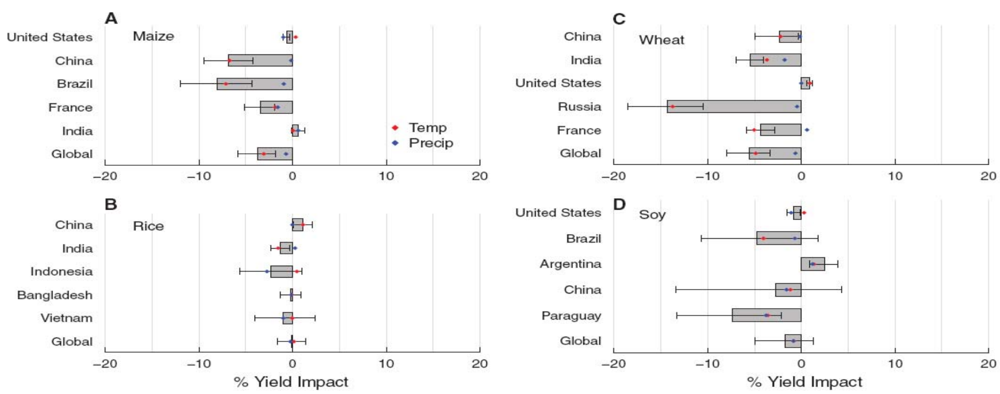

Figure 1. Estimated net impact of climate trends from 1980 to 2008 on crop yields for major producing countries and for global production (Source: Don Hofstrand, 2011)

A = Maize, B = Rice, C = Wheat, D = Soybeans *, Values are expressed as percent of average yields

*Gray bars show median estimate and error bars show 5 percent to 95 percent confidence internal from bootstrap resembling with 500 replicates. Red and blue dots show median estimate of impact for temperature trend and precipitation trend, respectively.

Note: the sum of the temperature (red dots) and precipitation (blue dots) estimates equals the total estimate shown by the gray bars.

The effects of climate change also need to be considered along with other evolving factors that affect agricultural production, such as changes in farming practices and technology. It has been keenly observed that sensitivity studies of world agriculture to potential climate changes have indicated that the effect of moderate climate change on world and domestic economies may be small, as reduced production in some areas is balanced by gains in others (Kane *et al*., 1991; Tobey *et al*., 1992). Agriculture is an important sector of the

U.S. economy. In addition to providing U.S. with much of food, crops, livestock, and seafood that are grown, raised, and caught in the United States contribute at least $200 billion to the economy each year (USGCRP, 2009). U.S. exports more than 30% of all wheat, corn, and rice on the global market (U.S. Census Bureau, 2011). Any change in climate parameters such as temperature, amount of carbon dioxide (CO_2), and the frequency and intensity of extreme rainfall and other weather condition could have significant impacts on crop yields (Fig. 2). Warmer temperatures may make many crops grow more quickly, but this could reduce crop yields for crops tend to grow faster in warmer conditions and this could have negative impact on yield from a given area of land (USGCRP, 2009).

For a particular crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and productivity. In some areas, warming may benefit the types of crops that are typically planted. Nevertheless, if temperature exceeds a particular crop's optimum temperature, yields can be declined. It has been established that higher CO_2 levels can increase crop yields. The yields for some crops, like wheat and soybeans, could increase by 30% or more under a doubling of CO_2 concentrations. The yields for other crops, such as corn, exhibit a much smaller response less than 10% increase in CO_2 concentrations (CCSP, 2008).

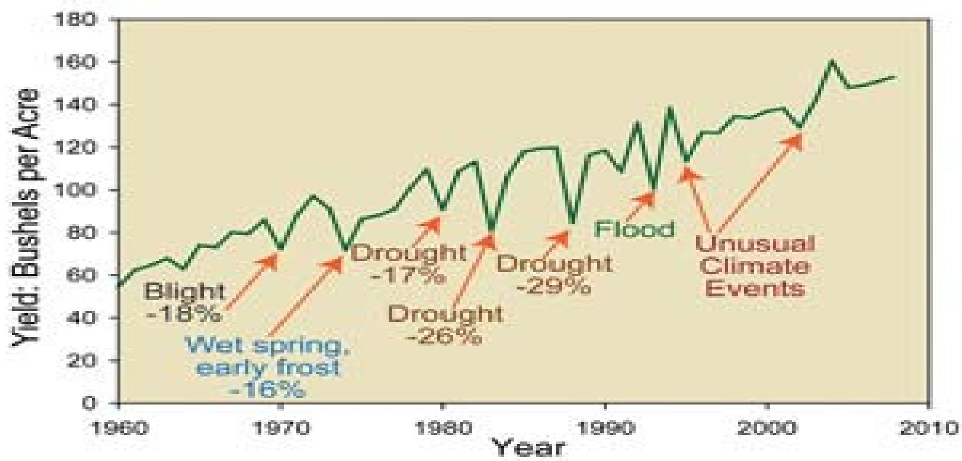

Figure 2. Impact of climate change in USA on corn yield in 2009
(Source: United States Global Change Research Program (USGCRP, 2009)

However, some factors may counteract these potential increases in yield. For example, if temperature exceeds a crop's optimal level or if sufficient water and nutrients are not available, yield increases may be reduced or reversed. In USA, there are reports that more extreme temperature and precipitation can prevent crops from growing such as extreme events, especially floods and droughts, can harm crops and reduce yields. For example, in 2008, the Mississippi River flooded just before the harvest period for many crops, causing an estimated loss of $8 billion for farmers (USGCRP, 2009). Many weeds, pests and fungi thrive under warmer temperatures, wetter climates, and increased CO_2 levels and farmers spend more than $11 billion per year to fight weeds in the United States (USGCRP, 2009). The result of these consequences is that the ranges of weeds and pests are likely to expand northward. This would cause new problems for farmers' crops previously unexposed to these species. Moreover, increased use of pesticides and fungicides may negatively affect human health (USGCRP, 2009).

In Nepal also, infestation of new insects, pests and weeds have recently been observed as problem on crops, animals and even in humans as the consequence of climate change. Noxious weeds such as *Parthenium hysterophorus* (White top Weed/ Congress Weed), *Pistiastratiotes* (water lettuce/Pani Banda) and *Mikaniamicrantha* (Bitter Vine or American Rope) have invaded crop and national reserve. The former two are becoming menace to crop production whereas the later one is so rapidly invading national reserve of Chitwan in central Terai and Bardiya in western Terai in such a way that endangered wild life one horned rhino and other herbivores could face forage and pasture limitation if these weeds are not brought under control immediately. Similarly, trans-boundary disease of bird flu in poultry, swine flu in humans, Ug-99 of wheat stem rust, brown plant hopper (BPH) in rice, and so on and so forth are causing heavy economic losses to developing countries including Nepal. These are becoming potential threats to human civilization. Recently Ebola virus in Africa has become a new threat to human beings across the globe threatening to food security in Africa (UN Report, Sep, 16, 2014). Who know these might have been critically favored by climate change?

Global agriculture has been facing prospect of a changing climate (IPCC, 1990a, 1992) to feed the world's population, projected to double its present level of five billion by about the year 2060 (International Bank for Reconstruction and Development/World Bank, 1990). There appears to be closely linked between agriculture and climate, the international nature of food trade and food security, and the need to consider the impacts of climate change in a global context. In areas with increased rainfall, moisture-reliant pathogens could thrive (USGCRP, 2009). Increases in atmospheric CO_2 can increase the productivity of plants on which livestock feed. Many fisheries have already been experiencing multiple stresses, including overfishing and water pollution. Climate change could enhance these stresses particularly temperature changes could lead to significant impacts. The ranges of many fish and shellfish species may change. Many marine species have certain temperature ranges at which they can survive. Many aquatic species can find colder areas of streams and lakes or move northward along the coast or in the ocean as result of ecosystem impact due to climate change (Fig. 3).

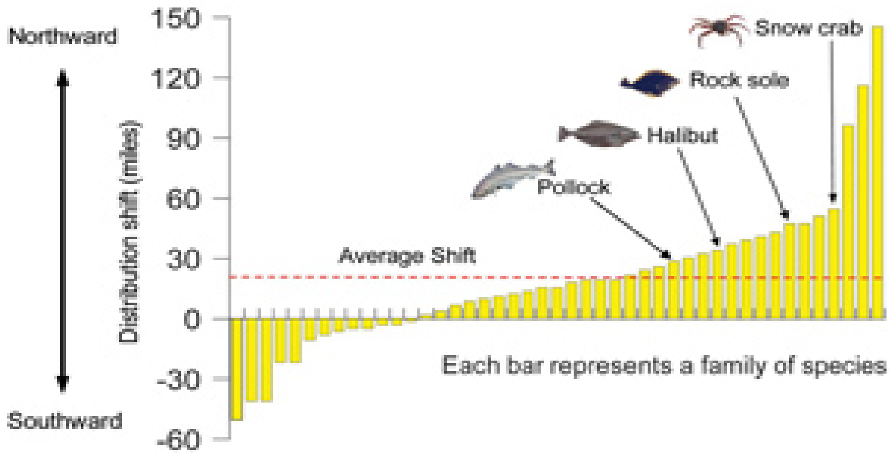

Figure3- The range of marine species shifted northward as water warmed

(Source: United States Global Change Research Program (USGCRP, 2009)

CLIMATE CHANGE AND GLOBAL FOOD SECURITY

Agricultural scientists of 18 countries have simulated potential changes in grain yields using compatible crop models (IBSNAT, 1989). The crops modeled were used for wheat, rice, maize, and soybeans. The crop models were run for current climate conditions, for arbitrary changes in climate (+2^{0}C and +4^{0}C increase in temperature and +/-20% precipitation), and for climate conditions predicted by general circulation models (GCMs) for doubled atmospheric CO_2 levels. The study consisted with the direct effects of CO_2, and precipitation held at current levels, average crop yields weighted by national production show a positive response to +2 ^{0}C warming and a negative response to +4 ^{0}C. The output showed that wheat and soybean yields increased 10-15% whereas maize and rice yields increased about 8% with a +2 ^{0}C temperature rise. Yields of all four crops turned negative at +4 ^{0}C, indicating a threshold of the compensation of direct CO_2 effects for temperature increases between 2 and 4 ^{0}C, as simulated in the IBSNAT crop models. Rice and soybean are most negatively affected at +4 ^{0}C. For example, the effects of latitude are such that in Canada, a +2 ^{0}C temperature increase with no precipitation change results in wheat yield increases (with direct effects of CO_2 taken into account), while the same changes in Pakistan result in average wheat yield decreases of about 12%. In general, 20% increase in precipitation improved the simulated yields of the crops tested, and 20% decrease lowered yields of all crops. Climate changes without the direct physiological effects of CO_2 cause decreases in simulated wheat yields in all cases, while the direct effects of CO_2 mitigate the negative effects primarily in mid- and high-latitudes (Rosenzweig, *et al*, 1993).

Climate change scenario with the use of compatible model predicted the greatest warming (5.25^{0}C global surface air temperature increase), causes average national crop yields to decline almost everywhere up to -50% in Pakistan (Rosenzweig, *et al,* 1993). In the model, assuming that full agricultural trade liberalization and no climate change by 2020 provides for more efficient resource use. The prediction leads to a 3.2% higher value added in agriculture globally and 5.2% higher agricultural GDP in developing countries (excluding China) by 2060 compared to the original reference scenario. This policy change results in almost 20% fewer people at risk from hunger. If this scenario continues global cereal production increases by 70 million metric tons with most of the production increases occurring in developing countries (Rosenzweig, *et al*, 1993). Under such circumstances losses in production are greater in developing countries and at the same time, price increases are reduced slightly from what would occur without full trade liberalization, and the number of people at risk from hunger is reduced by about 100 million. The effect of climate change on these trends is generally to reduce production, increase prices, and increase the number of people at risk from hunger. However, it is observed in the model that developed countries increase cereal production in these scenarios even with the projected lower economic growth rates, but developing countries decrease production under all climate change scenarios.

Key factors in agricultural productivity are technological advances such as improved crop varieties and irrigation systems, and weather. Among these entities climate possess prime impact on agriculture systems. For example, weak monsoon rains in 1987 caused largely reduced crop production in India, Bangladesh, and Pakistan, contributing to reversion to wheat importation by India and Pakistan (World Food Institute, 1988). So was the case in 1980s which also saw the continuing deterioration of food production in Africa due to persistent drought and low production potential of crops due to negative impact of climatic factors in agriculture production. As a result international relief efforts were implied to prevent widespread famine in Africa. Repercussion of climate change in agricultural trade has grown dramatically in recent decades and now provides significant increments of national food supplies to major importing nations and substantial income for major exporting nations.

The effect of temperature and precipitation trends on the yields of maize, rice, wheat and soybeans is shown in Table 1 (Don Hofstrand, 2011). The impact on yields is greater for temperature than for precipitation. The greatest yield impact of temperature was on wheat followed by maize. When the three percent yield gain from elevated CO_2 levels is added to wheat, soybeans and rice, the yield response for rice and soybeans become positive but remained negative for maize and wheat. It is the explicit evidence that climate change has negative effect on global food production.

Table1. Estimates of global impacts of temperature and precipitation trends on yields of four major crops, 1980-2008 (Source: Don Hofstrand, 2011)

Crop	Global production (1998-2002 avg. mil. metric tons)	Global yield impact of temperatures trends	Global yield impact of precipitation trends	Subtotal	Global yield impact of CO_2 trends	Total change
Maize	607	-3.1% (-4.9%, -1.4%)	-0.7% (-1.2%, 0.2%)	-3.8% (-5.8%, -1.9%)	0.0%	-3.8%
Rice	591	0.1 (-0.9, 1.2)	-0.2 (-1.0, 0.5)	-0.1 (-1.6, 1.4)	3.0	2.9
Wheat	586	-4.9 (-7.2, -2.8)	-0.6 (-1.3, 0.1)	-5.5 (-8.0, -3.3)	3.0	-2.5
Soybeans	168	-0.8 (-3.8, 1.9)	-0.9 (-1.5, -0.2)	-1.7 (-4.9, 1.2)	3.0	1.3

GLIMPSE OF CLIMATE CHANGE IN NEPAL

Climate change has been observed in Nepal in varying level of climates that are prevalent in diversified topography and vegetation (Paudel, 2010, 2012). There are impacts of climate changes in Terai (almost tropical region), mid-hills and valley (subtropical region), and mountains and the Himalaya (temperate and tundra regions) of Nepal. It was reported that the pioneer mountaineer Mr. Apa Sherpa, the Goodwill Ambassador to Climate Change (Sherpa 2010) scaled Mount Everest for the 21st time on 11 May 2011 and observed that there was no snow on the Everest trail and he waited snow fall for days at the base camps to scale Mt. Everest. Apa on 23 May 2010 noticed stream flowing on top of the Everest by melting ice (Shrestha, 2009). A country like Nepal could not explain more than this as the impact of climate changes in the Himalayan region – the experience of Apa! Because of climate change it is reported untimely start of monsoonal rainfall that resulted rain deficit in the eastern Terai lowlands in 2005/06, reducing crop production by 12.5% nationwide (Malla, 2008). In agriculture, about 10% of agricultural land was left fallow due to rain deficit on the one hand, while on the other hand in the mid- western Terai faced heavy rain with floods, which reduced crop production by 30% (Regmi, 2007). Adverse effect of climate change could lead to the extinction of some indigenous crop varieties such as many aromatic rice varieties including Basmati rice, some local wheat, maize, and other agricultural crops as well (Paudel, 2012). It was also observed that a severe winter cold wave in Nepal in 1998 had negative impacts on agricultural productivity and showed a high percentage of yield reduction for potato (27.8%), leaf mustard (36.5%), mustard seed (11.2%), lentil (37.6%), and chickpea (38%) (NARC 1987/88 to 1997/98). In Nepal, negative impacts of climate change are observed for food crops which are already infected by diseases and pests such as club root of *crucifiers*, blight of *solaneceous*, rust of wheat, blast of rice and leaf spot of maize and red ants which have become menace leading to decreasing crop productivity.

Until and unless such issues are tackled timely, there are less likely chances of coping climate change with respect to food security and poverty reduction to meet the MDGs set by the UN for 2015 for developing countries (Paudel, 2010). Almost in every year, Nepal has been facing vagaries of climate change in the form of flood, landslide, drought, untimely onset and exhaust of monsoon as a result there has been heavy toll of human (Figure 4): The Sunkoshi River land slide on August 2, 2014. Causality and losses of agriculture land and human settlements in the the Sunkoshi river land slide on August 2, 2014 in the central hills, Nepal was severe.

The August2, 2014 land slide in the Sunkoshi river killed 33 people and 122 were reported missing. Experts say this event, one of the deadliest in the country’s recent history, is a wake-up call for hazard mapping, early warning, and disaster managementhttp://www.irinnews.org/country/npa/nepal). There are other cases of such devastation in the Hindu Kush mountain regions and similar other mountain regions across the world which justify impact of climate change due to heavy and untimely down pour. Similar was the cases in India in June 2013, a multi-day cloudburst centered on the North Indian state of Uttarakhand caused devastating floods and landslides in the country's worst natural disaster since the 2004 tsunami (Fig. 5): Washing away of the religious site of the Kedarnath in Uttarakhand in June 2013. In this devastation of the holy shrine of the Kedarnath, some parts of Himachal Pradesh, Haryana, Delhi and Uttar Pradesh in India experienced the flood, some regions of Western Nepal, and some parts of Western Tibet also experienced heavy rainfall resulting over 95% of the casualties occurred in Uttarakhand. As of 16 July 2013, according to figures provided by the Uttarakhand government, more than 5,700 people were presumed dead (CBS news, 2013) which included total of 934 local residents (Fox News, 2013). This figure shows one of the sites of devastation in Uttrakhand in July 2013 due to heavy cloud burst in the region (https://encrypted-

tbn1.gstatic.com/images?q=tbn:ANd9GcR4T_xQZ4a4eLwtvRfW4__EUxD4lNPULDkrO-mWxqv3Xqq-p6z5).

Thus, it is imperative that climate change is intensifying existing problems including excessive rain in some places and reduced rain in other places, runoff and increased heat stress, recurrent drought and floods, heavy loss of lives, loss of rural livelihood, and food insecurity. Bates *et al* (2008) have reported high rate of glacial melt due to increases in in temperature accelerating the rate of such incidents increased between 1950s and 1990s from 0.38 to 0.54 events per year. Table 2 depicts the impact of climate change from 2030 to 2090 with respect to change in temperature and precipitation resulting in runoff (Bartlett *et al*, 2010).

Table 2. Bartlett *et al* (2010) have anticipated climate change impact in Nepal for temperature, precipitation and runoff as given below:

Temperature	• **Significant rise in temperature (^{0} c)** ➢ 0.5 to 2 by the 2030 ➢ 1.3 to 3.8 by the 2060 ➢ 1.8 to 5.8 by the 2090 • Increased in the number of days and nights considered hot by current standards • Highest temperature increase during the months of June to August at high elevations
Precipitation	• **Wide range of mean annual precipitation changes:** ➢ -34 to +22% by the 2030s ➢ -36 to +67% by the 2060s ➢ -43 to 80% by the 2090s • **Increase in monsoon rainfall towards the end of this century:** ➢ -14 to 40% by the 2030s ➢ -40 to +143% by the 2060s ➢ -52 to 135% by the 2090s
Runoff	• Higher downstream flows in the short term but lower stream flows in the long term due to retreating glacier and snow melt and ice melt • Shift from snow to rain in winter months • Increased extreme events including floods, droughts and GLOFs

The table above portrays the impacts of climate change on temperature and precipitation triggering runoff in the 21st century in Nepal. This is very much an alarming situation for Nepal where majority of population depends on farming for livelihood. It is, therefore, fundamental for Nepalese leaders, planners, and resource manager to think very urgently and decisively to begin national plan of adaptation to climate change.

ANALOGY OF CLIMATE CHANGE EFFECT IN NEPAL

Two places (Kakani of Nuwakot district and Dhangadhi of Kailali district) were selected to compare 10 years' meteorological data (temperature, total rainfall and number of rainy days) in Nepal (Fig 6 and 7). Kakaniis in central high hills (2030-m altitude) whereas Dhangadhiis in far western Terai (210-m altitude). Comparison for observed meteorological traits was done between two nearby years. It was found that in both of the sites for five years, although the years were not same, there was a rise in change of T max whereas for T min there was a rise for six years in Kanaki and three years in Dhangadhi. In both the sites, there was rise of change in average T max and T min. For the total rainfall also same pattern was observed as was followed in T max. Similarly, a change in average rainfall was recorded for five years in both the sites. Number of rainy days in both the sites was found decreased for six years, however, average change in total number of rainy days in Kakani was found increased while in Dhangadhi it decreased.

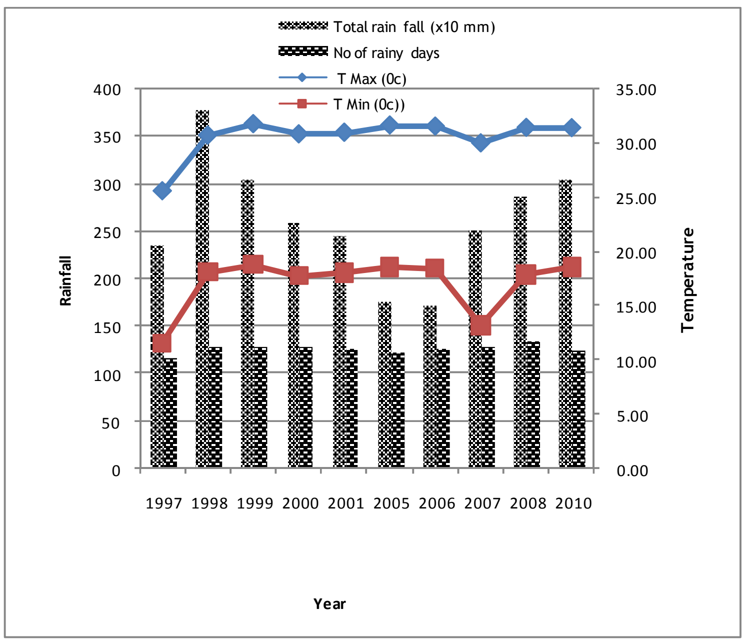

Figure 6. Ten years' meteorological data of Kakani (2030-m), Nepal

(Data received from the courtesy of Agriculture Environment Division in 2014, NARC)

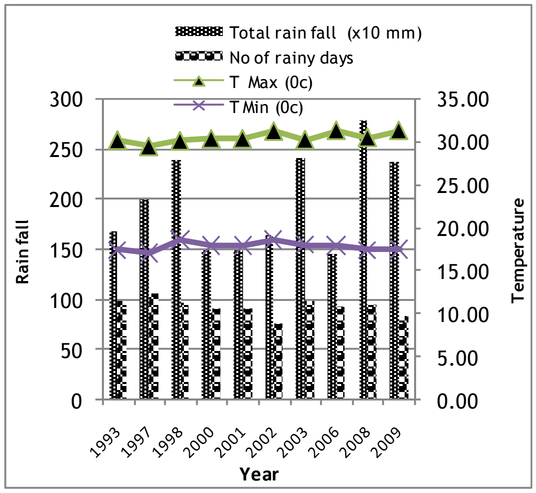

Figure7. Ten years' meteorological data of Dhangadhi (210-m), Nepal

(Data received from the courtesy of Agriculture Environment Division in 2014, NARC)

From 10 years' meteorological observation in Kakani and Dhangadhi it was found that change in amplitude of T max and T min is increasing in both locations. Total rainfall and number of rainy days in high hills site of Kakani is increasing while in Dhangadhi of far western Terai both the amount of rainfall and number of rainy days were decreasing over the period. Meaning to say that temperature and rainfall are affected in Nepal even in short span of 10 years. This could be the impact of climate change in Nepal where agriculture in these regions might have been affected due to the change in metrological parameters. Fluctuation in these parameters was more pronounced in Kakani than that of Dhangadhi. It suggests that mountains are more vulnerable to climate compared to Terai in Nepal.

ADAPTATION SCENARIO OF CLIMATE CHANGE IN NEPALESE PERSPECTIVE

In view of climate sensitive agriculture, farmers need timely information on weather and climate variability to adjust their farming practices to minimize adverse impacts on rural livelihoods, and food security (http://www.worldbank.org/en/news).The economies of developing countries depend heavily on climate-sensitive sectors such as agriculture, forestry, fishery, water supply, and other natural resources (Paudel, 2012). It is imperative that climate change adaptation is not separated from other priorities but is integrated into development planning, programs, and projects (World Bank 2008). FAO (2008) underlined the need to think of food, energy and climate as one interconnected issue. Thus, to save the world from impending climate catastrophe through mitigation viz; direct reduction of greenhouse gases and their offsets and adaptation viz; support towards adapting to the effects of climate change, are available options to be implemented in the immediate future. Of the several options, Nepal can select adaptation options based on hazard specificity and location specific preferences. FAO (2009) has provided practices to cope with climate change hazards, such as rain water harvesting and soil moisture conservation, slope stabilization and management, management of high/low temperature stress, crop diversification, community based seed production of staple crops, resource conservation, and cultivation of stress tolerant crop varieties. In Nepal, more than 90% of the population is dependent upon the land for fulfilment of their basic needs (food, fodder, fuel, fiber and timber). Anthropogenic causes such as deforestation overgrazing, and unscientific farming on steep slopes of Nepal and other developing countries have resulted in loss of flora and fauna, and have caused soil erosion, landslides in the hills, and flooding in the plain areas as well.

Of the many adoptive practices of coping adverse effect of climate change, Sloping Agriculture Land Technology (SALT) is one of the practices identified for promotion (FAO, 2009). Slope land management by plantation of fodder trees and appropriate crops such as citrus, tea and coffee on terrace to control erosion should be promoted in the mid-hills. Important option prioritized to stabilize the slopes is the hedge row planting. The alleys not occupied by permanent crops should be planted alternately to cereals such as corn, upland rice, cotton, fruits, vegetables, and legumes, etc. This cycle of cropping provides the farmers with several harvests throughout the year. The intervention would identify best suitable model for the mid-hill region.

Other viable and practical practices of adoption with respect to climate change on agriculture could be tunnel/plastic house farming and off season vegetable cultivation and community centered small scale fruit (apple, apricot, walnut, and mandarin orange), vegetable, and potato seed storage and so on. Hence, priority should be given for the development of localized tunnel farming technology by using new ways and techniques that are being practiced along north- south road accessible areas in the mid-hills from east to west of the country. Localized tunnel cultivation systems are sustainable and cause low environmental pollution to agriculture systems, in addition to reducing the high/low temperature risks that make income generation from off season production of vegetables; viz., tomato, cole crops (crops belonging to cruciferous family). Based on climatic suitability, rice, wheat, legumes and oilseeds are the major commodities of the Terai. Rice, maize, wheat, pulses and oilseeds are major commodities in the hills. And potato, barley, wheat, buckwheat, amaranth, and different millets are the commodities suitable for the mountains where these are being grown from time immemorial in Nepal. It has been established that quality seed alone can increase crop yields up to 10-25%. Seed production groups for important food crops (rice, maize, wheat, barley, millet) have shown encouraging results in many parts of the country. Improved seed produced by users' groups in a community based concept has helped increased crop production. This practice is one of the coping measures to mitigate climate change effect by availing quality seed to local communities. Along with other resource-conserving farming practices, conservation agriculture can improve rural incomes and livelihoods by reducing production costs, managing agro- ecosystem productivity, encouraging diversity for more sustainably, and minimizing unfavorable environmental impacts, especially in small and medium-scale farms.

NEPAL'S EFFORTS TO ADDRESS CLIMATE CHANGE

Nepal ranks the fourth most climate-vulnerable countries in the world and is highly exposed to a range of water related hazards such as floods, droughts and landslides (http://www.worldbank.org/en/news). A cabinet meeting of the Council of Minister of the Government of Nepal (GoN) was held at the base of the Everest in December 2009. The meeting came ahead of the United Nations Climate Summit in Copenhagen (known as Cop15), which began on 15th December 2009. A 10-point 'Everest Declaration' of the cabinet includes developing communities' capacity to cope up with climate change and working together with other countries to mitigate the impact of global warming (Shrestha, 2009). The declaration also supported developed countries' plans to contribute 1.5% of GDP to a climate fund and bring down greenhouse gases to pre-industrialization levels. Year round snow caped Himalayas including the Mount Everest in Nepal have experienced impact of climate change thereby immense glacier retreat in the Himalayan region. Had the Himalayan peaks are devoid of snow what would be the fate of rivers flowing from those mighty water towers, the Himalayas? The Himalayas are responsible to supply water to the perennial rivers flowing in the Indo-Gangetic, the Mekong, and Tibetan plateaus. Ultimately, Europe and the entire Asia-Pacific region would be affected immediately and in the long run the impact would be for the entire earths' civilization and the climate as a whole. Hence, there is no question of victimizing from the impact of climate change for a single country like Nepal whose contribution on global climate change is negligible (around 0.02%); i.e., miniscule compared to developed and industrialized countries (Paudel 2010).

A number of adoptive strategies have been applied to address consequences of climate change in agriculture in Nepal. Paudel (2012) has highlighted released of drought tolerant varieties of rice, wheat, maize and legumes. These varieties can withstand drought and can yield even in some fluctuation of moisture which should not be limiting production under stress environment. Rice in Nepal is mostly under transplanted condition, however, drought tolerant cultivars could be cultivated as direct seeding when the rainfall is unpredicted and there are very slim chances of cultivating transplanted rice as a result of change in rainfall patterns. On the other hand, varieties that can withstand submerged condition have also been released by the research such as Sworna Sub-1, IR-64, and Sanwa Mansuli are introgressed containing sub-1 gene which is submergence tolerant. It has been reported that up to 17 days of complete submergence could tolerate by Swarna Sub-1 rice variety under submerged condition. For high hill and temperate conditions (2500-m and above) cold tolerant rice varieties of Chandannath-1 & 3 and other have been developed and popularized especially in Jumla and Karnali regions (Paudel, 2011) where there is acute shortage of food and around 3.9 million people in the area suffered from hunger and malnutrition (Paudel, 2010). Similarly, rice varieties Machhapuchhere-3 and Chhomrong Local have been popularized in upper high hills of more than 2000-m (Karki, *et al*, 2010). Likewise, improved varieties of maize, wheat, maize, tomato and potato have been developed to address situation brought about by climate change such as emergence of new insects, pests and diseases and natural disasters of flood, drought, hail storm and many more. All of such negative consequences of climate change are not sufficiently addressed thereby efforts to limit these consequences of climate change on agriculture should immediately be taken into consideration in the highly vulnerable country like Nepal. Aside from releasing different varieties of crop, Nepal Agricultural Research Council (NARC) has recommended technologies to address vagaries of climate change (Paudel, 2012); these include resource conservation technologies of zero tillage, bed planting, permanent bed planting, strip tillage, minimum tillage, surface seeding, crop residue management and so on and so forth. There are composite technologies to address the effects of climate change on agriculture; these include gray leaf spot disease management of maize by growing resistant varieties. The crop husbandry technologies to mitigate adverse effect of climate change are early planting and wide spacing, balanced use of chemical fertilizers and integrated nutrient management, integrated pest management, and selective application of pesticides.

Nepal is blessed with diverse climate conditions ranging from 60-m to 8,848-m, the top of the world, despite this boon in Nepal, climate change has shown impacts on many indigenous breeds of animals and varieties of crops which are in the verge of extinction. These flora and fauna of plants and animals have been boon for the resource poor populace of Nepal. They include many indigenous crop species of aromatic rice: *Basmati, Thapa Chini, Kalanamak, Jhinuwa, KanakJira, Chananchura, TundeMasino, Anandi* (red and white), many local varieties of rice (*Ghaiya, Jundi, Marshii*), wheat, maize (*Sathiya, Murali, Dhinde, Sete, Panheli*), finger millet (*Okhle, Dalle, Paundure, Jhapre, Mutthe*), buck wheat (bitter, sweet, *Chuchhe, Bharule*), many grain legumes, vegetable legumes, and other minor crops (foxtail millet, sorghum, naked barley, *Panicum* millet, *Aamaranthus*, proso millet (white, yellow). Similarly, for animals including buffalo (*Parkote, Lime*), cattle (Yak and *Lulu* of high hills, Sri of mid hills, reported as extinction and NARC has recently recovered this species from Taplejung district of eastern hills), *Achhamigai* (smallest cow recorded in the world), goat (*Chyangra* for Pasmina wool), *Bhyanjlung* of sheep (carpet wool production), goat (*Khari, Sinhal,)*, *Bampudke Sungur* (native pig), *Sakhini Kukhura* (native fowl), and many other unrecorded species of crops and animals are endangered. There is a need to conserve such very important genetic materials which are becoming endangered due to the effect of climate change.

Important cereals of rice, maize and wheat yields in warm environments can be raised significantly by modifying agronomic practices of timely planting, incorporating residues and following appropriate crop rotations as proved beneficial in resource conservation techniques. Clearly crops of rice, wheat and maize yield in lower latitudes may decrease due to global warming, and may be further affected by water scarcity or drought. One approach to dealing with these heat-related constraints is to improve germplasms of these crops to provide higher tolerance to stresses associated with changed environments. Hence, new varieties screened by Nepal Agriculture Research Council (NARC) should be demonstrated to farmers focusing on enhancing the crop yield potential and to maintain yield under stress and fluctuation of environments including temperatures, rainfall and $C0_2$ concentration. In this way, they will assist in building cropping systems resilience to the global warming and natural hazards that could not jeopardize the livelihood of resource-poor farmers who depend on the harvest of these crops.

CONCLUSION

In the climate sensitive agricultural sector, farmers need timely information on weather and climate variability to adjust their farming practices and minimize adverse impacts on rural livelihoods, agricultural productivity and food security (http://www.worldbank.org/en/news). It has long been experienced that effect of climate change in general and agriculture in particular has been observed in Nepal. Changes in agriculture in varied agro-ecology of mountain, hill and Terai are observed with decrease in agriculture productivity due to the untimely onset of monsoon including erratic rain, flood, land slide, and droughts. Consequences of all climatic phenomena have resulted food and nutritional shortage in Nepal. Role of Nepal in global climate change is minimal compared to suffering from negative effect on agriculture which is the main stay of Nepalese people. Adaptation and mitigation are the available tools to address effect of climate change in agriculture and livelihood maintenance. Nepal is in the grip of climate change, however, there is very little to do with mitigation as Nepal does not emit significant quantity of greenhouse gases and the only way is the adaptation to cope up with effect of climate change. Development of crop varieties and animal breeds to suit to the changed environment are the viable adaptation strategies which could best address climate change scenario in Nepal. In this regard, agriculture research systems of Nepal has developed and maintained crop varieties and animal breeds to address climate change and such technologies have been popularized in the agro-ecological niches wherever feasible. This has helped, to some extent, sustain food security, and enhance livelihood in Nepal as well.

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