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Your Article:

Article Title (3 to 12 words)	**Changing Climate & Indian Agriculture**
Article Summary (In short - What is your article about – Just 2 or 3 lines)	According to the latest scientific assessment, the earth's climate system has demonstrably changed on both global and regional scales since the preindustrial era. Further evidence shows that most of the warming (of 0.1°C per decade) observed over the last 50 years, is attributable to human activities1. The Intergovernmental Panel on Climate Change (IPCC) projects that the global mean temperature may increase between 1.4 and 5.8 degrees Celsius (C) by 2100. This chapter addresses these challenges and their mitigation approaches. Historically, the responsibility for greenhouse gas emissions' increase lies largely with the industrialized world, though the developing countries are likely to be the source of an increasing proportion of future emissions. The projected climate change under various scenarios is likely to have implications on food production, water supply, coastal settlements, forest ecosystems, health, energy security, etc. The adaptive capacity of communities likely to be impacted by climate change is low in developing countries. The most effective way to address climate change is to adopt a sustainable development pathway by shifting to environmentally sustainable technologies and promotion of energy efficiency, renewable energy, forest conservation, reforestation, water conservation, etc.
Category	**Agriculture**

Your full article (between 500 to 5000 words) - - Do check for grammatical errors or spelling mistakes

According to the latest scientific assessment, the earth's climate system has demonstrably changed on both global and regional scales since the preindustrial era. Further evidence shows that most of the warming (of 0.1°C per decade) observed over the last 50 years, is attributable to human activities1. The Intergovernmental Panel on Climate Change (IPCC) projects that the global mean temperature may increase between 1.4 and 5.8 degrees Celsius (C) by 2100. This chapter addresses these challenges and their mitigation approaches. Historically, the responsibility for greenhouse gas emissions' increase lies largely with the industrialized world, though the developing countries are likely to be the source of an increasing proportion of future emissions. The projected climate change under various scenarios is likely to have implications on food production, water supply, coastal settlements, forest ecosystems, health, energy security, etc. The adaptive capacity of communities likely to be impacted by climate change is low

in developing countries. The efforts made by the UNFCCC and the Kyoto Protocol provisions are clearly inadequate to address the climate change challenge. The most effective way to address climate change is to adopt a sustainable development pathway by shifting to environmentally sustainable technologies and promotion of energy efficiency, renewable energy, forest conservation, reforestation, water conservation, etc. Critical components required for the strategic assessment of adaptation capacity and anticipatory adaptive planning is identified and examples of adaptive strategies for a number of key agricultural sectors are provided. Adaptation must be fully consistent with agricultural rural development activities that safeguard food security and increase the provision of sustainable ecosystem services, particularly where opportunities for additional financial flows may exist, such as payments for carbon sequestration and ecosystem conservation.

Introduction

Climate change is one of the most important global environmental challenges, with implications for food production, water supply, health, energy, etc. and Agriculture is the sector most vulnerable to climate change due to its high dependence on climate and weather and because people involved in agriculture tend to be poorer compared with urban residents. More than 60 per cent of the population is directly or indirectly relying on agriculture as a source of livelihood in this region. Agriculture is part of the problem and part of the solution. Addressing climate change requires a good scientific understanding as well as coordinated action at national and global level. This chapter addresses these challenges. Historically, the responsibility for greenhouse gas emissions' increase lies largely with the industrialized world, though the developing countries are likely to be the source of an increasing proportion of future emissions. The projected climate change under various scenarios is likely to have implications on food production, water supply, coastal settlements, forest ecosystems, health, energy security, etc. The adaptive capacity of communities likely to be impacted by climate change is low in developing countries. The efforts made by the UNFCCC and the Kyoto Protocol provisions are clearly inadequate to address the climate change challenge. The most effective way to address climate change is to adopt a sustainable development pathway by shifting to environmentally sustainable technologies and promotion of energy efficiency, renewable energy, forest conservation, reforestation, water conservation, etc

The Intergovernmental Panel on Climate Change (IPCC) in its fourth assessment report observed that, 'warming of climate system is now unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global sea level'. It also estimated that man-made (GHGs) emissions have risen by 70% over the past three decades and will increase notwithstanding current climate change mitigation policies and related sustainable development practices. Going by this widely accepted interpretation, adaptation is necessary only because mitigation of greenhouse gases may not completely halt climate change. Stern Review summarizes this view: „ adaptation is crucial to deal with the unavoidable impacts of climate change to which the world is already committed". CH_4 is produced when organic materials decompose in oxygen-deprived conditions, notably from fermentative digestion by ruminant livestock, from stored manures, and from rice grown under flooded conditions. N_2O is generated by the microbial transformation of nitrogen in soils and manures, and is often enhanced where available nitrogen (N) exceeds plant requirements, especially under wet conditions. Agricultural greenhouse gas (GHG) fluxes are complex and heterogeneous, but the active management of agricultural systems offers possibilities for mitigation.

Indian agriculture scenario

India is primarily an agriculture dependent nation, where majority of population depends on crop cultivation, fishery, forestry, etc. for their livelihood. In India, agriculture is substantially dependent on

the south-west monsoon. The Indian economy is mostly agrarian based and depends on the onset of monsoon and its further behaviour. The agriculture sector represents 35% of India's Gross National Products (GNP). It plays a crucial role in the country's development and will continue to occupy an important place in the national economy (Planning Commission, 2002). It sustains livelihood of nearly 75% of the population. The impact of climate change on agriculture will be one of the major deciding factors influencing the future food security of mankind on earth. The contribution of agriculture and allied activities to India's economic growth in recent years has been no less significant than that of industry and services. The importance of agriculture to the country is best summed up by this statement: "If agriculture survives, India survives".

In the backdrop of a burgeoning population where food and nutritional security is a constant challenge, agriculture has emerged as a key component for the growth of the Indian economy. With a contribution of approximately 15.7 % to India's GDP and 10.23 % (provisional) to the total exports in 2008 -09 as suggested by the latest reports and the fact that it provides employment to 58.2% of the population, a consistent growth of this sector is vital to meet other challenges as well. In India, agriculture is substantially dependent on the south-west monsoon. This is evident from the fact that the net irrigated area of the country is 60.9 million hectares from a total net sown area of 140.3 million hectares. Thus, a large part of the net sown area is rain-fed, thereby making the agriculture sector in India very sensitive to any changes in the pattern of rainfall. For instance, the impact of overall deficit of 23% in rainfall during the south-west monsoon in 2009-10, which adversely affected *Kharif* production, is reflected in the agriculture GDP growth rate which shows a decline of 0.2 per cent as against the previous year's growth rate of 1.6 per cent.

General trend of climate change

Climate change and climate variability are a matter of great concern to humankind. 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". IPCC defined it as "any change of climate over time whether due to natural cause or as a result of human activity".

Current projection

Analyses done by the Indian Meteorology Department and the Indian Institute of Tropical Meteorology, Pune (MS), generally show the same trends for temperature, heat waves, glaciers, droughts and floods, and sea level rise as by the Intergovernmental Panel on Climate Change of United Nations. Magnitude of the change varies in some cases. At all India level, there is no trend in monsoon rainfall during last 100 years, but there are some regional patterns. 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 for 100 years. The spatial distribution of temperature changes indicated a significant warming trend has been observed along the west coast, central India, and interior Peninsula and over northeast India. However, cooling trend has been observed in northwest and some parts in southern India.

Future projection

It is projected that by the end of the 21st century rainfall will increase by 15 – 31%, and the mean annual temperature will increase by 3°C to 6°C. The warming is more pronounced over land areas, with the maximum increase over northern India. The warming is also projected to be relatively greater in winter and post-monsoon seasons.

Global warming through emission of Green House Gases (GHGs) globally and Indian context

The GHGs are the main culprits of the global warming. The GHGs like Carbon Dioxide, Methane and Nitrous Oxide are playing hazards in the present times. These green house effect warming is called global warming. The effects of greenhouse effect are visible more prominently in the recent years, with number of natural calamities on the rise in the whole world. Although Carbon Dioxide, Methane and Nitrous Oxide occur naturally in the atmosphere, their recent significant atmospheric build-up is largely the result of anthropogenic activities. This increase has altered the composition of the Earth's atmosphere and will have an impact on future global climate. Out of all the GHGs, carbon dioxide (CO_2) is the most important greenhouse gas which recorded 80% increase from 21 to 38 giga tonnes (Gt) between 1970 and 2004 which constitutes 77% of total GHG emissions in 2004. It has been found that carbon dioxide contributes 60%, methane 15% and nitrous oxide 5% to the global warming (IPCC, 2007). The agriculture sector is the largest contributor to global anthropogenic non $-CO_2$ GHGs, accounting for 56% of emissions in 2005. Annual total non- CO_2 GHG emissions from agricultural production in 2010 was estimated to be 5.2─5.8 Gt CO_2 eq/yr and comprised about 10-12% of global anthropogenic emissions. Nitrous oxide acts as a green house gas in the troposphere and is the major source of ozone depletion. Forests, grasslands, oceans, soils, nitrogenous fertilizers, burning of biomass and fossil fuels are the sources of nitrous oxide. Soil with a contribution of about 65% is the major contributor to the total nitrous oxide emission.

Table 1.Atmospheric concentration, lifetime and global warming potential (GWP) of major greenhouse gases

Greenhouse gas	Atmospheric concentration	Life time (Years)	GWP (100 Years)
Carbon dioxide	387 ppm	Variable	1
Methane	1780 ppb	12	25
Nitrous oxide	319 ppb	114	298

Source: IPCC (2007)

Agriculture comprises several activities contributing to GHG emissions and globally, the most significant activities identified include:

1. Deforestation and other land-use changes as a source of CO_2,
2. Rice-wheat production systems as a sources of CH_4 and N_2O (and also source of CO_2 due to burning of agricultural residues) and
3. Animal husbandry as a source of CH_4.

Agriculture accounts for about 13-15% of global GHG emissions (as agriculture's share in global GDP is just about 4%, this suggests that agriculture is very GHG intensive. This figure is confined to direct GHG emissions at production level, not including production of agricultural inputs and fixed capital equipment, processing and trade of agricultural products (in GHG inventory reports, these emissions appear under energy supply, industries and transport).

Climate factors connected to climate change and agricultural productivity

1. Average temperature increase

An increase in average temperature can ;1) lengthen the growing season in regions with a relatively cool spring and fall; 2) adversely affect crops in regions where summer heat already limits production; 3) increase soil evaporation rates, and 4) increase the chances of severe droughts.

2. Change in rainfall amount and patterns

Changes in rainfall can affect soil erosion rates and soil moisture, both of which are important for crop yields. The IPCC predicts that precipitation will increase in high latitudes, and decrease in most

subtropical land regions—some by as much as about 20 percent. While regional precipitation will vary the number of extreme precipitation events is predicted to increase (IPCC, 2007).

3. **Rising atmospheric concentrations of CO_2**:

Increasing atmospheric CO_2 levels, driven by emissions from human activities, can act as a fertilizer and enhance the growth of some crops such as wheat, rice and soybeans. CO_2 can be one of a number of limiting factors that, when increased, can enhance crop growth. Other limiting factors include water and nutrient availability. While it is expected that CO_2 fertilization will have a positive impact on some crops, other aspects of climate change (e.g., temperature and precipitation changes) may temper any beneficial CO_2 fertilization effect (IPCC, 2007).

4. **Pollution levels such as tropospheric ozone:**

Higher levels of ground level ozone limit the growth of crops. Since ozone levels in the lower atmosphere are shaped by both emissions and temperature, climate change will most likely increase ozone concentrations. Such changes may offset any beneficial yield effects that result from elevated CO_2 levels

5. **Change in climatic variability and extreme events**:

Changes in the frequency and severity of heat waves, drought, floods and hurricanes, remain a key uncertainty in future climate change. Such changes are anticipated by global climate models, but regional changes and the potential effects on agriculture are more difficult to forecast.

Impact of climate change on Indian Agriculture.

The impact of climate change on agriculture will be one of the major deciding factors influencing the future food security of mankind on earth. Agriculture is not only sensitive to climate change but, at the same time, is one of the major drivers for climate change. Increasing temperatures and changes in rainfall pattern are impacting the agricultural sector. Although there are ongoing studies to understand the impacts, some studies have shown certain trends. Researchers use several methods to assess the impact of climatic variability ranging from the traditional approach of historical data analyses by various statistical tools to controlled environment studies to understand the impact of temperature, rainfall and CO_2 in crop growth and yield. Recent IPCC report and a few other global studies indicate a probability of 10 – 40% loss in crop production in India with increases in temperature by 2080 – 2100.

An increase in ambient CO_2 is usually considered beneficial as it results in increased photosynthesis in several crops, especially those with C_3 mechanism of photosynthesis. However, despite these beneficial effects, the combined increase in temperature and variability of rainfall would considerably affect food production. Some studies indicate a probability of 10-40 % loss in crop production in India with increase in temperature by 2080–2100. Some studies by the Indian Agricultural Research Institute (IARI) indicate the possibility of loss of 4-5 million tonnes in wheat production with every rise of 1º C temperature throughout the growing period even after considering carbon fertilisation but no other adaptation benefits. The modelling based estimates are in line with the field observations. It is, however, possible for farmers and other stakeholders to adapt to a limited extent and reduce the losses.

Increasing climatic variability associated with global warming will, 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. The projected increase in these events will result in greater instability in food production and threaten livelihood security of farmers. Increasing glacier melt in Himalayas will affect availability of irrigation especially in the Indo-Gangetic plains, which, in turn, has large consequences on our food production.

Impacts of climate change on different sectors of agriculture

1. **Crop:** - Crops grown are critical for the food supply here and around the world. India exports supply huge amount of all wheat, corn, and rice on the global market. Changes in temperature, amount of carbon dioxide (CO2), and the frequency and intensity of extreme weather could have significant impacts on crop yields. Warmer temperatures may make many crops grow more quickly, but warmer temperatures could also reduce yields. Crops tend to grow faster in warmer conditions. However, for some crops (such as grains), faster growth reduces the amount of time that seeds have to grow and mature. This can reduce yields (i.e., the amount of crop produced from a given amount of land).Increase in ambient CO2 concentration is beneficial since it leads to increased photosynthesis in several crops, especially those with C_3 mechanism of photosynthesis such as wheat and rice, and decreased evaporative losses. Despite this, yields of major cereals crops, especially wheat are likely to be reduced due to decrease in grain filling duration, increased respiration, and /or reduction in rainfall/irrigation supplies. Reduction in yields in the rainfed areas due to changes in rainfall pattern during monsoon season and increased crop water demand. Quality of fruits, vegetables, tea, coffee, aromatic, and medicinal plants may be affected. Incidence of pest and diseases of crops may alter because of more enhanced pathogen and vector development, rapid pathogen transmission and increased host susceptibility.
2. **Soil: -** Organic matter content, which is already quite low in Indian soils, would become still lower. Quality of soil organic matter may be affected. The residues of crops under the elevated CO_2 concentrations will have higher C:N ratio and this may reduce their rate of decomposition and nutrient supply. Rise in soil temperature will increase N mineralization, but its availability may decrease due to increased gaseous losses through processes such as volatilization and denitrification. There may be a change in rainfall volume and frequency, and wind may alter the severity, frequency and extent of soil erosion. Rise in sea level may lead to salt-water ingression in the coastal lands, turning them less suitable for conventional agriculture.
3. **Water: -** Demand for irrigation water would increase with rise in temperature and evapo transpiration rate. It may result in lowering of groundwater table at some places. The melting of glaciers in the Himalayas will increase water availability in the Ganges, Brahmaputra and their tributaries in the short-run, but in the long run, the availability of water will decrease considerably. A significant increase in runoff is projected in the wet season that, however, may not be very beneficial unless storage infrastructure is vastly expanded. This additional water in the wet season, on the other hand, may lead to increase in frequency and duration of floods. The water balance in different parts of India will be disturbed and the quality of groundwater along the coastal track will be affected more due to intrusion of sea water.
4. **Livestock: -** Climate change will affect fodder production and nutritional security of livestock. Increased temperature would enhance lignifications of plant tissues, reducing the digestibility. Increased water scarcity would also decrease production of feed and fodder. Major impacts on vector-borne diseases will be through expansion of vector populations in the cooler areas. Changes in rainfall pattern may also influence expansion of vectors during wetter years, leading to large outbreaks of diseases. Global warming would increase water, shelter, and energy requirement of livestock for meeting the projected milk demands. Climate change is likely to aggravate the heat stress in dairy animals, adversely affecting their reproductive performance. Changes in climate could affect animals both directly and indirectly.
   - Heat waves, which are projected to increase under climate change, could directly threaten livestock. A number of states have each reported losses of more than 5,000 animals from just one

heat wave. Heat stress affects animals both directly and indirectly. Over time, heat stress can increase vulnerability to disease, reduce fertility, and reduce milk production.

5. **Fishery: -** Increasing temperature of sea and river water is likely to affect breeding, migration and harvests of fishes. Impacts of increased temperature and tropical cyclonic activity would affect the capture, production and marketing costs of the marine fish. Coral bleaching is likely to increase due to higher sea surface temperature. Many fisheries already face multiple stresses, including overfishing and water pollution. Climate change may worsen these stresses. In particular, temperature changes could lead to significant impacts.
   - Changes in temperature and seasons could affect the timing of reproduction and migration. Many steps within an aquatic animal's lifecycle are controlled by temperature and the changing of the seasons. For example, in the Northwest warmer water temperatures may affect the lifecycle of salmon and increase the likelihood of disease. Combined with other climate impacts, these effects are projected to lead to large declines in salmon populations.
   - Many aquatic species can find colder areas of streams and lakes or move northward along the coast or in the ocean. However, moving into new areas may put these species into competition with other species over food and other resources.

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