Economic Impact of Climate Change on Agricultural Sector: A Review

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Abstract
Global warming is the most serious environmental threat of the 21st century. Extreme changes in global temperature over the last few decades have caused devastating natural disasters have immensely impacted on the agricultural sector as agricultural production is highly dependent on weather, climate and water availability, and is adversely affected by weather-and climate related disasters. This review paper summarizes the recent studies focused on (a) understanding and measuring the effect of climate change on the agricultural sector and (b) recent inventions and adaptations to cope up with the negative effects of climate change. The paper attempts to review how climate and agriculture is interrelated. It illuminates the vulnerability of the agricultural sector that depends highly on the climatic variables, like rainfall and temperatures. The exploration of climatic variations in this paper reveals the estimated economic costs of climate change on agricultural productivity of different regions and also gives an insight into how these climatic challenges at present and future can be best tackled in order to maximize agricultural output which in turn is the backbone of food sustainability of the nations worldwide.

Keywords: Climate Change, Economic Impact, Agriculture
JEL Codes: Q18, Q54

1. INTRODUCTION

Climate change is the variation in global or regional climates over time. It reflects changes in the variability or average state of the atmosphere over time scales ranging from decades to millions of years. These changes can be caused by processes internal to the Earth, external forces (e.g. variations in sunlight intensity) or, more recently, human activities. In recent usage, especially in the context of environmental policy, the term "climate change" often refers only to changes in modern climate, including the rise in average surface temperature known as global warming. In some cases, the term is also used with a presumption of human causation, as in the United Nations Framework Convention on Climate Change (UNFCCC, 1994).

Agriculture is the cultivation of animals, plants, fungi, and other life forms for food, fibre, bio fuel and other products used to sustain human life. Agriculture was the key development in the rise of sedentary human civilization, whereby farming of domesticated species created food economic surpluses that nurtured the development of civilization. The study of agriculture is known as agricultural science. Agriculture generally speaking refers to human activities, although it is also observed in certain species of ant and termite (Hölldobler, 1990). The major agricultural products can be broadly grouped into foods, fibres, fuels, and raw materials. In the 21st century, plants have been used to grow bio fuels, biopharmaceuticals, bioplastics, (Brikates, 2007) and pharmaceuticals. Specific foods include cereals, vegetables, fruits, and meat. Fibres include cotton, wool, hemp, silk and flax. Raw materials include lumber and bamboo. Other useful materials are produced by plants, such as resins. Biofuels include
methane from biomass, ethanol, and biodiesel. Floriculture nursery (horticulture), tropical fish and birds for the pet trade are some of the ornamental products.

**Economic impact of climate change:** Uzma Hanif, (2009) stated that climate change impacts the agrarian economies in multidimensional forms, because of their dependence upon the vagaries of nature. The ultimate climate change determines the paths and level of development in the long term. Climate change has raised serious concerns for developing countries to face tremendous social, environmental and economic impacts. As the change in climate is closely linked to food security and poverty of a vast majority of any country’s population, many developing countries are dependent mainly on agricultural sector making it highly vulnerable to the effects of climate change. Agriculture forms the primary sector of any agro-based economy and Mathieu Ouedraogo (2006) rightly mentioned that the activities of the secondary and tertiary sectors depend to a large extent on the activities of the primary sector, for example in the case of cotton and grain production, which is processed and transported by the secondary and tertiary sectors. The primary sector’s activities thus have a ripple effect on the rest of the economy. The whole GDP of any nation develops according to the rhythm of the primary sector.

**Importance of understanding Economic Impact of Climate Change:** Understanding climate change on natural and human based systems has become increasingly important as changing levels of greenhouse gases and alteration in earth surface characteristics bring about changes in the earth’s radiation budget, atmospheric circulation, and hydrologic cycle (Houghton et. al., 2001). The importance of understanding climate change impact on agriculture is essentially evident. The weather and climate intensely influence the productivity of quality agricultural products. Individual weather and climate factors like, solar radiation, heat accumulation, temperature extremes, precipitation, wind, etc, affect both the growth and quality or agro products of high economic value. The importance of understanding the ongoing impact of climate change on agriculture is often underestimated. Domestic policy considerations require that climate change be factored into development activities that are influenced by the weather and climate. At the same time, scientific evaluations of the immediacy of the impact of climate change and the extent of climate vulnerability are essential to the formulation of national negotiating positions at international climate-change negotiations (Jayaraman, 2011). The concern with climate change is heightened given the linkage of the agricultural sector to poverty. In particular, it is anticipated that adverse impacts on the agricultural sector will exacerbate the incidence of rural poverty. Impacts on poverty are likely to be especially severe in developing countries where the agricultural sector is an important source of livelihood for a majority of the rural population. For example, in Africa, estimates indicate that nearly 60–70 percent of the population is dependent on the agricultural sector for employment, and the sector contributes on average nearly 34 percent to gross domestic product (GDP) for every country (Mohamed et al. 2002).

2. **THE RELATIONSHIP AND DEGREE OF ELASTICITY BETWEEN CLIMATE AND AGRICULTURE**

Agriculture and climate are directly related exerting mutual effects. Climate change affects most significantly in agriculture out of the other economic sector because of its worldwide distribution and the strong linkage and dependence of the climate and environmental factors. Thus the effects of climate change on agricultural production impact the socio-economical dimension at both the macro and micro scales (Quasem, 2011). The agriculture sector is a key source of global GHG (Green House Gas) emissions (14 percent or 6.8 Gt of CO2 equation), but with a high technical mitigation potential (5.5-6 Gt of CO2 equation per year by 2030) (Mueller, 2009). It is discovered that 74 percent of emissions from agriculture are in developing countries. Mueller (2009) further notes that agriculture is a sector where mitigation action has strong potential co-benefits for sustainable development in terms of food security and poverty reduction among the 70 percent of the poor living in rural areas involved in environmental services and climate change adaptation like improving agro-ecosystem resilience. The study also reveals that most of the mitigation potential from agriculture could be achieved through soil carbon sequestration (89 percent) and roughly 70 percent could be realized in developing countries. A study by the Netherlands Environmental Assessment Agency (2005) mentioned that the relative fraction of man-made GHGs comes from eight categories of sources, as estimated by the Emission Database for Global Atmospheric Research. The value for each fraction is intended to provide a picture of global annual GHG emissions in
the year 2000. Rohde (2000) reveals that activities relating to agricultural by products and land use and biomass burning, two categories among eight, are contributing 22.5 percent to global GHG emissions. Molua (2006) stated that the basic climatic elements directly influence the spatial distribution of crop types and agricultural systems, because different crops require different amounts of rainfall, humidity, warmth and sunshine. In rain-fed agriculture, climate is the main factor determining crop types and yields. Beyond certain climatic limits, it becomes impossible or disadvantageous to cultivate certain types of crops. The different climate conditions that exist at different altitudes affect agriculture production differently. In another study using Ricardian cross-sectional approach to measure the relationship between the net revenue from growing crops and climate, net revenue is regressed on climate, water flow, soils and economic variables. The resulting regression explains the role that each variable plays today. “We find that net revenues fall as precipitation falls or as temperatures warm across all the surveyed farms. Specifically, the elasticity of net revenue with respect to temperature is -1.3. This elasticity implies that a 10% increase in temperature would lead to a 13% decline in net revenue. The elasticity of net revenue with respect to precipitation is 0.4” (Kurukulasuriy 2006).

3. AFFECTS OF CLIMATE CHANGE ON AGRICULTURE

Impacts of climate variability and change on the agricultural sector are projected to steadily manifest directly from changes in land and water regimes, the likely primary conduits of change. Changes in the occurrence and intensity of droughts, flooding, and storm damage are likely. Climate change is expected to result in long-term water and other resource shortages, worsening soil conditions, drought and desertification, disease and pest outbreaks on crops and livestock, sea-level rise, and so on. Vulnerable areas are expected to experience losses in agricultural productivity, primarily due to reductions in crop yields (Rosenzweig et al. 2002). Climate change and variability affects countries’ economies and households through a variety of channels. Rising temperatures and changes in rainfall patterns affect agricultural yields of both rain-fed and irrigated crops. The unchecked rise of sea levels leads to loss of land, landscape, and infrastructure. A higher frequency of droughts will change hydropower production, and an increase in floods can significantly increase the need for public investment in physical infrastructure (Stern 2006; World Bank 2007; Garnaut 2008; Yu et al. 2010). Depending on countries’ natural conditions and economic structure, climate change affects countries differently. For example, sub-Saharan Africa, is more vulnerable to an increase in climate variability, with projected large losses in their national output (Thurlow 2009). Countries with large delta regions, such as Vietnam, are projected to be hardest hit by rising sea levels, with strong implications for food security and the rural poor (Yu et al. 2010). Countries that are already experiencing water stress, especially those in the Middle East and North Africa, are likely to experience additional declines in agricultural yields, resulting in negative effects on rural incomes and food security (Breisinger et al. 2010). Climate change may also exacerbate climate variability and reduce agricultural production and incomes in countries that depend on annual floods such as Bangladesh or in drought-prone countries such as many in the Middle East (Yu et al. 2010, Breisinger et al. 2010). Long-lasting climate pressures, such as prolonged drought, will also increase the vulnerability of migratory groups to climate change which could be disastrous. Short-term migrants could be forced into becoming more permanent migrants by limiting the scope of areas to move to, resulting in dire consequences such as pressures on land and resources (Desanker, 2002).

Quasem (2011) stated in a study that climate change could reduce crop yield and areas vulnerable to drought could become marginal for cultivation thus posing a threat to national food security and exports earnings. Increasing temperatures will result in enhanced evapotranspiration, leading to a reduction of the water availability. An increase in the magnitudes of the storms will result in an increase in the frequency of floods and flood damage which in turn will increase salt intrusion causing less amount of water available to use in the agriculture. A rise in the air and water temperatures will reduce plant efficiency and power output leading to major economical costs. Geographic distribution limits and crop yield could be modified due to changes in precipitation temperature, cloud cover and soil moisture as well as increases in CO2 concentrations. High temperatures and diminished rainfall reduce soil moisture, reducing the water available for irrigation and impairing crop growth in non-irrigated regions. According to Chamhuri et al., climate change could influence food production adversely due to resulting geographical shifts and yield changes in agriculture, reduction in the quantity of water available for irrigation and loss of land

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through sea level rise and associated salinization. The risk of losses due to weeds, insects and diseases could increase. Physical damage, loss of crop harvest, drop in productivity, vigour and others related to crop potentials are examples of direct and indirect effects of the extreme climate change. Climate change may increase the amount of arable land in high-latitude region by reduction of the amount of frozen lands. IRRI, (2007) on the other hand stated that sea levels are also expected to get up to one meter higher by 2100, as a response to climate variation. A rise in the sea level would result in an agricultural land loss, in particular in areas such as South and South East Asia. Erosion, submergence of shorelines, salinity of the water table due to the increased sea levels, could mainly affect agriculture through flooding of low-lying lands such as Bangladesh, India and Vietnam.

In contrast, interestingly enough, climate change is also expected to result in some beneficial effects, particularly in temperate regions (Mendelsohn et al. 1999). The initial benefits arise partly because more carbon dioxide in the atmosphere reduces “water stress” in plants and may make them grow faster (Long et al., 2006). The lengthening of growing seasons, carbon fertilization effects, and improved conditions for crop growth are forecast to stimulate gains in agricultural productivity in high-latitude regions, such as in northern China and many parts of northern America and Europe. As a direct impact of climate and price change, farmland value is anticipated to increase by 31% while the indirect impacts from different scenarios is expected to increase simulated land value by up to 51%. Results reveal that climate change may not be a big threat for prairie agricultural economics if farmers employ appropriate adaptation strategies such as switching between crops and introducing new crops. Instead, climate change may provide an opportunity for agricultural producers in the prairies to gain from future price and environmental change (Afshin Amiraslany, 2010). Other beneficial implications of climate change include, higher wind speeds in the mid-latitudes that would decrease the costs of wind and wave energy (Breslow and Sailor, 2002). Less sea ice would improve the accessibility of arctic harbours, would reduce the costs of exploitation of oil and minerals in the Arctic, and might even open up new transport routes between Europe and East Asia (Wilson et al., 2004). Warmer weather would reduce expenditures on clothing and food, and traffic disruptions due to snow and ice (Carmicheal, et al., 2004). But initial economic gains from altered growing conditions will likely be lost as temperatures continue to rise. Regional droughts, water shortages, as well as excess precipitation, and spread of pest and diseases will negatively impact agriculture in most regions (Horin, 2008).

4. MEASURING THE ECONOMIC IMPACT OF CLIMATE CHANGE ON AGRICULTURE

The quantity and intensity of the research effort on the economic effects of climate change appears insufficient with the perceived size of the climate problem, the expected costs of the solution, and the size of the existing research gaps (Tol, 2009). Combining local and global climate change scenarios show welfare losses across all rural and urban household groups of between 1.6 – 2.8 percent annually, whereas the poorest household groups are the hardest hit (Breisinger et al., 2011). Early global estimates predict (without consideration of CO2 fertilization effects or adaptation) a 20–30 percent reduction in grain production (Darwin et al. 1995). Based on agronomic research in low latitude countries, Reilly et al. (1994, 1996) approximate global welfare changes in the agricultural sector (without adaptations) between losses of US$61.2 billion and gains of US$0.1 billion in contrast to losses of US$37 billion to gains of US$70 billion with appropriate adaptations in place. Approximation also suggests 4–24 percent losses in production in the developed countries, and 14–16 percent losses in developing countries (IPCC 1996). Murdiyarso (2000) highlights that rice production in Asia may also decline by 3.8 percent of production levels of 2000 (estimated at 430 metric tons) under likely future climate regimes. Lansigan et al. (2000) mentioned that variability in the form of typhoons, floods, and droughts has resulted in 82.4 percent of the total Philippine rice losses from 1970 to 1990. The cost of domestic losses in 1990 alone from climatic events had amounted to US$39.2 million.

With CO2 fertilization and trade effects, one study suggests net gains of $9–10.8 billion (Adams et al., 1993). In another study based on the United States, estimated impacts range from -$4.8 billion to $5.8 billion. The study also shows that climate change results in 38.9–55.3 percent of U.S. land assigned to a new land class, reflecting the new length of the growing season. Net changes in land classes reflect increments in land allocated to crop production, while in many scenarios, land in pasture also increases by
0.7–7.4 percent. The implication is that climate change will increase the total amount of land in agricultural production in the United States, even with 8.6–19.1 percent of cropland abandoned for production (Darwin et al., 1995). Using a dynamic crop model to simulate the effect of heavy precipitation on crop growth and plant damage, from excess soil moisture in order to estimate the impact on U.S. corn production it is found that damages of approximately $3 billion per year are likely to result from climate variability (Rosenzweig et al., 2002). Maddison (2000) finds that landowners are constrained by their inability to costlessly repackage their land. Assuming CO2 doubling, as well as increases in temperature of 1.5 degrees (C), and 7 percent increase in rainfall, results (Etsia et al., 2002) point out that Tunisia is likely to suffer losses in agricultural production of 7–22 percent Even with no climate change, the price of rice would rise by 62 percent, maize by 63 percent, soybeans by 72 percent, and wheat by 39 percent. Climate change would result in additional price increases of 32 to 37 percent for rice, 52 to 55 percent for maize, 11 to 14 percent for soybeans, and 94 to 111 percent for wheat (Nelson 2009). According to some estimates, the overall economic impact of climate change on the agricultural sector could be up to 10 percent of GDP (Hernes et al. 1995). In addition, under-preparedness to increased frequency or lengthening of periods of drought, higher temperatures, and climate variability (for example, extreme events) can be prohibitively costly and can severely undermine expensive long-term investments (Kurukulasuriya 2003).

5. INVENTIONS AND ADAPTATIONS TO COPE WITH CLIMATE CHANGE

Gabre-Madhin et al. (2002) state that technological change can bring about improvement in total factor productivity in two ways: reducing average fixed costs by increasing yields per fixed factor or reducing variable costs by reducing the cost of the technology itself. Smithers and Blay-Palmer (2001) identify two basic types of technological options namely, mechanical and biological, that is important for agriculture. Mechanical innovations include irrigation, conservation tillage, and integrated drainage systems, all of which have contributed significantly to the intensification of agricultural activity and permitted a wider range of agricultural activities than local resources would have otherwise permitted whereas biological options like investment in crop breeding, the promotion of climate-resistant varieties that offer improved resistance to changing diseases and insects, breeding of heat and drought-resistant crop varieties, the use of traditional varieties bred for storm and drought resistance, and investment in seed banks are necessary for success in overcoming vulnerability to climate impacts (Crosson, 1983). Current technological advances in irrigation, such as the use of centre pivot irrigation, dormant season irrigation, drip irrigation, gravity irrigation, and pipe and sprinkler irrigation make this possible (Lewandrowski and Brazee 1993; Reilly 1995; Benioff et al. 1996; Reilly et al. 1996; Downing et al. 1997; Parry et al. 2000).

Adaptation to climate change is a broad issue and needs to be undertaken at many levels. Many of these initiatives are self-funded (Stern 2007). Several studies discussed the issue of currently available supports from government for adaptability of the farmers (Alam et al. 2011d), and required new supports for future adaptability of farmers (Alam et al. 2011e). Adaptation to climate change and mitigation of its damages are presumed to be the best ways to deal with its effects in the short run. There is potential to decrease emissions of other non-carbon GHGs (N2O and CH4) through more efficient use of fertilizers and improved rice and livestock systems as livestock and livestock-related activities such as deforestation and increasingly fuel-intensive farming practices are responsible for over 18 percent of human-made GHG emissions, and 64 percent of global nitrous oxide emissions. The preceding study also reported that worldwide, livestock production occupies 70 percent of all land used for agriculture, or 30 percent of the land surface of the earth (Murad, 2010)

To maintain self sufficiency, the main strategy could be improving management options. The following are the three broad categories with mentioned sub-instruments (Quasem, 2011):

1. Management Related Instruments
   a. Irrigation scheduling and integrated pest management (IPM)
   b. Weather and climate information systems
   c. Higher cropping intensity and Diversification of cropping production on irrigated area
   d. Protected cultivation and Post-harvesting technology
   e. Income stabilization programs due to farmers income loss
2. Infrastructure Related Instruments
   a. Irrigation facilities integration
   b. Storage and milling facilities
   c. Other forms of mechanization
3. Community (CBOs and NGOs) Initiated Instruments:
   a. Small scale capacity building
   b. Credit facilities
   c. Marketing support

Among the most important and direct current adaptations to climate variability are a variety of farm level responses. For example: diversification of crop and livestock varieties, have been supported as having the potential to increase productivity against temperature and moisture stresses (Benioff et al. 1996; Smit et al. 1996; Chiotti et al. 1997; Downing et al. 1997; Baker and Viglizzo 1998). Diversity in seed genetic structure and composition has been recognized as an effective defence against numerous factors like disease and pest outbreak and climate hazards. Delcourt and Van kooten (1995) pointed out several options for addressing impacts on yields and soils from climate impacts, including changing land-use practices, rotating or shifting production between crops and livestock, and shifting production away from marginal areas that can help reduce soil erosion and improve moisture and nutrient retention. Studies also suggest abandonment of land altogether and the cultivation of new land as an effective adaptation option (Kaiser et al. 1993; Lewandrowski and Brazee 1993; Reilly 1995; El-Shaer et al. 1996; Erda 1996; Easterling 1996; Iglesias et al. 1996; Mizina et al. 1999; Parry 2000). Brklacich et al. (2000) suggest that altering the intensity of fertilizer and pesticide application along with capital and labour inputs can reduce risks from climate change in farm production. Farmer adaptation can also involve changing the timing of irrigation (de Loe et al. 1999) or use of other inputs such as fertilizers (Chiotti and Johnston 1995).

In addition, Baker et al. (1998) highlight shifts in biological diversity, species composition and/ or distribution as appropriate adaptation measures. The options also include change in grazing management or in mix of grazers or browsers; varying supplemental feeding; changing the location of watering points; altering the breeding management program; changes in rangeland management practices; modifying operation production strategies as well as changing market strategies. Adaptation measures like the use of vegetative barriers or snow fences to increase soil moisture, or windbreaks to protect soil from erosion are suggested by Easterling (1996) who also claims that changing land topography through land contouring and terracing and construction of diversions and reservoirs and water storage and recharge areas can help reduce vulnerability by reducing runoff and erosion and promoting nutrient restocking in soils. On the other hand, Abidtrup and Gylling (2001) report on the establishment of agro-forestry to mitigate increased risk of soil erosion in some European countries.

6. CONCLUSION

Climate change is a trans-border issue and its occurrence in every part of the world is inevitable. In managing climate change, a few developed countries (who in fact are the major carbon dioxide emitters), have drawn up and implemented relevant policies and strategies to minimize impacts on the economy. Developing or agro-based countries are expected to suffer most from climatic variations. The agriculture sector is the backbone of any agro-based economy and at the same time is the most vulnerable to extreme climate change. Floods and droughts are the most common phenomena or disaster on the extreme side that need to be managed holistically as the impacts are enormous, economically, socially and psychologically to people and nations. More importantly, climate change could affect the sustainability of food supply of the victim states and inflict poverty as a chain reaction. In addressing adverse effect of climate change on agriculture, specific adaptation measures to manage climate change are necessary. Although lots of work has been done in this particular arena, still further extensive research need to be carried out especially by the governments and private sectors of all stakeholder nations to determine and assess the exact economic impact of climate changes on the agricultural sector, and find out applicable remedies available naturally, or that might be designed to minimise the adverse effects of such climatic changes. Special focus need to be placed on formulating a single adaptation technique valid in both short and long term perspectives to
equalise the future climate variation, and how the enormous cost of such adaption can be managed (who would pay?) these are in fact the toughest questions unanswered by existing studies.

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