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Impact of Climate Change on Wheat and Rice Production: An Analysis

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Abstract

The impact of climate change on agriculture is being witnessed all over the world, but countries like India are more vulnerable in view of the huge population dependency on agriculture. Monsoons are changing more frequently. Droughts, floods, tropical cyclones, hot extremes and heat waves are making negative impact on agriculture production. Increasing glacier melt in Himalayas may affect the food production in future. Impact of climate is comparative more significant as compared to the past due to increasing global warming, natural calamities and this may result fluctuations in yield of many crops. Climate change may alter the distribution and quality of India's natural resources and may adversely affect the livelihood of its people. This paper is an attempt to analyze the impact of climate change on production of wheat and rice.

Keywords: Agriculture, climate change, crop production, rice, wheat

Introduction

Climate change normally indicates change in behaviour of weather elements over an area during a time span. As per the United Nations Framework Convention on Climate Change (UNFCC) "it is any change in climate that is attributable directly and indirectly to human activity that alters the atmospheric composition". Frequent occurrences of earthquakes, floods, cyclones, typhoons, tsunami and drought are also the result of climate change. Such events while affecting the human and cattle population leave a disastrous effect on land, water and vegetation of the area. India is primarily an agriculture-dependent nation, where majority of its population depends on crop cultivation, fishery, forestry, dairy etc. for their livelihood. Besides this, India has vast coast-line which suffers from occasional cyclones. Many of these areas are also threatened because of rising sea level, due to global warming.

Climate change influences agriculture and water sectors and eventually food security and livelihoods of a large section of the rural population in developing countries. Extreme weather events such as droughts, floods, heat waves and changes in the monsoon rains are already affecting agricultural production in India and farmers are struggling to adapt and sustain their livelihoods due to these changes. Global warming indicates that rise in temperature in India will be in the range of 3^{0}C to 6°C by the end of 21^{st} century. Droughts and floods as well as cold and heat waves are likely to increase due to rise in temperature and thereby the estimated crop loss in India will likely to be up to 30 per cent by 2080 AD (Singh, 2010). Even today, Indian agriculture is considered as a gamble with the monsoon and hence, rainfall plays a great role in food security. There are evidences of negative impacts on yield of wheat and paddy in parts of India due to increase in temperature, water stress and reduction in number of rainy days. Enhancing agriculture productivity, therefore, is critical for ensuring food and nutritional security for all, particularly the poor small and marginal farmers. In the absence of mitigation and adoption of strategies, the consequences of long-term climate change could be even more severe on the livelihood security of the poor.

Recent studies done at the Indian Agricultural Research Institute indicate that the possibility of loss of 4-5 million tons in wheat production in future with every rise of $1^{o}C$ temperature throughout the growing period. Increasing glacier melt in Himalayas may affect the availability of irrigation especially in the Indo-Gangetic plains, which in turn has large consequences on food production. Small changes in temperature and rainfall could have significant effect on quality of cereals, fruits, aromatic, and medicinal plants with resultant implications on their prices and trade. Population of pathogens and insect is influenced by temperature and humidity. Increase in these parameters may change their population dynamics resulting in yield loss.

Climate and its Variability in India

India is subject to a wide range of climatic conditions from the freezing Himalayan winters in the north to the tropical climate of the southern peninsula, from the damp, rainy climate in the north-east to the arid Great Indian Desert in the north-west, and from the marine climates of its vast coastline and islands to the dry continental climate in the interior. The most important feature in the meteorology of the Indian subcontinent and, hence, its economy, is the Indian summer monsoon. Almost all regions of the country receive their entire annual rainfall during the summer monsoon, while some parts of the south-eastern states also receive rainfall during early winter from the north-east monsoon.

In India, highest emission of GHG is from energy sector (61%) followed by agriculture (28%). GHG emission from industrial process is 8%. Greenhouse gases mostly consist of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO_2), chlorofluorocarbon (CFC) hydro fluorocarbon (HFC) and sulphur hexafluoride (SF). Major source of these gases are fossil fuel, all other burnings, refrigerators and AC machines, emission from automobiles and industries, agricultural activities etc.

When the solar radiation comes to the surface of the earth, a majority of its intensity is absorbed by earth and some of it is reflected back. Infra-red radiation passes to the atmosphere and some part is reflected back to the earth. Due to the formation of a thick layer of greenhouse gases most of the infra-red radiation gets reflected back to the earth, resulting in warming of earth surface. The global warming is attributed to the enhancement of Greenhouse effect. The earth's climate has been reported to be warming up at the rate of $0.1^{0}C$ per decade over the last 50 years. Although there is considerable uncertainty about future, all climate models indicate a rising trend in temperature. By 2100, a rise of 1.8^{0} to 4^{0} C is expected.

With the increase in temperature volume of water is going to expand. Similarly melting of glaciers and mountain snow will add to the volume of water in sea, resulting in rise in sea level. This phenomenon is becoming a threat to the coastal areas. Already some areas have completely submerged or partially submerged. Projected sea level rise is between 15-90 cm. Reports of area loss have been received from Sunderbans of West Bengal and also from Orissa.

Rise in atmospheric temperature leads to decrease in yield of crops; forest fires; floods due to higher precipitation; extreme weather leading to increase in the intensity of hurricane/cyclones; rise in sea levels due to the faster rate of melting of ice; glacier melting and disappearance; ocean acidification due to increased level of carbon dioxide; delay in winter and increase in summer span; and adverse impact on natural ecosystems, such as wetlands, grasslands and mountain ecosystems; changes in monsoon pattern; and adversely affect agriculture and food security.

Table 1: Monsoon performance 2003 to 2012 (June-September)

Year	Number of meteorological subdivisions			% of districts with normal/ excess rainfall	% of long period average rainfall for the country as a whole
	Normal	Excess	Deficient/Scanty		
2003	23	8	5	76	102
2004	23	0	13	56	87
2005	24	8	4	72	99
2006	21	6	9	60	100
2007	18	13	5	72	106
2008	31	2	3	76	98
2009	11	3	22	42	78
2010	17	14	5	70	102
2011	26	7	3	76	101
2012	22	1	13	58	92

Source: Indian Meteorological Department

Table 2: Region-wise monsoon (June-September) rainfall distribution from 2005-2012 (in millimeters)

Year	North-west India			Central India			South Peninsula			North-east India		
	Actual	Normal	% departure	Actual	Normal	% departure	Actual	Normal	% departure	Actual	Normal	% departure
2005	552.1	611.6	-10	1094.9	993.2	10	808.9	722.6	12	1140.9	1430.7	-20
2006	573.7	611.6	-6	1152.2	993.9	16	684.6	722.6	-5	1177.6	1427.3	-17
2007	520.8	611.6	-15	1073.8	993.9	8	907.3	722.6	26	1485.9	1427.3	4
2008	651.7	611.6	7	956.9	993.9	-4	692.5	722.6	-4	1364.0	1427.3	-6
2009	392.1	611.6	-36	794.8	993.9	-20	693.0	722.6	-4	1037.7	1427.3	-27
2010	688.2	613.0	12	1027.9	991.5	4	853.6	722.6	18	1175.8	1436.2	-18
2011	654.8	615.0	7	1073.6	975.5	10	715.2	715.5	0	1233.6	1438.3	-14
2012	569.3	615.0	-7	934.6	974.2	-4	644.0	717.7	-10	1275.3	1437.8	-11

Source: Directorate of Economic and Statistics, Department of Agriculture and Cooperation

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Rainfall Distribution during Monsoon 2012

The performance of Indian agriculture is still heavily dependent on rainfall and south west monsoon (June to September), comprising 75% of total annual rainfall, substantially affects production and productivity of agriculture. During 2012, south-west monsoon rainfall over the country as a whole was 8% less than the long period (LPA). The seasonal rainfall was 93% of its LPA over north-west India, 96% over central India, 90% over peninsular India and 89% over north-east India (Economic Survey, 2012-13). Out of a total of 36 meteorological subdivisions in the country, 23 received excess/normal rainfall and in the remaining 13 subdivisions rainfall was deficient. The performance of monsoon has been presented in Tables 1 and 2.

Impact of Climate Change on Wheat Production

Climate change could strongly affect the wheat crop. India is considered to be the second largest producer of wheat. The Northern Indian states such as Uttar Pradesh, Punjab, Haryana, Uttaranchal and Himachal Pradesh are some of the major wheat producing states. Here the impact of climate change would be profound, and only a 1°C rise in temperature could reduce wheat yield in Uttar Pradesh, Punjab and Haryana. In Haryana, night temperatures during February and March in 2003-04 were recorded 3°C above normal, and subsequently wheat production declined from 4106 kg/ha to 3937 kg/ha in this period (Ranuzzi and Srivastava, 2012).

An assessment of the impact of climate change on wheat production states that the country's annual wheat output could plunge by 6 million tones with every 1°C rise in temperature. However, utilizing adaptation strategies such as changing the planting dates and using different varieties, it is possible to moderate the losses. The assessment also found that the impact of climate change on wheat production varies significantly by region. North India and other areas with higher potential productivity were less impacted by a rise in temperature than the low-productivity regions. If there is no mechanism or strategy to cope with rainfall variability, then rain fed crops will be more heavily impacted than irrigated ones. Table 3 shows simulated impact of climate change of wheat.

Table 3: Simulated impact of climate change scenario on yield of Wheat in 2010

Region	Impact of climate change on yield %	
	Pessimistic scenario	Optimistic scenario
North	1.5	6.5
East	-0.3	7.7
Central	-2.0	6.5

Note: Pessimistic scenario reflects low increase in CO_2 and a high increase in temperature, whereas the optimistic scenario consists of a significant increase in CO_2 and a negligible increase in temperature

India is already showing sign of fluctuation in the productivity of wheat. A closer examination of the weather data indicates that the yield of wheat has a declining trend due to rising temperature and the monsoons fluctuation during the crop season. Climate change on wheat production has been given in Chart 1.

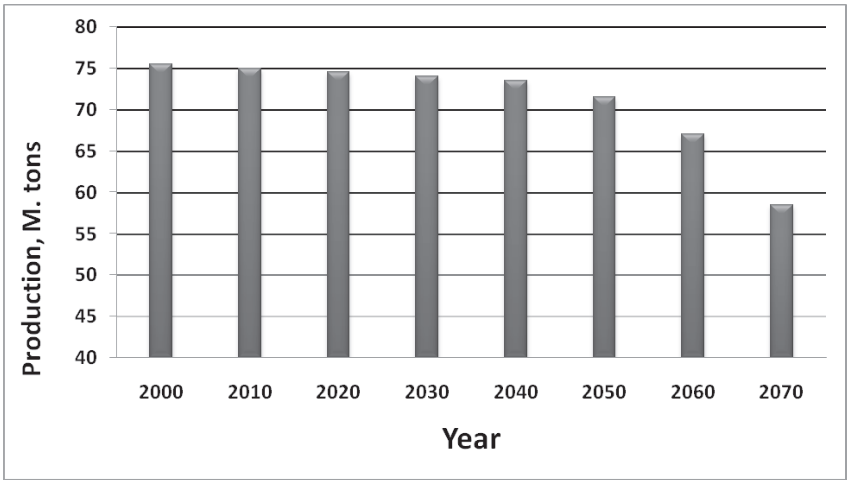

Figure 1: Potential Impact of climate change on Wheat production in India

The present wheat producing states like Punjab, Haryana and Western UP will be affected by low productivity by temperature increase.

Impact of Climate Change on Rice Production

Experts have predicted that as a consequence of melting polar ice caps and glaciers due to rising temperatures, seawater levels may rise on average by about 1 m by the end of the 21st century. Rice is grown in vast low-lying deltas and coastal areas; sea-level rise would therefore make rice production very vulnerable to climate change.

Rice is unique in that it can thrive in wet conditions where other crops fail. Uncontrolled flooding is a problem, however, because rice cannot survive if submerged under water for long periods of time. Flooding caused by sea-level rises in coastal areas and the predicted increased intensity of tropical storms with climate change will hinder rice production.

Salinity is also associated with higher sea levels as this will bring saline water further inland and expose more rice-growing areas to salty conditions. Rice is only moderately tolerant of salt and yields can be reduced when salinity is present.

Increases in both carbon dioxide levels and temperature will also affect rice production. Higher carbon dioxide levels typically increase biomass production, but not necessarily yield. Higher temperatures can decrease rice yields as they can make rice flowers sterile, meaning no grain is produced. Higher respiration losses linked to higher temperatures also make rice less productive.

Rice requires ample water to grow. Rainless days for a week in upland rice-growing areas and for about two weeks in shallow lowland rice-growing areas can significantly reduce rice yields. Average yield reduction in rain fed and drought-prone areas have ranged from 17 to 40% in severe drought years, leading to production losses and food scarcity.

Rice diseases, pests and weeds are strongly influenced by climate change. Water shortages, irregular rainfall patterns and related water stresses increase the intensity of some diseases.

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Rice is the staple food for a large majority of population and constitutes 43% of the total food (cereal and pulses) production. To meet the increasing demand of ever growing population, it is estimated that rice yields must increase by at least 45% by 2020 to meet the future demand (Mall and Aggarwal, 2002). On the contrary, several intensively cultivated areas such as in north India have started showing signs of rice yield stagnation and deterioration of soil health. Table-4 shows simulated impact of climate change scenario on rice.

Table 4: Simulated impact of climate change scenario on yield of rice in 2010

Region	Impact of climate change on yield %	
	Pessimistic scenario	Optimistic scenario
East	2.3	5.4
South	1.3	3.8
North	3.0	7.0

Note: Pessimistic scenario reflects low increase in CO_2 and a high increase in temperature, whereas the optimistic scenario consists of a significant increase in CO_2 and a negligible increase in temperature

India is already showing sign of fluctuation in the productivity of rice. A closer examination of the weather data indicates that the yield of rice has a declining trend due to rising temperature and the monsoons fluctuation during the crop season.

Research conducted by Indian Agricultural Research Institute (IARI) has shown that the grain yield of rice is not impacted by a temperature increase less than 1°C. However, from an increase of 1-4°C, the grain yield reduces on average by 10% for each degree the temperature increased. Thus, higher temperatures accompanying climate change will impact rice production creating the possibility of a shortfall. The impact of night time temperature rise on rice yields indicates that the warmer nights have an extensive impact on the yield of rice.

Rainfall pattern is a very important limiting factor for rain-fed rice production. Higher variability in distribution and a decrease in precipitation will adversely impact rice production and complete crop failure is possible if severe drought takes place during the reproductive stages.

The eastern region of India has diverse physiographic and agro-climatic land which supports genetic resources. According to a study done by the Indian Agriculture Research Institute, the impact of climate change with increased temperature will lead to decrease productivity in rice in the North Eastern region.

Climate change characterized by increasing carbon dioxide and temperature and uncertainty in rainfall can have a significant effect on crop growth, development and yield. Food security of developing countries such as India can, therefore, be further threatened if such a climate change would have a negative impact on crop growth and yields. It is, therefore, important to quantify the possible impact of climate change on rice yields.

Conclusion

The challenges that India's agriculture faces in the coming years remain enormous. There has been a significant rise in the frequency of extreme weather events in recent years affecting farm level productivity and impacting staple food grains availability at the national level. Within a season, severe droughts and floods are being experienced in the same region posing serious problems to the farmers, agriculture scientists and extension staff. Therefore, it is of utmost importance to enhance the resilience of Indian agriculture to climate change.

Climate change has emerged as a major challenge to our agriculture, indeed to the management of our economy as a whole. The immediate problems that our farmers face relate to intra-seasonal variability of rainfall, extreme events and unseasonal rains. These aberrations cause heavy losses to our crops every year. There is, therefore, an urgent necessity for the economy to speed up efforts to evolve climate-resilient crop varieties, cropping patterns and management practices.

The Indian Council of Agricultural Research has in fact started the “National Initiative on Climate Resilient Agriculture” (NICRA) towards this goal. This programme has three components: strategic research, technology demonstration and capacity building. The objectives of the programme are to enhance the resilience of Indian agriculture to climatic variability and climate change through the development and application of improved production and risk management technologies. ICAR is already putting in place robust mechanisms to strengthen interaction between agricultural scientists, farmers and also to ensure better convergence between research and development needs.

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