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Indian Agriculture and Climate Change

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Abstract:

Agriculture is a cause of climate change and also suffers from the consequences. Major adverse impacts of climate change on agriculture are owing to increase in temperature; change in rainfall pattern; weather hazards, decline in soil and water quality; shifting dynamics of insects, diseases, soil flora and fauna; intrusion of sea water on land and biotic and abiotic stresses arising due to climatic extremes. There could be a few positive impacts of climate change on agriculture in some locations because of change in temperature and moisture regimes. To address the consequences of climate change we need to develop adaption and mitigation options. There is an urgent need for creating an infrastructure both in terms of human resource and state of art physical facilities for collecting, collating and updating climatic data, essential prerequisite for modelling and forecasting the impact of impending climate change on agriculture. The strategies have to be built upon the current knowledge about climatic, ecological and economic systems' dynamics.

Climate is the most important determinant of crop productivity, particularly in country like India, where about 2/3rd of the cultivated area is rained. Climate change, therefore, is of serious concern having large-scale impacts, directly and indirectly, on agriculture. It is manifested with increase in global temperature, increased intensity of rainfall, rising sea level, melting of glaciers, shifting of crop growing season and frequent occurrences of extreme events such as drought and flood.

Keywords: Indian Agriculture and Climate Change Crop Productivity, Soil Productivity and Rainfall, Insects and Pests: Socio-Economic Aspects, Mitigation Options of Green House Gases Emission, Vulnerability and Adaptation Strategies.

Introduction:

Climate is changing naturally at its own nature, since the beginning of the evolution of earth, 4–5 billion years ago, but presently, it has gained momentum due to inadvertent disturbances. These changes may culminate in adverse impact on human health and the biosphere on which we depend. The multi-faceted interactions among the humans, microbes and the rest of the biosphere, have started reflecting an increase in the concentration of greenhouse gases (GHGs) i.e. CO_2, CH_4 and N_2O, causing warming across the globe along with other cascading con-sequences in the form of shift in rainfall pattern, melting of ice, rise in sea level etc. The above multifarious interactions among atmospheric composition, climate change and human, plant and animal health need to be scrutinized and probable solutions to the undesirable changes may be sought.

Vulnerability is the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed as well as the system's sensitivity and adaptive capacity. Vulnerability to climate change varies across regions, sectors, and social groups. Understanding the regional and local dimensions of vulnerability is essential to develop appropriate and targeted adaptation efforts. At the same time, such efforts must recognise that climate change impacts will not be felt in isolation, but in the context of multiple stresses. In particular, the dramatic economic and social changes associated with globalisation themselves present new risks as well as opportunities.

Indian Agriculture and Climate Change:

Agriculture sector alone represents 13 per cent of India's Gross National Product (GNP), plays a crucial role in the country's development and shall continue to occupy an important place in the national economy.[1] It sustains the livelihood of nearly 70% of the population. It seems obvious that any significant change in climate on a global scale will impact local agriculture, and therefore affect the world's food supply. Considerable studies have been carried out to investigate how farming might be affected in the different regions. Several uncertainties limit the accuracy of current projections. One relates to the degree of temperature increase and its geo-graphic distribution. Another pertains to the concomitant changes likely to occur in the precipitation patterns that determine the water supply to the crops, and the evaporative demand imposed on the crops in carbon dioxide enriched atmosphere. The problems of predicting the future course of agriculture in the changing world are compounded by the fundamental complexity of natural agricultural systems, and socio-economic systems governing the world food supply and demand. Many climatologists predict a significant global warning in the coming decades due to rising atmospheric carbon dioxide and other green house gases. As a consequence, major changes in the hydrological regimes have been also forecast to occur. Changes in the temperature, solar radiation, and precipitation will have an effect on crop productivity and livestock agriculture. Climate change will also have an economic impact on agriculture, including changes in farm profitability, prices, supply, demand, trade and regional comparative advantages. The magnitude and geographical distribution of such climate induced changes may affect our ability to expand the food production area as required to feed the burgeoning population of more than 10,000 million people projected for the middle of the next century.[2]

Agriculture is sensitive to short-term changes in weather and to seasonal, annual and longer-term variations in climate.

The Impact of Climate Change on Agriculture:

1. Crop Productivity:

Increase in atmospheric carbon dioxide has a fertilization effect on crops with C_3 photosynthetic pathway and thus, promotes their growth and productivity. On the other hand, an increase in temperature, depending upon the current ambient temperature, can reduce crop duration, increase crop respiration, effect the survival and distributions of pest populations thus developing new equilibrium between crops and pests, hasten nutrient mineralisation in soils, decrease fertilizer use efficiency. Indirectly, there may be considerable effects on land use pattern due to availability of irrigation water, frequency and intensity of inter- and intra-seasonal droughts and floods, and availability of energy. All of these can have tremendous impact on agricultural production and hence, food security of any region.

Wheat growth simulator developed at IARI, New Delhi, has been extensively tested for different agro-environments. In past, it has been successfully used for the resource management, forecasting of wheat yields and climate variability related studies. A strong linear decline in wheat yield was noticed with the increase in January temperature. For every degree increase in mean temperature, grain yield decreased by 428 kg/ha. Inter-seasonal climatic variability analysis carried out through yield response of wheat indicated that impact of the variability was lowest for Kota and highest for Solapur. Inter-seasonal climatic variability has been characterized through growth and yield response under different production environments, which clearly indicate the use of crop model as an indicator of climatic variability/change.[3]

2. Soil Productivity and Rainfall:

The most important process is the accelerated decomposition of organic matter, which releases the nutrients in short run, but may reduce the fertility in the long run. Soil temperature influences the rates at which organic matter decomposes, nutrients are released and taken up, and plant metabolic processes proceed. Chemical reactions, that affect soil minerals and organic matter, are strongly influenced by higher soil and water temperature. Soil productivity and nutrient cycling are, therefore, influenced by the amount and activity of soil microorganisms. Soil microorganisms fulfil two major functions, i.e. they act as agents of nutrient element transportation as well as store carbon and mineral nutrients (mainly N, P and S) in their own living biomass, acting as a liable reservoir for plant available nutrients with a fast turnover. The doubling of CO_2 increases plant biomass production, soil water use efficiency by the plants, and C/N ratios of plants. The changes in the C/N ratios of plant residues returned to the soil have impact on soil microbial processes and affect the production of trace gases Nitrogen and N_2O.

Results of the All India Co-ordinated Long-term Fertility Trials indicate that regions, having higher organic carbon content (>0.6%) in the beginning, showed a declining trend, whereas the regions with lower organic carbon content remained more or less static or slight increase in the organic carbon content was noticed in around 25 years. In general, Indian agricultural soils are low in organic carbon con-tent, and for achieving higher agricultural production, we have to depend upon the fertilizers. The hypothesis of increased organic carbon degradation with temperature rise has to be linked with the crop intensity factor, which is significantly higher for India, where proportion of the small and marginal land holdings is increasing due to rapid growth in population with time.[4]

The interaction of nitrogen, irrigation and seasonal climatic variability, particularly at low input of irrigation, has several implications. Under adequate moisture supply situation, like for Punjab and Haryana, the yield benefits are obtained up to higher nitrogen application, whereas in the regions of limited to moderate water supply situations, the increasing trends in yield are noted up to relatively lower values of nitrogen. At low levels of water availability, it is difficult to decide opti-mal levels of N fertilizer for maximizing yield returns in view of uncertainty of N response, which is strongly related to a good post monsoon rainfall received during crop growing period.

Analysis of the food grains production data for the last few decades reveals a tremendous increase in yield due to technological advancement, but it appears that impact of vagaries of monsoon has been large throughout the period. The annual food production showed an increasing trend, and the deviations around the technology trend line were significantly related to seasonal rainfall. But no definite trend is noticed in case of rabi season food production with the winter season’s rainfall, as majority of the food production in this season comes from the irrigated areas.

Rainfall Changes in rainfall due to global climate change may affect the surface moisture availability, which becomes important for germination and crop stand establishment in the rain fed areas. Modifications in the surface and ground water availabilities with the rainfall change are difficult to be observed when the land use and land cover are so rapidly changing.

Farmers have several agronomic management options to face the situation of water scarcity, through choice of crops, cultivars, adoption of suitable irrigation, nutrient and pesticides application schedules.

Soils dominate the cycling of many atmospheric trace gases because of the highest abundance and diversity of microbes in them. Earlier, equilibrium used to exist between the sources and sinks of GHGs, but a shift in this equilibrium has started becoming evident as a consequence of human induced activities. In order to comprehend the shift of source – sink equilibrium, one need to understand the processes involved in generating the net flux (a function of production processes, consumption processes and gas transport) at the soil atmosphere interface.

3. Insects and Pests:

Incidence of pest and diseases is most severe in tropical regions due to favourable climate/weather conditions, multiple cropping and availability of alternate pests throughout the year. Therefore, in the south Asia, pests and diseases deleteriously affecting the crop yields are prevalent. Climate sectors are the causative agents in deter-mining the population fluctuations of pests. They influence plant disease establishment, progression and severity. In fact, a clear understanding of population dynamics, as influenced by a biotic and biotic parameters of environment, is of much help in pest forecasting and to formulate control measures.

Indicators of climate change can be a few of the crop species, rhythm/migratory behaviour of specific insects/birds, etc. The global warming may affect growth and development of all organisms including insect-pests themselves. Among all the Abiotic factors, temperature is the most important one affecting insect distribution and abundance in time and space, since these are cold-blooded animals. The insects cannot regulate their body temperature and thereby, ambient temperature influences their survival, growth, development and reproduction.

The swarms of locust produced in the Middle East usually fly eastward into Pakistan and India during summer season and they lay eggs during monsoon period. The swarms as a result of this breeding return during autumn to the area of winter rainfall, flying to all parts of India and influencing kharif crops. Changes in rainfall, temperature and wind speed may influence the migratory behaviour of locust.

Diseases are often hurdles in increasing rice productivity. The rice blast, caused by Pyricularia grisea, is most prominent disease across the eco-systems. In the past, rice blast, brown spot and stem rot, were the serious diseases. Consequent to the adoption of high yielding varieties and associated agronomic practices during 1970's, diseases like bacterial leaf blight, sheath blight, sheath rot, tungro virus (transmitted by Nephotettix spp.) and bacterial leaf streak, have gained importance over the traditionally known diseases, especially stem rot and brown spot. False smut and discolouration of rice grain, caused by several fungi, have been of minor significance with occasional concern in certain regions only. While analyzing the effect of climatic variability and change on disease status, the interaction of land use and land cover change should also be taken into consideration.[5]

Climate and weather selectively induce specific diseases to develop. The mono-cyclic diseases, such as stem rot, sheath rot and false smut, are less influenced by

4. Socio-Economic Aspects:

Socio-economic linkage is relatively complex, and needs to be linked through the bio-physical modifications associated with the climate change. Land use and land cover change in our country is changing rapidly due to several driving forces. Socio-economic aspects can be dealt in two ways, one working out the cost-benefit analysis for various climate change scenarios by using econometric-process models and the other, generating the socio-economic scenario of future which links with the cropping system model for further impact analysis.

World Bank report (1998) analyzed climate change effects on Indian agriculture, through annual net revenues, by using Ricardian method the three methodologies, as adopted in the study, found Indian Agriculture sensitive to warming. The analyses further showed year-to-year climate sensitivity to the system's response. The studies revealed that net revenues fall precipitously with warmer April's, but also sensitive to warmer January and July. Crop revenues increased with October temperatures. Net revenues were also sensitive to precipitation, but the effects were smaller and off-setting. A warming scenario of +2.0 ˚C rises in mean temperature and a +7% increase in mean precipitation levels will create reduction in the net revenues, as revealed from the three approaches. The impact is differential on spatial and temporal scales. But the study seemed to be weak for linking with the biophysical aspects. Even then, this kind of study is a beginning of future plans of initiating the work in this regard.[6]

5. Mitigation Options of Green House Gases Emission:

The possible strategies for mitigating methane emission from rice cultivation can be made by altering water management, particularly promoting mid-season aeration by short-term drainage Organic amendments to flooded soils increase methane production and emission. However, application of fermented manure, like biogas slurry, reduces the emission. In addition, nitrification inhibitors have been shown to inhibit methane emission. Another mitigation option may be selection of low CH_4 emitting rice cultivars, as cultivars grown in similar conditions show pronounced variations in methane emission. Screening of rice cultivars with few unproductive tillers, small root system, high root oxidative activity and high harvest index are ideal for mitigating methane emission from rice fields.

Combined with a package of technologies, methane emission can best be reduced by (a) the practice of midseason drainage instead of continuous flooding, (b) direct crop establishment like dry seeded rice and (c) use of low C: N organic manure and biogas slurry.

Appropriate crop management practices, which lead to increase N use efficiency and yield, hold the key to reduce nitrous oxide emission. Application of nitrate (NO_3–N) fertilizers e.g. calcium ammonium nitrate (CAN), in crops with aerobic conditions and ammonium (NH_4–N) fertilizers e.g., ammonium sulphate, urea, in wetland crops also help reducing the nitrous oxide emission. Curtailing the nitrification process by the use of nitrification inhibitor may further decrease the N_2O emission from soil. There are some plant-derived organics, such as neem oil and neem cake, which can also act as nitrification inhibitors. These are being experimented in fields to reduce the emission of nitrous oxide and increase the fertilizer use efficiency. Other biotical inhibitors, such as karanja seed extract, have been found to retard nitrification by 60–70%. The efficacy of various mitigation technologies, however, needs to be tested in farmers' fields. Moreover, such technologies need to be also assessed for non-target effects and economic feasibility.[7]

5. Vulnerability and Adaptation Strategies:

There must be a clear understanding of vulnerable populations and regions, based on an assessment of the capacities to cope with climate variability and change. We are conscious that coping and adaptation strategies are not equally available to all affected populations. At the same time, it is important also to develop formal measures of vulnerability and their application to planning adaptation measures and strategies. The inter-disciplinary work involved requires various Ministries, Agencies and Expert Institutions to pool their resources, knowledge and information. We need to know much more about the factors influencing vulnerability and the aspects related to planning for adaptation. Our understanding in the area of vulnerability and adaptation tools needs to be mature and be refined so as to enhance their applicability[8].

India is particularly vulnerable to likely increase in the incidence of extreme events. The impacts of climate change could hinder development and progress in eradicating poverty and potentially aggravating social and environmental conditions. In the context of the current debate about climate change, it is necessary to show that the developing countries, like India, are taking considerable actions in terms of policies, programmes and projects. Technology transfer can speed up the modernization process and additional funds can accelerate government initiatives in energy conservation. However, policies for poverty alleviation must be on high priority.

An evergreen revolution is the pathway to sustainable advances in productivity per units of land, water and time without associated ecological or social harm. One of the weaknesses is mismatch between production and post-harvest technologies and between production and market demand, and the consequent need for the Government of India to undertake "trade relief" operations like cyclone, flood and drought relief. We can face the internal threats through integrated attention to regulation, education and social mobilization through Panchayat Raj institutions.

The Rural Knowledge Centres should provide computer aided and internet connected information services, so that farm families have timely and relevant meteorological, management and marketing information. Another area, which needs an urgent attention, is the restructuring of the State Land Use Boards in a manner that they are in a position to offer proactive advice to farm families on land use and cropping systems, based on likely monsoon behaviour, ecological efficiency and trends in prices and markets. Assured and remunerative marketing opportunities hold the key to sustaining farmers' interest in producing more[9].

Immediately, an action is needed to defend the productivity gains we have already made and to extend the same to the areas which have been bypassed by the farm revolution, particularly dry farming areas, and to make new gains through sustainable intensification, market – based farming systems diversification, and value addition to primary produce through agro-processing and agri-business.

Conclusion:

The climate change, as realized through trends of temperature rise and increased CO_2 concentration, is a major concern. In the recent past, the number of studies for assessing its impact on agriculture has increased. Crop growth models have been modified and tested for various important crops of this region under different climate change scenarios. But most of the results happen to be region specific and with certain assumptions. Accuracy in assessing the magnitude of the climate change on higher spatial and temporal resolution scale is the prime requirement for accurate estimates of the impact. The extent of inter- and intra-annual variability in climate happens to be large in this region, and the crops respond differentially to these changes. Understanding of this differential behaviour can aid in working out the impact of climate change. The vast genetic diversity in crops provides a platform to identify suitable thermal and drought tolerant cultivars for sustained productivity in the changed climate. Identification of suitable agronomic management practices can be a potential solution to optimize agricultural production in the changed climate. To have an overall assessment of soil health with the climate change, the possible alterations in soil physical, chemical and biological characters need to be looked into by also including land use and land cover change driving forces.

Intensive cultivation in our country has already started showing signs of yield stagnation in some parts of north-west India, raising the alarm of sustaining the yields by adoption of suitable agronomic management options. This concern has now to be viewed along with the climate change and its variability. Increased frequency of droughts and floods in this region, as anticipated in the climate change scenarios, caution us to identify suitable "no regrets and no risks" management options to face the situation. Crop simulation technique offers an opportunity to link the climate change with the other socio-economic and bio-physical aspects. These models can effectively work out the impact and also suggest suitable mitigation options to sustain the agricultural productivity.

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