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Climatic change and its impact on Indian Agriculture: An overview

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Abstract
Climate change is likely to contribute substantially to food insecurity in the future, by increasing food prices, and reducing food production. Food may become more expensive as climate change mitigation efforts increase energy prices. Water required for food production may become more scarce due to increased crop water use and drought. Competition for land may increase as certain areas become climatically unsuitable for production. In addition, extreme weather events, associated with climate change may cause sudden reductions in agricultural productivity, leading to rapid price increases. Agriculture is a major source of GHGs which contribute to the greenhouse effect and climate change. However, the changing climate is having far reaching impacts on agricultural production, which are likely to challenge food security in the future.

Keywords: Climatic, substantially, food insecurity, water, crop agriculture

Introduction
The evidence of changing climate from observations has grown significantly during recent years. At the same time improved ways of characterizing and quantifying uncertainty have highlighted the challenges that remain silent for developing long-term global and regional climate quality data records. Climate change and variability are concerns of human being. The recurrent droughts and floods threaten seriously the livelihood of billions of people who depend on land for most of their needs. The global economy is adversely being influenced very frequently due to extreme events such as droughts and floods, cold and heat waves, forest fires, landslips etc. The natural calamities like earthquakes, tsunamis and volcanic eruptions, though not related to weather disasters, may change chemical composition of the atmosphere. It will, in turn, lead to weather related disasters. Increase in aerosols (atmospheric pollutants) due to emission of greenhouse gases such as Carbon Dioxide due to burning of fossil fuels, chlorofluorocarbons (CFCs), hydro chlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) etc., Ozone depletion and UV-B filtered radiation, eruption of volcanoes, the “human hand” in deforestation in the form of forest fires and loss of wet lands are causal factors for weather extremes. Climate is an important factor of agricultural productivity. The fundamental role of agriculture in human welfare, concern has been expressed by many organizations and others regarding the potential effects of climate change on agricultural productivity. Interest of this matter has motivated a substantial body of research on climate change and agriculture over the past decade. Climate change is expected to agricultural and livestock production, hydrologic balances, input supplies and other components of agricultural systems. Climate change is caused by the release of ‘greenhouse’ gases into the atmosphere. These gases accumulate in the atmosphere, which result global warming. The changes in global climate related parameters such as temperature, precipitation, soil moisture and sea level. However, the reliability of the predictions on climate change is uncertain. There are no hard facts about what will definitely be the result of increases in the concentration of greenhouse gases within the atmosphere and no firm timescales are known. Agriculture is one sector, which is important to consider in terms of climate change. The agriculture sector both contributes to climate change, as well as will be affected by the changing climate.

Agriculture and climate
Indian agriculture is highly prone to the risks due to climate change; especially to drought,

because 2/3rd of the agricultural land in India is rainfed and even the irrigated system is dependent on monsoon rain. Flood is also a major problem in many parts of the country, especially in eastern part, where frequent flood events take place. In addition, frost in north-west, heat waves in central and northern parts and cyclone in eastern coast also cause havoc. In recent years, the frequency of these climatic extremes are getting more due to the increased atmospheric temperature, resulting in increased risks with substantial loss of agricultural production Agricultural facilities contribute approximately 20% of the annual increase in anthropogenic greenhouse gas emissions. This sector contributes to global warming through carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) gases emissions. The greenhouse gases allow the transmission of light reaching the earth, they block the transmission of heat (infra-red radiation) trying to escape from the atmosphere, thus trapping the heat as in a 'greenhouse.' CH_4 has the highest global warming potential, which is about 300 times the potential of CO_2 and about 20 times that of N_2O. The main gases sources are nitrogen fertilizers, flooded rice fields, soil management, land conversion, biomass burning and livestock production and associated manure management. The livestock industry accounts approximately from 5% to 10% of the overall contribution to global warming.

Carbon dioxide (CO_2)

Primarily, deforestation due to agricultural expansion and land speculation was caused a major source of carbon emissions. When natural vegetation is converted into agricultural land, a large proportion of the soil carbon can also be lost as plants and dead organic matter are removed. This event contributes approximately a third of the total CO_2 emissions globally. Therefore, CO_2 is also released during the burning of agricultural crop waste, for example, during the burning of cereal straw, sugar cane stubble and rice straw. In many countries, it is a common practice to burn large quantities of crop residue, which results killing of insects and other pests as well as disease-causing organisms and neutralizes soil acidity. To less extent, CO_2 is released from the fossil fuels used in agricultural production and from livestock production. Nowadays, high intensity animal production has become the biggest consumer of fossil energy in modern agriculture (Intergovernmental Panel on Climate Change (IPCC) 1996) [3]

Methane (CH_4)

Methane (CH4) is the most significant greenhouse gas released within the agriculture sector. Most of the methane releases come from paddy fields (91%) and less significantly from animal husbandry (7%) and the burning of agricultural wastes (2%). The quantification of rice paddy emissions has proven difficult as the emissions vary with the amount of land in cultivation, fertilizer use, water management, density of rice plants and other agricultural practices. Among many Asian countries, China is a very large source of CH_4 emissions. Livestock and associated manure management causes 16% of the total annual production of CH_4. These emissions are a direct result of the ability of buffalo and cattle to utilize large amounts of fibrous grasses that cannot be used as human food, or as feed for pigs and poultry. Buffalo and cattle contribute about 80% of the global CH_4 emissions from domestic livestock annually.

Nitrous Oxide (N_2O)

Most of the agriculture-based N_2O emissions come from nitrogen fertilizer usage, legume cropping and animal waste. Some N_2O emissions are also released during biomass burning. Many farmers use nitrogen fertilizers on their fields to enhance crop growth. The crop takes up most of the nitrogen, but some of them leach into surrounding surface and ground waters and some of it enters the atmosphere. The nitrogen flux depends on the microbial activity in the soil. For example, wet rice absorbs only one-third of the nitrogen in the fertilizers, while upland crops about half. The rest of nitrogen is denitrified and diffused into the atmosphere, which is contributing to global warming. However, the amount of N_2O emitted is much lower in volume than the amount of CH_4

Main projections for climate change at Global Level

The projections of future climate patterns are largely based on computer-based models of the climate system that incorporate the important factors and processes of the atmosphere and the oceans, including the expected growth in greenhouse gases from socio-economic scenarios for the coming decades. The IPCC has examined the published results from many different models and on the basis of the evidence has estimated that by 2100- The global average surface warming (surface air temperature change) will increase by 1.1 - 6.4 °C. The sea level will rise between 18 and 59 cm. The oceans will become more acidic. It is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. It is very likely that there will be more precipitation at higher latitudes and it is likely that there will be less precipitation in most subtropical land areas. It is likely that tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and heavier precipitation associated with ongoing increases of tropical sea surface temperatures.

Reduction of greenhouse gas emissions

Improved land use applications may work toward the reduction of greenhouse gas emissions. For instance, significant decreases of CH_4 emissions from agriculture could be achieved through better management of rice paddies. Additionally, irrigated rice fields have been found to produce more CH_4 than deep water rice. The intermittent soil drying and reduced land disturbances such as zero tillage and mulching will also help reduce emissions for these agricultural lands. Changes of cultivation practices, such as a shift from transplanting to direct seeding and appropriate water management can also contribute decreasing of CH_4 emissions. The reduction of organic material and mineral fertilizer use will help decrease emissions, together with the appropriate fertilizers application. Some changes in agriculture production could be beneficial and can reduce the necessity for soil disturbances, e.g., a shift from traditional to high yielding varieties, or switching from rice to some other field crops. However, rice is an important crop in Asia. (Charoensilp, *et al.* 1998) [1]

The intensively managed monogastric animals such as poultry and pigs have stabilized the level of emissions generated from the livestock industry, as these animals produce less emission than the large ruminants in the Asian countries. The reduction of CH_4 emissions from intensively managed cattle are somewhat limited because the CH_4 production per unit of cattle feed is small and the animals are for the most part already given a high-quality diet. Therefore, additional CH_4

decreases are possible by improving nutrition of traditionally managed ruminant animals. Improving treatment and management of animal wastes and by reducing biomass burning could also reduce CH_4 emissions. These practices could reduce CH_4 emissions by 15-56 percent from agriculture. However, this problem is that these options usually involve a tradeoff between productivity and CH_4 reduction. N_2O emissions could also be decreased with better application of nitrogen fertilizers and with better treatment and management of animal wastes Energy use has decreased greatly since the 1970s by the agriculture sector. However, fossil fuel use in agriculture and thus CO emissions could be further reduced by, for example, irrigation scheduling, minimum tillage, solar drying of crops and improved fertilizer management. The role of forests and vegetation is important as sources and sinks of greenhouse gases. The CO_2 emission is only one part of the carbon cycle. Assimilation of CO_2 also occurs where vegetation binds carbon into biomass. Carbon storage is important and dependent on the vegetation type in the soil. Vegetation and soils of unmanaged forests hold 20-100 times more carbon per unit area than agricultural lands. The land use changes and deforestation have diminished the global storage of carbon as well as the capacity to bind CO_2, with the result that more CO_2 is being released into the atmosphere. The amount of nitrogen is lost from the soil also depends on agricultural practices such as irrigation and plowing and on temperature, soil type and weather conditions. Another agriculture-based N_2O release is during the breaking of new land when nitrogen bound in the soil and vegetation escapes to the atmosphere.

The climate change effects on agriculture will differ across the world Determining how climate change will affect agriculture is complex; varieties of effects are likely to occur. Changes in temperature as well as changes in rainfall patterns and the increase in CO_2 levels projected to accompany climate change will have important effects on global agriculture especially in the tropical regions. It is expected that crop productivity will alter due to these changes in climate and due to weather events and changes in patterns of pests and diseases. The suitable land areas for cultivation of key staple crops could undergo geographic shifts in response to climate change.

Impacts on Pest

Some of the most dramatic effects of climate change on pests and diseases are likely to be seen among arthropod insects like mosquitoes, midges, ticks, fleas and sand flies, and the viruses they carry. With changes in temperature and humidity levels, the populations of these insects may expand their geographic range, and expose animals and humans to diseases to which they have no natural immunity. Plant pests, which include insects, pathogens and weeds, continue to be one of the biggest constraints to food and agricultural production. Fruit flies, for instance, cause extensive damage to fruits and vegetables production. Controlling such pests often requires the use of pesticides, which can have serious side effects on human health and the environment. Climate change may also play a role in food safety. A growing number of pests and diseases could lead to higher and even unsafe levels of pesticide residue and veterinary drugs in local food supplies. And changes in rainfall, temperature and relative humidity can readily contaminate foods like groundnuts, wheat, maize, rice and coffee with fungi that produce potentially fatal mycotoxins.

Impact of Climate Change on Disease, Any direct yield gains caused by increased CO2 or climate change could be offset partly or entirely by losses caused by phytophagous insects, plant pathogens and weeds. It is, therefore, important to consider these biotic constraints on crop yields under climate change.

Impacts on Plant Pathosystems: Climate change has the potential to modify host physiology and resistance and to alter stages and rates of development of the pathogen. The most likely impacts would be shifts in the geographical distribution of host and pathogen, changes in the physiology of host-pathogen interactions and changes in crop loss. Another important impact may be through changes in the efficacy of control strategies.

Geographical Distribution of Host and Pathogen

New disease complexes may arise and some diseases may cease to be economically important if warming causes a pole ward shift of agro climatic zones and host plants migrate into new regions. Pathogens would follow the migrating hosts and may infect remnant vegetation of natural plant communities not previously exposed to the often more aggressive strains from agricultural crops. The mechanism of pathogen dispersal, suitability of the environment for dispersal, survival between seasons, and any change in host physiology and ecology in the new environment will largely determine how quickly pathogens become established in a new region. Changes may occur in the type, amount and relative importance of pathogens and affect the spectrum of diseases affecting a particular crop. This would be more pronounced for pathogens with alternate hosts. Plants growing in marginal climate could experience chronic stress that would predispose them to insect and disease outbreaks. Warming and other changes could also make plants more vulnerable to damage from pathogens that are currently not important because of unfavorable climate.

Some Current Actions for Adaptation and Mitigation in India Adaptation, in the context of climate change, comprises the measures taken to minimize the adverse impacts of climate change, e.g. relocating the communities living close to the sea shore, for instance, to cope with the rising sea level or switching to crops that can withstand higher temperatures. Mitigation comprises measures to reduce the emissions of greenhouse gases that cause climate change in the first place, e.g. by switching to renewable sources of energy such as solar energy or wind energy or nuclear energy instead of burning fossil fuel in thermal power stations. Current government expenditure in India on adaptation to climate variability exceeds 2.6% of the GDP, with agriculture, water resources, health and sanitation, forests, coastal-zone infrastructure and extreme weather events, being specific areas of concern.

India's Policy Structure Relevant to GHG Mitigation India

Has in place a detailed policy, regulatory and legislative structure that relates strongly to GHG mitigation: The Integrated Energy Policy was adopted in 2006. Some of its key provisions are: Promotion of energy efficiency in all sectors Emphasis on mass transport Emphasis on renewable including biofuels plantations Accelerated development of nuclear and hydropower for clean energy Focused R & D on several clean energy related technologies

The experience gained so far enables India to embark on an even more proactive approach through National Action Plan on Climate Change (NAPCC). NAPCC identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively. It outlines a number of steps to simultaneously advance India's development and climate change related objectives of adaptation and mitigation. The following eight National Missions form the core of the National Action Plan, representing multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change: i. National Solar Mission ii. National Mission for Enhanced Energy Efficiency iii. National Mission on Sustainable Habitat 23 iv. National Water Mission v. National Mission for Sustaining the Himalayan Ecosystem vi. National Mission for a "Green India" vii. National Mission for Sustainable Agriculture viii. National Mission on Strategic Knowledge for Climate Change

Coping options for Farmers

Awareness on Climate Change: Farmers need to be sensitized on climate variability, climate change, its impact on crop production, and coping options.

Agromet Advisories: The farming community is provided with Agromet advisories. Its bulletins are prepared taking into account the prevailing weather, soil and crop condition and weather prediction. Measures / practices / suggestions to be taken in view of weather forecast to minimize the losses and optimize inputs (Land preparation, selection of crop & cultivars, Date of sowing, Date of harvesting, Irrigation scheduling, Pesticides & Fertilizer application, Extreme weather events, etc.). Agro-advisory bulletin consist of three parts (i) Weather events occurred during past week and weather forecast for five days ahead. These forecast includes weather parameters like cloud amount, rainfall, average Wind Speed, Wind Direction, RH, maximum and minimum temperature. (ii) It contains actual information on state and stage of crop growth, ongoing agricultural operations, disease and insect pest occurrence. (iii) It provides value added information on various farm activities to be taken based on weather. There are 23 State Agromet Service Centers. These prepare Agromet advisory in collaboration with State Department of Agriculture on Tuesday & Friday. The Agromet advisory is disseminated through All India Radio (AIR), Print Media, Doordarshan, Website and SMS.

The possible negative effects Climate change could influence agricultural production adversely due to resulting

Geographical shifts and yield changes in agriculture, Reduction in the quantity of water available for irrigation and Loss of land through sea level rise and associated salinization. The yields of different crops and geographic limits may be altered by changes in soil moisture, temperature, precipitation, cloud cover, as well as increases in CO_2 concentrations. The lowest rainfall and high temperature could reduce soil moisture in many areas, particularly in some tropical and mid-continental regions, reducing the available water for irrigation and impairing crop growth in non-irrigated areas of the many regions. The changes in soil properties such as the loss of soil organic matter, leaching of soil nutrients, salinization and erosion are a likely consequence of climate change for some soils in some climatic zones. The risk of losses due to weeds, insects and diseases is likely to increase. The range of many insects will change or expand and new combinations of diseases and pests may emerge as natural ecosystems respond to shifts in temperature and precipitation profiles. The effect of climate on pests may add to the effect of other factors such as the overuse of pesticides and the loss of biodiversity, which already contribute to plant pest and disease outbreaks. Agriculture in low-lying coastal areas or adjacent to river deltas may be affected by a rise in sea level. Flooding will probably become a significant problem in some already flood-prone regions of Asia such as China and further south in Eastern Asia. Decreases in productivity are most likely in these regions, which are already flood- insecure. The summer monsoon is predicted to become stronger and move north-westward. However, this increased rain could be beneficial to some areas. (World Resources Institute (WRI), 1998) [4] In addition to changes in the frequency of extreme climatic events, changes in rainfall and temperature could be damaging and costly to agriculture.

The possible positive effects

The some changes in soil moisture, increases in temperature and shifts in patterns of plant diseases and pests could lead to decreases in agriculture productivity. However, CO_2 fertilization could lead to some increases in agricultural productivity Atmospheric CO_2 levels are expected to have a positive effect on some plants, increasing their growth rate and cutting transpiration rates. Crop plants may also be able to use water more efficiently under higher CO_2 levels. Plants can be classified as C_3, C_4 or CAM depending on the photosynthetic pathways they employ C_3 plants such as potato, rice, soybean, wheat and vegetables, including most trees are likely to benefit from extra CO_2. The results of many experiments have confirmed that elevated CO_2 concentrations generally have beneficial effect on most crops. Factors known to affect the response include the availability of plant nutrients, the crop species, temperature, precipitation and other environmental factors C_4 plants are mainly tropical origin and include grasses and agriculturally important crops such maize, millet, sorghum and sugarcane. C_4 plants are expected to benefit less from increasing of CO_2. CAM plants are a variant of C_4 plants and these plants are not likely to be affected. Increasing of temperature may also bring beneficial effects in some areas of the world. An important effect of an increase in temperature, particularly where agricultural production is currently limited due to low average temperatures, would be the extension of the growing season available for plants and the reduction of the growing period required by these crops for maturation This would benefit not only high altitude farming, where increases in yields and the variety of crops grown can be achieved, but also high latitude regions, where the poleward shift of the thermal limits of agriculture would increase the productive potential. However, soils and other factors may not enable much of this potential to be realized. Higher rainfall in some areas might also enable higher production and provide more water for irrigation.

Preparing for climate change

Population growth will mean more land must be used for rice cultivation and other crop production and an increase in the number of farm animals without significant improvements in yield rates in the future. These factors will lead to increase of CH_4 and other greenhouse gases released to the atmosphere. Adjustments will be necessary in order to counterbalance any negative impacts of a changing climate. Farmers must have the ability to adjust to changes by adapting farming practices. Adaptation, such as changes in crops and crop varieties, improved water management and irrigation systems and changes in planting schedules and tillage practices will be important in limiting the negative effects and taking advantage of the beneficial effects of changes in climate. More efficient use of mineral fertilizers and other adjustments in agricultural practices could also act to counteract the effects of climate change. (Darwin *et al*., 1995) [2]. The biggest problem occurs with the uncertainty surrounding the effects of climate change and the unknown time frames. It is still uncertain who will be most impacted by the changes and this fosters a lack of initiative for taking action now to mitigate the effects of climate change. Thus, education will be a necessary factor in the preparation for climate change.

Conclusions

There will be both winners and losers, with some areas benefiting from increases in agricultural production as a result of climate change while other areas suffer decreases in the world. Climate change could also affect the welfare of economic groups differently. The regional increases and decreases associated with climate change are not expected to result in large changes in food production over the next century on a global scale. Therefore, impacts on regional and local food supplies in some low latitude regions could amount to large percentage changes in current production. Climate change may impose significant costs for these areas. In addition, warming beyond that reflected in current studies may impose greater costs in terms of total food supply. Projections from most economic studies show substantial economic losses as temperature increases beyond the equivalent of a CO_2 doubling. This reinforces the need to determine the magnitude of warming which may accompany the CO_2 buildup currently under way in the atmosphere.

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