



Climate Change and its Impact on Agricultural Productivity in India

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Climate change is one of the most critical environmental challenges of the present century, significantly affecting natural ecosystems, human health and agricultural systems worldwide. It is primarily driven by increased emissions of greenhouse gases such as carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O), resulting from anthropogenic activities including industrialization, deforestation and land-use changes. These emissions have disturbed the natural energy balance of the earth, leading to global warming and climatic variability in terms of temperature and precipitation patterns. Agriculture, being highly climate-sensitive, is directly influenced by changes in temperature, rainfall, humidity and solar radiation. In developing countries like India, where a large portion of the population depends on agriculture for livelihood and a significant share of cultivation is rainfed, climate change poses a serious threat to food security and economic stability. Changes in climatic variables not only affect crop growth and productivity but also influence soil health, water availability and pest dynamics, thereby increasing the vulnerability of the agricultural sector.

Climate Change Trends and Variability in India: India has been experiencing noticeable changes in climatic patterns over the past few decades. There has been a consistent increase in average temperature, along with significant variability in rainfall distribution and intensity. Studies indicate that the average global temperature has increased by approximately 0.74°C over the last century, and it is projected to rise further by 1.4°C to 5.8°C by the end of the 21st century. In the Indian context, climate models predict a temperature increase ranging from 2.33°C to 4.78°C, accompanied by more frequent and intense heat waves, irregular monsoon patterns and increased occurrence of extreme weather events such as droughts and floods. The monsoon, which is the backbone of Indian agriculture, has become increasingly unpredictable in terms of onset, duration and distribution, thereby increasing production risks, especially in semi-arid and rainfed regions.

Impact of Climate Change on Agricultural Productivity: Agricultural productivity is highly dependent on climatic factors, and even slight changes in these parameters can lead to significant variations in crop yield. Rising temperatures increase evapotranspiration rates, reduce soil moisture and shorten crop growth duration, ultimately leading to yield reduction. Erratic rainfall patterns can cause both drought and flooding conditions, adversely affecting crop growth and development. For instance, studies have shown that abnormal weather conditions such as delayed monsoon, excessive rainfall and higher temperatures can disturb crop physiology and reduce productivity, as observed in cotton cultivation in Gujarat. Similarly, projected climate change scenarios indicate a reduction in groundnut yield by 20–34% in Gujarat due to increased temperature and altered rainfall patterns. In addition, extreme climatic events such as heat waves and droughts further intensify the negative impacts on agriculture. Thermal stress affects vegetation health, reduces photosynthetic

activity and leads to agricultural drought conditions, thereby decreasing crop yield. Studies have demonstrated a strong relationship between temperature stress, vegetation indices and crop productivity.

Role of CO₂ and Technological Advancements in Agriculture: Climate change also involves an increase in atmospheric CO₂ concentration, which may have both positive and negative effects on agriculture. Elevated CO₂ levels can enhance photosynthesis, biomass production and water-use efficiency, particularly in C3 crops. However, these benefits are often offset by the adverse effects of increased temperature, water stress and pest incidence, resulting in an overall uncertain impact on crop productivity. In recent years, technological advancements such as remote sensing and satellite-based monitoring have emerged as important tools for assessing the impact of climate change on agriculture. Techniques like the Normalized Difference Vegetation Index (NDVI) enable continuous monitoring of vegetation health, crop condition and productivity at regional and global scales. These technologies provide valuable insights into the relationship between climatic variables and agricultural output, thereby supporting better decision-making and planning. Therefore, understanding the impact of climate change on agricultural productivity is essential for developing effective adaptation and mitigation strategies. In a country like India, where agriculture plays a crucial role in ensuring food security and supporting livelihoods, such analysis becomes highly significant for sustainable agricultural development.

Review of Literature

Climate change and its impact on agricultural productivity has been widely studied across different regions, crops and methodologies. Various researchers have analyzed the influence of climatic variables such as temperature, rainfall, carbon dioxide concentration and extreme weather events on crop growth and yield using statistical, simulation and remote sensing approaches.

Impact of Temperature and Rainfall on Crop Productivity: Temperature and rainfall are the most critical climatic factors influencing agricultural productivity. Several studies have demonstrated that rising temperatures and erratic rainfall patterns negatively affect crop growth and yield. Thakare et al. (2014) analyzed the impact of weather parameters on cotton productivity in Gujarat and reported that delayed monsoon, excessive rainfall during critical growth stages and higher temperatures adversely affected crop physiology, leading to reduced yield. Similarly, Rathore and Jasrai (2013) studied climatic variability in Gujarat and observed a significant increasing trend in temperature and variability in rainfall over the past decades, which poses a serious threat to agricultural sustainability. Patel et al. (2013) evaluated the impact of projected climate change on groundnut yield in Gujarat using simulation models and found that pod yield is likely to decrease by 20–34% under future climate scenarios due to increased temperature and altered precipitation patterns. These findings clearly indicate that climatic variability significantly influences crop productivity in India.

Effect of Climate Change on Crop Growth and Development: Climate change affects not only crop yield but also crop growth stages, phenology and development processes. Increased temperature leads to faster crop maturity, reduced crop duration and lower biomass accumulation. Sankaranarayanan et al. (2010) reported that increased temperature can reduce crop duration, increase evapotranspiration and negatively affect cotton yield, although elevated CO₂ may enhance biomass production. Similarly, Naikwade (2020) highlighted that higher temperature beyond optimum levels leads to reduced photosynthesis, increased respiration and ultimately lower crop productivity in cotton across global regions. Furthermore, Kumar and Gautam (2014) emphasized that changes in climatic variables such as temperature and precipitation significantly impact crop growth, disease occurrence and overall agricultural productivity in India.

Impact of Extreme Weather Events and Thermal Stress: Extreme weather events such as droughts, floods and heat waves have become more frequent due to climate change and have severe impacts on agriculture. These events disrupt crop growth and reduce yield

significantly. Bhuiyan *et al.* (2017) analyzed the impact of thermal stress on vegetation health and agricultural drought in Gujarat and found that high temperature combined with moisture stress significantly reduces vegetation health and crop yield. The study highlighted that thermal stress plays a crucial role in intensifying drought conditions and negatively affecting agricultural productivity. Similarly, studies have shown that increasing frequency of droughts and extreme weather conditions in India is leading to instability in agricultural production and increased risk of crop failure.

Role of CO₂ Concentration and Crop Response: The increase in atmospheric CO₂ concentration is another important aspect of climate change that influences agricultural productivity. Elevated CO₂ levels can enhance photosynthesis, increase biomass and improve water-use efficiency in crops, especially C3 plants. Sankaranarayanan *et al.* (2010) reported that elevated CO₂ concentration can increase cotton yield by improving photosynthetic activity and biomass production, but this positive effect is often counterbalanced by adverse temperature effects. Similarly, Naikwade (2020) also emphasized that while increased CO₂ may promote crop growth, higher temperatures and water stress may reduce overall productivity. Thus, the net effect of climate change on crop productivity depends on the interaction between CO₂ concentration, temperature and water availability.

Application of Remote Sensing and NDVI in Agricultural Studies: Recent advancements in remote sensing technologies have provided new opportunities to assess the impact of climate change on agriculture. The Normalized Difference Vegetation Index (NDVI) is widely used to monitor vegetation health and predict crop yield. Lopresti *et al.* (2015) demonstrated a strong relationship between NDVI and wheat yield, indicating that remote sensing can be effectively used for early yield prediction and monitoring spatial variability in crop productivity. Similarly, Panek and Gozdowski (2020) found a strong correlation between NDVI values and cereal yield across European regions, proving its effectiveness in forecasting crop production. Jabal *et al.* (2022) also highlighted that NDVI-based analysis combined with climatic variables such as rainfall and temperature provides better understanding of crop productivity under changing climate conditions. Overall, the review of literature indicates that climate change has a significant impact on agricultural productivity through changes in temperature, rainfall patterns, extreme weather events and atmospheric CO₂ concentration. The integration of advanced technologies such as remote sensing further enhances the understanding and prediction of these impacts, thereby supporting better agricultural planning and management.

Conclusion

Climate change poses a serious and growing threat to agricultural productivity in India by altering key climatic variables such as temperature, rainfall patterns and the frequency of extreme weather events. The review of literature clearly indicates that rising temperatures, erratic monsoon behaviour and increased occurrence of droughts and heat waves adversely affect crop growth, phenology and yield, particularly in rainfed regions. Although elevated atmospheric CO₂ may enhance crop productivity to some extent, its positive effects are often offset by heat stress, water scarcity and increased pest incidence. The integration of advanced tools such as remote sensing and NDVI has improved the monitoring and assessment of crop conditions under changing climatic scenarios. Therefore, there is an urgent need to adopt climate-resilient agricultural practices, efficient resource management and technology-driven approaches to ensure sustainable agricultural development and long-term food security in India.

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