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Climate Change and American Agriculture

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Abstract: **Climate change is no more an environmental concern. It has emerged as the biggest developmental challenge for the planet. Its economic impacts, particularly on the poor, make it a major governance issue as well. Changing weather patterns, including less predictable seasons and increasingly erratic rainfall, is one of the most important but least understood impacts of climate change. Long-term and seasonal weather patterns are critical to the viability of many natural resource-dependent livelihoods. The onset and duration of rainy seasons; the quantity of rainfall; its variability and even intra-seasonal rainfall shape farmers' decisions about sowing and harvesting, as well as the success or failure of their crops. Therefore, it is of great concern that many small landholding farmers and pastoralists report marked changes in the timing, quality and quantity of rainfall. Their observations are striking for several reasons, including geographic scope and the consistency of described changes. Climate change is worsening the odds of longstanding risks, such as heat stress, insufficient or too much rain at crucial moments in the plant cycle, in addition to pests and diseases. These interact with a range of escalating stresses on rural livelihoods, that is, land pressure, soil erosion, deforestation and depleted water resources that would exist regardless of climate change. Because of climate change, agriculture is doubly vulnerable. Hence the present study will look in to problems facing by farmers community as a result of climate change.**

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1. INTRODUCTION

Climate change is a phenomenon being experienced by the mankind since its origin on the earth. The Planet earth is going through this phenomenon ever since its birth. It is also a driving force of evolution that life on earth has undergone over the last million of years. Climate change necessarily brings about changes in the weather conditions. There is reason to believe that climate change could affect agricultural productivity, and cause increased health hazards and submergence of lands due to rise in the sea level to name a few. Climate change is the net result of many factors caused by continuous evolution of Planet Earth through many geological eras. However, there is growing concern about manmade developments causing, even if partially or insignificantly, the climate change outcomes. The industrialization that started from the late 17th century is believed to have accelerated the process of climate change by emissions of Greenhouse Gases (GHGs) to the atmosphere. The observed levels of GHGs have perhaps nearly crossed tolerance levels in the atmosphere so that the survival for many animal and human species is at stake, while developmental needs of human race are contributing to factors like deforestation, urbanization etc., that can hasten the process of climate change.

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as follows: "climate change refers to a change in the state of the climate that can be identified by changes in the mean or variability of its properties and that persists for extended periods, typically decades or longer".

Awareness on the impact of climate change has been increasing since 1960 when a group of people gathered together protesting against a polluting industry in Great Britain. The thinkers and social scientists have recognized the impacts of climate change since then and a movement to save the earth and the precious life on it gained momentum. The Stockholm Conference in the year 1972 was the first international recognition and manifestation of the urgency to address climate change as it affects both the developed and developing countries, though, the degree of impact could vary. The atmosphere is a global public good and it is commonly shared by all living beings in the earth's ecosystem. The awareness on the degradation of the environment and its impact on the climate system and the natural resources have gained momentum after the efforts of the United Nations, especially after the Stockholm Conference held during June, 1972. The Stockholm conference recognized the concept of 'Sustainable Development' and the impact of development and industrialization on the environmental quality of a nation. This conference led to the formation of the United Nations Environment Programme (UNEP).

United Nations Statistics Division (UNSD) recognized the subject of Climate Change as one of its priorities in the Environment Statistics. Climate Change comes under the ambit of the UN framework Convention on Climate Change (UNFCCC) wherein different countries are required to report their Green House Gases (GHGs) emission to the UN. There is also Inter Governmental Panel on Climate Change (IPCC) which reports to UNFCCC. With the financial assistance from UNEP, the UNSD brought out a framework for the collection of data on environment and related variables in 1984, called 'Framework for the Development of Environment Statistics' (FDES). FDES sets out the scope of environment statistics by relating the components of the environment to information categories that are based on the recognition that environmental problems are the result of human activities and natural events reflecting a sequence of action, impact, and reaction. In 1995, UNSD brought out a list of environmental indictors which evolved through the studies undertaken by them in the participating countries and in collaboration with the Inter-Governmental Working Group on Advancement of Environment Statistics. The FDES, however, covers most of the environmental indicators which are also related with climate change. It is therefore difficult to segregate climate change as a separate subject outside the domain of environment statistics.

2. OVERVIEW OF LITERATURE

Lonergan (1998) estimates that India's climate could become warmer under the conditions of increased atmospheric CO2. Climate change projections made up to the year 2100 for India indicate an overall increase in temperature by 2 to 4 °C, with no substantial change in precipitation (Kavikumar, 2010). However, different regions are expected to experience variations in the amount of rainfall;

Kumar and Parikh (1998) examine adaptation options while estimating the agricultural impacts. The relationship between farm level net revenue and climate variables is estimated using cross-sectional data in India. The authors demonstrate that even with adaptation by farmers of their cropping patterns and inputs in response to climate change, losses would remain significant. The loss in farm-level net revenue given a temperature rise of 2°C–3.5°C is estimated to range between 9 percent and 25 percent. Kumar and Parikh (1998) projected a 30–35 percent reduction in rice yields for India given a similar temperature increase (or losses in the range of US$3–4 billion). Moreover, the authors conclude that controlling for yearly weather deviations did not appear to make a significant difference, thereby suggesting that various other factors, such as government policy and prices, were having a major influence on variations in net revenues.

Mehta D.R., (2002) analysed the weekly rainfall data for 39 years (1958-1996) recorded at Main Dry Farming Research Station, G.A.U., Targhadia, for seasonal and weekly periods, weekly rainfall probabilities and yield prediction models using rainfall and productivity (1960-1995) worked out. As per the study the mean seasonal rainfall was 567 mm (CV 52 %) which received in 27 rainy days. The seasonal rainfall indicated that there is 33 % chance of drought with variable intensities and 38 % chance of getting more than normal rainfall. The mean weekly rainfall was 26 mm with a CV of 73 %.Initial probabilities exceeded P=0.6 of receiving> 20 mm rainfall/ week was observed in mw 27 and CV was also low. Sowing of Kharif crops should be undertaken during this period. Significant and positive correlation between yield and rainfall was observed for groundnut, pearlmiIlet and sorghum. The predictability of productivity of crops using seasonal rainfall is low at the centre for all the crops except groundnut which explained 56 % variation in productivity.

Rupa Kumar et al. (2003) concluded that under future scenarios of increased greenhouse gas concentrations (GHG) indicate marked increase in both rainfall and temperature into the 21st century, particularly becoming conspicuous after the 2040s in India. Over the region south of 25^0 N (south of cities such as Udaipur, Khajuraho and Varanasi) the maximum temperature will increase by 2–4^0C during 2050s. In the northern region the increase in maximum temperature may exceed 4^{0}C. This study also indicates a general increase in minimum temperature up to 4^{0}C all over the country, which may however exceed over the southern peninsula, northeast India and some parts of Punjab, Haryana and Bihar. There is an overall decrease in number of rainy days over a major part of the country. This decrease is more in western and central part (by more than 15 days) while near the foothills of Himalayas (Uttaranchal state) and in northeast India the number of rainy days may increase by 5–10 days. However, increase in GHG may lead to overall increase in the rainy days intensity by 1–4 mm/day except for small areas in the northwest India where the rainfall intensities decrease by 1 mm/day.

Shukla, P.R et al (2003) predicts that either direct effects due to changes in temperature, precipitation or CO_2 concentrations or indirect effects through changes in soils, distributions and frequency of infestation of pests, water stress, etc. there will be decline in GDP for India. The adaptability of farmers in India are severely restricted by the heavy reliance on natural factors and the lack of complementary inputs and institutional support systems which adds to the worsening of the scenarios.

Krishna Kumar K. et.al. (2004) in their paper presents an analysis of crop–climate relationships for India, using historic production statistics for major crops (rice, wheat, sorghum, groundnut and sugarcane) and for aggregate food grain, cereal, pulses and oilseed production. Correlation analysis provides an indication of the influence of monsoon rainfall and some of its potential predictors (Pacific and Indian Ocean sea-surface temperatures, Darwin sea-level pressure) on crop production. The study reveals that all-India annual total production (except sorghum and sugarcane), and production in the monsoon (except sorghum) and post-monsoon seasons (except rice and sorghum) were significantly correlated to all-India summer monsoon rainfall. Monsoon season crops (except sorghum) were strongly associated with the three potential monsoon predictors. Results using state-level crop production statistics and subdivisional monsoon rainfall were generally consistent with the all-India results, but demonstrated some surprising spatial variations. Whereas the impact of sub-divisional monsoon rainfall is strong in most of the country, the influence of concurrent predictors related to El Nino–southern oscillation and the Indian Ocean sea-surface temperatures at a long lead time seem greatest in the western to central peninsula.

Mall et al. (2006) provide an excellent review of climate change impact studies on Indian agriculture mainly from physical impacts perspective. The available evidence shows significant drop in yields of important cereal crops like rice and wheat under climate change conditions. However, biophysical impacts on some of the important crops like sugarcane, cotton and sunflower have not been studied adequately.

World Bank (2008) climate change is affecting agricultural regions throughout the world. It has been estimated that the overall economic impact on agriculture could be up to 10 percent of GDP. The countries that are most affected by climate change will have to increase their involvement in international trade as their environment worsens (and they become unable to adequately provide for themselves). Economic reforms that would help countries negatively affected by climate change could include the introduction of flexible land-use policies and the elimination of subsidies. Increased access to financial services such as credit, marketing systems, training and irrigation would also mitigate the impacts.

Guiteras (2009) studies temperature and precipitation effects in India, and uses a 40-year district-level panel to estimate the sensitivity of yields to climate changes. The study then predicts climate change effects beyond 2010 under a variety of climate change scenarios generated by external models. However, these results are averaged over the crops studied, and evidence suggests that crops differ in their sensitivities to climate changes. Thus, if farmers make crop choices partly in response to their suitability to regional climate conditions, these results may overestimate yield reductions.

Due to changes in rainfall pattern during the Kharif season (crops which are sown in the rainy season and harvested in the autumn season, or monsoon crops) and temperature variations in the Rabi season (crops sown in the winter and harvested in the spring, or winter crops), changes in the crops and crop rotations have been observed in Chhattisgarh. For example, the cultivated area under rice in the state is decreasing continuously. Because of the decreasing rainfall pattern, rice farming is failing in fragile ecosystems, for example upland areas. Similarly, during the Rabi season, the area of wheat is showing a decreasing trend (Sastri, 2009).

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The 4x4 Assessment Report by the Ministry of Environment and Forests (MoEF) (Kulkarni et al., 2010) provides information about the monsoon rain, temperatures and extreme events in the past as well as plausible scenarios for the future in all India. The mean annual minimum temperature has significantly increased by 0.27 °C per 100 years during the period 1901–2007. The number of heavy rainfall events is increasing almost over the entire landmass of the country. Moreover, the frequency and intensity of extreme events defined as one-day maximum precipitation shows an increasing trend everywhere except some northern parts of the country. A 10 per cent increase in the monsoon rainfall over central and peninsular India is projected in the 2030s. In addition, a 1.5-2 °C warming in the annual mean temperature over the Indian landmass is projected, while winter (Nov – Feb) and spring (Mar – Apr – May) seasons show relatively higher warming (Kulkarni et al., 2010).

Lobell et al (2011) examines a 20-year country-level panel to estimate historical global impacts of temperature and precipitation trends on crop yields, and find that changes have reduced yields for some crops. However, using country-level data may overlook climatic differences within each country, and could overstate yield losses if farmers in regions more prone to harmful climate changes for affected crops are less likely to grow those crops, or employ differential production processes.

Yunous Vagh (2012) in his case study employed both qualitative and quantitative methods for the analysis of geographic data in an agricultural context. The geographic data was made up of land use profiles that were juxtaposed with previously captured rainfall data from fixed weather stations in Australia which was interpolated using ordinary krigeing to fit a grid surface. The resultant stochastic annual rainfall profiles for a selected study area within the South West Agricultural region of Western Australia were used to identify areas of high crop production. The areas within the study area were spatially scaled to individual shires. The rainfall was sampled for the years 2002, 2003, 2005 as a mix of low and high rainfall and high production attributes. The patterns suggested that crop production was closely linked to the annual rainfall for some shires, with location being of significance at other shires.

3. CLIMATE EFFECTS ON U.S. AGRICULTURE

Agricultural systems are primarily defined by prevailing spatial and temporal distributions of climatic and edaphic (soil-related) conditions. As such, changes in key climate variables (e.g., seasonal temperatures or precipitation patterns) can result in changes-perhaps significant – in the mix of commodities produced and the systems and technologies that farmers employ to produce them.

Climate change presents a novel challenge to U.S. agriculture because of the sensitivity of agricultural system response to climatic variability and the complexity of interactions between agriculture and the global climate system. Interactions within the agricultural social-ecological system can result in synergistic effects that dampen or amplify the system response to climate change and complicate development of effective mitigation and adaptation options for U.S. agriculture. Developing the knowledge needed to manage agricultural production in a changing climate is a critical challenge to sustaining U.S. agriculture in the 21st century.

While the U.S. agricultural system has the ability to respond to changes or fluctuations in markets, technology, and the environment to a great degree, individual agricultural products differ in their ability to adapt to changing climate conditions. For example, crops have different cardinal temperatures – the critical temperature range for ideal lifecycle development. These vary by species and between vegetative and reproductive growth stages. Basic temperature responses by crops range from a base-temperature requirement, i.e., the point at which growth begins, and a temperature maximum where growth ceases. Between these extremes exists an optimum temperature where plant growth is fastest. In general, optimum temperatures are lower for the reproductive stage than the vegetative stage, i.e., plants are less able to tolerate high temperatures during the reproductive stage. Increasing temperature generally accelerates progression of a crop through its life-cycle (phenological) phases, up to the species-dependent optimum, above which development (node and leaf appearance rate) slows. Temperature increases projected for the United States under high and low scenarios of future GHG emissions are therefore an important factor in projecting future U.S. agricultural productivity.

However, increasing air temperature is only one factor to consider under current and future climate change scenarios; local management practices such as irrigation will also influence effects on agriculture. For example, amply irrigated plants growing under arid conditions create microenvironments that are 10°C cooler than ambient air temperature due to evapotranspiration cooling. Variables such as solar and reflected long-wave radiation, wind speed, air humidity, and plant stomatal conductance also affect to what degree temperature will influence crop growth and development. Many climatic factors affect agricultural performance, and a complete understanding of climate change effects on U.S. agriculture requires an understanding of these variables and how they interact.

Like temperature, precipitation has a direct influence on agriculture. In many areas of the Nation, precipitation is projected to increase, particularly in northern regions, but the incidence of drought is also expected to increase in some areas, and changes in timing and rain/snow mix may increase the management challenge of delivering water to crops at the right time through irrigation systems and practices. The intensity of precipitation events is also expected to increase. Excess precipitation, both in the form of short bursts or through increased amounts over longer episodes, can be just as damaging as too little precipitation, leading to increased erosion and decreased soil quality. Increased evapotranspiration due to warmer temperatures can result in less available water – even with increased precipitation – especially in soils with limited soil water holding capacity. Corn is susceptible to excess water in the early growth stages, which can result in reduced growth or even plant death, while deficit soil water leads to less growth and yield if the stress occurs during the grain filling period of growth.

In addition to their direct effects on plants, changes in temperature and precipitation also affect the amount of water in the atmosphere. With increases in water vapor, cloud cover is expected to increase, leading to a decrease in incoming solar radiation. This effect has already been observed in the solar radiation record around the world. Stanhill and Cohen (2001) observed a 2.7 per cent reduction per decade during the past 50 years, with the current solar radiation totals reduced by 20 W m-2. Changes in solar radiation will directly affect crop water balance and evapotranspiration and have less effect on crop productivity due to other factors limiting productivity (e.g., water and temperature) (Hatfield et al. 2011). In a later, U.S.-centered study, Stanhill and Cohen (2005) evaluated data from across the United States for sunshine duration and global irradiance (solar radiation), finding that after 1950 there has been a decrease in solar duration, with sites in the Northeast, West, and Southwest showing notable decreases. They suggested that more detailed solar radiation records will be required to quantify temporal changes in solar radiation related to cloudiness and aerosols. Reduction in solar radiation in agricultural areas in the last 60 years as revealed by models (Qian et al. 2007) is projected to continue (Pan et al. 2004) due to increased concentrations of atmospheric GHGs, which may partially offset acceleration of plant growth. A study on solar radiation by Medvigy and Beaulieu (2011) examined the variability in solar radiation around the world. They concluded there was an increase in solar radiation variability that was correlated with increases in precipitation variability and deep convective cloud amounts that may affect solar energy production and terrestrial ecosystem photosynthesis. Any change in solar radiation resources under climate change will affect the agricultural system.

Finally, changes in CO2, temperature, precipitation, and radiation over the next century will be accompanied by other changes in atmospheric chemistry that have implications for agriculture. One of the most significant of these is expected changes in concentrations of ground level ozone. The number and complexity of these biophysical interactions demonstrates the necessity of systemic analyses of potential climate effects on agriculture. All of the factors mentioned above will affect U.S. agriculture over the coming century, but their ultimate effect will also depend on social and economic feedbacks.

4. SPECIFIC IMPACTS

In North America, over past some decades, economic damage from severe weather has increased drastically. The U.S.A. and Canada will experience climate changes through direct effect of local changes (*viz*. temperature, precipitation and extreme weather events) and also through indirect effects. North American agriculture will be exposed to many severe weather extremes from time to time. The study in North America reveals that moderate climate change is likely to increase yield for rainfed agriculture by 5 to 20 per cent. It has been observed in Canada that the length of vegetation growing has increased by 2 days per decade since 1950. Table 1 gives the area, harvest and yield per acre of important crops in USA during 2015 and 2016.

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Table 1: Crop Area Planted and Harvested, Yield, and Production in Domestic Units – United States: 2015 and 2016

Crop	Area planted (1,000 acres)		Area harvested (1,000 acres)		Yield per acre		Production (1,000 acres)	
	2015	**2016**	**2015**	**2016)**	**2015**	**2016**	**2015**	**2016**
Rice	2,625	3,150	2,585	3,097	7,472 (in pounds)	7,237 (in pounds)	193,148	224,145
Cotton All	8,580.5	10,074.5	8,074.9	9,521.7	766 (in bales)	855 (in bales)	12,888.0	16,958.5
Sorghum	8,459	6,690	7,851	6,163	76.0 (in bushels)	77.9 (in bushels)	596,751	480,261
Soybean	82,650	83,433	81,732	82,736	48.0 (in bushels)	52.1 (in bushels)	3,926,339	4,306,671
Corn	88,019	94,004	80,753	86,748	168.4 (in bushels)	174.6 (in bushels)	13,601,964	15,148,038

Source: United States Department of Agriculture Crop Production, 2016 Summary, National Agricultural Statistics Service, January 2017, pp.101-102.

Corn for grain production is estimated at 15.1 billion bushels, down 1 percent from the November forecast but up 11 percent from the 2015 estimate. The average yield in the United States is estimated at 174.6 bushels per acre. This is down 0.7 bushel from the November forecast but 6.2 bushels above the 2015 average yield of 168.4 bushels per acre. Area harvested for grain is estimated at 86.7 million acres, down slightly from the November forecast but up 7 percent from 2015.

Sorghum grain production in 2016 is estimated at 480 million bushels, up 4 percent from the November forecast but down 20 percent from the 2015 total. Planted area for 2016 is estimated at 6.69 million acres, down 21 percent from the previous year. Area harvested for grain, at 6.16 million acres, is down 22 percent from 2015. Grain yield is estimated at a record 77.9 bushels per acre, up 1.4 bushels from the previous forecast and up 1.9 bushels from 2015.

Rice production in 2016 is estimated at 224 million cwt, down 5 percent from the previous forecast but up 16 percent from the revised 2015 total. Planted area for 2016 is estimated at 3.15 million acres, up 20 percent from 2015. Area harvested, at 3.10 million acres, is also up 20 percent from the previous crop year. The average yield for all United States rice is estimated at 7,237 pounds per acre, down 256 pounds from the previous forecast and 235 pounds below the United States average of 7,472 pounds per acre.

Soybean production in 2016 totaled a record 4.31 billion bushels, down 1 percent from the November forecast but up 10 percent from 2015. The average yield per acre is estimated at a record high 52.1 bushels, 0.4 bushel below the November forecast but 4.1 bushels above the previous record yield in 2015. Harvested area is up 1 percent from last year to a record 82.7 million acres.

All cotton production is estimated at 17.0 million 480-pound bales, up 3 percent from the December forecast and up 32 percent from 2015. The United States yield is estimated at 855 pounds per acre, up 34 pounds from the December forecast and up 89 pounds from last year. Harvested area, at 9.52 million acres, is down 1 percent from the December forecast but up 18 percent from last year.

5. CONCLUSION

Over last century, yields of major crops in USA have increased (but as a result of effect of multiple factors *viz.* technology, fertilizer use, seed stocks, management techniques and also due to climate change). Hence, vulnerability of American agriculture to Climate Change is multi-dimensional, which is determined by interactions among various factors. Unsustainable land use practices may tend to increase the vulnerability of agriculture in USA great plains to climate change.

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