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Changing Climate and Indian Farming: A Brief Overview.

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Abstract:

India's agriculture, which has historically relied on regional agroclimatic zones and monsoonal patterns, is altering dramatically as a result of shifting climatic conditions. This review examines how India's agricultural practices have changed in response to altering soil fertility, increased frequency of extreme weather events, altered precipitation patterns, and shifting temperature regimes. It looks at past agricultural adaptations, the shift from conventional to contemporary methods, and the variations in affects and reactions by location. The report also emphasizes the importance of community-based activities, government policies, technology interventions, and climate-smart agriculture techniques in fostering resilience. In light of India's changing environment, this review highlights the critical need for inclusive, sustainable, and adaptable agricultural frameworks to guarantee food security and farmer livelihood by combining recent research and statistics.

Key words: Agricultural practices, Climate conditions, Sustainable, and adaptable agriculture

INTRODUCTION

More than 60% of Indians still make their living through earning from farming, which is closely linked to the country's climate. India's climate has experienced monsoonal fluctuations, droughts, floods, and rising temperatures from the Harappan era to the twenty-first century, all of which have had an impact on agricultural systems. Understanding of past adaptation and contemporary reactions is essential for sustainable agriculture as the threat posed by several type of successive climatic changes in India. Even though the Green Revolution allowed India to become "self-sufficient" in the production of food grains (Abrol and Sangar, 2006), it also brought with it a number of socioeconomic issues (such as rising farm input costs and regional disparities) and environmental issues (such as declining soil fertility, waterlogging, pollution of ground and surface water, and heightened pests and diseases) (Cummings, 2019).

Alongside these various challenges, climate change has introduced a new threat to agriculture in India as a whole and specifically to food security (Rao et al., 2016). Furthermore, India is recognized as one of the countries that is most vulnerable to the impacts of climate change (INCCA, 2010). Recent studies indicate a significant increase in temperature, droughts, heat waves, extreme rainfall, and intense cyclonic activity (Rohini et al., 2016; Sharma and Majumder, 2017; Ray et al., 2019).

Ancient to Medieval Agricultural Practices and Climate Adaptation

One of the last-mile strategies for protecting agriculture from the effects of climate change is unquestionably adaptation. However, the main requirements for a successful adaptation are comprehension and the targeted behaviour change. Since adaptation is a two-step process, decisions to reduce potential losses must be made

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after the perception of climate change has occurred (Maddison, 2007; Deressa et al., 2009). By 4500 BC, the Indus Valley Civilization had developed irrigation techniques. This advancement led to the establishment of more organized communities that featured drainage and sewage systems, which contributed to the growth and success of the Indus civilization. The civilization implemented advanced irrigation and water storage solutions, including artificial reservoirs at Girnar that originated around 3000 BC, and a basic canal irrigation network from approximately 2600 BC. Archaeological evidence indicates that an animal-drawn plow was first utilized in the Indus valley civilization around 2500 BC.

In the Harappan and Vedic eras, agriculture was rain-fed and reliant on seasonal monsoons, according to archaeological and literary records from the Vedic period (1500–500 BC) and the Harappan Civilization (2500–1900 BCE). Using crude ploughs and irrigation channels, crops such as wheat, barley, lentils, and eventually rice were cultivated (Possehl, 2002).

Iron appears frequently in the later Vedic writings (1000–500 BC). It describes the cultivation of a variety of fruits, vegetables, and cereals. The cuisine consisted of meat and dairy items; animal husbandry played a significant role. The ground was repeatedly ploughed. The seeds were dispersed. A certain cropping order and fallowing were advised. Manure was made from cow dung, and irrigation was used. The understanding of climate uncertainty is demonstrated by the inclusion of rain ceremonies in the Rigveda and Atharvaveda (Lal, 1997). Crop diversification and drought-resistant crop selection were viable responses to rainfall unpredictability used by ancient farmers (Ali, 2006).

Pre-Modern Period and Climatic Anomalies

By 300 BC, the Mauryan Empire prioritized grain storage systems and implemented canal irrigation (Kautilya's Arthashastra). Due to favourable monsoon patterns, agriculture intensified during the Gupta period (320–550 CE), particularly in eastern India's rice-growing regions (Habib, 2011). In addition, the Mauryan Empire (322–185 BC) classified soils and recorded weather for agricultural purposes. Additional support from the Mauryan Empire encompassed the construction and maintenance of dams, as well as the provision of horse-drawn chariots, which are swifter than traditional bullock carts (Habib, 2011).

Traditional agricultural cycles and food security were upset by the introduction of commercial crops like indigo, cotton, and tea during British colonial policies (1757–1947). Famines like the Bengal Famine of 1943 resulted from a failure to adjust to monsoon unpredictability. There are several irrigation canals on the Sutlej River, and a Rampur canal was built on the river in 1857 (Sen,1981).

During the period of British rule, India generated exports of rice, opium, and indigo to various nations. In the latter half of the 19th century, there was a slight increase in the area of land being cultivated, and by the end of the century, agricultural production had expanded at an average rate of about 1% per year. Regions like Punjab, the Narmada Valley, and Andhra Pradesh became central to agrarian reform due to their extensive canal systems for irrigation. The global conflicts significantly influenced the agricultural system in India (Roy, 2006).
Nonetheless, water accessibility was enhanced by certain irrigation facilities, such as Punjab's canal systems, which were built under British rule (Stone, 2002).

Post-Independence Era and the Green Revolution

The largest dam in India is the Bhakra Dam, which was completed in 1963. Special initiatives were implemented to increase the supply of cash crops and food. The Integrated Production Programme (1950) and the Grow More Food Campaign (1940) both addressed the supply of cash crops and food, respectively. Soon after, India released five-year plans focused on agricultural growth. Soon after, under government supervision, there was land reclamation, land development, mechanization, electrification, the use of chemicals, particularly fertilizers, and the creation of an agriculture-oriented "package approach" that promoted a number of activities rather than just one. The Green Revolution in India, the Yellow Revolution

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(oilseed: 1986-1990), Operation Flood (dairy: 1970-1996), the Blue Revolution (fishing: 1973-2002), and other "production revolutions" were started starting in the 1960s. The agricultural industry, which was already reaping the benefits of the 1991 economic changes as well as the more recent developments in biotechnology and agro-processing, saw notable expansion after that year. S. M. Dev (2006). High-yield crop types were brought about by the green revolution, which also led to a rise in the use of pesticides and fertilizers. DDT and Lindane (BHC/HCH) account for around 90% of India's pesticide use. Organic farming is becoming more popular, especially for commodities that are exported.

Strategy Used in Agricultural Sector under Five Year Plans

The establishment of community development programs and agricultural extension services across the nation, the expansion of irrigation facilities, fertilizers, pesticides, agricultural machinery, high-yielding seed varieties, and the development of transportation, power, marketing, and institutional credit are some of the measures intended to boost agricultural production and rural employment. To alleviate the pressure of population on land, strategies were implemented including the development of agro-based enterprises and handicrafts in rural areas, enhancing rural transportation and communication, and promoting the movement of individuals from agriculture to the industrial and service sectors. Finally, land reforms were introduced to achieve fairness and justice in rural India, which involved eliminating intermediaries such as Zamindars, implementing tenancy laws to safeguard tenants, establishing limits on land holdings, and redistributing surplus land to smallholders, marginal farmers, and landless labours (Paul, 2024).

Green Revolution

The Green Revolution—which included the introduction of high-yielding seed varieties after 1965, as well as increasing use of fertilizers and irrigation—provided the boost in output required to make India self-sufficient in food grains, hence enhancing Indian agriculture. Since the introduction of Green Revolution crops, famine in India has not returned, despite the fact that it was formerly thought to be inevitable. Wheat gave the best results out of all the high-yielding seeds. An important part of raising knowledge of these techniques was done by All India Radio (AIR). In addition to high-yielding seeds and irrigation systems, farmers' zeal sparked the agricultural revolution, which is also attributed to All India Radio (Swaminathan, 2006).

Between 1965 and the beginning of the 1980s, northern and northwest India benefited greatly from the Green Revolution, which led to a significant increase in the production of food grains, mostly rice and wheat. Although food-grain yields increased during the 1980s, the significant shifts that occurred between 1965 and 1980 were not repeated. By FY 1980, high-yielding wheat varieties had been planted on over 75% of the total farmed area. The corresponding percentage for rice was 45 percent. Although the area planted to high-yielding types kept growing throughout the 1980s, overall growth was slower. The eighth plan sought to create more productive variants of other crops and make high-yielding types accessible throughout the nation (Swaminathan, 2006).

Current Climatic Challenges on Agriculture

Climate change has a wide range of affects on agriculture, many of which are making it more difficult for agricultural operations to provide global food security. Due to water constraint brought on by drought, heat waves, and flooding, rising temperatures and shifting weather patterns frequently lead to poorer crop yields. The likelihood of multiple locations experiencing crop failures at the same time may also rise as a result of these climate change consequences. Although this risk is uncommon at the moment, the world's food supply could suffer greatly if these crop failures happened at the same time (Kornhuber et al., 2016; Franziska et al., 2019). It is anticipated that a number of pests and plant diseases may increase in frequency or spread to new areas. Many of the same problems are predicted to afflict animals around the world. These problems include increased heat stress, shortages of animal feed, and the proliferation of vector-borne illnesses and parasites. A CO_2 fertilization effect is brought on by human actions that raise the atmospheric CO_2 level, mostly the combustion of fossil fuels. The negative impacts of climate change on agriculture are somewhat mitigated

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by this phenomenon. Lower amounts of vital micronutrients in the crops are the price paid, though. (Kerr Bezner et al., 2022).
In the foreseeable future, there won't be much of an impact on global food security. In 2021, between 720 million and 811 million individuals suffered from undernutrition, and about 200,000 of them experienced catastrophic levels of food insecurity (FAO, 2021).

By the year 2050, between 8 and 80 million more individuals are expected to face starvation threats as a result of climate change. The estimated range depends on the extent of future temperature increases and the effectiveness of adaptive measures (Kerr Bezner et al., 2022). Then, hundreds of millions of people will probably have better food security thanks to increases in agricultural output (Janssens et al., 2013; Van Dijk et. al., 2021). It is uncommon to see predictions that go farther into the future—to 2100 and beyond. Concerns have been raised regarding how future extreme weather events may affect food security. However, at this point, a widespread worldwide hunger brought on by climate change is not anticipated in the twenty-first century (Mycoo et al., 2022; Bradshaw et al., 2022). According to the IPCC's Sixth Assessment Report (2021), rising temperatures and shifting precipitation might cause India's agricultural productivity to drop by 10–40% by the year 2100.

Regional Climate Trends

Over time, scientific knowledge of the potential effects of climate change on global food security has changed. According to the most recent IPCC Sixth Assessment Report from 2022, between 8 and 80 million more people will be at danger of starvation by 2050 under all scenarios, with almost all of them living in Sub-Saharan Africa, South Asia, and Central America. It does not, however, rule out the potential of an overall decrease in hunger risk when compared to current conditions because this comparison was made in relation to a world without climate change (Bezner Kerr et. al., 2022). According to the last Special Report on Climate Change and Land (RCP6.0), in a scenario with relatively high emissions, In 2050, the cost of cereals could increase by 1–29%, depending on the socioeconomic trajectory. This would put 1–181 million low-income individuals at danger of starvation in comparison to a scenario in which climate change does not exist (Mbow et al., 2019).

Diversification of climatic condition in India shown in regular droughts and groundwater depletion in northwest India, floods and crop submersion in eastern India. In southern India, dry spells and sporadic showers but in northeast India, Jhum cultivation land loss and landslides happen (Bezner Kerr et. al., 2022).

Adaptation Strategies and Technological Innovations

India's agricultural technology is evaluated in this section. The following technologies are included in our review: (i) genetic enhancement (ii) natural resource management (iii) farm mechanization (iv) conservation agriculture (v) climate smart agriculture (vi) genetic modification and biotechnology (vii) biofortification (viii) frontier technologies and (ix) digital technologies. Through the identification of adoption barriers, we examine the acceptance of these technologies and their effects on the agriculture industry, farmers' welfare, the environment, and natural resources (Chowdhuri et. al., 2025).

The review mentioned above can be summed up as follows: (i) Better cultivars had a big influence on changing Indian agriculture, boosting output, and guaranteeing food security. In the perspective of the global community, India evolved from a nation lacking sufficient food to one that has an abundance of it. (ii) Geographical location and commodity type have an impact on the adoption trends of enhanced cultivars. (iii) The adoption of better cultivars has a clear effect on farmers' incomes, agricultural production, and productivity. (iii) The adoption of improved cultivars affects poverty, equity, and employment. (v) Negative externalities are becoming more apparent, particularly the detrimental effects on the environment and sustainability of natural resources, and they require improved management through suitable technologies and efficient regulations. (vi) The secret to the faster and more extensive spread of better cultivars is a targeted approach (Chowdhury et. al., 2025).

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Policy Measures for recovery of climatic conditions:

The following are the main elements of India's agricultural policy: Increasing Input Productivity: The Agricultural Policy aims to increase the efficacy and efficiency of agricultural inputs such irrigation, fertilizer, herbicides, and High-Yielding Variety seeds etc. The goal of the policy is to boost crop yields and general production by making the best use of these inputs (Swami et. al., 2018).

Crop diversification and value addition: Value addition is the process of enhancing the value of agricultural products by packaging, processing, and other methods, which enables farmers to obtain better prices and earn more money. Growing multiple crops instead of depending just on one is known as crop diversification.

Assisting Poor and Marginal Farmers: Through a number of initiatives, the Agricultural Policy seeks to meet the needs of poor and marginal farmers. In order to make farming more accessible and sustainable for people with little resources, this includes implementing land reforms to eliminate middlemen, increasing institutional credit to offer financial support, and offering subsidies or incentives.

Modernizing Agricultural Practices: This entails implementing and embracing cutting-edge farming techniques and technologies. Modern irrigation systems, mechanization, and precision agriculture are all part of the Agricultural Policy.

Environmental Protection and Soil Health: Protecting the environment entails putting policies in place to stop pollution, water loss, and soil erosion. Crop rotation, organic farming, and the use of cover crops are methods that help maintain the health of the soil. The long-term goal of the Agricultural Policy is to maintain agricultural productivity while reducing adverse environmental effects.

Agricultural Research and Extension Services: To increase production and sustainability, agricultural research aims to create new farming methods, crop types, and technology. Safeguarding the environment involves implementing measures to prevent pollution, conserve water, and combat soil erosion. Practices such as crop rotation, organic farming, and employing cover crops contribute to soil vitality. The ultimate objective of the Agricultural Policy is to enhance farming productivity while minimizing negative impacts on the environment. Agricultural research seeks to develop innovative agricultural techniques, crop varieties, and technologies to boost production and sustainability. Extension activities include educating farmers about this study through display plots, consulting services and training programmes (Swami et. al., 2018).

Eliminating Bureaucratic Barriers: This section of the Agricultural Policy focuses on the necessity of simplifying administrative procedures and lowering administrative barriers that impede agricultural advancement. The Agricultural Policy seeks to facilitate the efficient and autonomous operation of farmers and agricultural organizations by streamlining processes associated with land purchase, subsidy distribution, and credit availability (GOI, 2022).

Role of Traditional Knowledge and Agro-ecology

Stories, songs, proverbs, folklore, rituals, and cultural beliefs are all examples of how traditional knowledge is transmitted orally between generations (Battiste & Henderson, 2000). Indigenous knowledge offers vital insights into the natural environment, culture, and resource management. It is ingrained in local farming methods and is developed from decades of experience. This understanding offers sustainable techniques that work with ecosystems and represents a close relationship with nature. Scholars such as Beltran (2000) stress its significance in influencing agricultural practices and preserving ecological balance. By encouraging the appropriate use of natural resources, indigenous knowledge also contributes to the preservation of

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biodiversity.
Indigenous knowledge in agriculture links farmers to their socioeconomic and environmental surroundings. As Bonny and Vijayaragavan (2001) point out, new crop types have been introduced, yet many of them don't work in native settings. Local communities respond by conserving indigenous cultivars that satisfy regional demands, lower production costs, and guarantee environmental sustainability. Kimmerer (2002) points out that by preserving genetic variety, these local crops also aid in the conservation of biodiversity. However, traditional systems are under danger due to the substantial degradation of biodiversity caused by human activity.

FUTURE DIRECTIONS AND CONCLUSION

The 17 goals and 169 targets that make up the Sustainable Development Goals (SDGs), which were accepted as the United Nations (UN) Agenda for 2030, provide a roadmap for a sustainable future for future generations. In order to address the global sustainability issues, the Sustainable Development Goals (SDGs) seek to reduce global poverty, inequality, and hunger; manage environmental degradation and climate change; and lessen risk management during extreme weather events (Altieri, 2018).

To tackle worldwide sustainability challenges, the Sustainable Development Goals (SDGs) aim to alleviate poverty, inequality, and hunger on a global scale; tackle environmental decline and climate change; and enhance risk management in the face of severe weather incidents. Despite the fact that agriculture is undoubtedly threatened by climate change, India's long history of adapting to the changing climate, together with contemporary policy and technology support, offers a promising future (Grove, 1998).

Climate change adaptation is essential for the nation's food and nutrition security as well as the stakeholders' financial security. Decisions toward adaptation are influenced by a wide range of factors, including awareness campaigns, farmer attitudes, education, agricultural experience, and the infrastructure assistance that is available. Low income, a tiny landholding, and a lack of education, for instance, can limit an individual's potential for adaptation (Singh, 2020). As access to knowledge and information enhances the chances of adaptation, younger farmers who are willing to take risks tend to adapt more successfully (Jha and Gupta, 2021). Financial constraints and insufficient weather knowledge present challenges to adaptation strategies, which often come with high costs (Pandey et al., 2018).

According to a study by Swami and Parthasarathy (2020), the difficulties differ depending on the strategy's choice and the specific strategy in question. For instance, among the institutional variables, the availability of Kisan credit cards, soil health cards, and crop insurance are the main obstacles to the adoption of farmer-favored solutions. For academics and policymakers to create awareness-raising or sensitization campaigns that inform farmers about active adaptation, this evidence of passive adaptation is crucial.

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