The Planta RBS, Vol.-6, Issue-1, April 2025: 1794 – 1801 // ISSN: 3048:8494
Manaware et.al. (Series Chapter No. – 195 // ISBN: 978-81-965701-4-9)
https://www.pgrindias.in

CHAPTER TITLE: CLIMATE CHANGE AND ITS IMPACT ON AGRICULTURE

Rashami Manaware[1], Pratibha Yadav[2], Ranjana Chouhan[3]

[1,2]Mata Jijabai Govt PG Girls College, Indore, Madhya Pradesh, India
[3]School of Biotechnology, DAVV, Indore, Madhya Pradesh, India
Corresponding E-mail: rashmi02w@gmail.com

Received: 14 February, 2025 Accepted: 28 March, 2025

Abstract

Climate change due to human actions like industrialization, deforestation, and modification of agricultural land is inducing great transformations in worldwide climate patterns. It has also induced more emission of greenhouse gases (GHG) that contribute to higher temperatures, changed rainfalls, and more CO2 concentrations. Asia, which contains more than 60% of the world's population, is extremely exposed, and its agriculture systems are at risk from the increased frequency and intensity of extreme weather events, changes in climates, and increased sea levels. Principal effects include lowered crop production, particularly for staple crops such as rice, wheat, and maize, livestock, and fisheries. Rising temperature, changing precipitation, weather-related disasters, soil erosion, and the infestation of pests and diseases are some of the most salient threats to food security. The agricultural industry has to implement adaptation measures to reduce these risks, such as farm innovations such as AI for crop monitoring, sustainable farming practices such as crop rotation and conservation tillage, and carbon sequestration through agroforestry. Moreover, food waste reduction can play an important role in ensuring sustainable food systems and climate change mitigation. Combatting climate change in agriculture involves a multi-faceted approach that includes technological innovation, policy reform, and cooperation among governments, the private sector, and individuals. In order to promote long-term food security and a sustainable future, it is essential to mainstream climate resilience into agricultural production and minimize the environmental footprint of food systems.

Keywords: climate change, agriculture, greenhouse gases, adaptation strategies, food security, food waste, sustainable practices, carbon sequestration, temperature rise, precipitation patterns.

Citation: Manaware Rashami, Pratibha Yadav, Ranjana Chouhan (2025), Climate Change and Its Impact on Agriculture. *The PLANTA Research Book Series, 6* (1), 1794-1801. www.pgrindias.in

Introduction

Climate change pertains to drastic, long-term alterations in the anticipated weather patterns over regions or the entire globe. It is defined by deviation from typical weather patterns, which may take long periods, sometimes decades, other times millions of years. However, human action, especially industrialization, urbanization, tree cutting, and land use practices, has caused this natural phenomenon to speed up by enhancing the release of greenhouses gases (GHGs). This sudden transformation resulted in warmer temperatures, shifting patterns of precipitation, and an increased level of atmospheric CO2 (IPCC, 2019).

The greenhouse effect, which is essential for supporting life on our planet, naturally contributes to a warm climate by trapping heat in the atmosphere. Although this process favors crop growth and general productivity, the increasing level of GHGs—like carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O)—as a result of human activities has intensified global warming (Mahato, 2014). Consequently, the temperature of the earth's surface has increased by around 0.74°Cover the late 19th century, and is expected to increase even more to 1.4°C to 5.8°C by the year 2100, with different effects in different regions. This temperature increase is followed by an increase in CO2, N2O, and CH4 levels, each playing a role in climate change with different intensities that can restructure ecosystems and agricultural production worldwide(IPCC, 2019).

Asia, where more than 60% of global population lives, is gravely affected by global climate change, especially in the rural communities with prevalent poverty. Having a huge and rapidly expanding population with much of its human resources reliant on agriculture, it is highly exposed to climate change in the weather patterns. Such shifts comprise extreme weather, long-lasting droughts, and sea level rise, all of which jeopardize the stability of food production systems (Guo et al., 2018; Hasnat et al., 2019). With relatively low GHG emissions, although compared to other parts of the world, China and India are among the top emitters of carbon in the world, thus making it difficult for the region to attain food security and economic stability (Gouldson et al., 2016; Ahmed et al., 2019).

Against this backdrop, the agricultural sector in Asia is becoming increasingly vulnerable to the volatile effects of climate change. Increased risks of flooding, droughts, and other climate-related shocks impose huge pressure on the livelihoods of smallholder farmers and agricultural productivity. Mitigating the impacts of GHG emissions while adapting to the new climate is essential in addressing the changing threats of climate change, which is vital for long-term food security and sustainable development in Asia, and needs innovative solutions and efficient policies.(Yadav and Lal, 2018; Rao et al., 2019).

The Science of Climate Change

Asia is extremely prone to the effects of climate change, which strongly challenges its farm productivity, food security, and natural resources. Climatic modeling projects an increase in global warming by 1.5°Centigrate between 2030 & 2050 and specifically impacts desert areas inPakistan, China, and India (IPCC, 2019). More frequent occurrence of extreme weather conditions such as heatwaves, unpredictable rainfall, and cyclones will be causing disruption to agricultural systems, particularly the rice and wheat cropping system that sustains half of Asia's population (Ghaffar et al., 2022). Higher temperatures and water scarcity are lowering crop yields, particularly wheat and rice, by reducing growing seasons and impacting crop quality (Asseng et al., 2019). Livestock agriculture is also vulnerable, as heat stress decreases forage quality and livestock production (Das, 2018). Forests and aquaculture sectors are equally affected, with alteration of forest structure, risk enhancement of forest fires, and loss of habitat for fish (Chitale et al., 2018; Jahan et al., 2017). In addition, climate extremes like floods, droughts, and ocean acidification are impacting fisheries and aquaculture, which are crucial to the economy of the region (Ahmad et al., 2019). Since millions of people rely on agriculture, it is important to establish adaptive measures to fight climate-induced threats and achieve food security in Asia(Downing et al., 2017).

Key Climate Change Effects on Agriculture

Climate change can impact agriculture through their direct and indirect impacts on the precipitation, Extreme weather condition, soils, Temperature, Crop and livestock and pests and disease. Rise in atmospheric carbon dioxide has a fertilization effect on crops with C3 photosynthetic pathway and hence enhances their growth and productivity.

Temperature Rise: Temperature is an important factor in agricultural production, with low and high temperatures affecting crop development and yield. High temperature is especially a major risk to crops, particularly at the flowering and grain-filling stages. At temperatures above optimal, they will disrupt key physiological processes in plants such as photosynthesis, respiration, and transpiration. This results in low crop yields and quality, as heat stress causes damage to plant tissues, lowers the efficiency of pollination, and impairs root function. For example, rice, wheat, and maize are especially sensitive to temperature, with research indicating that even a minor rise in temperature can lead to significant yield losses.
With increasing global temperatures as a result of climate change, these adverse impacts are likely to be more extensive, compromising food security, especially in areas that already experience sensitivity to climate variability. Additionally, high-temperature effects are exacerbated by other climate dimensions like drought and uneven patterns of rainfall. To counter these impacts, developing climate-tolerant crop varieties and practicing sustainable agriculture are a must to enable farmers to adjust to the climatic changes and have stable production to feed a surging population globally(Parthasarathi et al., 2022)

Shifting Precipitation Patterns: Precipitation has a significant effect on agricultural productivity since it has a direct impact on the availability of soil moisture and crop growth. Rainfall variability, such as the variability in amount, timing, and distribution, may result in agricultural planning and management difficulties. For rain-fed agriculture, the onset, termination, and duration of rainfall are important factors that control crop yield. In cases where rainfall is low, crops suffer from drought stress, hence decreased productivity. Conversely, too much rain can cause waterlogging, erosion, and leaching of nutrients, which have adverse impacts on crop health and soil structure(Bedane et al., 2022)

Extreme Weather Events: Weather catastrophes result in billions of dollars' worth of losses and enormous loss of life around the world. Droughts, floods, heat waves, severe storms, wildfires, and other extreme weather conditions lead to deaths, damage, and immense agricultural losses annually in different parts of the world. There has been a rising number of and intensity of such circumstances over the last few decades. Extreme weather conditions can hugely impact crop production, and, in turn, agricultural output. The vast majority of crops are vulnerable to the immediate effects of elevated temperatures, decreased precipitation, flooding, and premature freezes at critical growth phases. Furthermore, crops are also impacted indirectly by altered soil processes, nutrient cycling, and pest populations(Motha, 2011).

Soil: Lower quality and amount of organic substances content, already relatively low in Indian soil. Under increased CO_2 level, crop residues will have elevated C:N ratio, which will decrease their rate of decomposition and nutrient release. Rise of soil temperature will accelerate N mineralization but availability might decline as a result of elevated gaseous losses via mechanisms like volatilization and denitrification. Modification in the volume and frequency of rainfall and wind speed could modify the severity, frequency and degree of soil erosion. Sea-level rise can result in salt-water intrusion into coastal areas making them less conducive for traditional farming (Pareek, 2017).

Pests and Diseases: Food production systems are highly vulnerable to climate fluctuation such as fluctuation in precipitation and temperature, which results in an outbreak of diseases and pests thus lowering in food security of the nation by impacting harvest (Anupama Mahato 2004). Fluctuation in incidence and distribution of pests and pathogens leads to indirect impacts (Sutherst et al. 1995). Decline in farm production with climate change-induced variation in patterns of pests and diseases. Winter is a period of dry season, and so rising temperature and slightly more precipitation with the existing dry season may promote diseases and insect pests (Yadav et al 2020). Climate change speeds up the speed of the insect and pest reproduction cycle. Demand for pesticides usage in a greater extent due to the rising in the insect population, causing more negative impacts to the ecosystem and human society (Malla 2008).

Crop production and Livestock: Drought periods below temperature levels would halt or even wreck growth of the crop that would lead to decrease in crop yields (Mendelsohn 2014). The dominant pattern of average yearly enthusiasm towards net income varies according to seasons; the marginal would be decisive (if warm) or either unfavorable (if cold) (Chen et al. 2016). (Swaminathan et al. 2010) demonstrate that a 10C rise in temperature lowers wheat output by 4 - 5 percent. A study by the (IMF 2017) reports that for emerging market economies a 10C increase in temperature would lower agricultural output by 1.7%-, and 100-millimeters reduction in rain would lower growth by 0.35%. Animals are also affected by climate change (Ngondjeb 2013) and also harmful for aquaculture production (Mishra 2014). Livestock would be impressed in 2 ways by climate change: the quantity and quality of forage of steppe could be affected and there could be a direct effect on livestock due to higher temperatures. Under a 5.0°C increase in temperature, livestock yields in the U.S. would be reduced by 10% for cow/calf and dairy farming in Appalachia, the Southeast, the Delta States, the Southern Plains, and Texas; under a 1.5°C warming, yield reduction was projected at 1%. Being the next industries of crop agriculture, the production of livestock and processed food would also decline with increasing input costs. Global production of livestock and processed food would decline by 5.9% and 4.6%, respectively (Zhai and Zhuang., 2012).

Adaptation Strategies for Agriculture

Agricultural Innovation: Through predictive analytics, machine learning, and real-time data, AI enhances weather forecasting, soil analysis, pest control, and crop monitoring. Machine learning algorithms, IoT sensors, and drones facilitate accurate watering, fertilization, and early disease detection in crops, while generative AI models simulate climatic conditions for adaptive seed development. With its challenges of elevated implementation expenses and data privacy issues notwithstanding, the integration of field data and satellite imagery by AI assists farmers in maximizing resources, enhancing productivity, and ensuring sustainable agriculture, finally enhancing food security and alleviating climate change effects (Bell and Broklyn, 2024).

Sustainable Practices: Organic farming practices are central to soil health, diversity, and conservation. Crop rotation minimizes erosion and nutrient loss, and composting is cheap, environmentally friendly fertilization. Cover crops eliminate erosion and enhance soil fertility through nitrogen fixation. Conservation tillage leaves crop residue on the land, minimizing erosion and saving water. Integrated Pest Management (IPM) utilizes biological, cultural, and chemical techniques to keep pesticide use at a minimum. Agroforestry combines trees with crops to improve soil fertility and biodiversity. Precision agriculture maximizes the use of resources using data and technology, whereas organic farming supports natural farming techniques. Water-saving methods like drip irrigation and green manure improve soil health and water use efficiency, leading to sustainable agriculture (Duguma, and Bai, 2025).

Mitigation of Climate Change through Agriculture

Carbon Sequestration: Carbon sequestration in agriculture involves the capture and storage of carbon dioxide (CO2) in the atmosphere within soil and plant biomass to prevent climate change. This can be done through numerous means, including carbon-sequestering farms, agroforestry, conservation tillage, and cover cropping (Rodrigues et al., 2023). Such methods improve soil fertility, boost organic matter, and encourage sustainable agriculture that not only minimizes greenhouse gas emissions but also enhances water retention and soil fertility. Incorporating carbon capture in agricultural practices presents an attractive option for mitigating the carbon impact of agriculture and supporting global climate objectives (Thamarai et al., 2024).

Sustainable Food Systems: Food waste is one of the key sustainability issues that impacts economic, environmental, and social systems. Food waste reduction has the potential to contribute to the attainment of several Sustainable Development Goals (SDGs), such as SDG 2 (zero hunger), SDG 12 (sustainable consumption), SDG 13 (climate action), and SDG 14 (life below water). Food redistribution, supply chain management of waste, and sustainable food management are some of the primary strategies for reducing food waste (Swetha et al., 2024). Innovations in technology, including smarter inventory management and energy-efficient processing, are important in preventing waste at every step of the food supply chain. Moreover, policy support for circular economy measures and improved consumption practices can prevent the environmental footprint of food waste, including reduced greenhouse gas emissions. Collaborative action among stakeholders, such as governments, companies, and consumers, is necessary to build a sustainable food system that is in line with the SDGs and helps towards a more sustainable future for everyone (Manzoor et al., 2024).

Conclusion

In summary, climate change presents serious challenges to agriculture, food security, and sustainable development, especially in countries such as Asia, where agriculture is highly reliant on stable climatic conditions. The effects of extreme weather events risk crop yields,increasing temperatures, altered precipitation patterns, livestock productivity, and food system stability. Adaptation measures, including agricultural innovation, sustainable agriculture, and carbon sequestration, are important in reducing these impacts. In addition, food waste reduction through redistribution, enhanced supply chain management, and sustainable consumption can help in the attainment of some of the Sustainable Development Goals (SDGs), including zero hunger, responsible consumption, and climate action. Joint action by governments, companies, and individuals is needed to establish a sustainable and resilient food system that not only addresses the problems of climate change but also delivers food security to generations to come while minimizing the environmental footprint.

References

Ahmad, S., Abbas, G., Ahmed, M., Fatima, Z., Anjum, M. A., Rasul, G., Khan, M. A., and Hoogenboom, G. (2019). Climate warming and management impact on the change of phenology of the rice-wheat cropping system in Punjab, Pakistan. *Field Crops Res*. 230, 46–61. doi: 10.1016/j.fcr.2018.10.008

Ahmed, A. U., Appadurai, A. N., and Neelormi, S. (2019). Status of climate change adaptation in South Asia region. *Status Climate Change Adapt. Asia Pacific* 18, 125–152. doi: 10.1007/978-3-319-99347-8_7

Anupama, M. (2004). Climate change and its impact on agriculture. *International Journal of Scientific and Research Publications*, *4*(4), 1-7. ISSN 2250-3153.

Asseng, S., Martre, P., Maiorano, A., Rotter, R. P., O'leary, G. J., Fitzgerald, G. J., et al. (2019). Climate change impact and adaptation for wheat protein. *Glob. Change Biol*. 64, 155–173. doi: 10.1111/gcb.14481

Bedane, H. R., Beketie, K. T., Fantahun, E. E., Feyisa, G. L., andAnose, F. A. (2022). The impact of rainfall variability and crop production on vertisols in the central highlands of Ethiopia. *Environmental Systems Research*, *11*(26). https://doi.org/10.1186/s40068-022-00275-3

Bell, C., AndBroklyn, P. (2024). AI in agriculture: Revolutionizing crop monitoring and disease management through precision technology. *Machine Learning Research*.

Chen, S., Chen, X., and Xu, J. (2016). Impacts of climate change on agriculture: Evidence from China. *Journal of Environmental Economics and Management*, *76*, 105–124. https://doi.org/10.1016/j.jeem.2015.01.005

Chitale, V., Silwal, R., and Matin, M. (2018). Assessing the impacts of climate change on distribution of major non-timber forest plants in Chitwan Annapurna Landscape, Nepal. *Resources* 4, 7–66. doi: 10.3390/resources7040066

Das, S. K. (2018). Impact of climate change (heat stress) on livestock: adaptation and mitigation strategies for sustainable production. *Agric. Rev*. 39, 35–42. doi: 10.18805/ag. R-1777

Downing, M. M. R., Nejadhashemi, A. P., Harrigan, T., and Woznicki, S. A. (2017). Climate change and livestock: impacts, adaptation, and mitigation. *Climate Risk Manag*. 16, 145–163. doi: 10.1016/j.crm.2017.02.001

Duguma, A. L., and Bai, X. (2025). How the Internet of Things technology improves agricultural efficiency. *Artificial Intelligence Review*, *58*, 63. https://doi.org/10.1007/s10462-024-11046-0

Habib ur Rahman, M., Ghaffar, A., Ahmad, S., Haider, G., Ahmad, I., Khan, M. A., Hussain, J., Ahmad, S., Afzaal, M., Sh, F., & Ahmad, A. (2022). Adaptations in cropping system and pattern for sustainable crop production under climate change scenarios. In *Improvement of Plant Production in the Era of Climate Change* (pp. 1-10). CRC Press. https://doi.org/10.1201/9781003286417-1

Gouldson, A., Colenbrander, S., Sudmant, A., Papargyropoulou, E., Kerr, N., McAnulla, F., Hall, S (2016). Cities and climate change mitigation: economic opportunities and governance challenges in Asia. *Cities* 54, 11–19. doi: 10.1016/j.cities.2015.10.010

Guo, H., Bao, A., Ndayisaba, F., Liu, T., Jiapaer, G., El-Tantawi, A. M., & De Maeyer, P. (2018). Space-time characterization of drought events and their impacts on vegetation in Central Asia. *JOURNAL OF HYDROLOGY*, *564*, 1165–1178. https://doi.org/10.1016/j.jhydrol.2018.07.081

Hasnat, G. T., Kabir, M. A., and Hossain, M. A. (2019). Major environmental issues and problems of South Asia, Particularly Bangladesh. *Handb. Environ. Mater. Manag*. 7, 109–148. doi: 10.1007/978-3-319-73645-7_7

International Monetary Fund (IMF). (2017). The effects of weather shocks on economic activity: How can low-income countries cope? In *IMF Publication* (Chapter 3).

IPCC (2019). *Global warming of 1.5°C. Summary for Policy Makers. Switzerland: World Meteorological Organization, United Nations Environment Program, and Intergovernmental Panel on Climate Change*. Bern.

Jahan, I., Ahsan, D., and Farque, M. H. (2017). Fishers' local knowledge on impact of climate change and anthropogenic interferences on Hilsa fishery in South Asia: evidence from Bangladesh. *Environ. Develop. Sustain*. 17, 461–478. doi: 10.1007/s10668-015-9740-0

Mahato, A. (2014). Climate change and its impact on agriculture. *International Journal of Scientific and Research Publications*, 4(4), 1-4. Retrieved from http://www.ijsrp.org

Malla, G. (2008). Climate change and its impact on Nepalese agriculture. *The Journal of Agriculture and Environment*, *9*, 62–71.

Manzoor, S., Fayaz, U., Dar, A. H., Dash, K. K., Shams, R., Bashir, I., Pandey, V. K., and Abdi, G. (2024). Sustainable development goals through reducing food loss and food waste: A comprehensive review. *Future Foods*, *9*, 100362. https://doi.org/10.1016/j.fufo.2024.100362

Mendelsohn, R. (2014). The impact of climate change on agriculture in Asia. *Journal of Integrative Agriculture*, *13*(4), 660–665. https://doi.org/10.1016/S2095-3119(13)60701-7

Mishra, D., and Sahu, N. C. (2014). Economic impact of climate change on the agriculture sector of coastal Odisha. *APCBEE Procedia*, *10*, 241–245. https://doi.org/10.1016/j.apcbee.2014.10.046

Motha, R. P. (2011). The impact of extreme weather events on agriculture in the United States. In *Publications from USDA-ARS / UNL Faculty, U.S. Department of Agriculture: Agricultural Research Service, Lincoln, Nebraska*

Ngondjeb, Y. D. (2013). Agriculture and climate change in Cameroon: An assessment of impacts and adaptation options. *African Journal of Science, Technology, Innovation and Development*, *5*(1), 85–94. https://doi.org/10.1080/20421338.2013.782151

Pareek N. (2017). Climate change impact on soils: adaptation and mitigation. *MOJ Eco Environ Sci*.;2(3):136-139. DOI: 10.15406/mojes.2017.02.00026

Parthasarathi, T., Firdous, S., Mariya David, E., Lesharadevi, K., andDjanaguiraman, M. (2022). Effects of High Temperature on Crops. *IntechOpen*. doi: 10.5772/intechopen.105945

Rao, N., Lawson, E. T., Raditloaneng, W. N., Solomon, D., and Angula, M. N. (2019). Gendered vulnerabilities to climate change: insights from the semi-arid regions of Africa and Asia. *Climate Develop*. 11, 14–26. doi: 10.1080/17565529.2017.1372266

Rodrigues, C. I. D., Brito, L. M., and Nunes, L. J. R. (2023). Soil Carbon Sequestration in the Context of Climate Change Mitigation: A Review. *Soil Systems*, *7*(3), 64. https://doi.org/10.3390/soilsystems7030064

Sutherst, R. W., Maywald, G. F., andSkarratt, D. B. (1995). Predicting insect distributions in a changed climate. In R. Harrington & N. E. Stork (Eds.), *Insects in a changing environment* (pp. 59–71). Academic Press.

Swaminathan, M. S. (2010). An evergreen revolution. In *Science and Sustainable Food Security: Selected Papers of M. S. Swaminathan* (pp. 325-329).

Swetha, S., Itigi, P., Veeresh, P., andAinapur, S. (2024). Food waste reduction and sustainable food systems: Strategies, challenges, and future directions. *Journal of Scientific Research and Reports*, *30*(5), 328-336. https://doi.org/10.9734/jsrr/2024/v30i51948

Thamarai, P., Deivayanai, V. C., Saravanan, A., Vickram, A. S., andYaashikaa, P. R. (2024). Carbon mitigation in agriculture: Pioneering technologies for a sustainable food system. *Trends in Food Science & Technology*, *147*, 104477. https://doi.org/10.1016/j.tifs.2024.104477

Yadav, D., Gupta, A., Gupta, P., Ranjan, S., Gupta, V., andBadhai, S. (2020). Effects of climate change on agriculture.

Yadav, S. S., and Lal, R. (2018). Vulnerability of women to climate change in arid and semi-arid regions: the case of India and South Asia. *J. Arid Environ*. 149, 4–17. doi: 10.1016/j.jaridenv.2017.08.001

Zhai, F., and Zhuang, J. (2012). Agricultural impact of climate change: A general equilibrium analysis with special reference to Southeast Asia. In *S. A. J. D. (Ed.), Climate change and agriculture: An integrated approach* (pp. 1–25). SAGE Publications.