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CLIMATE CHANGE AND AGRICULTURAL PRODUCTIVITY: A THEORETICAL AND EMPIRICAL REVIEW

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ABSTRACT
Climate change presents highly complex and several challenges for developing countries, particularly for low income countries including malnutrition, hunger, forced migration, poverty and seasonal unemployment. Agriculture is a more vulnerable to climate change. Climate changes causes crop damages, low productivity and high production cost that would lead to decrease income of farmers, high poverty level and inequality, and would reduce the farmer's active involvement in agriculture. This study reviews theoretical and empirical literature on the analysis the impact of climate change on various sector of an economy. Further, discusses the literature pertaining to effects of climate change on agriculture GDP, per capita GDP, per capita income, agricultural productivity and productivity of various crops in developed and developing economies.

KEYWORDS: Agricultural Productivity, Climate Change Estimation Method, Developing Countries, Vulnerability

INTRIDUCTION

I. General Overview of Climate Change in the World

There are several opinions among the researchers regarding climate change and its impacts on agriculture and other sectors of economy. Because climate change and agriculture sector has complex relationship, and higher temperature would influence the production patterns (Bosello and Zhang, 2005). Agriculture is a more vulnerable sector, physically and economically to climate change compared to other sectors of the economy (Gbetibouo and Hassan, 2005). Further, climate change affects all livelihoods, occupying around 40% of the land globally, consuming 70% of global water resources and affecting biodiversity at all scales (Masters *et al.* 2010). Climate changes causes crop damages, low productivity and high production cost that would lead to decrease income of farmers, high poverty level and inequality, and would reduce the farmer's active involvement in agriculture (Alam *et al.* 2011). This study also showed that uncertainty in climatic parameters would cause frequent sickness, diseases, and health hazard to the farmers. Climate change worsens the living conditions for many who are already vulnerable, particularly in developing economies due to lack of assets and adequate insurance coverage (Greg *et al.* 2011). Climate change presents highly complex and several challenges for developing countries, particularly for low income countries including malnutrition, hunger, forced migration, poverty and seasonal unemployment (Arndt *et al.* 2012). Economic structure, geographical and agro-ecological characteristics of the country are also responsible for climate sensitivity.

Moreover, several cross country studies also provide empirical evidence that low-income economies are more vulnerable due to climate change compared to high income countries (Mallikarjuna, 2013; Horowitz, 2009; Lee, 2009; Mendelsohn *et al.* 2006; Cline, 2007; and Zhai Zhuang *et al.* 2009). Mallikarjuna (2013) pointed out that cereal production could be decreased by 10% in developing countries and the number of hungry people would grow by 10-16% or 60-350 million by 2020. Horowitz (2009) undertook a macro level analysis to assess the income-temperature relationship for a cross country comparison using Solow-Swan model with log-log and log-cubic regression model. The study showed that a 10C increase in temperature across countries would cause a decline of 3.8% in world's GDP. Lee (2009) applied a multi-region, multi sector computable general equilibrium model with constant elasticity substitution (CES) production function model to assess the impact of climate change on global food production, prices and land use of crop yield. Projected results of the study under the Intergovernmental Panel on Climate Change (IPCC) Special Report on Emission Scenarios (SRES) of A2, demonstrated that developing economies are more adversely affected due to climate change. The study suggests that crop yields would decrease in developing countries since these countries are located at lower latitude while high latitude economies would benefit in crop yield. Mendelsohn *et al.* (2006) estimated that how per capita GDP and per capita income will be influenced by increase in temperature and precipitation for different income group countries by year 2100. The study showed that poor countries which are located in lower latitude would be in serious situation by climate change; while those countries located at high latitude (richest countries) are likely to benefit. Cline (2007) observed that global agriculture output capacity (including carbon fertilization) would lead to decline approximately by 3% by the year 2080. Agriculture output would decline by 16% if the fertilization effect was not considered, while in India, there would be highest loss of agriculture output accounting for 30% decline amongst South Asian countries. Zhai and Zhuang (2009) examined the potential impact of global climate change on agriculture production and trade using a Computational General Equilibrium Modeling (CGEM) in China. The study demonstrated that climate change would result in a 1.3% decline in GDP and a welfare loss equivalent of 1.1%, whereas the global real GDP would decline by 1.4%, and India would suffer largest GDP loss of 6.2% by 2080. Individual country-wise studies also showed that climate change has several negative implications on price stability, income of farmers, poverty alleviation and food security in most of larger agrarian economies. Onyeji and Fischer (1993) analyzed that climate change has decreased the agricultural productivity, declined consumer incomes, per capita food consumption and raised food prices in Egypt. Pandey (2009) presented that climate change would push crops; livestock and farmers out of their established niches; and it would increase severity of floods and droughts, shorten growth cycles and reduce grain filling rates, and increase incidence and severity of transboundary pests. Tirado *et al.* (2010) mentioned that increase in temperature and changes in rainfall patterns have impacts on the persistence and patterns of occurrence of bacteria, viruses, parasites and fungi, and the patterns of their corresponding food borne diseases. Breisinger *et al.* (2011) also observed that climate change would increase food prices, and increase agriculture GDP in Yemen, but it would cause decrease in real income of landless households and food security level. The study also confirms that rising food prices would increase the agriculture GDP but would reduce the food accessibility power of landless people who are poor.

This study is divided in five major sections and organized as follows: the first section provides the general overview of climate change and its negative implication on agricultural productivity, poverty eradication and food security at global level. The second section deals with the empirical review for impacts of climate change on developed countries. The third section analyses losses of agricultural productivity and crop productivity due to climate change in developing economies. Comprehensive review of literature regarding climate change and its effect on Indian agriculture is given in the section four. Brief summary of earlier studies and gap in literature which inspire us to undertake this study delineated in the last section.

II. Climate Change and Agricultural Productivity in Developed Economies

This section provides the literature review regarding climate change and its effect on agricultural productivity (monetary terms) and productivity of food grain and non-food grain crops (commercial crops) in developed countries. In order to estimate the impact of climate change on agricultural productivity in developed economies, the researchers have used different kinds of methods. Most of researchers applied Ricardian cross section model to evaluate the situation of agricultural productivity in presence of climate change and socio-economic variables using primary data at farming household level and secondary data. Ricardian model is most crucial method that includes the adaption strategies applied by farmers to mitigate the adverse effect of climate change in cultivation. Although, originally the method was proposed by classical economist David Ricardo (1772-1823), that time the model was used to estimate the land value. Mendelsohn *et al.* (1994) estimated economic impact of global warming on land prices using a Ricardian cross section approach in United States. The empirical findings of the study showed that the effect of global warming would vary across counties therefore projected results showed that global warming would be slightly beneficial to American agriculture. Mendelsohn *et al.* (2011) using similar method in two time periods, 1978-82 and 1982-2002, indicated that warming effect was beneficial to farming during, 1978-82, while regression result for time period, 1982 to 2002, implied that warming effect was harmful in U.S. Nastis *et al.* (2012) and Li and Suzuki (2013) applied Cobb-Douglas production function model to estimate the impact of climate change on agricultural productivity in Greek and United States, respectively. Nastis *et al.* (2012) observed that agricultural productivity decreased with increase in temperature, during the last three decades while precipitation was positively associated with agricultural productivity in Greek. Li and Suzuki (2013) indicate that maize production will be affected differently to same climate change scenarios across United States. A large group of researchers also used a stochastic production function model to evaluate the risk increasing or decreasing input (climatic and non-climatic factors) for crop productivity in developed as well developing economies (Kim and Pang, 2009; Chalise and Ghimire, 2013; Carew *et al.*, 2009; Cabas *et al.*, 2010). Kim and Pang (2009) demonstrated that rice mean yield was positively associated with increase in temperature and negatively associated with increase in precipitation while temperature and precipitation were risk increasing input for rice yield variability in Korea. The study suggested that climate change would be challenging to rice producer, consumer and Korean government to adjust in rice price instability and market risk. Chalise and Ghimire (2013) illustrated that temperature has a positive impact on peanut yield while precipitation also has a positive effect on peanut yield up to certain limit however, excessive precipitation would have a negative effect on peanut yield in USA. Carew *et al.* (2009) showed that precipitation and temperature have the positive effect on wheat mean yield while precipitation and temperature have a positive association with wheat yield variability; this implies that both are risk increasing inputs for wheat yield variability in Canada. Cabas *et al.* (2010) examined that climatic factors have a significant impact on mean yield of corn, soybean and winter wheat with the length of the growing season across the crop; and increase in temperature and precipitation would decrease mean yield and increase yield variability in Canada. Finger and Schmid (2007) examined the effect of climatic factors on corn and winter wheat production using a non-linear programming approach in Swiss agriculture.

Empirical result of the study indicated that adaptation activities, yields and yields variability highly depended on climate change and output prices (Luximon and Nowbuth, 2010). They estimate the relationship between food grain crop production, rainfall, temperature and consumption of fertilizers in Mauritius using a correlation matrix model. They find that rainfall and temperature has statistically insignificant positive and negative impact on food crop production, respectively in Mauritius. Based on extensive literature reviewed here it can be understood that climate has negative and significant impact on agricultural productivity. The yield variability of crops is also significantly influenced by climate change in most of the developed countries except USA.

III. Climate Change and Agricultural Productivity in Developing Economies

This section shows that how agricultural productivity and yield of food grain and cash crops significantly gets affected due to climate change in developing countries. How existing researchers have employed various methods to investigate the impact of climate change on mean yield and yield variability of different crops in developing economies. Ricardian model, Cobb-Douglas production model, stochastic production function model, agro-ecological zone model and other models were applied by researchers to estimate the influence of climatic factors and non-climatic variables on agricultural productivity, and mean yield and yield variability of crops. Firstly, we reviewed the studies which have used Ricardian cross-sectional model to estimate the climatic effect on agricultural productivity in developing economies. Ricardian model based study by Fonta *et al.* (2011) indicated that the increase in temperature during summer and winter significantly reduced crop net revenue per hectare land while increase in precipitation in spring season would significantly increase net revenue per hectare in Nigeria. The study also showed that climate change will reduce the net revenue per hectare land in year 2020, 2060, and 2100 under all the scenarios from the Special Report on Emission Scenarios (SRES) model. Ajetomobi *et al.* (2011) showed that increase in temperature will reduce net revenue for dry land rice farms whereas increase in temperature would increase net revenue for irrigated rice farms in Nigeria. Eid *et al.* (2006) observed that a rise in temperature would have negative effects on farm revenue in Egypt. Mano and Nhemachena (2007) estimated that net farm revenues are negatively affected by increase in temperature and positively by increase in precipitation. Speranza and Feres (2010) found that small and large farmers would be equally affected by global warming but if biomass diversity is taken into account than there could be different effects on land value according to categories of farm size in Brazil. Deressa *et al.* (2005) observed that sugarcane production is highly sensitive to climate change and it has a negative impact on sugar production in South Africa. Fofana (2011) showed that land productivity and farm income declines due to climate change, and estimates imply that farm productivity and farm income decrease by 15 to 20% and 5 to 20%, respectively, when if the temperature increases by 1^{0}C in Africa. Kurukulasuriya and Mendelsohn (2008) employed a Ricardian model and provide a future prediction of agricultural productivity by 2020 in 11 countries of Africa. The study illustrated that climate change could have strong negative effect on currently dry and hot locations by 2020. Future prediction of the study suggests that if future warming is mild than crop net revenues can increase by 51% for dryland while net revenue could lead to decrease by 43% if future climate are hot and dry. Kabubo-Mariara and Karanja (2007); Maddison *et al.* (2007) pointed out that African agricultural would be more vulnerable due to variability in climatic parameters. Seo and Mendelsohn (2007) observed that land value and net revenue are sensitive to climate change. Empirical findings of the study indicate that rain-fed farms are more sensitive to temperature while irrigated farms are more sensitive to precipitation in Latin America. Seo and Mendelsohn (2008) estimated that if temperature increases by 1°C than the farmland values decrease on average by US$ 175 on per hectare in South American agriculture (Argentina, Uruguay, Chile, Brazil, Venezuela and Colombia). The study also revealed that South American agriculture is highly vulnerable to climate change and farmers could lose 50% of their revenue by the end of century as increase in temperature. Seo *et al.* (2005) observed the damage of agricultural productivity induced by climate change in Sri Lanka. Empirical result shows that increases in rainfall are predicted to be beneficial as a whole in all five Atmosphere Ocean General Circulation Model (AOGCM) scenarios but increases in temperature are predicted to be harmful. Further, estimates also imply that the effect vary from -11 billion rupees (-20%) to +39 billion rupees (+72%) depending on the climate scenarios. Dry regions would be expected to lose large portions of their current agriculture due to warming while cooler regions are predicted to remain the same or increase their production. Molua (2009) estimated the loss of net farm revenues due to variation in temperature and precipitation in Cameroon. The results indicate that a 7% and 14% decrease in precipitation would lead to decrease net farm revenues by US$ 2.86 billion and US$ 3.48 billion, respectively, while farm net revenue may decrease by US$ 0.79 billion and US$ 1.94 billion with increase in temperature by 2.50C and 50C, respectively, in Cameroon. In Pakistan, Ahmed and Schmitz (2011); Shakoor *et al.* (2011) observed a non-liner relationship between agricultural productivity and climatic factors, the relationship showed that the increases in climate factors would be beneficial to crop farming up to a certain extent, but beyond a certain limit the impacts would be negative. These studies evaluated the loss of farm net revenues due to climate variability. Ahmed and Schmitz (2011) estimation also indicated that the annual loss in farm net revenue could be from US$ 100 to 200 on per hectare with increase in temperature in crop growing season; while Shakoor *et al.* (2011) illustrated that net farm revenue per annum would reduce by Rs. 4180 with 1% increase in temperature. These studies indicated that climate change has a negative and significant effect on agricultural productivity and effect varies on irrigated and non-irrigated farms. In Iran, Vaseghi and Esmaeili (2008) find a nonlinear impact of climatic factors on net revenue per hectare. Acquah and Kyei (2012a) found a linear and non-linear relationship among the climatic factors and mean maize yield in Ghana. The study showed that net revenue on per hectare land would decrease by 41% as increases in greenhouse gases in atmosphere by the year 2100. Yu *et al*

(2010) illustrated that rice production may be reduced by 2.7 million tons by 2015 due to climate change in Vietnam. Based on Ricardian cross-sectional model, these studies suggested that better irrigation facilities would be useful to mitigate the adverse effects of climate change in most of the developing countries (Fonta *et al.* 2011; Ajetomobi *et al.* 2011; Eid *et al*. 2006). Haim *et al*. (2008) also suggested that additional irrigation facilities and application of fertilizers can mitigate the negative consequence of climate change and may reduce farming losses without changing sowing dates in Israel. However, study by Deressa *et al*. (2005) observed that irrigation did not prove an effective option to mitigate the adverse effect of climate change in sugarcane production in South Africa. Whereas, Falco *et al.* (2011) mentioned that household profiles like age and literacy of the households head were the crucial drivers of adaptation to mitigate the adverse effects of climate change on farm productivity and farm net revenues in Ethiopia. Yesuf *et al.* (2008) illustrated that future climate change information, access to credit facility and extension services (both formal and farmer to farmer) would to useful to mitigate the negative consequence of climate change in Ethiopia. Another group of researcher used Cobb-Douglas production model to assess the effect of climate change on agricultural productivity in a cross country and country level analysis. Lee *et al.* (2009) observed that higher temperature and more precipitation in summer season increases agricultural production while South and Southeast Asia would be in risk due to greater fall in temperature. The study concludes that agricultural production would decrease as increase in annual temperature while if rainfall increases than it would get benefited in 13 Asian countries. Kawasaki and Herath (2011) showed that cropped area, solar radiation and temperature are found to be most significant factors for rice cultivation. The study observed that increase in solar radiation and temperature would lead to decrease in rice yield while rainfall effect on rice production was insignificant in Thailand. Mahmood *et al.* (2012) find positive and negative effect of temperature and precipitation on rice yield, respectively, in Pakistan. The study estimates that rice yield would lead to increase by 2.09% and 4.33% with increase in temperature by 10C and 30C, respectively. Similar model was applied by Haim *et al.* (2008) to assess the climate change impact on wheat and cotton yields, and generate the future projection for 2070-2100 using two different scenarios in Israel. The estimates of the study imply that cotton yield decreases with significant economic losses (-240 and -173% in A2 and B2 scenarios, respectively), while wheat yield varies among climate scenarios, it becomes negative under severe scenario changes (from -145 to -273%), but it could benefit under moderate scenarios (-43 to +35%). Linear regression models were also used by various researchers to estimate the influence of climate change on agricultural productivity with primary and secondary data. Jain (2007) assessed the influence of climatic factors in various weather seasons on net revenue in Zambia. Estimates of the study imply that climatic factors have negative impact on net revenue. Mongi *et al.* (2010) observed that agricultural productivity has declined continuous due to decrease in rainfall and increase in temperature in Tanzania. Acquah and Kyei (2012a) illustrated that increase in rainfall and crop area expansion have a positive and statistically significant effect on mean maize yield while mean maize yield was adversely affected with increase in temperature in Ghana. Mary and Majule (2009) used descriptive analysis to investigate the effect of temperature and rainfall on crop and livestock production based on household level field survey in Tanzania. The study observed that there is decrease in rainfall and increase in temperature which has negative effect on crop production and management of different crops. Akintunde *et al.* (2013) applied an Error-Correction Model (ECM) to examine the impact of agro-climatic factors on productivity of cocoa, palm kernel and palm oil crops in Nigeria. The study indicate that rainfall, sunshine, temperature, exchange rate, producer price and GDP have positive and significant influence on cocoa yield while cocoa yield is negatively affected due to increase in humidity. Further, the study showed that exchange rate, humidity, radiation, rainfall, producer price are seen to have positive effect on palm kernel. Sunshine and temperature has a negative association with palm kernel. Palm oil yield is positively influenced by rainfall, radiation, producer price, humidity while radiation, temperature, sunshine and GDP have negative impacts on palm oil yield in Nigeria.

Stochastic production function approach also employed to assess the effect of climatic factors on mean yield and yield variability of crops by various researchers i.e., Poudel *et al.* 2014; Acquah and Kyei, 2012b). These studies indicated that climatic factors have a significant association with mean yield and yield variability of crops. Poudel *et al.* (2014) showed that precipitation and maximum temperature has a positive and significant effect on maize yield, while rice yield is negatively affected by maximum temperature and precipitation in Nepal. The study reveal that increasing precipitation is helpful to decrease rice and wheat yield variability while minimum temperature was found helpful to reduce the rice and maize yield variability. The major finding of the study indicates that mean yield of maize and rice decreases as low precipitation and high temperature. The study also showed that mean yield of these crops was significantly affected by climatic conditions and the effects varied across crops. Acquah and Kyei (2012b) estimated that maize yield is positively associated with crop area and negatively correlated with rainfall and temperature. Estimates imply that increase in crop area and temperature would enlarge maize yield variability while rainfall increase would decrease the maize yield variability in Ghana.

Agro-ecological zone modeling was applied by many researchers to see the effect of climatic factors on agricultural productivity in developing economies. Empirical results based on this kind of analysis also reveal that climate change has negative and significant effect on agricultural productivity in various economies. Benhin (2008) undertook a cross country analysis to assess the impact of climate change on net revenues in South African countries (Burkina Faso, Cameroon, Ghana, Niger, Senegal, Egypt, Ethiopia, Kenya, South Africa, Zambia and Zimbabwe). The study observed that a 1% increase in temperature will lead to decrease of around US$ 80.00in net crop revenues and a 1 mm/month decrease in precipitation will decrease net crop revenues per unit land by around US$ 2.00. Seo *et al.* (2009) showed that hot and dry climate change scenarios will increase the damages in agricultural production. The damages are estimated to reach 27% in the year 2100, whereas in case of mild and wet scenarios, farmers will be benefitted in Africa. In China, Ye *et al.* (2013) estimate the impact of climate change on food crop yield as well as food security and make future prediction using Crop Estimation through Resource and Environment Synthesis (CERES) model. Study results predict that food crop yield would increase by +3–11 % under A2 scenarios and +4 % under B2 scenario during 2030–2050. The study also demonstrated that China would be able to achieve a food production of 572 and 615 million tonnes (MT) in 2030, then 635 and 646 MT in 2050 under A2 and B2 scenarios, respectively.

IV. Climate Change and Indian Agriculture

This section reviews the impacts of climate change on Indian agriculture. In India, numerous studies have found that climate change negatively affects the agricultural productivity (in terms of quantity and monetary) of major food grain and commercial crops. Ricardian cross section model was used by Kumar (2009); Palanisami *et al.* (2010) in India. Kumar (2009) undertook a macro level analysis and observed that climate change would result in 9% reduction in agricultural farm revenues in 16 states of India. Palanisami *et al.* (2010) have undertaken a micro level study to identify the climatic change impact on cropped area and paddy and maize productivity in Godavari river Basin (India). The estimates reveal that cropped area of paddy and maize crops were significantly influenced due to climate change. Further, results imply that rainfall and temperature influences the paddy productivity while maize productivity increases as increase in temperature. The study suggests that intensity of climate change impacts varies across regions. Masters *et al.* (2010) also suggest that it is expected that total farm net revenue may decline between 9-25% for a temperature rise of 2–3.5% in India. Alam (2013) employed Auto Regressive Distributed Lag (ARDL) model and Error Correction Model (ECM) to assess the impact of climate change on agricultural productivity. The study incorporated CO2 emission to capture the impact of climatic factors on agricultural productivity, and observed that climate change has negative impact on agricultural productivity and economic growth in India. Gupta *at al.* (2012) undertook macro level analysis to examine the impact of climate change on rice, sorghum and millet crop productivity using Cobb-Douglas production model for major agriculturally intensive states of India. The study showed that climate change is likely to reduce the yields of rice, sorghum and millet crops. Kar and Kar (2008) applied similar method to investigate the influence of changing rainfall pattern on gross farm revenue per hectare in Orissa. The study observed that gross farm revenue per hectare and income of the poor farmers has declined due to low rainfall. Finally, the study suggested that investment in irrigation would improve farm income. Ramulu (1996) showed that rainfall does not have any significant impact on sugarcane crop in Andhra Pradesh. Kaul and Ram (2009) found that excessive rains and extreme variation in temperature would affect the productivity of jowar crop, thereby incomes and food security of farming families is negatively affected in Karnataka, India. Nandhini *et al.* (2006) mentioned that cultivable land under rice has declined due to scarcity of inputs and scanty rainfall and majority of the population were living under poverty condition in Tamil Nadu (India). Asha *et al.* (2012) also showed that yields of sorghum, maize, pigeon pea (Arhar), groundnut, wheat, onion and cotton has decreased by 43.03, 14.09, 28.23, 34.09, 48.68, 29.56 and 59.96 kilogram per hectare, respectively, in rainfed areas. The study observed that almost 100% and 92.22% of the small and sample farmers, respectively. The study also reported that the reduction in the rainfall was the significant reason for yield reduction in Dharwad district in Karnataka (India). Birthal *et al.* (2014) also observed a negative association of maximum temperature with productivity of rice, maize, sorghum, pigeon pea and groundnut crops while minimum temperature positively correlated with these crops using district-wise panel data in India. The study reported that rainfall also found positive effects on productivity of rice, sorghum, pigeon pea and groundnut crops. Auffhammer *et al.* (2011) estimated the influence of climatic factors on rice yield using linear regression model in India. The study showed that hundreds of millions of rice producers and consumers are facing problem due to climate change. Major finding of study indicated that rice yield would have been 1.7% higher on average if the monsoon characteristics were unchanged since 1960. Based on above review literature it can be concluded that changing rainfall pattern is significant factor that is affecting yield of crops. The study concluded that climatic factors would be beneficial if climatic parameters are unchanged in India. Kumar *et al.* (2011b) observed that climate change has shifted and shortened crop duration in major crops like rice and sugarcane, and it is significantly affected cane productivity in Uttar Pradesh and Uttarakhand. Kumar *et al.* (2011b) mentioned that decline in irrigated area for maize, wheat and mustard in northeastern and coastal regions; and for rice, sorghum and maize, may cause loss of production and food insecurity of population due to climate change in Western Ghats of India. Kalra *et al.* (2008) undertook a state-wise analysis for four states of India, namely Punjab, Haryana, Rajasthan and Uttar Pradesh. The study concluded that wheat, mustard, barley and chickpea production has decreased as variation in seasonal temperature. Ninan and Bedmatta (2012), based on their cross section analysis of crops, mentioned that impact of climate change will vary across crops and across regions. The study also observed that increase in temperature is most responsible cause for decline in agricultural production of various crops in different parts of India. Another group of researchers employed crop simulation model to predict the productivity of crops (Kumar and Parikh, 2001; Kapur *et al.* 2009; Haris *et al.* 2010; Srivastava *et al.* 2010). These all the studies have projected that productivity of various food and non-food grain crops would decline in different scenarios (based on IPCC estimated scenarios) in India. Saseendran *et al.* (2000) found that increment in temperature by 50C can lead to continuous decline in the yield of rice and every one degree increment of temperature will cause 6% decline in yield in Kerala (India). Simulation model was used by Kumar and Parikh (2001) for rice and wheat crops, and projected that large-scale changes in climate would lead to significant reductions in crop yields, which in turn would adversely affect agricultural production by 2060, and may affect the food security of more than one billion people in India. Attri and Rathore (2003) observed that wheat yield is increased by 29-37% and 16-28% under rainfed and irrigated conditions, respectively in different genotypes under a modified climate in northwest India. But further increase in temperature by 30C will reduce the beneficial effect of enhanced CO2 on wheat yield. The study also suggests that changes in sowing time and selection of genotype could be useful to mitigate the potential impact of climate change. CERES-Rice and CERES-Wheat model applied by Hundal and Kaur (2007), concluded that an increase in minimum temperature by 1 to 30C from above normal has to decline productivity of rice and wheat by 3% and 10%, respectively, in Punjab. CROPGRO-Soybean model used by Bhatia *et al.* (2008) showed that soybean productivity is adversely affected with soil moisture conditions and water lodging problems in 21 major soybean producers regions in India. Kapur *et al.* (2009) suggest that projected surface warming and changing in rainfall pattern may lead to decrease in arable land and crops yields by 30% by the mid-21st century; as a result, there could be higher pressures on agriculture output in India. Srivastava *et al.* (2010) found that climate change will reduce monsoon sorghum productivity by 14% in central zone (CZ) and by 2% in south central zone (SCZ) by 2020. The study suggests that yields are likely to be affected more in 2050 and 2080 scenarios; climate change impacts on winter crop are projected to reduce yields by 7%, 11% and 32% by the year 2020, 2050 and 2080, respectively, in India. Haris *et al.* (2010) found that rice production may decrease by 31% in 2080 due to climate change in Bihar (India). Geethalakshmi *et al.* (2011) concluded that productivity of rice crop has declined by 41% with 40C increase in temperature in Tamil Nadu (India). Srivastava *et al.* (2012) mentioned that change in global climate is a matter of serious concern to sugarcane cultivators for sustainable development of the crop; and sugarcane is very sensitive to temperature, rainfall, solar radiations etc., therefore, a significant effect on its production and sugar yield is expected to decline in future.

V. Summary and Concluding Remarks

This study provides the extensive literature review regarding climate change and its impact on per capita gross domestic product (GDP), per capita income, agriculture GDP, agricultural productivity and yield of individual crops in a cross country analysis. In the first section, we have reviewed of the theoretical and empirical literature on climate change, most of studies show that there is significant and negative effect on all sectors of economy as indicated that through gross domestic product (GDP), per capita income, agricultural productivity and food security at global level. The second section provided empirical results estimating the impact of climatic factors on agricultural productivity in developed countries while in the third section the studies based on empirical analysis for developing economies have been discussed. The empirical finding estimating effects of climate change on Indian agriculture are given in fourth section. Based on existing literature we understand that agricultural sector is very sensitive to climate change throughout the world. Most of the studies give a clear indication that climate change decreases agricultural productivity or net revenue in the different regions of India, other developing and developed countries. Climate change in future may increase the food problem, and can decrease the employment opportunities and increase poverty in India. In India, a number of studies estimated the effect of climate change on various crops. Most of studies showed that climate change has decreased the agricultural productivity or net revenue of most of food grain crops in different regions of India. However, we could not find any study which evaluates the impact of climatic factors on mean yield and yield variability of all the major food grain and cash crops (commercial crops) at macro level in India. Based on this gap in existing literature we attempt to conduct current study that investigating the effect of climatic factors on mean yield and yield variability of various crops in two time period (sowing and growing time of each crop) for thirteen major states of the country.

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