CLIMATE CHANGE: IMPLICATIONS FOR INDIAN AGRICULTURE

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ABSTRACT *The Intergovernmental Panel on Climate Change has projected that the global mean surface temperature will rise by 2.0 - 4.5ºC by 2100 due to increase in carbon dioxide concentration in the atmosphere. Climate variability is also projected to increase, leading to uncertain onsets of monsoons and more frequent extremes of weather, such as more severe droughts and floods. These environmental changes are known to affect all aspects of the hydrological cycle, which, in turn, may alter the balance between food demand and supply in time and space in many parts of the world. Regions such as South Asia and Africa are expected to be particularly vulnerable to these environmental changes due to their large population, predominance in agriculture and limited resource base. To ensure future water and food security, greater attention is now needed on adaptations to climatic change, which include among others increased investment in adaptation and mitigation research, improved land use and natural resource management policies, and improved risk management though early warning system and crop insurance.*

Key words Agriculture; food production; GHG emissions; adaptive capacity; climate variability.

INTRIODUCTION

Intergovernmental Panel on Climate Change (IPCC) in its recently released report has reconfirmed that the global atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), greenhouse gases (GHGs), have increased markedly as a result of human activities since 1750 and now far exceed pre-industrial values determined from ice cores spanning many thousands of years (IPCC, 2007a). The CO_2, CH_4 and N_2O concentrations in atmosphere were 280 ppm, 715 ppb and 270 ppb in 1750 AD. In 2005, these values have become 379 ppm, 1774 ppb and 319 ppb, respectively (IPCC, 2007a). The increase in GHGs was 70% between 1970 and 2004. The global increases in CO_2 concentration are due primarily to fossil fuel use and land use change, while those of methane and nitrous oxide are primarily due to agriculture.

These increases in GHGs have resulted in warming of the climate system by 0.74°C between 1906 and 2005. Eleven of the last twelve years (1995-2006) rank among the 12 warmest years in the instrumental record of global surface temperature (since 1850). The rate of warming has been much higher in recent decades. This has, in turn, resulted in increased average temperature of the global ocean, sea level rise, decline in glaciers and snow cover. There is also a global trend for increased frequency of droughts, as well as heavy precipitation events over most land areas. Cold days, cold nights and frost have become less frequent, while hot days, hot nights and heat waves have become more frequent.

IPCC has projected that temperature increase by the end of this century is likely to be in the range 2 to 4.5°C with a best estimate of about 3°C, and is very unlikely to be less than 1.5°C (Fig. 1). It is also likely that future tropical cyclones will become more intense, with larger peak wind speeds and more heavy precipitation. Himalayan glaciers and snow cover are projected to contract. It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent. Increases in the amount of precipitation are very likely in high-latitudes, while decreases are likely in most subtropical land regions, continuing observed patterns in recent trends. The projected sea level rise by the end of this century is likely to be 0.18 to 0.59 m.

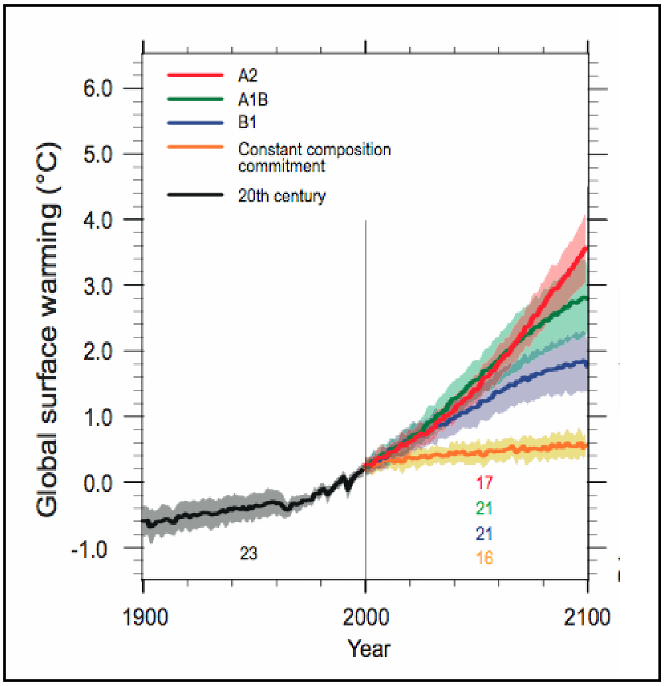

Fig. 1 Projected rise in surface temperature by different models (IPCC, 2007a).

Analyses done by the India Meteorology Department, and the Indian Institute of Tropical Meteorology, Pune, generally show the same trends for temperature, heat waves, glaciers, droughts and floods, and sea level rise as by the IPCC although the magnitude of the change varies. The analysis of monsoon rainfall data of last 100 years at all India level does not show any trend, but there are some regional patterns (NATCOM, 2004). Areas of increasing trend in monsoon rainfall are found along the west coast, north Andhra Pradesh and north-west India, and those of decreasing trend over east Madhya Pradesh and adjoining areas, north-east India and parts of Gujarat and Kerala (-6 to -8% of normal over 100 years). Surface air temperature for the period 1901-2000 indicates a significant warming of 0.4°C over these 100 years. The spatial distribution of temperature changes indicates a significant warming trend that has been observed along the west coast, central India, and interior Peninsula and over northeast India. However, a cooling trend has been observed in northwest and some parts of southern India. Instrumental records over the past 130 years do not show any significant long-term trend in the frequencies of large-scale droughts or floods in the summer monsoon season. The total frequency of cyclonic storms that form over Bay Bengal has remained almost constant over the period 1887-1997. There are evidences that glaciers in Himalayas are receding at a rapid pace (Kulkarni and Bahugana, 2002; IPCC, 2007b).

It is projected that by the end of the 21st century rainfall over India will increase by 15-40%, and mean annual temperature will increase by 3-6°C (NATCOM, 2004). The warming is more pronounced over land areas, with maximum increase over northern India. The warming is also relatively greater in winter and post-monsoon seasons.

Such global climatic changes will affect agriculture through direct and indirect effects on crops, soils, livestock and pests. Increase in atmospheric CO_2 has a fertilization effect on crops with C3 photosynthetic pathway and thus promotes their growth and productivity. Increase in temperature, depending upon the current ambient temperature, on the other hand, can reduce crop duration, increase crop respiration rates, alter photosynthate partitioning to economic products, effect the survival and distributions of pest populations thus developing new equilibrium between crops and pests, hasten nutrient mineralization in soils, decrease fertilizer use efficiencies, and increase evapotranspiration. Indirectly, there may be considerable effects on land use due to snowmelt, availability of irrigation, frequency and intensity of inter- and intra-seasonal droughts and floods, and availability of energy. All of these can have a tremendous impact on agricultural production and hence food security of any region.

IMPACTS OF GLOBAL CLIMATE CHANGE ON FOOD PRODUCTION

The net availability of food at any given time depends on a number of local, regional, national and international factors. Climate change associated variables such as CO_2 and temperature can influence food availability through their direct effect on growth processes and yield of crops. In addition, it may also impact crop production through indirect effects caused by changes in the hydrological balance discussed above. Soil organic matter transformations, soil erosion, and changes in pest profiles associated with global warming may further impact crop production. Equally important determinants of food supply are socio-economic environment including government policies, capital availability, prices and returns, infrastructure, land reforms, and inter- and intra-national trade that might be affected by climatic change.

In recent times, Aggarwal et al. (2000) have shown that in northern India rice yields during last three decades are showing a declining trend and this is possibly related to increasing temperatures. Similar trends have also been noticed recently in the Philippines (Peng et al., 2004). There have been only limited studies on the impact of climate change in India. The following is a brief summary of the key results available today on future implications of above-mentioned climatic changes on various aspects of agriculture:

IPCC (2007b) has projected that crop productivity is likely to increase slightly in temperate environments (e.g. in northern Europe and north America) for local mean temperature increases of upto 1-3°C depending on the crop. This may decrease with further increase in temperature in some regions. The report also projects that cereal yields in seasonally dry and tropical regions such as India, are likely to decrease for even small local temperature increases (1-2°C). As a result of these changes, globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1-3°C, but above this range it is projected to decrease. This is likely to have consequences on international food prices and trade. South Asian and African countries would need to take concrete measures to increase their domestic production and adaptive capacity to climate change.

Although increase in CO_2 is likely to be beneficial to several crops such as rice, wheat and pulses, associated increase in temperatures, and increased variability of rainfall would considerably impact food production. IPCC (2007b) and a few other global studies indicate considerable probability of loss in crop production in India with increases in temperature. Some of these projected loss estimates for the period 2080-2100 are 5 to 30% (Rosenzweig and Parry, 1994; Fischer et al., 2002; Parry et al., 2004; IPCC, 2007b). These long-time horizon estimates generally assume business as usual scenario, and a limited or nil adaptation by all stakeholders.

There are a few Indian studies on this theme and they generally confirm similar trend of agricultural decline with climate change (Aggarwal and Sinha, 1993; Rao and Sinha, 1994; Saseendran et al., 2000; Mall and Aggarwal, 2002; Aggarwal and Mall, 2002). More recent studies done at the Indian Agricultural Research Institute indicate the possibility of loss of 4-5 million tons in wheat production with every rise of 1^{o}C temperature throughout the growing period even after considering benefits of carbon fertilization (Fig. 2). This analysis assumes that irrigation would remain available in future at today’s levels and there is no adaptation.

It is, however, possible for farmers and other stakeholders to adapt to a limited extent and reduce the losses (subsequent section discusses possible adaptation options). Simple adaptations such as change in planting dates and crop varieties could help in reducing impacts of climate change to some extent. For example, the study carried out at the Indian Agricultural Research Institute indicates that losses in wheat production at 1^{o}C increase in temperature can be reduced from 4-5 million tons to 1-2 million tons if a large percentage of farmers could change to timely planting and changed to better adapted varieties (Fig. 2). These adaptation benefits become smaller as temperature increases further.

Regional changes in the distribution and production of particular fish species are expected due to continued warming, with adverse effects projected for aquaculture and fisheries.

Increasing climatic variability associated with global warming could, nevertheless, result in considerable seasonal/annual fluctuations in food production. All agricultural commodities even today are sensitive to such variability. Droughts, floods, tropical cyclones, heavy precipitation events, hot extremes, and heat waves are known to negatively impact agricultural production, and farmers’ livelihood.

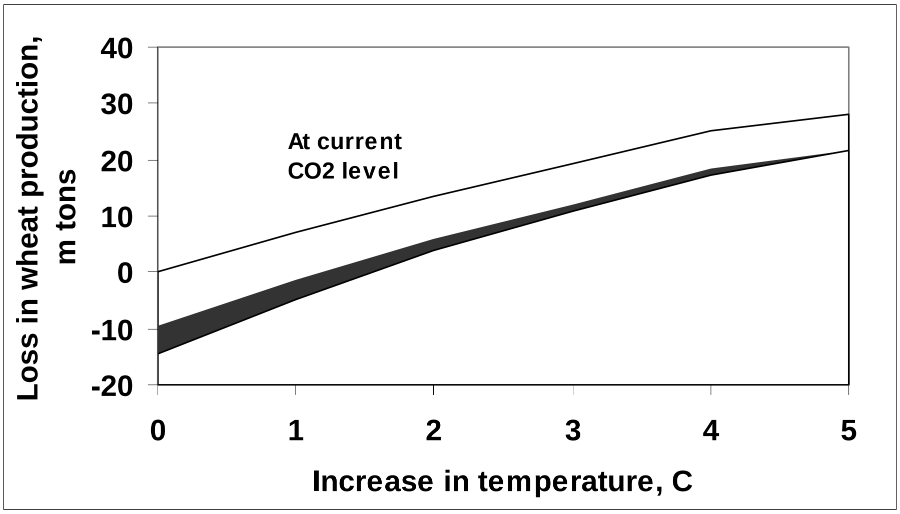

Fig. 2 Projected loss in wheat production due to increasing temperature at current and 550 ppm CO_2 levels. The shaded areas of the curve indicate losses that can be offset by adaptation options such as change in planting dates and variety.

Food production needs to be increased considerably in future to meet increasing demand associated with population and income growth. There is a considerable biological yield gap still available for most crops that forms the basis of raising food production. This is also a major route for increasing production to meet future demands given the support of policy and economic development. What could be quite worrying for us is that climate change reduces these yield gaps leading to stagnation in food production growth much sooner than expected.

IPCC (2001) showed a significant increase in runoff in many parts of the world including India. This, however, may not be very beneficial because the increase was largely in the wet season and the extra water may not be available in the dry season unless storage infrastructure could be vastly expanded. This extra water in the wet season, on the other hand, may lead to increase in frequency and duration of floods. The increased melting and recession of glaciers associated with global climate change could further change the runoff scenario. In recent decades, Himalayan glaciers have recessed between 2.6 to 28 m/yr (Kulkarni and Bahugana, 2002). Mass balance studies indicate significant increase in glacial degraded runoff volume in the last decade from 200 mm in 1992 to 455 mm in 1999 (Dobhal et al., 2004).

Fertilizer use efficiency in India is generally very low (30-50%). Increasing temperature in future is likely to further reduce fertilizer use efficiency. This will lead to increased fertilizer requirement for meeting future food production demands which are higher due to income and population growth. At the same time, greater fertilizer use leads to higher emissions of greenhouse gases. A large number of resource-poor farmers in tropics are not able to apply desired levels of fertilizers, irrigation and pest control. Simulation studies done at different levels at N management indicate that the crop response could vary depending upon the N management and the climate change scenario (Aggarwal, 2003). In the agroecosystems where inputs use remains low, as in today's rainfed systems, the direct impact of climatic change would be small.

Small changes in temperature and rainfall could have significant effect on quality of fruits, vegetables, tea, coffee, aromatic, and medicinal plants with resultant implications on their prices and trade.

Crop-pest interactions will change significantly with climate change leading to impact on pest distribution and crop losses. Crop-weed competition will be affected depending upon their photosynthetic pathway. C3 crop growth would be favored over C4 weeds affecting the need for weed control. The accompanied temperature increase may further alter the competition depending upon the threshold ambient temperatures. Diseases and insect populations are strongly dependent upon temperature and humidity. Any increase in these parameters, depending upon their base value, can significantly alter their population, which ultimately results in yield loss. With small changes, the virulence of different pests changes. For example, at 16 ^{o}C, the length of latent period is small for yellow rust. Once the temperature goes beyond 18 ^{o}C, this latent period increases but that of yellow and stem rusts decreases (Nagarajan and Joshi, 1978). The appearance of black rust in north India in sixties and seventies was related to the temperature dependent movement of spores from south to north India (Nagarajan and Joshi, 1978).

Global warming could increase water, shelter, and energy requirement of livestock for meeting projected milk demands. Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their productive and reproductive performance (IPCC, 2007b).

ADAPTATION STRATEGIES IN AGRICULTURE

Any perturbation in agriculture can considerably affect the food systems and thus increase the vulnerability of a large fraction of the resource poor population. We need to understand the possible coping strategies by different sections and different categories of producers to global climatic change. Such adaptation strategies would need to simultaneously consider the background of changing demand due to globalization and population increase and income growth, as well as the socio-economic and environmental consequences of possible adaptation options (Aggarwal et al., 2004; Easterling et al., 2004). Developing adaptation strategies exclusively for minimizing the negative impact of climatic changes may be risky in view of large uncertainties associated with its spatial and temporal magnitude. We need to identify 'no-regrets' adaptation strategies that may anyway be needed for sustainable development of agriculture. These adaptations can be at the level of individual farmer, society, farm, village, watershed, or at national level. Some of the possible adaptation options are discussed below:

Changes in land use and management Small changes in climatic parameters can often be managed reasonably well by altering dates of planting, spacing and input management. Development of alternate cultivars, and farming systems (such as mixed cropping, crop-livestock) that are more adaptable to changes in the environment can further ease the pressure.

Development of resource conserving technologies Recent researches have shown that surface seeding or zero-tillage establishment of upland crops after rice gives similar yields to when planted under normal conventional tillage over a diverse set of soil conditions. In addition, such resource conserving technologies restrict release of soil carbon thus mitigating increase of CO_2 in the atmosphere. Greater emphasis on water harvesting and improving the efficiency of regional as well as farm water use efficiency could help to face uncertain rainfall.

Improved land use and natural resource management policies and institutions Adaptation to environmental change could be in the form of crop insurance, subsidies, pricing policies, and change in land use. Necessary provisions need to be included in the development plans to address these issues of attaining twin objectives of containing environmental changes and improving resource use productivity. Policies are needed that would encourage farmers to conserve water, energy, and soil resources. For example, financial compensation/incentive for enriching soil carbon, and increasing the efficiency of irrigation water uses through drip and sprinkler methods could encourage farmers to improve soil health, manage with less water, and assist in overall sustainable development.

Improved risk management though early warning system and crop insurance The increasing probability of floods and droughts and other uncertainties in climate may seriously increase the vulnerability of resource-poor farmers to global climate change. Early warning systems and contingency plans can provide support to regional and national administration, as well as to local bodies and farmers to adapt. Policies that encourage crop insurance can provide protection to the farmers in the event their farm production is reduced due to natural calamities.

Reducing dependence on agriculture Although the share of agriculture in gross domestic product in India has declined to 20% but 58% population continues to remain dependent on this. Such trends have resulted in fragmentation and decline in the size of land holdings leading to inefficiency in agriculture and rise in unemployment, underemployment, and low volume of marketable surplus and, therefore, increased vulnerability to global change. Institutional arrangements, such as cooperatives and contract farming that can bring small and marginal farmers together for increasing production and marketing efficiencies are needed.

CONTRIBUTION OF INDIAN AGRICULTURE TO GLOBAL WARMING

CH_4 and N_2O are important greenhouse gases contributing 15% and 5%, respectively, to the enhanced greenhouse effect. Agricultural and associated sectors produce about 50 and 70%, respectively, of the total anthropogenic emissions of these gases (IPCC, 2007a). Biological generation of CH_4 in anaerobic environment including enteric fermentation in ruminants, flooded rice fields, and anaerobic animal waste processing, are the principal sources of CH_4 from agriculture. Agriculture sector contributes 28% of the total GHG emissions from India (NATCOM, 2004, Fig. 3). In a more recent estimate Bhatia et al. (2004) estimated for the base year 1994-95, that the CH_4 and N_2O emissions from Indian agricultural fields were 2.9 Tg (61 Tg CO_2 equivalent) and 0.08 Tg (39 Tg CO_2 equivalent), respectively.

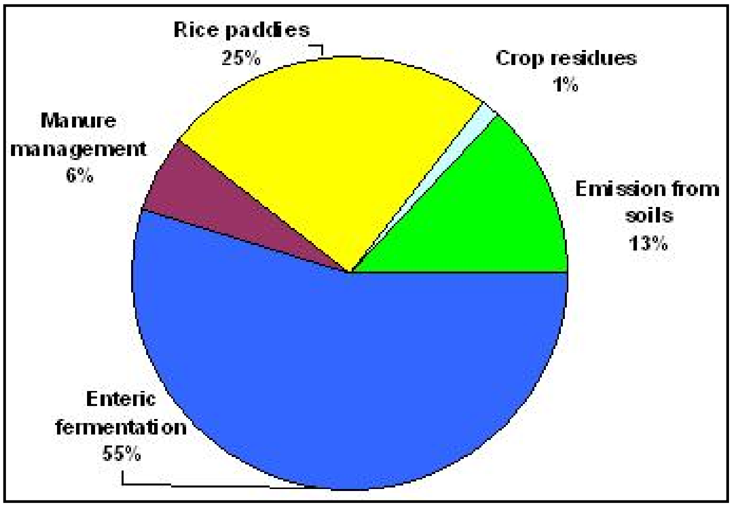

Fig. 3 Relative contribution of different sectors in agriculture to GHG emissions (Source: NATCOM, 2004).

Mitigation of GHG Emissions from Indian Agriculture

There are several approaches that can assist in reducing GHG emissions. These have been tested at experimental scale and need large-scale testing from the mitigation perspective. Improved water and fertilizer management in rice paddies could reduce emissions of GHGs. There are possibilities for crop diversification as value added from different crops is gaining importance under globalization and supply chain management. Improved management of livestock population and its diet could also assist in mitigation of GHGs. Approaches to increase soil carbon such as organic manures, minimal tillage, and residue management should be encouraged. These have synergies with sustainable development as well. Use of nitrification inhibitors, such as neem-coated urea, and fertilizer placement practices need further consideration for GHG mitigation. Improving the efficiency of energy use in agriculture by using better designs of machinery, and by conservation practices could also lead to mitigation. Changing land use by increasing area under biofuels, agro-forestry also mitigates GHG emissions. This, however, may have trade-offs with goal of increasing food production.

CONCLUSIONS

Global climate change has considerable implications on Indian agriculture and hence on our food security and farmers livelihood. We need to urgently take steps to increase our adaptive capacity. This would require increased support to adaptation research, developing regionally differentiated contingency plans for temperature and rainfall related risks, enhanced research on seasonal weather forecasts and their applications for reducing production risks, and evolving new land use systems, including heat and drought tolerant varieties, adapted to climatic variability and changes and yet meeting food demand. Strengthening current institutions and policy can also increase adaptive capacity. There is an urgent need to strengthen our surveillance mechanisms for various pests. We also need to support community partnerships in developing food and forage banks to manage scarcity during projected increased periods of drought and floods. Mechanisms for integrated management of rainwater, surface, and ground water need to be developed. Once a crop is planted farmers need insurance cover to manage risks associated with extremes of temperature and precipitation events. Weather-derivatives should be provided to increasing number of farmers at an early date.

For mitigation of GHGs from agriculture, there is a need to renew focus on nitrogen fertilizer use efficiency with added dimension of nitrous oxides mitigation. Widespread testing of neem cake, and neem coated urea, known to inhibit N_2O emissions, would be rewarding. Studies are also needed to determine optimal size of livestock population in different agro-ecological regions considering national milk requirement, GHG emissions and social issues. Financial incentives for improved land management including resource conservation/ enhancement (water, carbon, energy), and fertilizer use efficiency should be considered. These could also assist in sustainable development.

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