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Impact of climate change on agriculture in India

Upasana Mohapatra[1], Tapas Ranjan Sahoo[2] **and** Debadatta Sethi[3]
[1]Department of Agricultural Economics, Odisha University of Agriculture and Technology, BHUBANESWAR (ODISHA) INDIA
[2]Department of Agronomy, Odisha University of Agriculture and Technology, BHUBANESWAR (ODISHA) INDIA
[3]Department of Soil Science and Agricultural Chemistry, Odisha University of Agriculture and Technology, BHUBANESWAR (ODISHA) INDIA
(Email : umohapatra02@gmail.com)

ABSTRACT

India's agriculture is more dependent on monsoon from the ancient periods. Any change in monsoon trend drastically affects agriculture. Climate change is any significant long-term change in the expected patterns of average weather of region (or the whole Earth) over a significant period of time. It is about non-normal variations to the climate, and the effects of these variations on other parts of the Earth. Agriculture sector is the most sensitive sector to the climate changes because the climate of a region/country determines the nature and characteristics of vegetation and crops. Increase in the mean seasonal temperature can reduce the duration of many crops and hence, reduce final yield. The increased level of greenhouse gases (GHGs) (carbon dioxide (CO_2), water vapor (H_2O), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) etc.) due to anthropogenic activities has contributed to an overall increase of the earth's temperature, leading to a global warming. The net effect of climate change on world agriculture is likely to be negative. Although some regions and crops will benefit, most will not. Indirect climate impacts include increased competition from weeds, expansion of pathogens and insect pest ranges and seasons, and other alterations in crop agro-ecosystems.

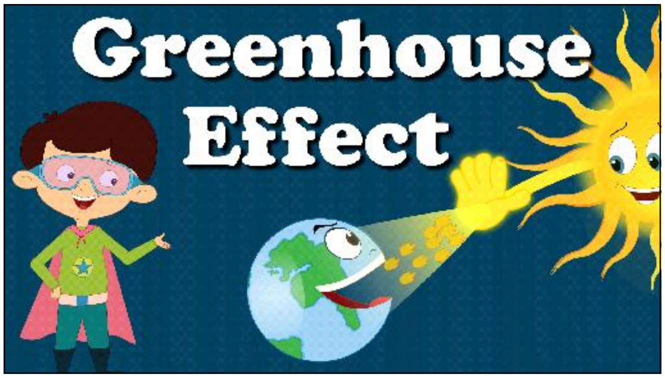
Climate change is any significant long-term change in the expected patterns of average weather of region (or the whole Earth) over a significant period of time. It is about non-normal variations to the climate, and the effects of these variations on other parts of the Earth. These changes may take tens, hundreds or perhaps millions of year. But increased in anthropogenic activities such as industrialization, urbanization, deforestation, agriculture, change in land use pattern etc. leads to emission of greenhouse gases due to which the rate of climate change is much faster. Climate change scenarios include higher temperatures, changes in precipitation, and higher atmospheric CO_2 concentrations.

Agriculture represents core sector of the Indian economy and provides food and livelihood opportunities. The agricultural sector plays a crucial role in the country's development. Food grain production quadrupled during the post-independence era; this growth is projected to continue. Climate is the primary determinant of agricultural productivity. Given the fundamental role of agriculture inhuman welfare, concern has been expressed by federal agencies and others regarding the potential effects of climate change on agricultural productivity. Interest in this issue has motivated a substantial body of research on climate change and agriculture over the past decade.

There are three ways in which the greenhouse effect may be important for agriculture. First, increased atmospheric CO_2 concentrations can have a direct effect on the growth rate of crop plants and weeds. Secondly, CO_2-induced changes of climate may alter levels of temperature, rainfall and sunshine that can influence plant and animal productivity. Finally, rises in sea level may lead to loss of farmland by inundation and increasing salinity of groundwater in coastal areas.

Impacts of climate change :

The greenhouse effect: The greenhouse effect is a natural process that plays a major part in shaping the earth's climate. It produces the relatively warm and hospitable environment near the earth's surface where humans and other life-forms have been able to develop and prosper. However, the increased level of greenhouse gases (GHGs) [carbon dioxide (CO_2), water vapor (H_2O), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6) etc.] due to anthropogenic activities has contributed to an overall increase of the earth's temperature, leading to a global warming. The average global surface temperature have increased by 0.74^0C since the late 19^{th} Century and is expected to increase by 1.4^0C-5.8^0C by 2100 AD with significant regional variations (IPCC, 2007). The



atmospheric CO_2 concentration has increased from 280 ppm to 395 ppm, CH_4 concentration increased from 715 ppb to 1882 ppb and N_2O concentration from 227 ppb to 323 ppb from the year 1750 and 2012. The Global Warming Potential (GWP) of these gases *i.e.*, CO_2, CH_4 and N_2O are 1, 25 and 310, respectively.

Over the next 30-50 years, CO_2 concentrations will increase to about 450 parts per million by volume (ppmv). The CO_2 response is expected to be higher on C_3 species (wheat, rice, and soybeans), which account for more than 95 per cent of world's species than on C_4 species (corn and sorghum). C_3 weeds have responded well to elevated CO_2 levels, symbolizing the potential for increase weed pressure and reduced crop yields.

Crop responses : Climate change scenarios include higher temperatures, changes in precipitation, and higher atmospheric CO_2 concentrations which may affect on yield (both quality and quantity), growth rates, photosynthesis and transpiration rates, moisture availability, through changes of water use (irrigation) and agricultural inputs such as herbicides, insecticides and fertilizers etc. Environmental effects such as frequency and intensity of soil drainage (leading to nitrogen leaching), soil erosion, land availability, reduction of crop diversity may also affect agricultural productivity.

An atmosphere with higher CO_2 concentration would result in higher net photosynthetic rates. Higher CO_2 concentrations may also reduce transpiration (*i.e.* water loss) as plants reduce their stomatal apertures, the small openings in the leaves through which CO_2 and water vapor are exchanged with the atmosphere. The reduction in transpiration could be 30 per cent in some crop plants. However, stomatal response to CO_2 interacts with many environmental (temperature, light intensity) and plant factors (e.g. age, hormones) and, therefore, predicting the effect of elevated CO_2 on the responsiveness of stomata is still very difficult. In rice, extreme maximum temperature is of particular importance during 3 flowering which usually lasts two to three weeks. Exposure to high temperature for a few hours can greatly reduce pollen viability and, therefore, cause yield loss. Spikelet sterility is greatly increased at temperatures higher than 35° C and enhanced CO_2 levels may further aggravate this problem, possibly because of reduced transpirational cooling The distribution of wild crop relatives, an increasingly important genetic resource for the breeding of crops, will be severely affected leading to fragmentation of the distribution and even extinction.

Climate variability and food grains production in India: It is important to note that the climate-sensitive sectors (forests, agriculture, coastal zones) and the natural resources (groundwater, soil, biodiversity, etc.) are already under stress due to socio-economic pressures. Climate change is likely to exacerbate the degradation of resources and socio-economic pressures. Thus, countries such as India with a large population dependent on climate-sensitive sectors and low adaptive capacity have to develop and implement adaptation strategies.

Economic consequences: Price will rise for the most important agricultural crops–rice, wheat, maize, and soybeans. This, in turn, leads to higher feed and therefore meat prices. As a result, climate change will reduce the growth in meat consumption slightly and cause a more substantial fall in cereals consumption, leading to greater food insecurity. The economic consequences of any yield changes will be influenced by adaptations made by farmers, consumers, government agencies, and other institutions. Farmers may adapt by changing planting dates, substituting cultivars or crops, changing irrigation practices, and changing land allocations to crop production, pasture, and other uses. Consumers may adapt by substituting relatively low priced products for those that become relatively high priced as a result of the effects of climate change. Inclusion of such adaptive responses is critical to a valid assessment, given that these responses result in less adverse effects than if such responses are excluded, and in some studies even reverse the direction of the net economic effect (from negative to positive).

– The net effect of climate change on world agriculture is likely to be negative. Although some regions and crops will benefit, most will not.

– While increases in atmospheric CO_2 are projected to stimulate growth and improve water use efficiency in some crop species, climate impacts, particularly heat waves, droughts and flooding, will likely dampen yield potential.

– Indirect climate impacts include increased competition from weeds, expansion of pathogens and insect pest ranges and seasons, and other alterations in crop agro-ecosystems.

Agricultural productivity and food security : Food security is both directly and indirectly linked with climate change. Any alteration in the climatic parameters such as temperature and humidity which govern crop growth will have a direct impact on quantity of food produced. Indirect linkage pertains to catastrophic events such as flood and drought which are projected to multiply as a consequence of climate change leading to huge crop loss and leaving large patches of arable land unfit for cultivation and hence threatening food security. The net impact of food security will depend on the exposure to global environmental change and the capacity to cope with and recover from global environmental change. On a global level, increasingly unpredictable weather patterns will lead to fall in agricultural production and higher food prices, leading to food insecurity.

Food insecurity could be an indicator for assessing vulnerability to extreme events and slow-onset changes. This impact of global warming has significant consequences for agricultural production and trade of developing countries as well as an increased risk of hunger.

Livestock response to climate change : Livestock can also be affected by climate and, hence, climate change. Specifically, livestock can be affected in two ways by climate change: the quality and amount off orage from grasslands may be affected and there may be direct effects on livestock due to higher temperatures. There are few studies which address climate change effects on livestock, but those which do show effects on performance. For example, warmer summer temperatures are estimated to have a suppressing effect on livestock appetite, which leads to lower weight gain (Adams *et al.,* 1998). Climate change tended to have adverse impacts on livestock production (e.g. low milk production) through both declining forage quality and increased ambient temperature. There is evidence that intensively managed livestock systems are potentially more adaptable to climate change than crop systems because they are better able to adapt to extreme events.

Hydrologic: The hydrologic cycle now includes more frequent and intense droughts and floods in many agricultural regions. These events can damage and at times even destroy crops.

Heat: Over the next 30-50 years, average temperatures will likely increase by at least 1.0^{0}C. Anticipated regionally-dependent changes include increase number of heat waves and warm nights, a decreasing number of frost days, and a longer growing season in temperate zones.

Climate change-mitigation and adaptation in agriculture :

– Assisting farmers in coping with current climatic risks by providing value-added weather services to farmers. Farmers can adapt to climate changes to some degree by shifting planting dates, choosing varieties with different growth duration, or changing crop rotations.

– An Early warning system should be put in place to monitor changes in pest and disease outbreaks. The overall pest control strategy should be based on integrated pest management because it takes care of multiple pests in a given climatic scenario.

– Participatory and formal plant breeding to develop climate-resilient crop varieties that can tolerate higher temperatures, drought and salinity.

– Developing short-duration crop varieties that can mature before the peak heat phase set in.

– Selecting genotype in crops that have a higher per day yield potential to counter yield loss from heat-induced reduction in growing periods.

– Preventive measures for drought that include on-farm reservoirs in medium lands, growing of pulses and oilseeds instead of rice in uplands, ridges and furrow system in cotton crops, growing of intercrops in place of pure crops in uplands, land grading and leveling, stabilization of field bunds by stone and grasses, graded line bunds, contour trenching for runoff collection, conservation furrows, mulching and more application of Farm yard manure (FYM).

– Efficient water use such as frequent but shallow irrigation, drip and sprinkler irrigation for high value crops, irrigation at critical stages.

– Efficient fertilizer use such as optimum fertilizer dose, split application of nitrogenous and potassium fertilizers, deep placement, use of *Neem, Karanja* products and other such nitrification inhibitors, liming of acid soils, use of micronutrients such as zinc and boron, use of sulphur in oilseed crops, integrated nutrient management.

– Seasonal weather forecasts could be used as a supportive measure to optimize planting and irrigation patterns.

– Providing greater coverage of weather linked agriculture-insurance.

– Adoption of resource conservation technologies such as no-tillage, laser land leveling, direct seeding of

Table 1 : Predicted effects of climate change on agriculture over the next 50 years

Climatic element	Expected changes by 2050's	Confidence in prediction	Effects on agriculture
CO_2	Increase from 360 ppm to 450 - 600 ppm (2005 levels now at 379 ppm)	Very high	Good for crops: increased photosynthesis; reduced water use
Sea level rise	Rise by 10 -15 cm Increased in south and offset in north by natural subsistence/rebound	Very high	Loss of land, coastal erosion, flooding, salinisation of groundwater
Temperature	Rise by 1-2°C. Winters warming more than summers. Increased frequency of heat waves	High	Faster, shorter, earlier growing seasons, range moving north and to higher altitudes, heat stress risk, increased evapotranspiration
Precipitation	Seasonal changes by ± 10%	Low	Impacts on drought risk' soil workability, water logging irrigation supply, transpiration
Storminess	Increased wind speeds, especially in north. More intense rainfall events.	Very low	Lodging, soil erosion, reduced infiltration of rainfall
Variability	Increases across most climatic variables. Predictions uncertain	Very low	Changing risk of damaging events which effect crops and timing of farm operations

Source: Climate change and Agriculture, MAFF (2000)

rice and crop diversification which will help in reducing in the global warming potential. Crop diversification can be done by growing non-paddy crops in rain fed uplands to perform better under prolonged soil moisture stress in *Kharif*.

– Provision of more funds to strengthen research for enhancing adaptation and mitigation capacity of agriculture.

Predicted effects of climate change on agriculture over the next 50 years : Warming will accelerate many microbial processes in the soil-floodwater system, with consequences for the C and N cycle. Crop residue decomposition patterns may change. Increased soil temperature may also lead to an increase in autotrophic CO_2 losses from the soil caused by root respiration, root exudates, and fine-root turnover. Climate change impacts will also impact on rice production through rising sea level rise. Most studies project decreased yields in non-irrigated wheat and in rice, and a loss in farm-level net revenue between 9 per cent and 25 per cent for a temperature increase of 2–3.5°C. Fungal and bacterial pathogens are also likely to increase in severity in areas where precipitation increases. Under warmer and more humid conditions cereals would be more prone to outbreaks of pest and diseases thereby reducing yield.

India's agriculture is more dependent on monsoon from the ancient periods. Any change in monsoon trend drastically affects agriculture. Even the increasing temperature is affecting the Indian agriculture. In the Indo-Gangetic Plain, these pre-monsoon changes will primarily affect the wheat crop (>0.5°C increase in time slice 2010-2039; IPCC, 2007). In the states of Jharkhand, Odisha and Chhattisgarh alone, rice production losses during severe droughts (about one year in five) average about 40 per cent of total production, with an estimated value of $800 million. Increase in CO_2 to 550 ppm increases yields of rice, wheat, legumes and oilseeds by 10-20 per cent. A 1°C increase in temperature may reduce yields of wheat, soybean, mustard, groundnut, and potato by 3-7 per cent. Productivity of most crops to decrease only marginally by 2020 but by 10-40 per cent by 2100 due to increases in temperature, rainfall variability, and decreases in irrigation water. The major impacts of climate change will be on rain fed or un-irrigated crops, which is cultivated in nearly 60 per cent of cropland. A temperature rise by 0.5°C in winter temperature is projected to reduce rain fed wheat yield by 0.45 tonnes per hectare in India. Possibly some improvement in yields of chickpea, *Rabi* maize, sorghum and millets; and coconut in west coast.

Conclusion : Climate is the primary determinant of agricultural productivity which directly impact on food production across the globe. Food production systems are extremely sensitive to climate changes like changes in temperature and precipitation, which may lead to outbreaks of pests and diseases thereby reducing harvest ultimately affecting the food security of the country. The net impact of food security will depend on the exposure to global environmental change and the capacity to cope with and recover from global environmental change. Coping with the impact of climate change on agriculture will require careful management of resources like soil, water and biodiversity. To cope with the impact of climate change on agriculture and food production, India will need to act at the global, regional, national and local levels.

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