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The impact of climate change on Indian agriculture: Embracing sustainable practices

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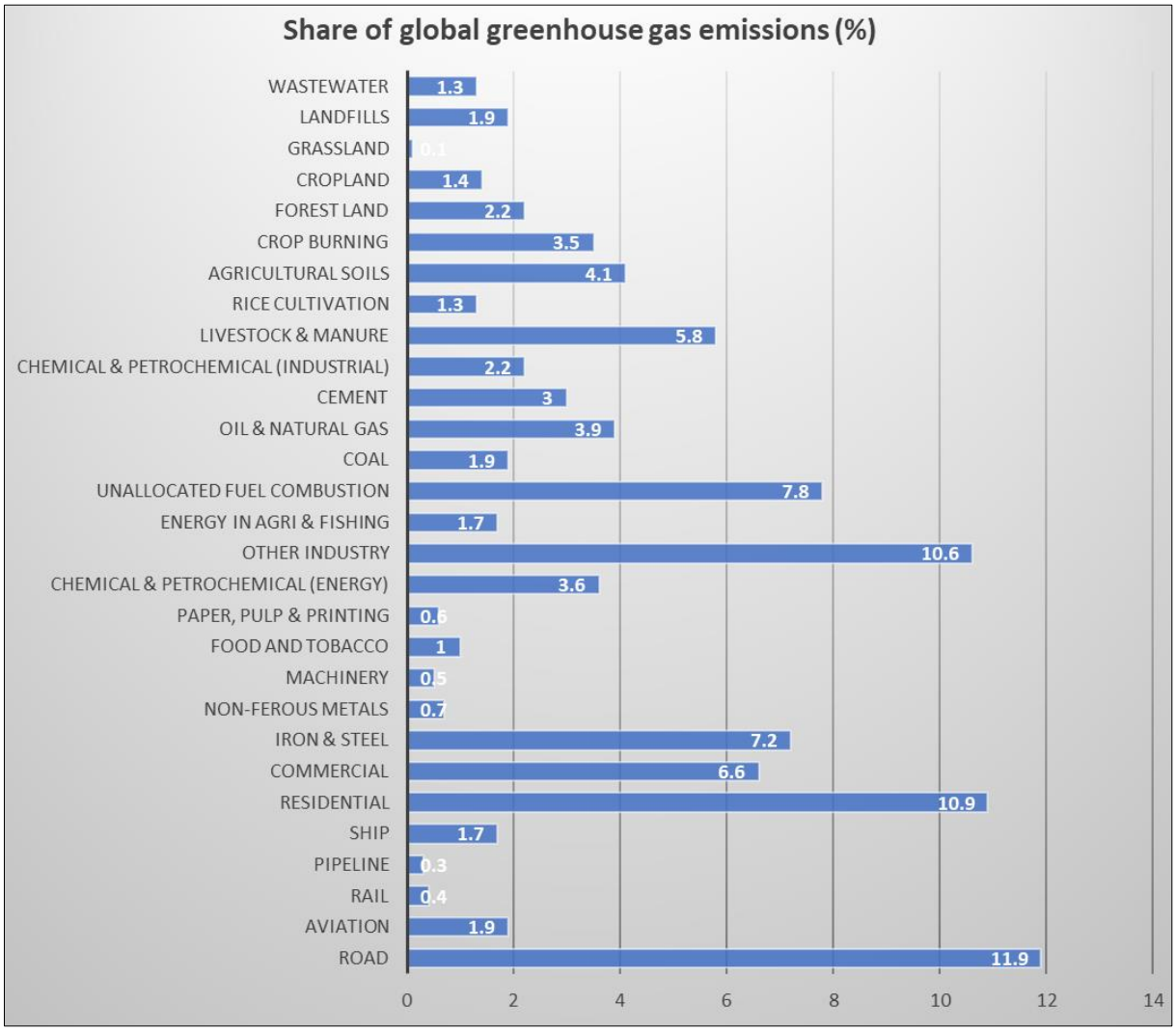
Abstract
Agriculture has long been the backbone of India's economy, providing a living for millions of people and ensuring the nation's food security. India is fortunate to have a vast and diversified geographic area, as well as a strong agricultural culture. Most of the population works in Agriculture business, which also significantly boosts the country's GDP, especially in rural areas. In addition to being essential to farmers' livelihoods, agriculture also keeps the general population alive by ensuring a consistent supply of food. On the other hand, a rise in greenhouse gas emissions has been caused by urbanization, population growth, and rapid industrialization. To address this issue, India has made great strides in developing and implementing policies and initiatives to reduce climate change effect. This article provides a comprehensive review of India's key projects, laws, and programs for reducing emissions, promoting renewable energy, and enhancing climate resilience. Through an examination of these actions and their outcomes, we aim to shed light on India's dedication to combating the global climate change.

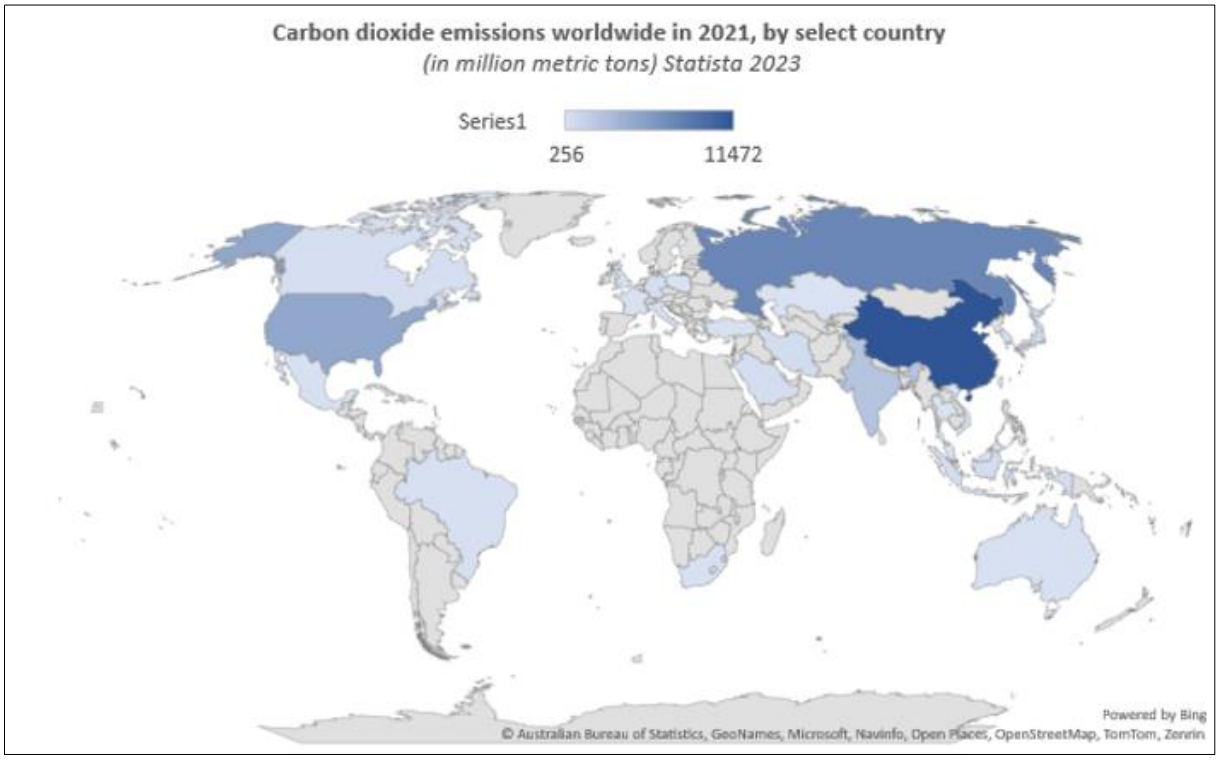
Keywords: Indian agriculture, climate change, adaptation and mitigation strategies, food security

Introduction
To feed a growing population and adapt to the negative consequences of climate change, Indian agriculture is at a crossroads. In India, agriculture employs more than 50% of the workforce (NSSO, 2019) [23], and millions of smallholder farmers rely on it for survival (Mishra *et al.*, 2019) [20]. The Indian subcontinent has experienced a noticeable change in atmospheric conditions during the past few decades. These long-term patterns changes in temperature, precipitation, and weather are known as climate change, and they are primarily caused by human activities. On the other hand, global warming, which is brought on by greenhouse gas emissions into the atmosphere, is one of the main causes of climate change. (Mikhaylov, *et al.*, 2020) [15]. These gases, like carbon dioxide and methane, retain solar heat, raising temperatures and causing changes to the climate. Carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the three main greenhouse gases that contribute to global warming. According to data from the Global Carbon Budget (2022) the world's CO_2 emissions from industrial processes and the combustion of fossil fuels reached about 37.12 billion metric tons.

The average global temperature has increased by roughly 1 degree Celsius according to the National Oceanic and Atmospheric Administration in the last 100 years (Adnan and Khan 2021) [1]. So, another aspect of climate change that has significant ramifications for Indian agriculture is rising temperatures. According to a recent study (Lobell and Gourdji, 2012) [13], increased heat stress has a detrimental effect on agricultural growth and development, especially for temperature-sensitive crops like wheat and rice. More frequently occurring extreme heat events result in failed crops and lower yields (Asseng *et al.*, 2011) [4]. It is becoming more and more important to take adaptation measures, such as growing heat-tolerant crop types (Rathi *et al.*, 2020) [25]. In addition, the timing of the monsoons, which are essential for agricultural activity, has become difficult to anticipate due to shifting patterns of rainfall. Crop failures and a lack of water are results of increasing droughts and irregular precipitation. With many species experiencing risks from shifting habitats, climate change is a factor in the loss of biodiversity. Thus, the writers of this article attempt to describe the numerous ways in which climate change has impacted Indian agriculture and highlighted mitigating measures.



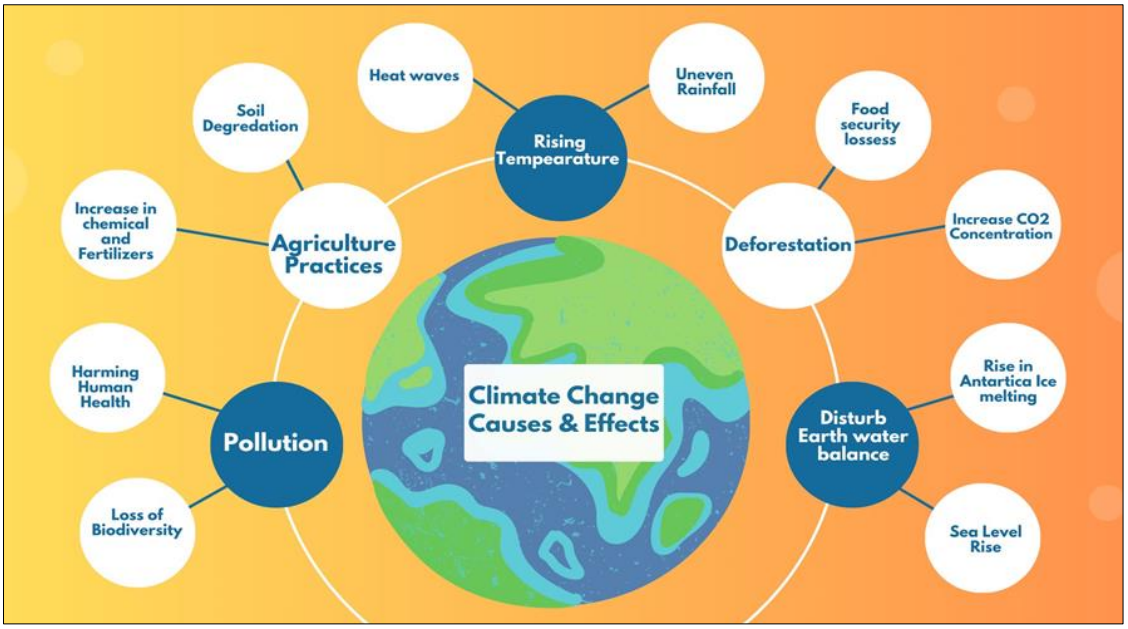
Source: Climate Watch, The World Research Institute (2020)



Climate change and Indian agriculture

The impact of climate change on Indian agriculture is significant since agriculture has been and will continue to be a key component of India's economy. However, issues like soil erosion, water scarcity, the use of chemical pesticides, etc. have made traditional farming practices difficult.

- **Impacts on Crop Yields and Food Security**: Decreasing crop yields in India are a result of the interaction of shifting climatic patterns and rising temperatures. Major staple crops including rice, wheat, and maize are susceptible to production losses brought on by climate change, according to studies (Lobell *et al.*, 2011) [14]. Reduced yields can have significant effects on both the lives of millions of farmers and the security of food supply.
- **Increased Pests and diseases:** Warmer temperatures and shifting climatic patterns have created an atmosphere that is conducive to the growth of pests and diseases (Skendzic *et al.* 2021) [28]. Insect and weed pests that damage crops severely have evolved into more hardy and aggressive species. The difficulties faced by farmers are further exacerbated by the rise of plant and animal diseases. These outbreaks increase the need of chemical pesticides and antibiotics, which pollutes the environment and poses health hazards. They also decrease crop production.
- **Soil Degradation and Erosion:** Climate change has also increased soil erosion and degradation, which has a negative influence on agricultural productivity. Extreme weather conditions, such as prolonged periods of heavy rain and flooding, hasten soil erosion and cause the loss of fertile topsoil. The health of the soil is also impacted by rising temperatures and shifting moisture levels, which makes it vulnerable to deterioration and nutrient depletion. Sustainable farming practices are severely hampered by soil erosion and deterioration, which makes soil conservation necessary.
- **Challenges with Water Resources and Irrigation:** According to Shah *et al.* (2007) [27], climate change has made water scarcity worse in many parts of India, hurting both rainfed and irrigated agriculture. The availability of water resources for agriculture is threatened by melting Himalayan glaciers and changed precipitation patterns (Immerzeel *et al.*, 2020) [9].



Climate change causes & effects

Climate change adaptation and mitigation

Indian agriculture must adopt sustainable practices if it is to meet the difficulties posed by climate change. These consist of:

- **Adopting Sustainable Agriculture Methods in India:** Adopting sustainable farming methods is essential to reducing the negative effects of climate change on Indian agriculture. Farmers may adjust to changing climate conditions and preserve long-term agricultural sustainability by using organic farming practices, effective water management techniques, and crop diversity (Krishna *et al.*, 2021) [11]. Precision farming and conservation agriculture are sustainable strategies that increase the adaptability of crops to changing climatic circumstances (Jat *et al.*, 2019) [10]. In order to encourage environmentally friendly and climate-resilient farming methods, the Indian government launched the National Mission for Sustainable Agriculture (NMSA) in 2010. It places a strong emphasis on increasing soil health, water use efficiency, and the use of organic farming (NMSA, 2021) [21].
- **Implementing Organic Farming Techniques:** Using natural fertilizers, such as compost and manure, is prioritized over the use of industrial pesticides. Organic farming boosts biodiversity, lowers pollution, and helps maintain soil health by using less chemicals. Additionally, using organic farming methods makes crops more resistant to the effects of climate change and less prone to pests and disease. One of the leading producers of organic goods worldwide is now India, the National Programme for Organic Production (NPOP), which promotes farmers to switch to organic farming practices, certifies organic products. Another program that is flourishing and gaining popularity in areas like Andhra Pradesh and Karnataka is Zero Budget Natural Farming (ZBNF), by focusing on natural inputs and

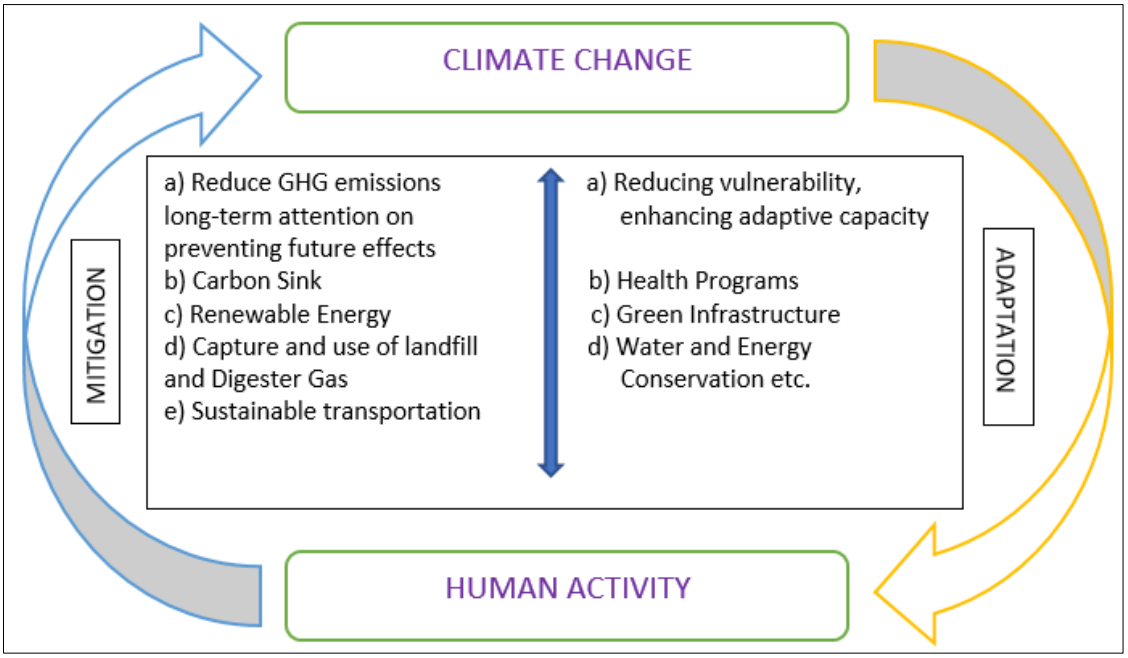
reducing the use of outside inputs, it encourages chemical-free farming (AP ZBNF, 2021) [3].

- **Efficient Water Management Techniques:** Climate change has made water scarcity an even bigger problem in Indian agriculture. The best use of water resources can be achieved by implementing effective water management strategies like drip irrigation and rainwater harvesting (Kumar *et al.*, 2019) [12]. These methods increase crop water efficiency, which increases crop yields in areas with limited water resources. They also reduce water waste. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY): This program intends to reduce water waste in agriculture by increasing irrigation coverage and streamlining water use efficiency (Ministry of Agriculture and Farmers Welfare, 2021) [16]. Another water saving scheme is National Water Mission: To increase climate resilience, this mission focuses on effective water management, conservation, and lowering water usage across a variety of sectors (MoWR, RD&GR, 2021) [19].
- **Afforestation and Reforestation:** India has started reforestation and afforestation programs to increase biodiversity and carbon sequestration. The Green India Mission seeks to promote sustainable forest management while expanding the number of trees and forests (MoEFCC, 2021) [17].
- **Renewable Energy Initiatives**

a. National Solar Mission: The mission, which was started in 2010, intends to promote solar energy in India by establishing high goals for expanding solar capacity. India is now one of the major markets for solar energy in the world thanks to tremendous advancements in solar power generation (MNRE, 2021) [18].

b. National Wind Energy Mission: Through legislative support and incentives, India's wind energy capacity has also experienced significant expansion, helping the nation meet its goals for renewable energy (MNRE, 2021) [18].

- Climate-Resilient Crop Varieties: Resilience can be increased by breeding and implementing heat- and drought-tolerant varieties of crops (Dwivedi *et al.*, 2019) [7].
- Electric Mobility and Green Transportation: To cut emissions from the transportation industry, India is pushing electric cars (EVs) and environmentally friendly transportation options. These measures include incentives, subsidies, and the building of charging infrastructure (NITI Aayog, 2021) [22].
- International Agreements and Collaborations: India has actively participated in international climate agreements, including the Paris Agreement. The country is committed to reducing its emissions intensity while simultaneously addressing climate adaptation challenges (UNFCCC, 2021) [29].
- Precision Agriculture: Precision agriculture can maximize yields and resource usage efficiency by utilizing technology for precise resource management (Senthilkumar *et al.*, 2020) [26].



Climate change adaptation and mitigation

- Climate Information Services: Providing farmers with timely climate information can aid in decision-making (Krishna *et al.*, 2021) [11].

Conclusion

The impact of climate change on Indian agriculture is undeniable, to overcome these challenges and ensure the long-term sustainability of the agricultural sector, it is imperative to embrace sustainable practices. Farmers can adapt to changing climatic circumstances and lessen their risk by employing organic farming practices, effective water management strategies, and crop diversity. It is crucial to move toward sustainable agriculture in order to protect the environment and natural resources as well as the country's long-term food security. India can support global sustainability goals while safeguarding the welfare of its agricultural sector and the country as a whole by implementing measures that put a priority on soil health, water conservation, and biodiversity preservation. Initiatives and policies from the government are necessary, but it takes

coordinated effort by farmers and all other stakeholders to address the complicated problem of climate change in Indian agriculture. Let's work together to ensure that Indian agriculture has a sustainable life. For a brighter future, we need to work together to create an agricultural industry to robust and sustainable.

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