Impacts of Climatic Changes on Agriculture in India and Mitigation Strategies

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Abstract- Agriculture and climate change are deeply intertwined. The serious impacts of climatic changes on biotic and abiotic resources are being witnessed world over. It has drastically curtailed the availability of various resources on the earth, especially water. Climate change affects agriculture through changes in average temperatures, rainfall; onslaught and gravity of pests and diseases; changes in contents and concentrations of atmospheric gases ;changes in the nutritional parameters of some foods; and changes in sea level. The adverse effects of climate change are unabatedly adding pressure on our agriculture system which is ,as such, crippling under rising demands for food owing to population explosion. The per unit yields are expected to be lower than without climate change because of changes in temperatures, crop water requirements, water availability and quality. Climate change is expected to negatively affect both crop and livestock production systems in most regions of India. A range of policies and practices can reduce the risk of negative climate change impacts on agriculture.

Keywords- Agriculture productivity, Climate change, Rainfall, Temperature

I. Introduction

Later half of the 20th century has witnessed heating up of earth's atmosphere due to unabated rise in temperature. The primary cause of this rise in temperature is attributed to accumulation of greenhouse gases(GHGs) in the atmosphere. Anthropogenic sources of GHGs primarily include emissions from power, industry and agriculture sectors; extensive deforestation and changes in land use management practices. The GHGs predominantly comprise of carbon dioxide (CO_2), methane (CH_4),Nitrous oxide(N_2O). They trap the outgoing Infra Red(IR) radiations from the earth's surface and consequently raise the temperature of the atmosphere. Climate model projections summarized in the IPCC Fifth Assessment report indicated that during the 21st century, the global surface temperature is likely to rise a further 0.3 to 1.7 °C (0.5 to 3.1 °F) in the lowest emissions scenario, and 2.6 to 4.8 °C (4.7 to 8.6 °F) in the highest emissions scenario. In the last century, Earth's average surface temperature rose by 0.74°C. The rate of warming almost doubled in the last half of this period (0.13°C per decade in the later half of century as against 0.07°C per decade in earlier part of century)(Figure 1). The Inter-Governmental Panel on Climate Change has projected the temperature increase to be between 1.1 °C and 6.4 °C by the end of the 21st Century [1]. The climatic changes are expected to influence and exacerbate the rising demands of food supply for the ever growing population of India. Agriculture production is dependent on multitude of factors including seed quality, sowing time and methods, farming practices and most importantly the climatic conditions. Non-conducive climatic conditions such as high temperatures , erratic precipitation pattern and increased CO_2 concentration are expected to significantly impact crop growth and productivity. The increase in temperature reduces crop duration, increases crop respiration rates, alters photosynthesis, affects the survival and distribution of pest populations, hastens nutrient mineralization in soils, decreases fertilizer-use efficiencies and increases evapo-transpiration rate. India will also begin to experience more seasonal variation in temperature with more warming in the winters than summers [2,3].

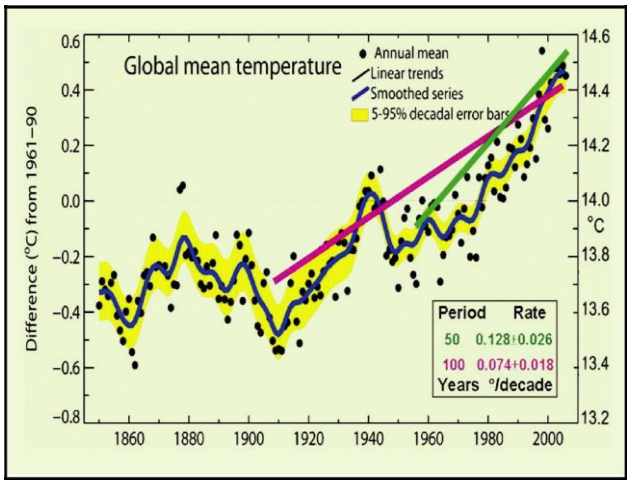

Figure 1. Trends in global temperature over the years (IPCC, 2007)

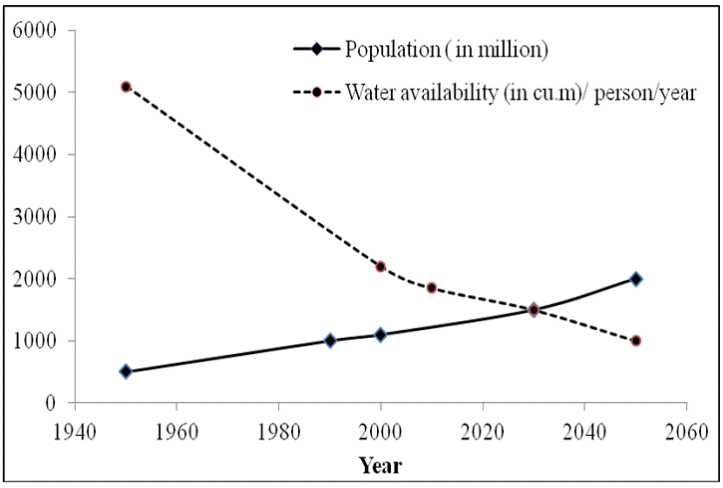

Figure 2: Observed and projected decline in per capita average annual freshwater availability and growth of population from 1950 to 2050

In the forthcoming days, predictions by various climate models point towards more extreme weather conditions, increased number of droughts, heavy rainfall and storms in agricultural production regions. Such extreme weather conditions will influence and impose severe hazards associated with crop failure. Water is the most critical domestic, industrial and understood in right perspective. A decline has been projected in mean per capita annual freshwater availability and growth of population from 1951 to 2050 [4] as shown in Figure 2. Global climatic changes can affect agriculture through their direct and indirect effects on the crops, soils, livestock and pests (Table 1).

Table 1. Potential impacts of climate change on different sectors of agriculture

Sector	Impact
Crop	• Increase in ambient CO_2 concentration is beneficial since it leads to increased photosynthesis in several crops, especially those with C3 mechanism of photosynthesis such as wheat and rice, and decreased evaporative losses. Despite this, yields of major cereals crops, especially wheat are likely to be reduced due to decrease in grain filling duration, increased respiration, and / or reduction in rainfall/irrigation supplies. • Increase in extreme weather events such as floods, droughts, cyclones and heat waves will adversely affect agricultural productivity. • Reduction in yields in the rainfed areas due to changes in rainfall pattern during monsoon season and increased crop water demand. • Incidence of cold waves and frost events may decrease in future due to global warming and it would lead to a decreased probability of yield loss associated with frost damage in northern India in crops such as mustard and vegetables. • Quality of fruits, vegetables, tea, coffee, aromatic, and medicinal plants may be affected. • Incidence of pest and diseases of crops to be altered because of more enhanced pathogen and vector development, rapid pathogen transmission and increased host susceptibility.
Water	• Demand for irrigation water would increase with rise in temperature and evapo-transpiration rate. It may result in lowering of groundwater table at some places. • The melting of glaciers in the Himalayas will increase water availability in the Ganges, Brahmaputra and their tributaries in the short-run, but in the long- run, the availability of water will decrease considerably. • A significant increase in runoff is projected in the wet season. This additional water in the wet season, on the other hand, may lead to increase in frequency and duration of floods. • The water balance in different parts of India will be disturbed and the quality of groundwater along the coastal track will be affected more due to intrusion of sea waters.

Soil	• Organic matter content, which is already quite low in Indian soils, would become still lower. Quality of soil organic matter may be affected. • The residues of crops under the elevated CO_2 concentrations will have higher C:N ratio, and this may reduce their rate of decomposition and nutrient supply. • Rise in soil temperature will increase N mineralization, but its availability may decrease due to increased gaseous losses through processes such as volatilization and denitrification. • There may be a change in rainfall volume and frequency, and wind may alter the severity, frequency and extent of soil erosion. • Rise in sea level may lead to salt-water ingression in the coastal lands, turning them less suitable for conventional agriculture.
Livestock	• Climate change will affect fodder production and nutritional security of livestock. Increased temperature would enhance lignification of plant tissues, reducing the digestibility. Increased water scarcity would also decrease production of feed and fodder. • Major impacts on vector-borne diseases will be through expansion of vector populations in the cooler areas. Changes in rainfall pattern may also influence expansion of vectors during wetter years, leading to large outbreaks of diseases. • Global warming would increase water, shelter, and energy requirement of livestock for meeting the projected milk demands. • Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their reproductive performance.
Fishery	• Increasing temperature of sea and river water is likely to affect breeding, migration and harvests of fishes. • Impacts of increased temperature and tropical cyclonic activity would affect the capture, production and marketing costs of the marine fish. • Coral bleaching is likely to increase due to higher sea surface temperature.

Source: Aggarwal *et al*. (2009a)[5]

In India, average food consumption at present is 550g per capita per day, whereas in China and USA it is 980 and 2850 g, respectively [6]. The country faces major challenges to increase its food production to the tune of 300 MT by 2020 in order to feed its evergrowing population which is likely to reach 1.30 billion by the year 2020. The country's farmers need to produce 50% more grain by 2020 to cater to the food demands of this increased population [7]. In India, the agricultural crop year is from July to June. The Indian cropping season is classified into two main seasons viz., Kharif and Rabi which are based on the monsoon. The kharif cropping season is from July to October and the Rabi cropping season is from October to March (winter). Summer crops are grown between March and June. Climate change has already caused significant damage to our present cropping season and crop profile and it further threatens to bring even more serious consequences in the future (WHO, 1992). Despite expansion of area under irrigation, droughts that are caused by inadequate and uneven distribution of rainfall, continue to be the most important climatic aberrations, which influence the agricultural production in India. Wheat yields are predicted to fall by 5-10% with every increase of 1°C and overall crop yields could decrease up to 30% in South Asia by the mid-21st century [7].

II. Impact of Climate Change on Agricultural Productivity

Indian agriculture is highly dependent on the onset, retreat and magnitude of monsoon rainfall. Climate modelers and IPCC documents have projected possibilities of increasing variability in Asian Monsoon circulation in a warmer world. Climate change has a significant impact on crop evapotranspiration (ET). It is reported that there is an increase of 14.8% in evapotranspiration (ET) with increase in temperature by 20%. It has also been reported that ET is less sensitive to solar radiation and wind speed compared to temperature [8]. A rise in the mean temperature above a threshold level will cause a reduction in agricultural yields. A change in the minimum temperature is more critical than a change in the maximum temperature. Grain yield

of rice, for example, declined by 10% for each 1 °C increase in the growing season minimum temperature above 32 °C [9]. The climate change impact on the productivity of rice in Punjab (India) has shown that with all other climatic variables remaining constant, temperature increases of 1 °C, 2 °C and 3 °C, would reduce the grain yield of rice by 5.4%, 7.4% and 25.1%, respectively [10]. The experimental evidence suggests that a rise in day or night temperature beyond its optimum level has a harmful effect on production of cool season legume crops such as chickpea [11]. It has been reported that a 1 °C increase in temperature reduces the yield of rice by 5-8 per cent, of maize by 10.0 per cent and of sorghum by 7 per cent[12].Soil temperature affects the rates of organic matter decomposition and release of nutrients. At high temperatures, though nutrient availability will increase in the short-term, in the long-run organic matter content will diminish, resulting in a decline in soil fertility. As temperature increases, the insect-pests will become more abundant through a number of inter-related processes including increased rates of population development, growth, migration and over-wintering. The balance between insect pests, their natural enemies and their hosts is likely to get altered due to climate change. The rise in temperature will favour insect development and winter survival. A rise in atmospheric CO_2 concentrations may lead to reduced foliar nitrogen levels thereby resulting in decline of food quality for plant-feeding insects. The epidemiology of plant diseases will be altered. The prediction of disease outbreaks will be more difficult in periods of rapidly changing climate and unstable weather. Climatic changes including increased incidence of extreme weather may reduce the effectiveness of pesticides on targeted pests or result in more injury to non-target organisms.

III. Mitigation Strategies for Climate Change Impacts

India has made a National Action Plan on Climate Change(NAPCC) in 2008 comprising of eight national missions. It is a comprehensive action plan which outlines measures on climate change related adaptation and mitigation while simultaneously advancing development These include national missions for solar energy, enhanced energy efficiency, sustainable habitat, conserving water, sustaining the Himalayan ecosystem, a “Green India”, sustainable agriculture and strategic knowledge platform for climate change. The eight missions form the core of the plan, representing multi-pronged, long termed and integrated strategies for achieving goals in the context of climate change. However, the onus lies on the people of India to render adequate impetus to these programmes. Water harvesting, "Per drop more crop" approach, groundwater recharge, revival of existing water bodies and various conservation technologies are some of the means to fight the menace of climate change. The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) was launched on 1st July, 2015 with the motto of ‘Har Khet Ko Paani’ for providing end-to end solutions in irrigation supply chain, viz. water sources, distribution network and farm level applications. This project not only focuses on creating sources for assured irrigation, but also creating protective irrigation by harnessing rain water at micro level through ‘Jal Sanchay’ and ‘Jal Sinchan’. Micro irrigation needs to be popularised to ensure ‘Per drop-More crop’. The states have the leeway to chalk out their own irrigation development schemes based on District Irrigation Plans and State Irrigation Plans. New crop varieties with higher yield potential and resistance to multiple stresses (drought, flood, salinity) are required to be developed so as to maintain yield stability. Exploitation of breeding programmes including improvement in germplasm of important crops for heat-stress tolerance should be the key targets. Improvement in water-use and nitrogen-use efficiencies is being attempted since long. These efforts are of much relevance in the climate change scenarios as water resources for agriculture are likely to dwindle in future. High temperatures and heavy precipitation events under the climate change scenarios may reduce Nitrogen-use efficiency, thus causing volatilization and leaching losses. Apart from this, crop demand for nitrogen is likely to increase in order to exploit the beneficial effects of elevated CO_2 concentrations. Therefore, it is important to improve the root efficiency for mining water and absorption of nutrients. Genetic engineering can be gainfully utilized for ‘gene pyramiding’ so as to pool all the desirable traits in one plant to get the ‘ideal plant type’ which may also be ‘adverse climate-tolerant’ genotype.

IV.Conclusion

Climate change is a global phenomenon affecting *interalia* agricultural productivity to a great extent. One of the most important consequences of climate change is alteration in precipitation pattern, its timing and

magnitude. This has caused widespread accelerated depletion of usable water from all available sources and adversely affected crop growth and yield. The scenario fits India to a T wherein agriculture still predominantly thrives on rainwater. It can be safely concluded that the impacts of climate change has a direct bearing on the Indian region. Agriculture sector is the most prone as it requires to meet the towering demands of fibre and food needs of 1.25 billion people. Hence, to deal with the impact of climate change, the potential adaptation strategies are: developing cultivars that are tolerant to heat, salinity, flood and drought; modification in crop management practices, better water management, adopting new farm techniques such as resource conserving technologies (RCTs), crop diversification, integrated pest management techniques, better weather forecasting and crop insurance and harnessing the indigenous technical knowledge of farmers.

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