Effect of climate change on food production and its implication in Nepal

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Abstract

Climate change is a complex phenomenon. Now climate change has become a buzz word in general and particular to agriculture and food security. It is true for developing countries where there is a dearth of information to support and reject such a complex phenomena of this universally important aspect of nature. Climate change is as unpredictable as the movement of a bird in the sky that even an ornithologist cannot predict the movement of a falcon that is swinging in the air and so is the case of climate change even for meteorologists working in the World Meteorological Station. The main concern about climate change and food security is that changing climatic conditions can initiate a vicious circle where infectious diseases cause or compound hunger, which, in turn, make the affected populations more susceptible to infectious disease. The result can be a substantial decline in labor productivity and an increase in poverty and even mortality. Essentially all manifestations of climate change, such as drought, higher temperatures, or heavy rainfalls could have an impact on the disease pressure on plants and animals. Also, climate change could affect food safety and food security. It is anticipated that due to climate change many flora and fauna including humans, higher plants and animals will face new diseases due to easily expansion of diseases causing epidemic cycle making more favorable to pathogens in different parts of the world. There will be a continuous outbreak of such diseases making hunger and malnutrition more severe than ever and consequently affect for important food commodities due to changing climate of tropical, temperate and equatorial zones, the main biodiversity zones for population and food production as well. Hence, this paper tries to provide a brief review on climate change with respect to food security and crop production, which, ultimately, could suggest agronomic measures to mitigate the impacts of climate change and adopt vagaries of climate change in the days ahead for an agrarian country like Nepal.

Key words: Climate change, food security, food sovereignty, food crisis

Introduction

Climate change defined

The climate change is related to changes in the concentration of the greenhouse gases (water vapor, CO_2, CH_4, N_2O, and CFCs), which trap infrared radiation from the earth's surface and thus cause the greenhouse effect. This effect is a natural phenomenon, which helps maintain a stable temperature and climate on earth. Human activities, such as fossil fuel combustion, deforestation, and some industrial processes have led to an increase in greenhouse gases concentration. Consequently, more infrared radiation has been captured in the atmosphere, which causes changes in the air temperature, precipitation patterns, sea-level rise, and melting of glaciers (Central European University, 1999).

Sinha *et al*, (1988) state that the climate changes envisaged to the 21^{st} next century are mostly attributed to the increasing concentration of CO_2 and other "greenhouse gases". Since CO_2 is an essential reactant in photosynthesis to produce organic matter. It is postulated that farmers could look forward to better harvests (Wittwer, 1986). Rosenberg (1987) made an analysis of gas exchange and concluded that climate change, at least as far as CO_2 concentration effects are concerned, may prove advantageous. However, Gifford (1987) made a more cautious assessment of CO_2 effects by including temperature change as an additional component. Sinha *et al* (1988) made following observations for assessing the effects of climate change, including CO_2 concentration on crop yields:

- The highest yields in C3 crops are obtained around a mean daily temperature of 15^{0}C and in C4 crops around 30^{0}C.
- The temperature optimal for vegetative growth and the reproductive phases are often different. An increase of temperature beyond a mean of 22^{0}C causes sterility in rice resulting in reduced grain yield, though it has no effect on photosynthesis (Fig.1). In wheat, an increase in mean temperature above 16^{0}C results in a decrease in grain weight and a poor yield (Fig.2). A higher temperature significantly reduces tillering, which is essential to building shoot population.
- The crops having a high growth rate in the pre-flowering phase usually deplete soil moisture, which is necessary to normally complete the grain development phase. Consequently, high initial growth, in the absence of irrigation, results in a poor grain yield despite high dry matter accumulation.
  However, there is little new evidence that climate change significantly alters the prevalence of many explained and unexplained consequences to the universe. Several studies have confirmed and quantified the effects of temperature on common forms of food poisoning, such as *Salmonellosis*. These studies show an approximately linear increase in reported cases for each degree increase in weekly temperature. Moreover, there are evidences that temperature variability affects the incidence of diarrhoeal and other communicable diseases. Extreme rainfall and prolonged drought events can increase the risk of outbreaks of diseases particularly where traditional water management systems are insufficient to handle the new extremes. Drinking water limitation is becoming a normal phenomenon of metropolitan city in the world in general and developing world in special. Likewise, the impacts of flooding will be felt most strongly in environmentally degraded areas, and where basic public infrastructure, including sanitation and hygiene, is lacking. Ultimately climate change will thus lower capacity of people to effectively use food. These are the widespread pros and cons of climate change. Many social unrest and conflicts in developing world are related to water scarcity which may be the effect of climate change that brings prolonged drought and excessive rain even in monsoonal dependent countries such as south and south East Asia where SW monsoon is the sources of water for rice, the main food of the people living in these parts of the world. However, all of such issues would be beyond the discussion of this paper and our discussion will be focused on climate change with respect to food security and crop production pertaining to agriculture research and development (R&D).

Global scenario of climate change

Gifford (1987) estimated the rise in temperature that would cancel out the advantageous effects of CO_2 fertilization (Table 1 and 2). At locations ranging from 50^{0}N in Canada to 37^{0}S in Australia a rise of 1.5^0 to 2.4^{0}C is required to cancel the advantageous effects of CO_2 on grain yield, presumably under irrigated conditions. In the absence of irrigation, crop yields may in fact be reduced. The optimistic predictions for agricultural production made by several people in the recent past based on CO_2 fertilization effects should not lead to complacency about the question of food security. These projections have been based on a study of the individual effects of only one or two factors. It should be recognized that agricultural production is a complex process. The available evidence on CO_2 fertilization effects, when two or more factors are simultaneously considered is, at best, inconclusive (Fig. 1and 2).

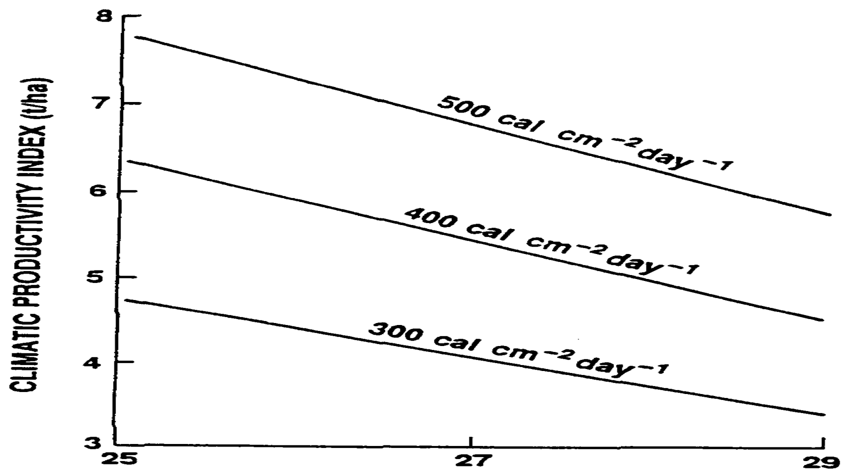

Figure 1.
Effect of increasing temperature on the productivity of rice at different rates of radiation (Yoshida, 1978).

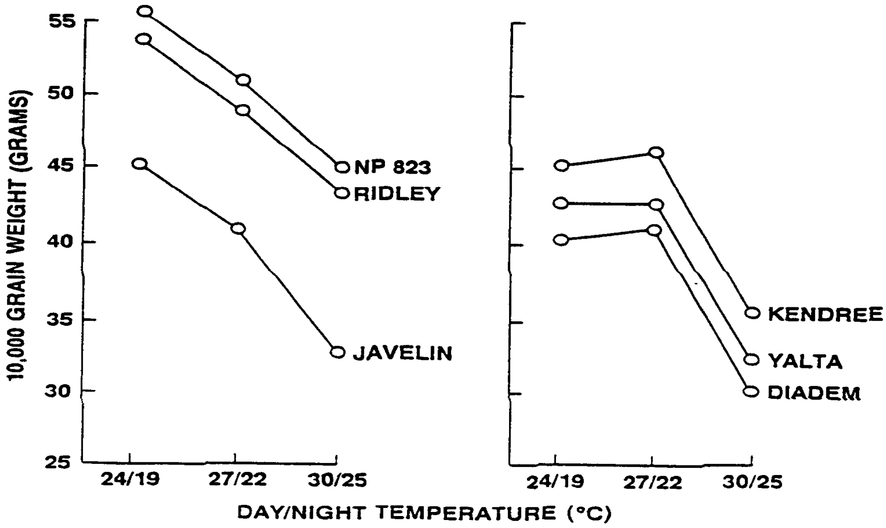

Figure 2.
Effect of increasing temperature on grain development in wheat (Asana, 1976).

Source for Fig. 1&2: Sinha et al, 1988

Table 1. Effect of doubling of atmospheric $C0_2$ on the area and productivity of rice (total production in 1985=465 million metric tons)*

Region/country	Share of production (%)	Yield (t/ha)	2 x $C0_2$ climate scenario		Effect of crop production**	
			ΔT (^{0}C)	Soil moisture condition	Area	Yield
China	37	5.3	3	Wetter	+	+
India	20	2.2	3	Wetter	+	+
Indonesia	8	2.1	2	Drier	-	+
Bangladesh	5	4.1	3	Wetter	+	+
Developing countries	94	3.1	2-4	Wetter	+	+

**For rice, sterility effects of increasing temperature may neutralize increase in production

Table 2.Effect of doubling of atmospheric $C0_2$ on the area and productivity of maize (total production in 1986=490 million metric tons)*

Region/country	Share of production (%)	Yield (t/ha)	2 x $C0_2$ climate scenario		Effect of crop production	
			ΔT (^{0}C)	Soil moisture condition	Area	Yield
USA	46	7.4	4	Drier	+	-
Western Europe	8	5.5	4	Drier	+	-
China	13	3.5	3	Wetter	+	+
Brazil	4	1.9	3	Wetter/Drier	+	+
Developed countries	65	6.0	4	Drier	+	-
Developing countries	35	2.2	3	Wetter	+	+

*Source for Table 1&2 (Sinha *et al*, 1988)

Food security defined

The Food and Agriculture Organization (FAO, 2002) defines food security as a ‘‘situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life’’.

Climate change and food security

There are different mathematical models to predict impact of climate change on agriculture and food production in complex ways. It affects food production directly through changes in agro-ecological conditions and indirectly by affecting growth and distribution of incomes, and thus demand for agricultural produce. Impacts have been quantified in numerous studies and under various sets of assumptions (IPCC, 2007). Continued emissions of greenhouse gases will bring changes in land suitability and crop yields. IPCC considers four families of socio-economic development and associated emission scenarios, known as Special Report on Emissions Scenarios (SRES) A2, B2, A1, and B1 (IPCC, 2004). Of relevance to this review, of the SRES scenarios, A1, the ‘‘business-as-usual scenario,’’ corresponds to the highest emissions, and B1 corresponds to the lowest. The other scenarios are intermediate between these two. Importantly for agriculture and world food supply, SRES A2 assumes the highest projected population growth of the four and is thus associated to the highest food demand. Depending on the SRES emission scenario and climate models considered, global mean surface temperature is projected to rise in a range from 1.8°C (with a range from 1.1°C to 2.9°C for SRES B1) to 4.0°C (with a range from 2.4°C to 6.4°C for A1) by 2100 (IPCC, 2007). In temperate latitudes, higher temperatures are expected to bring predominantly benefits to agriculture: the areas potentially suitable for cropping will expand, the length of the growing period will increase, and crop yields may rise.

Depending on the SRES emission scenario, the atmospheric CO_2 concentration is projected to increase from 379 ppm today to 550 ppm by 2100 in SRES B1 to 800 ppm in SRES A1. Higher CO_2 concentrations will have a positive effect on many crops, enhancing biomass accumulation and final yield. However, the magnitude of this effect is less clear; with important differences depending on management type (e.g., irrigation and fertilization regimes) and crop type (IPCC, 2001). Experimental yield response to elevated CO_2 show that under optimal growth conditions, crop yields increase at 550 ppm CO_2 in the range of 10% to 20% for C3 crops (such as wheat, rice, and soybean), and only 0–10% for C4 crops such as maize and sorghum (IPCC, 2007). Yet the nutritional quality of agricultural produce may not increase in line with higher yields. Some cereal and forage crops, for example, show lower protein concentrations under elevated CO_2 conditions. Finally, a number of recent studies have estimated the likely changes in land suitability, potential yields, and agricultural production on the current suite of crops and cultivars available today. Therefore, these estimates implicitly include adaptation using available management techniques and crops, but excluding new cultivars from breeding or biotechnology. There are reports that there will be a more pronounced regional shifts, with a considerable increase in suitable cropland at higher latitudes (developed countries: 160 million ha) and a corresponding decline of potential cropland at lower latitudes (developing countries: 110 million ha). An even more pronounced shift within the quality of cropland is predicted in developing countries. The net decline of 110 million ha is the result of a massive decline in agricultural prime land of 135 million ha, which is offset by an increase in moderately suitable land of 20 million ha. This quality shift is also reflected in the shift in land suitable for multiple cropping. In sub-Saharan Africa alone, land for double cropping would decline by between 10 million and 20 million ha, and land suitable for triple copping would decline by 5 million to 10 million ha. At a regional level (Fischer et al, 2002) similar approach indicate that under climate change, the biggest losses in suitable cropland are likely to be in Africa, whereas the largest expansion of suitable cropland is in the Russian Federation and Central Asia.

Climate change and food supplies

Global and regional weather conditions are also expected to become more variable than at present, with increases in the frequency and severity of extreme events such as cyclones, floods, hailstorms, and droughts (IPCC, 2001). By bringing greater fluctuations in crop yields and local food supplies and higher risks of landslides and erosion damage, they can adversely affect the stability of food supplies and thus food security. How strongly these impacts will be felt will crucially depend on whether such fluctuations can be countered by investments in irrigation, better storage facilities, or higher food imports. In addition, a policy environment that fosters free trade and promotes investments in transportation, communications, and irrigation infrastructure can help address these challenges early on.

Climate change and food utilization

Climate change will also affect the ability of individuals to use food effectively by altering the conditions for food safety and changing the disease pressure from vector, water, and food-borne diseases.

Climate change and access to food

Access to food refers to the ability of individuals, communities, and countries to purchase sufficient quantities and qualities of food. Presently it has been experienced that due to surge in food prices people in the developing countries have put their earnings more than 60% for foods which has jeopardized access to health, education and other aspects that have direct impact on quality of life of masses in these parts of the world. This could be the impact of climate change resulting to the shift of agricultural based population to other forms of daily livelihood.

Quantifying the impacts on food security

It is very likely that climate change would increase the number of people at risk of hunger compared to scenario with reference to no climate change; for instance, it is estimated that climate change would increase the number of undernourished by 5–26%, compared with no climate change or by between 5 million and 10 million and 120 million to 170 million people (Fischer et al, 2002, Sinha et al, 1988). Climate change with respect to food security, on the basis of prediction of mathematical models, has been summarized in a great detail (Sinha et al, 1988 and Sinha SK, 1987). Such models attempt to predict the changes in critical climate elements for a doubling of the CO_2 concentration. Although there is little agreement between various models about the specific magnitudes of the regional changes during the next 50 to 100 years, and details needed for regional planning, there is considerable agreement on the global changes, which may be summarized as follows:

- The lower atmosphere will warm and the stratosphere will cool.
- The annual average global warming will be 1.5 to 4^0 C. This is much greater than any natural climate change. The rise in temperature is, in general, greater in the Northern Hemisphere than in the Southern Hemisphere and increases (by a factor of 2 to 3) pole wards.
- The temperature rise will be greater (by about 50%) in winter than in summer. Consequently, we may expect the production of winter season crops to be more affected than that of summer crops.
- Freeze-free periods will lengthen in higher latitudes so that larger areas may be brought under cultivation, if soil conditions are suitable. The increase in the freeze-free period will depend on the current length of this period, e.g., a 1^0C rise in temperature will lengthen an 80-day freeze-free period by about 20 days but a 120- to 130-day period by only 6 days.
- General warming will be accompanied by a weakening of temperature differences between the equator and the poles, which will affect the atmosphere's general circulation. This could lead to longer dry periods.
- The global average annual precipitation will increase by about 7 to 11%, but its regional and temporal variations are uncertain.
- Relationship between precipitation and evaporation is not likely to change in the lower latitudes. Evaporation will increase more than precipitation in the mid- to higher latitudes.
- Soil moisture conditions will be "wetter" in some regions of the world (35^0 N-35^0S), but "drier" in others, compared with present conditions.
- A sea-level rise is foreseen but its magnitude and time-scale are uncertain. The effects on agriculture in coastal regions could be disastrous.
- Agro-climatic zones will shift poleward (about 100 km per degree of warming).
- The variability of temperature and precipitation may decrease because of the weaker circulation. The regional variations are uncertain.
- Only changes in mean climate conditions are specified by the models. Sizeable uncertainties remain about the timing, intensity and direction of specific effects.

Policy implication for R&D to mitigate climate change

There are ways to mitigate immediate adverse impact of climate change by adopting adequate agronomic practices pertaining to crop production and management. Such practices consisted of narrowing the gap between the maximum and the average national yields of crops would be the main objective of future research and development. Consequently, it would be important to analyze the contribution of different industrial inputs and environmental factors to assess the realizable potential of the genetically superior cultivars. The actual realization of this potential will be governed by the technologies adopted with respect to three factors such as land and water management, crop management, and post-harvest management. The availability of energy will be a significant factor affecting production. Developments in the use of non-polluting, renewable resources of energy will play a significant role in conserving the resource base of agricultural production.

Brief overview of food crisis in nepal with respect to climate change scenario

United Nations (UN) has termed present food crisis as Tsunami and World Bank states that a 20% rise in food prices pushes 100 million people back into poverty. Jean Ziegler, the UN Special Rapporterur on right to food laments that every five seconds a child under 10 dies from hunger and malnutrition. These are the likely scenario of global food crisis of 21st century where UN has put forth Millennium Development Goals (MDGs) to be achieved by 2015. If food crisis remains as such and world does not take care of these alarming situations of food crisis there are likely chances that MDGs *per se* set for developing countries could be nullified as a result of food crisis. FAO classifies Nepal, Bangladesh, Pakistan, Srilanka etc. as severe localized food insecure countries. UN WFP warns 3.8 million (now 3.9 million) people in Nepal face food insecurity due to rise in food prices. Similarly, Nepal Rastra Bank, 2008 (as cited by Khadka, 2008) reports that price rise of edible (grain, cereals, fresh vegetables and pulses only) by 23% within a year and WFP has warned that there will be a 10% price rise every month till next harvesting if India continues ban on rice and wheat export to Nepal (Khadka, 2008). As a result, there will be direct effects in 38 districts (mostly mid and far western hills) as food stock falls short by 50%. The situation of food crisis in Nepal is so alarming that Terai, the grain bowl of Nepal, has indicated food deficits in the current year and the whole of the country will face food shortage if the scenario of food production does not improve substantially. A growing demand of agriculture commodities coupled with their rising prices has placed both opportunity and constraint to agricultural based countries. The opportunity is there because farmers in these countries could get higher price of their produce in one hand and in other hand there is a risk that if government policy is not directed toward producing more foods there is likely danger that food will divert to rich countries where there is ample opportunity of purchasing power of general public. As a result, hunger and malnutrition would loom large in these parts of the agricultural based countries. FAO (2008) has envisaged that the recent rapid increases in the international prices of many basic food commodities have raised many questions from policy-makers, the media, the public, and the farmers who have the opportunity to benefit from the situation. Those who have the most reason to be concerned are the vulnerable people who have to adjust to the consequences of their decreased purchasing power, which in some cases, affect their ability to buy enough food to feed their families. In Nepal, the reverse is true because as of now around 3.9 million people in mid and far western region are facing acute food shortage and people especially children and pregnant women are adversely affected by hunger and malnutrition. Poverty is rife in these regions which is one of the prime reasons of conflict and unrest of people in the country. Government of Nepal is air lifting food from urban areas to these regions to mitigate the problem which is, in long run, making people dependent on outsourcing food. Instead of this practice of air lifting foods from out side, long term strategy of making regional and local food self sufficiency should come as the mitigation strategy of the food crisis in Nepal. All of such consequences have been tried to link with climate change.

Impact of climate change in Nepal could be observed in varying level of climates that are prevalent in diversified topography and vegetation present in Nepal. Broadly there are impacts of climate changes in Nepal; Terai (almost tropical region), mid hills and valley (subtropical region), and mountains and Himalaya (temperate and tundra regions). Nepal is a unique place representing in the form of world climatic laboratory to study impact of climate change. It is reported (Ujaylo FM, 27 June 2009) that there is no snow in the Kapi Himal of mid western region at 15000 feet and pioneer mountaineer Mr. Apa Sherpa, super Sherpa, Campaign Ambassador, and Goodwill Ambassador to Climate Change (2010) observed drastic changes in the climate of the Himalayas regions and speaks “the changes in weather patterns are drastic. It didn’t snow at all during December, January and February, when it should snow heavily, and it finally snowed massively in May, when usually it’s dry.” Apa scaled the Mount Everest 19 times up to June 2009 experienced while climbing the Everest in June 2009 that there was no snow in the Everest trail and he waited snow fall for days at the base camps to scale the Everest for without snow the scaling of the Everest is virtually impossible and there is no chance of kissing the Everest (*Sagarmatha,*) peak, the roof of the world. He broke his own record and scaled the Everest 20th time on 23 May 2010 and noticed that there was stream flowing on top of the Everest by melting ice. What could be the more astounding impact of climate changes in the Himalayan region than this? A country like Nepal could not explain more than this as the impact of climate changes in the Himalayan region- the experience of Apa! These are some of the the serious alarm of climate changes for a poor country like Nepal whose more than 65% population depend on agriculture and more than 32% of GDP comes from the agriculture as well. If the Himalayas 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 platues and finally Europe and whole of Asia-pacific regions of the world 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 is negligible (around 0.02%) against the massive negative consequences of it to her. There should be serious attention of public and private institutions to address climate change issues and its impact on agriculture in general and particular to the developing countries including Nepal whose contribution to climate change is miniscule. Both basic and adoptive researches are a demand of the day to address climate change issues. There are incidences of new pests and diseases in crops and animals which are the basis food for humans and animals as well. In Nepal, negative impacts of climate change are observed for food crops by infection of 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 to decreasing crop productivity. Research institute like Nepal Agriculture Research Council (NARC), university, and labs are facing acute shortage of human resources, logistic and budgetary facilities. 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.

In 2010, Pascal Lamy, Director General, World Trade Organization, admitted that agriculture subsidy would remain at levels up to four times higher than in industry as a contribution to the problem of food security (THT, February 25, 2010). Therefore, it explains that agriculture should get more investment at least four time surge of budget in Nepal to get priority to address food shortage. However, agriculture in

Nepal since seventh five year plan has not received priority from the government as a consequence present food shortage has been looming large. In 2010, Nepal faces food deficit of 0.316 million metric tons due to 0.5 million metric tons decrease of rice production compared to the last year (Republica Daily May 30, 2010). It is worth to increase local productivity of crops instead of air lifting rice to the remote areas where there is food shortage. Therefore, it is anticipated that government of Nepal should give due priority to address local food shortage by providing incentives to boosting local food productivity. This can be done by investing more on local food resources instead of providing transport subsidies to air lift food aids from outside. If such issues are not addressed timely the adverse impact of climate change in Nepal could affect remote areas making food shortage more vulnerable in coming days.

Conclusion

There remains a basic question to be asked that what are the implications of climate change for the world food security system? To answer this question it is necessary to examine the effects of climate change with respect to the regional food production as a result of changes in mean climate as well as the variability of the food production resulting from increased climate variability. In the ultimate analysis, the annual variability of total food production as well as the regional share of production is the determinants of food security. Therefore, from the discussion it is obvious that climate change will affect all four dimensions of food security, namely food availability (i.e., production and trade), access to food, stability of food supplies, and food utilization. The importance of the various dimensions and the overall impact of climate change on food security will differ across regions and over time and, most importantly, will depend on the overall socio-economic status that a country has accomplished as the effects of climate change set in. Essentially all quantitative assessments show that climate change will adversely affect food security. At the same time climate change will increase the dependency of developing countries on imports and emphasize existing focus of food insecurity. Within the developing world, the adverse impacts of climate change will fall disproportionately on the poor. Less is known about the role of climate change for food stability and utilization, at least in quantitative terms. However, climate change will affect those particularly adversely that are still more dependent on agriculture and have lower overall incomes to cope with the impacts of climate change. Climate change is a global phenomenon and effect of climate is applicable to globally. It is obvious that impact of climate change has been experienced in Nepal as well. Therefore, a country like Nepal where agriculture is the backbone should make relevant investment in agriculture R&D and should address issues of climate change in policy level and implementation level without any delay.

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