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Impact and Assessment of Climate Change on Agricultural Production in India: A Geographical Perspective

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Abstract:
Climate change is an imminent global challenge that poses significant threats to our planet's ecosystems, human societies, and overall well-being. Climate change refers to long-term shifts in temperature and weather patterns (UN) 2023 has shown all too clearly that climate change is here, and human activities have been the main driver of climate change. At the core of climate change is Global Warming which has triggered the melting of glaciers, sea level rise, weather fluctuation, erratic rainfall, and an increase in temperature patterns over the next century is predicted. The main objectives of this research paper is to examine the various causes of climate change in India and what is the impact of climate change on agricultural production in different parts of the country. The entire study is based on secondary sources of data. The result of the study shows that agricultural sector, which is already having difficulties as a result of the growing need for food, is being negatively impacted by climate change. In India, agriculture is very important because it is the foundation of the country's economy and provides a living for most of the population. 17.4% of India's GDP, or its gross domestic product, is derived from agriculture (Economic Survey, 2015–16). Drought, heat waves, storms, flooding, delayed monsoons, and variations in seasonal temperatures are some of the elements that negatively affect agricultural operations, such as planting, tending, and harvesting crops like Zaid, Rabi, and Kharif. These factors affect India's agricultural productivity as well as livestock farming. The study also reveals that Climate change has resulted in altered cropping patterns and decreased output of crops such as sugarcane, ground nuts, and paddy in states like Gujarat, Maharashtra, Orissa, West Bengal, Uttar Pradesh, and Bihar. Some Indian states, including Bihar, Maharashtra, and Kerala, have demonstrated climate variability by experiencing drought-like conditions in certain areas and flood-prone areas in others. Also, it results in the failure of crops, which drives farmers in some states to take their own lives due to crippling debt. On top of that, there is a risk to food security, a change in the quality of nutrition, a modification in pest and disease, but—above all—it is making life harder for the people having poor socio-economic status.

Keywords: Climate change, Sustainable Development, Agricultural crops, Drought, Unseasonal Rainfall, Cyclone, Heat Weaves

Introduction

India, a sprawling nation, encompasses 2.4% of the world's geographical area and is home to 16.2% of the global human population, along with 15% of the global livestock population. The agricultural sector serves as the foundation of the Indian economy, with nearly 60% of the population directly or indirectly relying on it. According to the Economic Survey of 2015-16, agriculture and allied sectors contribute approximately 17.4% to the Gross Domestic Product (GDP) of India. Agriculture is the backbone of the Indian economy, vital for ensuring food and livelihood security across the nation. The agricultural sector heavily relies on the onset and behaviour of the monsoon.The food production landscape in India is highly responsive to climate variations, including fluctuations in monsoon rainfall and seasonal temperature changes. Even small shifts in temperature and rainfall can exert notable impacts on the quality of fruits, vegetables, tea, coffee, aromatic and medicinal plants, as well as basmati rice. Projections indicate that a temperature rise of 3 to 5ºC by the conclusion of the 21st century could lead to crop production losses ranging from 10% to 40% in India. India holds the global lead in the production of milk, pulses, and jute, and secures the second position in the production of rice, wheat, sugarcane, groundnut, vegetables, fruits, and cotton. Despite these impressive achievements, Indian farmers continue to face challenges, struggling to attain returns that cover even the cost of production.However, the adaptability of Indian farmers faces significant constraints due to their heavy dependence on natural elements and the absence of complementary inputs and supportive institutional systems.

The persistent effects of climate change pose a threat to livelihoods, particularly those reliant on agriculture for food security. Agriculture, being heavily influenced by climate, faces significant jeopardy from climate change. The climate serves as the foremost factor determining agricultural productivity, with climate change exacerbating the vulnerability of climate-dependent crop production.The global averagesurface temperature has increased byapproximately 0.6ºC over the past century, andfurther, it will be increased by 1.4–5.8ºC (IPCC) over the end of 21 century. It has manifested interms of events like melting glaciers, rising sealevels, extreme weather and floods. (NAPCC,2008; Kannan, 2009; Dhaliwal et al., 2011;NATCOM, 2012; Ninan&Bedamatta, 2012;Adhinarayanan, 2013; Rattani, 2018; & IPCC,2022).Human actions have been identified as the primary cause of the predominant warming trend (0.1°C per decade) witnessed over the last five decades.

Objectives of the Study:

The following objectives have been taken into consideration: -

1. To examine the various causes of climate change in India
2. To know the impact of climate change on agricultural production in different parts of the country.
3. To give some valuable suggestions and mitigation to improve agriculture cropping with regards to climate change.

Database and Research Methodology:

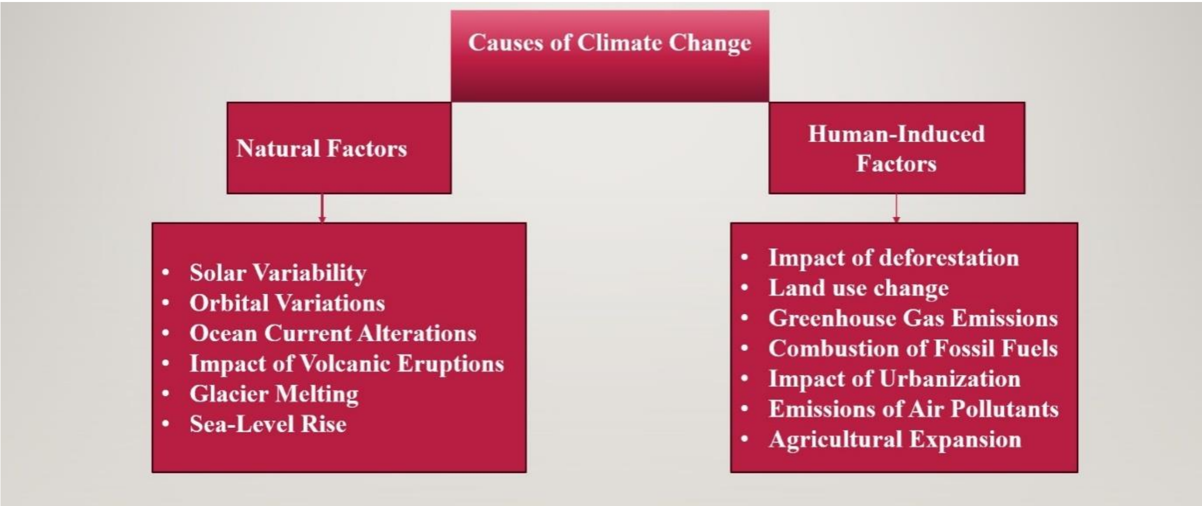
The entire study is based on secondary sources of data. The data has been obtained from Ministry of Agriculture and Farmers' Welfare, Indian Meteorological Department (IMD, Pune)Indian Council of Agricultural Research (ICAR),Ministry of Environment, Forest and Climate Change,Indian Agricultural Research Institute (IARI),Google Scholar,JSTOR, Food and Agriculture Organisation,Intergovernmental Panel on Climate Change (IPCC) etc.

Result and Analysis: Various agricultural scientistshave observed that in the absence of adaptation measures, rainfed rice yields in India are expected to decline by 20% in 2050 and 47% in 2080, while irrigated rice yields are expected to decline by 3.5% in 2050 and 5% in 2080. Climate change is expected to reduce wheat yield by 19.3% in 2050 and 40% in 2080 scenarios towards the end of the century, with large geographical and temporal fluctuations. Climate change is expected to diminish kharif maize yields by 18 and 23% in 2050 and 2080, respectively.

Around 70% of India's landmass is projected to encounter varying degrees of threat by 2050 due to a temperature increase (>2°C) and a deficit in precipitation patterns. Key agricultural states like Bihar, West Bengal, Telangana, and certain areas of Gujarat and Maharashtra are expected to experience heightened climate-induced risks, potentially significantly affecting future agricultural production.The loss in net revenue at the farm level is estimated to range between 9% to 25% for a temperature rise of 2ºC to 3.5ºC. (Kumar & Parikh, 2001; Kumar, 2010; Ninan&Bedamatta, 2012; Ranuzzi& Srivastava, 2012; Mahato, 2014; Rao et al., 2019; & Vanaja, 2019).

Causes of Climate Change

According to EPA (2014), a variety of factors arising from natural phenomena and human activities may cause changes in the earth's energy balance and contribute to climate change. These factors include fluctuations in the amount of solar energy reaching the Earth, changes in the reflectivity of the Earth's atmosphere and surfaces, and changes in the greenhouse effect, which directly affect the amount of heat retained by the Earth's atmosphere



A) Natural Factors

Although human activities primarily drive climate change, several key natural factors also play a significant role in shaping the climate system (EPA, 2010; IPCC, 2013).

1. Solar Variability

The climate is influenced by natural fluctuations affecting the amount of solar energy reaching the Earth's surface (EPA, 2010; IPCC, 2018). Variations in the sun's activity can directly impact the intensity of solar radiation reaching the Earth. The distribution of heat energy across the globe is influenced by the angle at which sunlight strikes the Earth's surface, varying by location, time of day, and season due to the Earth's orbit around the Sun and its axial tilt (Khavrus, V. and Shelevytsky, I., 2010). Changes in solar output may affect the climate both directly, by altering the rate of solar heating of the Earth and atmosphere, and indirectly, by influencing cloud formation processes. The intensity of solar radiation can result in either warming (during periods of heightened solar activity) or cooling (during periods of reduced solar activity) (USGCRP, 2014; IPCC, 2018).

2. Orbital Variations

Earth's climate is influenced by a series of factors concerning the planet as a whole, in its relationship to the sun in space, as highlighted by Rutgers University (2018). These factors encompass the tilt of Earth's axis, also known as its obliquity, the eccentricity of Earth's orbit, which determines how circular or elliptical the orbit is, and Earth's position in the precession of the solstices and equinoxes. This procession leads to varying distances between Earth and the Sun during different seasons, contributing to changes in climate (William F.R, 2007).

3. Ocean Current Alterations

Since the 1950s, geologists and oceanographers have accumulated compelling evidence indicating that changes in ocean current circulation significantly contribute to climate fluctuations (Cunningham, 2005; Tierney et al., 2013). Ocean currents represent continuous, directed movements of seawater driven by various forces, including wind patterns, wave dynamics, and disparities in temperature and salinity levels (England et al., 2014). The circulation of ocean currents plays a pivotal role in regulating global climate conditions and sustains primary productivity and marine ecosystems (Duteil et al., 2014). Ice-core records retrieved from Greenland further suggest abrupt shifts in circulation patterns.During the last glacial period, dramatic temperature fluctuations were induced by variations in strength, as noted by Jayne, S. R. and Marotzke, J. (2001), and Fischer E. M. and Knutti R. (2015). According to Bryden, H. L. and Imawaki, S. (2001), the Atlantic Meridional Overturning Circulation (AMOC) transports warm upper waters to far-northern latitudes and circulates cold deep waters southward across the Equator. Its heat conveyance significantly contributes to the moderate climate experienced in maritime and continental Europe. Any deceleration in the overturning circulation would carry profound implications for climate change.

4. Impact of Volcanic Eruptions

Volcanic eruptions expel molten rock, known as lava, along with greenhouse gases and other substances from deep within the Earth, affecting the atmosphere (Robock, 2000). The gases, ashes, and dust particles emitted during volcanic eruptions exert significant influences on climate dynamics. Most of the particles released from volcanoes contribute to cooling the planet by blocking incoming solar radiation (Hyde and Crowley, 2000). Volcanic activities also release substantial amounts of water vapor and carbon dioxide into the atmosphere (IPCC, 2012). Despite the relatively small size of volcanoes compared to the Earth, their impact on climate is not negligible, especially when considering geological history (William F. Ruddiman, 2007). According to Rutgers University (2018), about four billion years ago, during Earth's early stages when it was hot and devoid of life, tectonic activity, including frequent earthquakes and volcanic eruptions, was considerably more pronounced.

5. Glacier Melting

Anthropogenic impacts have significantly altered the global water cycle since the 1960s, leading to the retreat of glaciers and increased surface melting of the Greenland ice sheet since 1993 (Peterson et al., 2013). These influences have contributed to the loss of Arctic Sea ice since 1979 and have notably elevated global upper ocean heat content (0–700 m). A rise in global mean sea levels has been observed since the 1970s (You and Ringler, 2010; IPCC, 2014). Between 1992 and 2011, both the Greenland and Antarctic ice sheets experienced mass loss, while glaciers worldwide continued to diminish (You and Ringler, 2010). Warming of the atmosphere and oceans, along with reduced snow and ice cover, have been documented (IPCC, 2012). Glaciers are expected to persist in diminishing size, with melting rates projected to escalate, further contributing to sea level rise (Savage et al., 2015). Glacier retreat is evident globally, including in the Alps, Himalayas, Andes, Rockies, Alaska, and Africa (NRC, 2011). According to Peterson et al. (2013), Antarctica and Greenland have collectively lost approximately 134 and 287 gigatonnes of ice per year since 2002.

6. Sea-Level Rise

The anticipated rise in average sea levels is primarily attributed to two factors: thermal expansion of the oceans and the melting of glaciers and ice sheets (Peterson et al., 2013). Thermal expansion, driven by the warming of ocean waters, causes water to expand as it warms, leading to increased volume and rising sea levels (You and Ringler, 2010; Hansen, 2016).

Loss of land-based ice, including glaciers and ice sheets, further contributes to rising sea levels. The increased melting of these ice formations has resulted in a global average rise of about 17 cm since 1900, driven by both thermal expansion of ocean water and glacier ice melt (Peterson et al., 2013; Hansen, 2016). Over the past century, the rate of sea level rise has accelerated from 1 mm/year to 3 mm/year today.

The primary drivers of changes in ocean water volume include the expansion of warm ocean water and the transfer of water from land-based ice formations to the ocean, particularly from glaciers and ice sheets (Fischer and Knutti, 2015; Savage et al., 2015).

B) Human-Induced Factors

Human activities have caused and are causing permanent changes in the Earth's surface and atmospheric composition (IPCC, 2007a). Human activities that contribute to climate change include burning fossil fuels, clearing forests, and changing agricultural land, urban areas, and road networks. All these activities result in the release of greenhouse gases into the atmosphere (EPA, 2010).

1. Impact of deforestation

Forests play a central role in the Earth's climate system and serve a variety of functions. Most importantly, they absorb carbon dioxide from the atmosphere and convert it into biomass through photosynthesis (FAO, 2010). Forests act as natural carbon dioxide filters, storing more carbon than they release, which is why they are called carbon sinks in their natural state (Negar and Jean 2014). Forest cover helps regulate air and surface temperatures by absorbing carbon dioxide. Therefore, the reduction in forest cover may lead to significant increases in temperature (Yuksel G., 2014). Conversely, increased forest cover in the tropics increases evapotranspiration, leading to a cooling effect. Increased evapotranspiration can lead to cooler weather during the growing season and reduce the intensity of heat-related events (Department of Agriculture, 2011; FAO, 2011a).

When forests are burned or cleared for purposes such as agriculture, ranching, infrastructure or urbanization, the flow of carbon from the atmosphere to the forest ceases, both currently and throughout the life expectancy of the trees (FAO, 2010). Deforestation also results in the release of carbon stocks accumulated in trees and forest floors (David E., 2018). In recent years, current deforestation has led to unprecedented increases in atmospheric carbon dioxide (Adnan et al., 2011). Changes in forest cover directly affect Earth's surface temperature through changes in water and energy exchange (IPCC, 2020). The loss of forest cover disrupts global and regional climate patterns and can lead to catastrophic rainfall patterns.

2. Land use change

Land use change, land use intensification, and climate change play a role in desertification and land degradation (IPCC, 2020). Changes in land use—such as conversion to forest, agriculture, urban development, etc.—can produce local warming and cooling effects by changing the reflectivity of the Earth's surface (affecting the reflection of sunlight) and regional moisture changes (Adnan et al. People, 2011), David, 2018). Unsustainable land management practices and land use patterns lead to negative economic consequences, which are exacerbated by climate change (IPCC, 2020). Land-use change, particularly the conversion of forests and peatlands to agricultural land, releases carbon stored in biomass and soil and increases total CO2 emissions by 10 to 15% (FAO, 2011a).

3. Greenhouse Gas Emissions

Since the pre-industrial era, the land surface air temperature has risen nearly twice as much as the global average temperature due to the emission of greenhouse gases (IPCC, 2007a; IPCC, 2020). Global surface temperatures have increased by approximately 0.6°C since 1900. This warming probably exceeds that of any century since 200 AD, with the 1990s being identified as the warmest decade in the last millennium. While temperature variations occur across different regions, nearly all regions have experienced warming over the past 25 years (Yuksel, 2014; IPCC, 2018). Ongoing emissions of greenhouse gases from industrialized nations are resulting in hydrometeorological events, sea-level rise, and seasonal unpredictability (Adnan et al., 2011; Yuksel, 2014). Globally, economic and population growth remain significant drivers of increases in CO2 emissions from fossil fuel combustion. CO2 emissions from fossil fuel combustion and industrial processes accounted for approximately 78% of the total increase in greenhouse gas emissions from 1970 to 2010 (EPA, 2010; IPCC, 2014).

4. Combustion of Fossil Fuels

The global agricultural food sector accounts for over 30 percent of global end-use energy demand, primarily sourced from fossil fuels, and emits approximately 22% of total anthropogenic greenhouse gases (FAO, 2011a). According to NRC (2011), the Earth is experiencing warming due to the addition of heat-trapping greenhouse gases such as CO2, N2O, CH4, and water vapor to the atmosphere, primarily through the combustion of fossil fuels. With the escalating use of fossil fuels, the concentration of these gases in the atmosphere escalates. The combustion of fossil fuels (coal, oil, and natural gas) and activities like cement production elevate CO2 levels, thereby reducing the amount of CO2 absorbed by trees. The increase in CO2 concentration stands as the largest contributor to global warming (IPCC, 2018).

5. Impact of Urbanization

Urbanization is recognized as a catalyst for economic growth, facilitating the transition of surplus labour from rural agricultural sectors to urban industrial centres, thus contributing to overall economic development (Muntasir M. and Syed Y.S., 2018). However, unplanned urbanization can yield negative repercussions, adversely affecting economies, fostering deforestation, promoting environmental degradation, and exacerbating global warming and climate change (Zhang, N, Yu, K., and Chen, Z., 2017). Urban sprawl can exacerbate warming within cities and their environs, particularly during heat-related episodes such as heat waves, a phenomenon known as the heat island effect. Furthermore, heightened urbanization can intensify extreme rainfall events within urban areas or downwind regions, amplifying the risks associated with flooding (IPCC, 2020).

6. Emissions of Air Pollutants

Certain industrial and agricultural activities release pollutants (distinct from Greenhouse Gases) that generate aerosols—minute droplets or particles suspended in the atmosphere (IPCC, 2020). Some aerosols influence cloud formation, with effects ranging from warming to cooling based on their composition and location. For instance, black carbon particles or soot, emitted during the combustion of fossil fuels or vegetation, typically induce warming by absorbing incoming solar radiation (USGCRP, 2009). Additionally, Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF6), collectively referred to as F-gases, find application in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol propellants (IPCC, 2013). Unlike water vapor and ozone, F-gases possess prolonged atmospheric lifetimes, with certain emissions impacting the climate over decades or centuries (USGCRP, 2014). Although black carbon exists as a solid particle or aerosol rather than a gas, it contributes to atmospheric warming. Unlike Greenhouse Gases, black carbon has the capacity to directly absorb incoming and reflected sunlight, aside from absorbing infrared radiation (IPCC, 2013; Sims, Gorsevski, and Anenberg, 2017).

7. Agricultural Expansion

Agricultural practices, such as the application of nitrogen-based fertilizers, elevate the levels of Nitrous oxide (N_2O) in the atmosphere, contributing to climate change (MoA, 2011). Similarly, human activities such as livestock rearing, rice cultivation, landfill operations, and natural gas utilization primarily emit Methane (CH_4), a significant contributor to climate change. CH_4 emanates from swamp decomposition, ruminant digestion, notably from cattle, and leakage during fossil fuel extraction (Braman et al., 2010). Human-induced activities have caused CH_4 concentrations to surpass pre-industrial levels, more than doubling during the 20th century (EPA, 2010). Furthermore, Halocarbons, encompassing chlorofluorocarbons (CFCs), chemicals employed as refrigerants and fire suppressants, pose potential threats to climate stability and can harm the ozone layer. The expansion of croplands leads to substantial declines in biodiversity (MoA, 2011; IPCC, 2020)

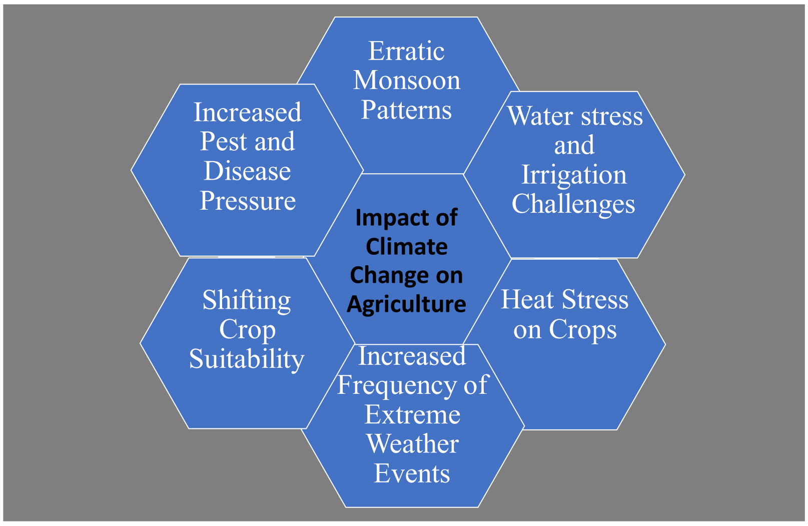
Impact of Climate Change on agriculture

Climate change is negatively impacting the Indian agricultural sector, which relies heavily on monsoon rains and has a huge population involved in agriculture, affecting crop yields, water availability, pests and diseases, and overall food security. Agricultural production's quantity and nutritional quality rely on a dynamic balance of biophysical resources such as soil quality, water availability, sunlight, CO_2, temperature, and pollinator abundance.

Production declines due to climatic extremes, pests, infections, and air pollution. Farmers adapt to the local environment through established infrastructure, farming practices, and personal experience, yet are flexible in dealing with weather and seasonal unpredictability. Climate change is predicted to affect agriculture, posing both threats and chances for improvement.According to the ICAR report, forecasts regarding crop production under medium-term climate change scenarios suggest a potential decrease in crop yields ranging from 4.5% to 9% by the year 2039.

Birthal et al. (2014) analyzed the fluctuations of climate factors such as temperature and rainfall in India from 1969 to 2005. Their study aimed to assess the repercussions on crop yields. Their findings indicate that substantial alterations in temperature and rainfall patterns resulting from climate change could result in a 15% reduction in rice yields and a 22% decrease in wheat yields. A 1°C increase in temperature is projected to diminish farmers' net income by $2 per hectare in specific districts. Kumar and Sharma (2013) examined the influence of climate sensitivity on crop productivity using panel data spanning from 1980 to 2009, employing the Cobb-Douglas production function model. Their analysis revealed that climatic variables exert a negative and statistically significant impact on the per-unit land productivity of wheat, barley, sorghum, maize, and other crops. A 1% rise in maximum temperature is associated with a 2.6% reduction in rice productivity. For Punjab, a vital grain-producing region, Hundal and Prabhjyot-Kaur (2007) estimated that over the past three decades, minimum temperatures have either decreased by 0.02°C/year or increased by 0.07°C/year, while maximum temperatures have decreased by 0.005-0.06°C/year, and rainfall has increased by 2.5-16.8 mm/year. A 1.0°C temperature increase is anticipated to decrease rice and wheat yields by 3% and 10%, respectively. Furthermore, if maximum temperatures decline by 0.25-1.0°C and minimum temperatures rise by 1.0-3.0°C, rice and wheat yields would decrease by 0.8% and 3.0%, respectively. At the national level, Khan et al. (2009) assessed the impact of climate change on Indian agriculture, concluding that wheat productivity experiences a linear decline with increasing mean minimum temperature. With each 1°C rise in mean temperature, wheat yield declined by 430 kg/ha. The study projected that a 2°C temperature increase would result in a 10-15% decrease in crop yield across various regions, while a 4°C rise would lead to a 20-30% reduction in crop output.

Indicators that serve as evidence of the climate change phenomenon include-



Inconsistent monsoon patterns: The monsoon is vital for India's agriculture, serving as a crucial water source for irrigation and influencing planting and harvesting timelines. It has induced heightened variability in monsoon behaviors, affecting the timing, duration, and intensity of rainfall. Unforeseeable and irregular monsoons may contribute to droughts or excessive rainfall, causing water scarcity or waterloggingsoil erosion, and nutrient leaching, these unpredictable conditions can negatively impact crop production.

Crop heat and Changing crop suitability: Elevated temperatures linked to climate change heighten the susceptibility of crops to heat stress. Heatwaves occurring during crucial growth phases can inflict damage on crops, diminish photosynthesis, and hinder fruiting, resulting in decreased yields. Crops such as wheat, rice, maize, and vegetables are particularly vulnerable to the adverse effects of heat stress. Climate change might affect the adaptability of specific crops in different parts of India.Changes in temperature and rainfall patterns may make certain locations less appropriate for traditional crops, while others may become more ideal for new crops.

Changing growing conditions: Climate change causes temperature and precipitation patterns to fluctuate, directly impacting agricultural productivity. Rising temperatures can cause heat stress in crops, reducing photosynthesis and yields. Changes in rainfall patterns, such as more frequent droughts or high rainfall events, can interrupt planting and harvesting dates, limit water availability, and increase soil erosion.

Increased insect and disease pressure: Climate change made a shift in the distribution and abundance of pests and diseases, thereby reducing agricultural productivity. Warmer temperatures can promote the proliferation of certain pests, such as insects and weeds, resulting in increased infestations and crop damage. Changes in rainfall patterns can also foster the spread of illnesses.

Food security: Climate change and food security are interconnected as climate variations can directly impact a nation's capacity to provide food for its population. India is currently self-sufficient in food grain production, it is important to consider future food production to keep up with population increase, especially in the face of changing weather conditions.The increasing frequency and intensity of extreme weather events can result in crop failures, disruptions in food supply chains, and price instability. It raises the vulnerability of populations, particularly those in developing nations, to heightened risks of food poverty and malnutrition.

Rice		**Wheat**	
Year	**Production**	**Year**	**Production**
1989-2000	17.96%	1989-2000	34.37%
2001/2007-08	3.45%	2001/2007-08	3.51%
5%–26% by the year 2080			

(Source: Indian Agricultural Research Institute (IARI))

The study illustrates the growth of major crops and their per-hectare yield in India during the periods 1989-2000 and 2001/2007-08. Between 1989-2000 and 2007-08, rice production decreased from 17.96% to 3.45%, while wheat production declined from 34.37% to 3.51%. These trends suggest a potential risk to India's food security in the future due to the looming threat of climate change, potentially leading to a rise in the number of people threatened by hunger by 5%–26% by the year 2080.

Crop failure and suicide victims in the farming community: Crop failure is often caused by harsh weather circumstances such as droughts, floods, or extreme temperatures, which have a direct impact on farmers' income. When crops fail, farmers may have difficulty repaying debts, covering operational costs, or meeting their necessities. Financial distress causes increasing debts, limited livelihood possibilities, and greater vulnerability to economic shocks, especially in states like Maharashtra, Karnataka, and Andhra Pradesh, where agriculture is a major livelihood. However, suicide rates among farmers can fluctuate over time and are influenced by various factors including economic conditions, government policies, access to support services, and cultural attitudes toward mental health.The National Crime Records Bureau of India reported that a total of 296,438 Indian farmers had died by suicide between 1995 and 2014. Out of these, 60,750 farmer suicides were in the state of Maharashtra since 1995 and the remaining in Odisha, Telangana, Andhra Pradesh, Madhya Pradesh, Gujarat and Chhattisgarh, all states with loose financial and entry regulations

A study conducted in 2014, found that there are three specific characteristics associated with high-risk farmers: "those that grow cash crops such as coffee and cotton; those with 'marginal' farms of less than one hectare; and those with debts of 300 Rupees or more." The study also found that the Indian states in which these three characteristics are most common had the highest suicide rates and also accounted for "almost 75% of the variability in state-level suicides. (2014 University of Cambridge) (Kennedy, Jonathan; King, Lawrence (2014))

Alteration in agricultural yield: Due to climate change in Andhra Pradesh state paddy and groundnut production has been decreasing; likewise, in Maharashtra state sugarcane yield has decreased by 25-30 % production, and in Orissa, West Bengal and Bihar states paddy production has decreased by 12%.

Impact on crop quality and nutritional content: The effects of climate change on crops have resulted in a decline in both the nutritional quality and content. Elevated levels of carbon dioxide (CO2) can contribute to a reduction in protein content in specific crops, diminishing their nutritional value.

Additionally, notable weather events and shifts in growth conditions can impact crop quality attributes such as taste, texture, and storage characteristics.

Socio-economic impact: India has a substantial population of smallholder farmers. They are impoverished and have low socioeconomic status. Rural conditions are more critical. According to the World Bank (2013), 70% of Indians are impoverished and live in rural areas, with 75% of families relying on rural income.The eastern part of central India, including districts in Chhattisgarh, Odisha, and Jharkhand, exhibits a high percentage of people living below the poverty line. This percentage further escalates in the vicinity of forest-dominated tribal areas (Ahmad et al., 2018; Ahmad et al., 2019b). Tribal communities are particularly vulnerable to the impacts of climate change (Minj, 2013), while certain districts in central India, identified as hotspots for farmer suicides (Goparaju& Ahmad, 2019), require special attention in implementing Climate-Smart Agriculture (CSA). In addition to other factors, the severity of the Hunger Index in these regions is found to be alarming (Menon et al., 2009)

Climate Change and States Production

A recent World Bank assessment examined the effects of climate change with a particular emphasis on two drought-prone areas in Andhra Pradesh and Maharashtra as well as an area in Orissa that is prone to flooding. Dryland farmers in Andhra Pradesh may see a 20% reduction in their revenue. Maharashtra may see a significant drop in sugarcane output, of 25–30%. In the meantime, Orissa is predicted to have significant increases in floods, which could cause rice harvests in some regions to drop by as much as 12%. According to Kumar and Parikh (2001a), significant yield losses for wheat and rice are predicted as a result of projected large-scale climate change. As a result, this would negatively affect agricultural output by 2060, which might affect the food security of more than one billion people in India. An examination of the expected outcomes for the years 1980–2049 by Saseendran et al. (2000) indicates that temperature increases of up to 50°C can result in a continuous decrease in rice production, with yields in Kerala, India, dropping by up to 6% for each degree above that threshold. Minimum temperatures rising by 1.0°C to 3.0°C above average have resulted in a 10% drop in wheat and a 3% decline in rice yield in Punjab, according to Hundal and Prabhjyot Kaur (2007). Temperatures as low as 25°C can cause a delay in the grain-filling stage of wheat. After then, an increase in temperature of 1°C shortens the grain-filling length by approximately 5% and the reproductive phase by 6%; as a result, the grain yield and harvest index decrease. A 4°C rise in temperature would have a huge effect on food grain production, especially wheat, according to Karim et al. Temperature increases cause productivity to decline significantly; for example, wheat and rice are reduced by about 28% and 68%, respectively. On the other hand, a doubling of atmospheric CO_2 combined with a similar rise in temperature would result in a 31% decline in wheat productivity and an overall 20% increase in rice production. It was found that boro rice will provide a respectable crop in the event of major climate change. The productivity of gram and ragi is also negatively impacted by a rise in the maximum temperature. On the other hand, it positively affects wheat and arhar productivity. (Prabhjyot-Kaur &Hundal, 2007; Parikh & Kumar, 2001a, 2001b). Climate change may cause production losses in irrigated areas for rice, sorghum, and maize in India's Western Ghats, as well as for wheat, mustard, and maize in northeastern and coastal regions (Kumar et al., 2011). Kaul and Ram (2009) found that extreme temperature changes have a significant effect on the production of the Jowar crop and protracted downpours, which has an effect on the incomes of agricultural households and food security in Karnataka, India. Increases in the maximum temperature have a statistically significant detrimental impact on sugarcane, cotton, and sesame crops, according to an empirical study for commercial non-food grain crops. Any departure from the average minimum temperature has a negative and statistically significant effect on linseed productivity. The variability in average rainfall has negatively impacted the productivity of sugarcane. Production of cash crops is predicted to suffer from climate-related problems. Singh (2012). Climate change has had a significant impact on cane productivity in Uttar Pradesh and Uttarakhand, according to Boopen&Vinesh (2011).

Mitigation and Strategies

- Greenhouse Gas Emission Reduction
- Crop Diversification
- Soil and Water Management
- Sustainable Pest Management
- Weather Forecasting Application
- Water Efficient Techniques
- Crop Residue management
- Use of Renewable Source of Energy
- Conservation Tillage

Conclusion

In the contemporary era, Climate change is a reality. Climate change has seriously affected agricultural production of India. There is an urgent need to recognise the innovative and creative strategies for climate change's adaption and mitigation. On the one hand, the population of India is increasing rapidly and on the other hand, agricultural production is negatively affected by climate change. These two factors have posed a huge challenge and created a shortage of food supply, leading to massive hunger and starvation.
In the last two decades, farmers have changed their profession to secondary and tertiary activities. Finally, we should remember **"In chilled winter or summer intensive heat, farmers and ranchers work hard in the open field, so the world can eat".**

Present and Future Scenario

In India, the significance of climate change risks is pronounced, yet the preparedness and capacity to address these changes remain inadequate These climate-induced risks imperil crop yields due to rising temperatures recurrent droughts, and periodic floods. Projections based on temperature and precipitation trends suggest that arid and semi-arid regions will face severe climate change impacts shortly, particularly by 2050. Carleton (2017) identifies these areas as hotspots for farmer suicides due to escalating temperatures. Moreover, impoverished districts in states like Orissa, Chhattisgarh, and Bihar face looming threats. Future precipitation deficits are also anticipated in parts of the Western Ghats, renowned for their biodiversity and agricultural significance.
Based on the aforementioned study, it is evident that greenhouse gas (GHG) emissions, anthropogenic pressure on land use and land cover (LULC), socio-economic conditions, soil moisture distribution, and deficits are highly pronounced in India. The current temperature and precipitation patterns, along with future trends, pose significant challenges that may adversely affect agricultural production over time. This analysis underscores the urgent need for a cohesive policy framework to prioritize regions grappling with the new realities of climate change, thereby fostering resilience among marginalized populations. There is a crucial necessity to develop concrete policies through institutional efforts that address the underlying

socio-economic and climatic challenges faced by agriculture-dependent communities across the nation. These policies should facilitate Climate-smart agriculture (CSA) practices rooted in indigenous knowledge to enhance farm outputs and improve the livelihoods of the populace.

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