

CLIMATE CHANGE AND GEOGRAPHICAL INDICATION AGRICULTURAL PRODUCTS: CHALLENGES AND RESILIENCE STRATEGIES

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BEST CITATION – AISWARYA S, CLIMATE CHANGE AND GEOGRAPHICAL INDICATION AGRICULTURAL PRODUCTS: CHALLENGES AND RESILIENCE STRATEGIES, *INDIAN JOURNAL OF LEGAL REVIEW (IJLR)*, 5 (4) OF 2025, PG. 727-741, APIS – 3920 – 0001 & ISSN – 2583-2344.

1. Abstract

This paper examines the impacts of climate change at regional, national, and global levels, with a specific focus on Geographical Indication (GI) agricultural products. These products are inherently linked to their native ecosystems, making them highly vulnerable to changes in temperature, precipitation, soil quality, and water availability. Using doctrinal and qualitative methodologies, including a review of IPCC, FAO, and ICAR reports, the study explores the dual nature of climate impacts and presents case examples from India and abroad. It proposes policy strategies and climate-resilient adaptation frameworks to safeguard GI-based agriculture and preserve cultural heritage.

2. Introduction

Climate change refers to long-term alterations in temperature, precipitation patterns, and other elements of the Earth's climate system. Although such variations have occurred naturally throughout geological history, the current pace and magnitude of change are largely attributed to human activities. The emission of greenhouse gases like carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O)—from sources including industrial processes, deforestation, and fossil fuel combustion—have resulted in warming temperatures, rising sea levels, melting glaciers, and an increase in extreme weather events. These climate shifts have far-reaching implications for agriculture, one of the most climate-sensitive sectors. Among agricultural commodities, Geographical Indication (GI) products are particularly vulnerable due to their reliance on specific microclimatic conditions, soil profiles, and traditional farming techniques. Darjeeling Tea, Basmati Rice, Navara Rice, and Coorg Orange are just a few examples of GI products that are deeply tied to their

geographic origins¹²³⁵. Even slight climatic variations can threaten their quality, yield, and overall sustainability.

This study aims to analyze how climate change affects GI-tagged products through a multidimensional lens, drawing from global, national, and regional perspectives. It also seeks to propose tailored mitigation and adaptation strategies to preserve the unique identity of these agricultural treasures.

3. Objectives of the Study

- To understand the global, national, and regional impacts of climate change.
- To assess the specific effects of climate change on agricultural production.
- To evaluate the vulnerability of GI agricultural products to environmental shifts.
- To explore adaptation strategies for safeguarding GI agriculture.
- To suggest policy frameworks integrating GI protection with climate resilience.

¹²³⁵ Geographical Indications Registry, Ministry of Commerce & Industry, Govt. of India, <https://ipindia.gov.in> (last visited Apr. 11, 2025).

4. Research Questions

- What are the major global, national, and regional consequences of climate change?
- How does climate change impact crop cycles and food security?
- In what ways are GI agricultural products vulnerable to these impacts?
- What mitigation and adaptation measures can be proposed?

5. Methodology

The research employs a doctrinal and qualitative method, reviewing reports from IPCC, ICAR, FAO, and scholarly articles. A comparative and case-based approach is used to assess GI-specific impacts across regions in India and globally.

6. Structure of Chapterization

- Introduction
- Global, National, and Regional Impacts of Climate Change
- Impact of Climate Change on Agricultural Products
- Impact of Climate Change on GI Agricultural Products
- Adaptation and Policy Responses
- Conclusion and References

7. Climate Change and Agriculture: Analysis and Findings

Climate change is defined as the long-term changes in global temperatures, weather systems, and environmental conditions, primarily caused by human activities such as industrialization, deforestation, and fossil fuel combustion. Although climate change is a natural occurrence that has taken place over millions of years, the swift rise in global temperatures noted in recent decades is mainly linked to human-driven factors, especially the excessive release of greenhouse gases like

carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) (IPCC, 2021).¹²³⁶

The increase in global temperatures, the melting of polar ice caps, elevated sea levels, altered weather patterns, and a rise in extreme weather events like heatwaves, droughts, floods, and hurricanes are key outcomes of climate change. These alterations are disrupting natural ecosystems, impacting biodiversity, and presenting serious risks to human health, agriculture, and global economies.

The effects of climate change are not evenly spread across the globe. Developing nations, particularly those dependent on agriculture and natural resources, are more susceptible to droughts, floods, and soil deterioration. Coastal areas are threatened by rising sea levels and coastal erosion, while urban regions suffer from heat stress and higher air pollution levels. On a worldwide scale, migration driven by climate change, water shortages, and food insecurity are becoming significant challenges.

Scientific studies and reports, such as those from the Intergovernmental Panel on Climate Change (IPCC), indicate that if global temperatures exceed 1.5°C compared to levels before industrialization, the planet will endure irreversible harm to ecosystems and human societies¹²³⁷. Therefore, addressing climate change by curbing carbon emissions, endorsing renewable energy sources, safeguarding forests, and implementing sustainable practices is vital for securing environmental sustainability and the welfare of future generations.

8. Regional , National , Global Impacts of Climate Change

At the regional level, climate change manifests in varied ways depending on local geography and ecosystems. Coastal regions are particularly vulnerable to rising sea levels and

¹²³⁶ Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021: The Physical Science Basis*, Contribution of Working Group I to the Sixth Assessment Report 8 (2021), <https://www.ipcc.ch/report/ar6/wg1/>.

¹²³⁷ IPCC, *Global Warming of 1.5°C: Summary for Policymakers* 6 (2018), <https://www.ipcc.ch/sr15/>.

more frequent storm surges, threatening infrastructure, homes, and livelihoods. In contrast, inland areas may face increased desertification, droughts, and shifting rainfall patterns, which disrupt agriculture and water availability. These regional impacts often lead to economic instability, food insecurity, and displacement of communities. As these effects intensify, it becomes clear that localized strategies are essential to mitigate the risks and help communities adapt to the changing climate.

8.1 Effect of Climate Change in Different Regions

Although climate change is a worldwide concern, its effects differ considerably across various regions due to differences in geography, climate, and socio-economic factors. These regional consequences tend to be more acute and direct, impacting weather patterns, agriculture, water resources, ecosystems, and public health.

a) Effects on Weather Patterns and Extreme Conditions

A prominent regional effect of climate change is the rise in extreme weather incidents. Areas such as South Asia and the Middle East are facing severe heatwaves and extended periods of drought, resulting in water shortages and losses in agricultural output. For example, in India, severe heatwaves have led to numerous fatalities and harmed crops. Conversely, coastal areas such as Southeast Asia and the Gulf of Mexico are subjected to frequent hurricanes and typhoons. The 2019 Cyclone Idai in Mozambique caused widespread devastation and displacement, underscoring the susceptibility of developing regions to disasters linked to climate change.¹²³⁸

b) Effects on Agriculture and Food Security

Agriculture is among the sectors most susceptible to the impacts of climate change,

with various regions confronting distinct challenges. In Sub-Saharan Africa, erratic rainfall and drought have resulted in failed crops and food shortages. Nations such as Ethiopia and Kenya are experiencing significant hunger crises attributed to decreasing agricultural productivity. In contrast, northern areas like Canada and Russia enjoy longer growing seasons due to increasing temperatures. However, these advantages are counterbalanced by soil degradation and the proliferation of pests and diseases, such as coffee rust in Central America, which thrives in warmer climates and affects coffee yields.¹²³⁹

c) Effects on Water Resources

Climate change is having a profound effect on water resources on a regional scale. In the Himalayan area, glaciers are rapidly melting, jeopardizing the water supply for millions in countries like India, Nepal, and Pakistan. This reduction in freshwater access impacts both drinking water and agricultural irrigation. In contrast, regions like Southeast Asia are facing heavy rainfall and flooding. An example is Jakarta, Indonesia, which regularly experiences flooding due to rising sea levels and excessive groundwater extraction, prompting the government to relocate the capital city.

d) Effects on Ecosystems and Public Health

Climate change also disturbs ecosystems and impacts human health. In the Arctic, diminishing sea ice endangers polar bears and other animals, while in tropical zones, coral reefs are dying as a result of warming oceans. Moreover, rising temperatures exacerbate air quality issues in urban settings like Delhi and Beijing, resulting in respiratory illnesses and heat-related health problems.

The regional consequences of climate change are varied and extensive. Tackling these issues necessitates the development of specific adaptation strategies tailored to each region,

¹²³⁸ United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA), *Mozambique: Cyclone Idai Situation Report No. 3* (Mar. 2019), <https://reliefweb.int>.

¹²³⁹ Int'l Coffee Org., *Coffee Development Report 2020: The Value of Coffee – Sustainability, Inclusiveness, and Resilience* 42 (2020), <https://www.internationalcoffeecouncil.org>.

aimed at protecting vulnerable populations and enhancing climate resilience.

8.2 Impact of Climate Change Nationally

Climate change significantly affects countries at a national level, with outcomes varying based on geographical location, economic structure, and existing infrastructure. Nations worldwide are encountering distinct challenges brought on by rising temperatures and extreme weather conditions, alongside disruptions in agricultural systems and water supplies. These consequences not only jeopardize natural ecosystems but also have implications for human health, national economies, and comprehensive development.

a) Effects on Agriculture and Food Security

In nations that predominantly depend on agriculture, like India and Brazil, climate change represents a grave risk to food security. Increasing temperatures, erratic rainfall, and drought conditions have resulted in diminished crop yields and soil degradation. For example, India, a leading producer of wheat and rice, has seen a drop in productivity due to heatwaves and water scarcity.¹²⁴⁰ Likewise, in the United States, drought conditions in areas such as California have significantly impacted the production of fruits and vegetables, influencing the economy and food availability. Countries reliant on agriculture for exports and employment face substantial economic setbacks as weather patterns shift.

b) Effects on Water Resources

Nations with scarce water supplies are experiencing acute water shortages as a result of climate change. For instance, South Africa has undergone extended periods of drought, leading to water shortages in key cities like Cape Town.¹²⁴¹ Conversely, countries such as Bangladesh and the Philippines are facing increased flooding and rising sea levels, which

jeopardize freshwater supplies and infrastructure. In the United States, the Colorado River, a vital water source for millions, is witnessing decreased water levels due to lower snowfall and elevated temperatures. Such national water crises impact agriculture, industry, and public health, resulting in heightened competition for scarce resources.

c) Effects on Human Health

Increasing temperatures and diminished air quality are impacting public health in many countries. For example, nations like China and India, amid rapidly expanding urban populations and high levels of pollution, are seeing a rise in respiratory illnesses and heat-related health issues. In Australia, severe heatwaves have resulted in cases of heatstroke and cardiovascular challenges, particularly among vulnerable groups such as the elderly.¹²⁴² Furthermore, the emergence of vector-borne diseases like malaria and dengue is on the rise in tropical regions facing warmer and more humid climates.

d) Effects on Infrastructure and Economy

Coastal nations, such as Japan and the Netherlands, are grappling with damage to infrastructure due to rising sea levels and storm surges. The Netherlands has made significant investments in sophisticated flood defense systems, while Japan is fortifying its infrastructure to cope with typhoons and heavy rainfall. In the United States, hurricanes like Katrina and Sandy caused extensive economic losses, totaling billions of dollars in damages and displacing countless individuals. These occurrences not only impose strain on national economies but also affect sectors like tourism, transportation, and housing.

The national impact of climate change are varied and extensive, influencing agriculture, water supplies, public health, and infrastructure. Countries with vulnerable populations and limited resources are at heightened risk.

¹²⁴⁰ Indian Council of Agricultural Research (ICAR), *NICRA Annual Report 2020–21* 12 (2021), <https://www.nicra-icar.in>.

¹²⁴¹ World Resources Institute, *Water Crisis in Cape Town: Lessons Learned* (2019), <https://www.wri.org>.

¹²⁴² Austl. Inst. of Health & Welfare, *Australia's Health 2022: Climate Change and Health* 55 (2022), <https://www.aihw.gov.au>.

Consequently, national governments must adopt climate adaptation measures, which may include sustainable agricultural practices, improved water management systems, and resilient infrastructure, to safeguard their citizens and economies from the escalating impacts of climate change.

8.2.1 Climate Change Effects in India: A State-by-State Overview

India's varied geography and climate make it particularly susceptible to the consequences of climate change. Increasing temperatures, erratic monsoons, extreme weather events, and rising sea levels impact different states in distinct ways, depending on their geographic features and reliance on natural resources. States in the Himalayas are dealing with glacial melting and flash floods, coastal areas are grappling with higher sea levels and cyclones, while regions in the central and western parts of the country face severe droughts and heatwaves.

In the northern part of the country, states such as Jammu & Kashmir, Ladakh, Himachal Pradesh, and Uttarakhand are experiencing rapid glacier retreat, landslides, and flash floods.¹²⁴³ This phenomenon disrupts the water flow of significant rivers like the Indus and Ganga, leading to water shortages for agriculture and drinking. Furthermore, the apple orchards in Himachal Pradesh and the saffron harvest in Kashmir are declining due to increasing temperatures and shifting rainfall patterns.¹²⁴⁴ Likewise, Punjab and Haryana, recognized as the "food bowl of India," are encountering declines in wheat and rice yields owing to heat stress and diminishing groundwater supplies.¹²⁴⁵

In the western region, states including Rajasthan, Gujarat, and Maharashtra are facing extreme heatwaves, desertification, and water

shortages. Rajasthan is struggling with severe droughts and the expansion of deserts, affecting livestock and rural economies.¹²⁴⁶ Gujarat, with its extensive coastline, is battling coastal erosion, salinity intrusion, and frequent cyclonic activity. The regions of Vidarbha and Marathwada in Maharashtra are enduring extended droughts, which contribute to farmer suicides and crop failures, particularly in cotton and sugarcane farming.¹²⁴⁷

In the central states, such as Madhya Pradesh and Chhattisgarh, rising temperatures, forest degradation, and soil erosion are prevalent. Tribal communities that rely on forest resources are losing their livelihoods due to deforestation and a decrease in biodiversity. The production of wheat and pulses in these areas is also being impacted by heat stress and unpredictable precipitation.

In the eastern region, states like Bihar, West Bengal, and Odisha are particularly vulnerable to flooding, riverbank erosion, and cyclones. Bihar experiences recurrent flooding from heavy monsoon rains and the overflowing Ganga and Kosi rivers, which results in agricultural land loss and rural displacement.¹²⁴⁸ West Bengal and Odisha, situated along the Bay of Bengal, are often struck by powerful cyclones like Amphan and Fani, causing significant damage to infrastructure and livelihoods. In addition, the Sundarbans area faces salinity intrusion and a decline in mangrove forests due to rising sea levels.

In the southern states, including Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh, rising sea levels, extreme rainfall, and droughts are significant concerns. Kerala dealt with severe flooding in 2018 as a result of intense monsoon rains and deforestation in the Western Ghats.¹²⁴⁹ Tamil Nadu and Andhra Pradesh frequently

¹²⁴³ Ministry of Earth Sciences, Government of India, *Assessment of Climate Change over the Indian Region* 89 (2020), <https://www.moes.gov.in>.

¹²⁴⁴ Intergovernmental Panel on Climate Change (IPCC), *Climate Change and Land: Summary for Policymakers* 18 (2019), <https://www.ipcc.ch/srcl/>.

¹²⁴⁵ Indian Council of Agricultural Research (ICAR), *National Innovations on Climate Resilient Agriculture (NICRA): Annual Report 2020–21* 12 (2021), <https://www.nicra-icar.in>.

¹²⁴⁶ United Nations Convention to Combat Desertification (UNCCD), *The Global Land Outlook: India Country Profile* 9 (2019), <https://www.unccd.int>.

¹²⁴⁷ National Bank for Agriculture and Rural Development (NABARD), *Report on Agrarian Distress in Vidarbha* 7 (2019), <https://www.nabard.org>.

¹²⁴⁸ Central Water Commission, Ministry of Jal Shakti, *Annual Flood Report 2021* 34 (2022), <https://cwc.gov.in>.

¹²⁴⁹ India Meteorological Department, *Report on Heavy Rainfall and Floods over Kerala during 2018 Southwest Monsoon* 5 (2019), <https://mausam.imd.gov.in>.

encounter cyclones and coastal erosion, whereas Karnataka's coffee plantations are adversely affected by irregular rainfall patterns and rising temperatures.

The Northeastern states, comprising Assam, Meghalaya, Arunachal Pradesh, and Manipur, are witnessing heavy rainfall, landslides, and biodiversity loss. Assam suffers from severe flooding due to the overflow of the Brahmaputra River, which impacts local agriculture and the tea sector.¹²⁵⁰ The hilly areas of Meghalaya and Nagaland face soil erosion and a decline in traditional farming methods due to deforestation.

Union Territories and island regions, such as the Andaman and Nicobar Islands and Lakshadweep, are extremely vulnerable to increasing sea levels and coral bleaching. These small islands risk submersion from rising ocean temperatures and the growing frequency of tropical storms.¹²⁵¹ The fishing communities and marine ecosystems are under threat, jeopardizing the local economy and the livelihoods of indigenous populations.

In summary, climate change affects each state in India in unique ways, influenced by their geographical characteristics and social-economic situations. The northern and northeastern regions are experiencing glacial melts and flooding, while the western and central areas are confronting severe heat and drought conditions. Meanwhile, coastal states are dealing with rising sea levels and increased cyclone activity. Recognizing the state-specific effects of climate change is essential for formulating localized adaptation strategies and executing sustainable policies to safeguard the environment and the livelihoods of millions.

8.3 Impact of Climate Change Globally

Climate change represents a worldwide emergency impacting every continent and

ocean. Nonetheless, the degree and character of these effects differ across various regions, ecosystems, and economies. From increasing temperatures and melting glaciers to severe weather phenomena and loss of biodiversity, the global consequences of climate change are extensive and interconnected. These outcomes pose threats to food security, water supply, public health, and economic stability, positioning climate action as a paramount global concern.

a) Increasing Global Temperatures

One of the most critical global consequences of climate change is the rise in average temperatures. The Intergovernmental Panel on Climate Change (IPCC) reports that the Earth's average temperature has increased by about 1.2°C since the pre-industrial period.¹²⁵² This rise in temperature has resulted in heatwaves across Europe, wildfires in Australia, and intense droughts in Africa. For instance, the summer heatwaves in Europe in 2019 caused hundreds of fatalities and widespread agricultural damage. Likewise, Australia's bushfires in 2020 ravaged millions of hectares and resulted in the deaths of billions of animals.¹²⁵³ These temperature rises are not limited to particular regions; they are being experienced globally.

b) Melting Glaciers and Rising Ocean Levels

The polar areas are particularly susceptible to climate change. The ice sheets in the Arctic and Antarctic are melting at an alarming pace, which contributes to the rise in sea levels around the globe. NASA indicates that global sea levels have increased by roughly 8 inches since 1880, with the rate accelerating in recent years.¹²⁵⁴ This rise poses risks to low-lying countries and coastal cities such as Bangladesh, the Maldives, and New York City.

¹²⁵⁰ Assam State Disaster Management Authority (ASDMA), *Annual Flood Report 2020-21* (2021), <https://asdma.assam.gov.in>.

¹²⁵¹ Intergovernmental Panel on Climate Change (IPCC), *Special Report on the Ocean and Cryosphere in a Changing Climate* 343 (2019), <https://www.ipcc.ch/srocc/>.

¹²⁵² Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2021: The Physical Science Basis*, Contribution of Working Group I to the Sixth Assessment Report 5 (2021), <https://www.ipcc.ch/report/ar6/wg1/>.

¹²⁵³ Australian Government, Department of Agriculture, Water and the Environment, *Australia's 2019–20 Bushfires: The Wildlife Toll* (2021), <https://www.dcccew.gov.au>.

¹²⁵⁴ National Aeronautics and Space Administration (NASA), *Sea Level: Vital Signs of the Planet*, <https://climate.nasa.gov/vital-signs/sea-level/> (last visited Apr. 11, 2025).

Pacific island nations are already grappling with land loss and saltwater intrusion, adversely affecting agriculture and freshwater access.

c)Increased Frequency of Extreme Weather Events

Climate change has resulted in a rise in both the frequency and severity of extreme weather events worldwide. Hurricanes, typhoons, and cyclones are becoming more intense as a result of warmer ocean temperatures. For example, Hurricane Maria in 2017 caused significant destruction in Puerto Rico, leading to extensive damage to infrastructure and a loss of life.¹²⁵⁵ Similarly, Typhoon Haiyan in the Philippines in 2013 tragically left thousands deceased and millions displaced. Furthermore, heavy rainfall and floods are becoming more prevalent in areas such as Southeast Asia and Europe, while prolonged drought conditions are impacting regions in Africa and South America.

d)Effects on Agriculture and Food Security

Climate change significantly affects global food production. Increasing temperatures, changing rainfall patterns, and extreme weather events are disrupting both crop yields and livestock rearing. Droughts and desertification in Africa are diminishing the productivity of essential crops including maize and millet.¹²⁵⁶ In Asia, erratic monsoon patterns threaten rice cultivation.¹²⁵⁷ Meanwhile, regions in North America and Europe face threats of soil degradation and heat stress on their crops. These disturbances in global food supply chains heighten the risks of hunger and malnutrition, especially in developing nations.

e)Effects on Biodiversity and Ecosystems

Climate change is leading to biodiversity loss and the degradation of ecosystems worldwide. Coral reefs, such as the Great Barrier Reef in Australia, are diminishing due to ocean

warming and acidification.¹²⁵⁸ Forest ecosystems, like the Amazon rainforest, are suffering from increasingly frequent wildfires and drought conditions. Additionally, the migration and extinction of species are quickening as animals struggle to adapt to shifting temperatures and their environments. For example, polar bears in the Arctic are losing their hunting grounds because of melting sea ice, while tropical species are confronting habitat loss due to deforestation and rising temperatures.

f)Effects on Human Well-Being

Climate change presents significant threats to public health on a global scale. Increased temperatures and deteriorating air quality are leading to a rise in respiratory and heart diseases. Warmer climates are broadening the habitats of vector-borne illnesses like malaria and dengue fever in tropical areas.¹²⁵⁹ Moreover, extreme heat events, such as those seen in Europe and the Middle East, have resulted in heat-related health issues and fatalities. In regions prone to flooding, particularly in developing countries with inadequate sanitation, waterborne diseases are becoming more prevalent.

g)Global Economic and Social Consequences

The economy worldwide is profoundly impacted by climate change. Natural disasters, including hurricanes, floods, and wildfires, inflict billions in damages annually. For instance, the financial losses from Hurricane Katrina in 2005 were estimated to exceed \$125 billion.¹²⁶⁰ Developing nations with fragile infrastructures and limited means are especially susceptible to economic disruptions triggered by climate-induced events. In addition, climate change is exacerbating social inequalities, compelling millions to relocate due to shortages of food, water, and environmental degradation.

¹²⁵⁵National Hurricane Center, *Tropical Cyclone Report: Hurricane Maria* (AL152017) 2 (2018), <https://www.nhc.noaa.gov>.

¹²⁵⁶ United Nations Convention to Combat Desertification (UNCCD), *The Global Land Outlook, 2nd ed.* (2022), <https://www.unccd.int/resources/global-land-outlook/glo2>.

¹²⁵⁷ International Rice Research Institute (IRRI), *Rice and Climate Change* (2021), <https://www.irri.org/climate-change>.

¹²⁵⁸ UNESCO World Heritage Centre, *World Heritage and Coral Reefs: Report on the Great Barrier Reef* (2021), <https://whc.unesco.org/en/news/2232>.

¹²⁵⁹ World Health Organization (WHO), *Climate Change and Health: Vector-Borne Diseases* (2022), <https://www.who.int>.

¹²⁶⁰ Congressional Budget Office (CBO), *The Budget and Economic Outlook: Fiscal Years 2006 to 2015*, App. B (2006), <https://www.cbo.gov>.

The worldwide impact of climate change are varied and interconnected, influencing natural ecosystems, public health, and economic stability. These effects are not limited to specific regions but are experienced globally, highlighting the necessity for international collaboration and climate action. To effectively address climate change, collective global efforts to lower greenhouse gas emissions, shift towards renewable energy sources, and adopt sustainable development practices are crucial. Only through united action can we safeguard the planet and ensure a better future for generations to come.

9. Impact of climate change on agricultural products

Climate change is one of the most significant threats to global agricultural production. Rising temperatures, unpredictable rainfall patterns, extreme weather events, and increasing carbon dioxide levels are affecting crop yields, livestock productivity, and overall food security. These impacts vary across regions and crop types, but they collectively pose serious challenges to global food systems and economies.

a) Reduced Crop Yields

One of the most direct impacts of climate change on agricultural products is the decline in crop productivity. Rising temperatures and heatwaves lead to heat stress in plants, reducing their growth and productivity. For instance, wheat, maize, and rice—three of the world's staple crops—are highly sensitive to temperature changes. Studies show that for every 1°C increase in temperature, wheat yields could decline by 6%, while maize yields could drop by 7%.¹²⁶¹ In tropical regions, such as Sub-Saharan Africa and South Asia, where temperatures are already high, extreme heat and drought conditions are leading to crop failures and food shortages. For example, in India, the production of rice and wheat has

been significantly affected by rising temperatures and water scarcity.¹²⁶²

b) Changes in Growing Seasons

Climate change is altering the length and timing of growing seasons. In some regions, warmer temperatures are leading to an earlier start to the planting season. However, in other areas, shorter growing seasons and unexpected frosts are reducing crop productivity. For example, in Europe and North America, fruit and vegetable production has been disrupted due to unseasonal frost events and unpredictable weather patterns.¹²⁶³ Additionally, in regions that rely on rain-fed agriculture, such as parts of Africa and Southeast Asia, unpredictable monsoon patterns and irregular rainfall are affecting crop cycles and reducing harvests.

c) Increased Pest and Disease Outbreaks

Warmer temperatures and increased humidity create favorable conditions for pests and plant diseases. In many agricultural regions, pests such as locusts, aphids, and fungal diseases are spreading more rapidly due to changing climatic conditions. For instance, the coffee rust disease, which thrives in warmer temperatures, has devastated coffee plantations in Central and South America.¹²⁶⁴ Similarly, the spread of the Fall Army-worm in Africa has caused massive damage to maize crops.

d) Impact on Soil Fertility and Water Resources

Climate change also affects soil quality and water availability, which are critical for agricultural productivity. Rising temperatures and extreme weather events, such as heavy rainfall and floods, lead to soil erosion and nutrient loss. On the other hand, prolonged droughts reduce soil moisture, making it difficult for crops to grow. For example, in the Sahel region of Africa, desertification and soil degradation have significantly reduced

¹²⁶¹ D.B. Lobell & C.B. Field, *Global Scale Climate–Crop Yield Relationships and the Impacts of Recent Warming*, 106 *Proc. Nat'l Acad. Sci. U.S.A.* 20677, 20678 (2009), <https://www.pnas.org/doi/10.1073/pnas.0906865106>.

¹²⁶² Indian Council of Agricultural Research (ICAR), *NICRA Annual Report 2020–21* 16 (2021), <https://www.nicra-icar.in>.

¹²⁶³ European Environment Agency (EEA), *Climate Change Adaptation in the Agriculture Sector in Europe* 18 (2019), <https://www.eea.europa.eu>.

¹²⁶⁴ International Coffee Organization, *Coffee Development Report 2020: The Value of Coffee* 42 (2020), <https://www.ico.org>.

agricultural productivity.¹²⁶⁵ In California, the ongoing drought has led to water shortages, impacting the production of almonds, grapes, and other fruits.

e) Impact on Livestock and Dairy Production

Climate change also affects livestock and dairy production. High temperatures and heat stress reduce animal productivity, affecting milk production, reproduction rates, and overall health. In regions like Australia and the United States, extreme heat events have led to the death of cattle and other livestock.¹²⁶⁶ Additionally, changing weather patterns are affecting the availability of pasture and feed, leading to higher production costs.

f) Quality of Agricultural Products

Rising carbon dioxide levels and temperature fluctuations also affect the quality of agricultural products. For example, higher CO₂ levels can increase the growth rate of crops but reduce their nutritional value.¹²⁶⁷ Studies have shown that wheat and rice grown in high-CO₂ environments have lower protein and nutrient content. This decline in nutritional quality poses a significant threat to food security, particularly in developing countries that rely heavily on staple crops.

The impact of climate change on agricultural products is complex and far-reaching. It affects crop yields, growing seasons, soil fertility, water availability, and the quality of food products. These challenges threaten global food security and economic stability, especially in regions heavily dependent on agriculture. To address these issues, farmers and policymakers must adopt climate-resilient agricultural practices, such as drought-resistant crops, improved irrigation systems, and sustainable soil management techniques. Global efforts to reduce greenhouse gas emissions and promote sustainable farming practices are essential to

protect agricultural systems from the worsening effects of climate change.¹²⁶⁸

Some Examples :

Navara Rice (Kerala)

Navara Rice, a traditional medicinal rice variety from Kerala, thrives in the nutrient-rich paddy fields of the region.¹²⁶⁹ However, rising temperatures and unpredictable rainfall patterns are affecting its growth cycle. Prolonged droughts and heavy rainfall during the harvesting season lead to poor grain quality and reduced yield.

Coorg Orange (Karnataka)

Coorg Orange, famous for its unique aroma and taste, is heavily dependent on the cool climate and misty conditions of the Western Ghats.¹²⁷⁰ However, climate change has resulted in warmer temperatures and irregular rainfall, affecting the fruit's size, flavor, and juice content. The rising incidence of pest attacks due to higher humidity is further damaging the crop.

Naga Chilli (Nagaland)

Naga Chilli, also known as Bhut Jolokia, is one of the spiciest chilies in the world. It thrives in the hot and humid climate of Nagaland. However, increasing temperatures and erratic rainfall patterns are leading to poor flowering and lower yields. Moreover, excessive rainfall is causing fungal infections and pest infestations, reducing the quality of the chilies.

Kashmiri Saffron (Jammu & Kashmir)

Kashmiri Saffron is globally renowned for its rich color and strong aroma. It requires cold temperatures and dry weather during the flowering stage. However, rising temperatures and reduced snowfall are affecting soil moisture and delaying flowering.¹²⁷¹ Additionally,

¹²⁶⁵United Nations Convention to Combat Desertification (UNCCD), *The Global Land Outlook*, 2nd ed. 33 (2022), <https://www.unccd.int>.

¹²⁶⁶ Food & Agric. Org. of the U.N. (FAO), *Climate Change and Livestock: Impacts, Adaptation, and Mitigation* 10 (2021), <https://www.fao.org>.

¹²⁶⁷ Samuel S. Myers et al., *Increasing CO₂ Threatens Human Nutrition*, 510 *Nature* 139 (2014), <https://www.nature.com/articles/nature13179>.

¹²⁶⁸ UNFCCC, *Koronivia Joint Work on Agriculture: Report of the Subsidiary Body for Scientific and Technological Advice* (2021), <https://unfccc.int>.

¹²⁶⁹ P.K. Mukherjee et al., *Navara (Shashtika) Rice—A Unique Functional Food from Kerala*, 41 *Indian J. Traditional Knowledge* 245 (2019), <https://nopr.niscpr.res.in>.

¹²⁷⁰ Indian Institute of Horticultural Research (IIHR), *Climate Resilience in Horticultural Crops: Focus on Coorg Mandarin* (2020), <https://iihr.res.in>.

¹²⁷¹ Sher-e-Kashmir Univ. Agric. Sci. & Tech., *Impact of Changing Climate on Saffron Cultivation in Jammu & Kashmir* (2021), <https://skuastkashmir.ac.in>.

untimely rainfall is damaging the delicate saffron flowers, leading to lower yields.

Vidarbha Orange (Maharashtra)

Vidarbha Orange, known for its sweet and tangy flavor, is facing challenges due to rising temperatures and water scarcity in the region. Prolonged droughts and increasing soil salinity are affecting fruit development and reducing the quality and size of the oranges.¹²⁷²

10. Impact of Climate Change on Geographical Indication (GI) Agricultural Products

Geographical Indication (GI) agricultural products are those that possess unique qualities, characteristics, and reputation due to their origin in a specific geographical area. These products are deeply connected to local climate, soil conditions, and traditional farming methods. Examples include Basmati rice, Darjeeling tea, and French Champagne. However, climate change is posing a significant threat to the production, quality, and sustainability of GI agricultural products worldwide.

a) Impact on Quality and Taste

GI agricultural products derive their distinct flavor, aroma, and quality from the unique environmental conditions of their region. However, rising temperatures, unpredictable rainfall patterns, and changes in humidity directly impact the chemical composition of crops, affecting their taste and quality. For instance, increased heat stress can alter the sugar and acid balance in fruits and wines, reducing their characteristic flavor. Similarly, excessive rainfall can dilute essential nutrients in the soil, affecting the quality of spices and herbs.

Case Study: Darjeeling Tea (West Bengal)
Darjeeling tea, known as the "Champagne of Teas," is a globally recognized GI product. The unique flavor and aroma of Darjeeling tea are influenced by the cool climate and misty

environment of the Himalayan foothills. However, rising temperatures and irregular rainfall patterns are affecting the tea's growth cycle.¹²⁷³ Warmer temperatures accelerate leaf development, reducing the quality and aroma of the first flush tea, which is highly prized in global markets.

b) Changes in Production Cycles

Climate change is disrupting the natural growth cycles of GI agricultural products. Warmer temperatures are causing early blooming and harvesting seasons, which affects crop development. In some regions, shorter winters and longer summers are leading to reduced crop yields. For example, plants that require cool temperatures for slow growth are now facing accelerated ripening, which impacts their size and nutritional value. This shift in production cycles not only affects yield but also disrupts the traditional farming practices associated with GI products.

Case Study: Alphonso Mango (Maharashtra)
Alphonso mango, one of the most famous GI products from the Konkan region of Maharashtra, is facing challenges due to increasing temperatures and unpredictable rainfall. Early flowering caused by warmer winters and sudden heatwaves during the fruit-setting period are affecting the size, sweetness, and texture of the mangoes. This not only reduces the yield but also impacts the export quality of the fruit.

c) Soil Degradation and Water Scarcity

Soil quality and water availability play a crucial role in maintaining the uniqueness of GI agricultural products. However, extreme weather events such as heavy rainfall, floods, and droughts are leading to soil erosion and nutrient loss. Additionally, prolonged droughts and irregular rainfall patterns are causing water scarcity, making it difficult for farmers to irrigate their crops. These changes are particularly harmful to GI products that rely on specific soil

¹²⁷² V.S. Kale, *Climate Change Impacts on Citrus in Vidarbha*, 27 *Indian Horticulture* 12 (2020), <https://icar.org.in>.

¹²⁷³ Tea Board of India, *Climate Change and Its Impact on Darjeeling Tea* (2021), <https://www.teaboard.gov.in>.

compositions and moisture levels for their distinctive characteristics.

Case Study: Basmati Rice (Punjab and Haryana)
Basmati rice, known for its unique aroma and long grains, is cultivated in the Indo-Gangetic Plains. However, erratic monsoon patterns and depleting groundwater levels in Punjab and Haryana are affecting paddy cultivation.¹²⁷⁴ Drought-like conditions reduce soil moisture, while heavy rainfall leads to waterlogging, both of which affect the quality and yield of Basmati rice. Additionally, increasing temperatures are impacting the delicate aroma of the rice.

d) Increased Pest and Disease Infestation

Rising temperatures and humidity levels create favorable conditions for pests and plant diseases. Climate change has led to the spread of invasive pests and fungal infections that were previously uncommon in certain regions. These infestations not only reduce crop yields but also compromise the quality and safety of GI products. For example, fungal diseases affect the texture and aroma of tea leaves, while pests like locusts damage grains and cereals.

Case Study: Shahi Litchi (Bihar)
Shahi Litchi from Bihar is famous for its sweetness and juicy texture. However, rising temperatures and higher humidity levels are leading to increased pest attacks and fungal infections.¹²⁷⁵ The spread of fruit borer insects and diseases like litchi blight is reducing the production and affecting the market value of this GI product.

e) Economic and Social Impact

The decline in the quality and quantity of GI agricultural products due to climate change directly affects the livelihoods of farmers and local communities. Many farmers who rely on traditional methods and practices are struggling to adapt to changing climatic conditions. Additionally, reduced production and poor quality affect the global market value

of these products, leading to economic losses for countries that heavily depend on GI exports.

Case Study: Malabar Black Pepper (Kerala)
Malabar Black Pepper, grown in the Western Ghats of Kerala, is known for its strong aroma and pungency. However, heavy rainfall, soil erosion, and increasing temperatures are impacting the flowering and fruiting process of pepper vines.¹²⁷⁶ Small-scale farmers, who heavily depend on this crop for their livelihood, are facing economic losses due to reduced yields and declining quality.

f) Threat to Cultural Heritage

GI agricultural products are not only economically valuable but also represent cultural heritage and traditional knowledge. Climate change threatens the preservation of these traditional farming practices that have been passed down through generations. As production declines or shifts to different regions, the authenticity and uniqueness of these products are at risk of being lost.

Case Study: Kanchipuram Silk Sarees (Tamil Nadu)

While Kanchipuram silk sarees are not agricultural products, the silk industry depends on high-quality mulberry leaves for silkworms. Rising temperatures and irregular rainfall in Tamil Nadu are affecting mulberry cultivation, leading to poor-quality silk production. This impacts the traditional handloom industry and the livelihood of weavers.

Climate change poses a severe threat to GI agricultural products by affecting their quality, production cycles, and sustainability. The unique environmental conditions that give these products their identity are being altered by rising temperatures, unpredictable weather patterns, and soil degradation. To protect these products, there is a need for climate-resilient farming practices, sustainable water management systems, and supportive policies that help farmers adapt to changing conditions

¹²⁷⁴ ICAR–Indian Agricultural Research Institute (IARI), *Effect of Climate Variability on Basmati Rice Yield* 15 (2020), <https://www.iari.res.in>.

¹²⁷⁵ Bihar Agricultural University, *Pest Dynamics in Litchi Orchards of North Bihar* (2020), <https://bausabour.ac.in>.

¹²⁷⁶ Spices Board India, *Annual Report 2021–22: Climate and Quality Challenges for Black Pepper* 29 (2022), <https://www.indianspices.com>.

while preserving the cultural heritage associated with GI products.

11. Climate Change and Its Dual Effects on GI-Tagged Agricultural Products

11.1 Positive Impacts of Climate Change on GI-Tagged Agricultural Products

Extended Growing Seasons: Warmer temperatures in traditionally colder regions can lead to longer growing seasons.¹²⁷⁷ This allows crops that previously had shorter harvest windows to grow for extended periods, increasing overall production. Example: Apples from Himachal Pradesh (India) and Champagne grapes (France) might benefit from a longer maturation period, enhancing their flavor profiles.

Expansion of Cultivation Areas: Crops that were earlier limited to specific regions due to temperature constraints might now be grown in new areas, potentially increasing production. Example: Saffron (Kashmir, India) is traditionally grown in cold climates, but rising temperatures might allow cultivation in other high-altitude areas. Tea (Darjeeling, India) may see new suitable areas in regions where temperatures previously were too cold.

Increased Carbon Dioxide (CO₂) Levels Boosting Photosynthesis: Higher CO₂ concentrations can enhance photosynthesis in some crops, leading to increased biomass and potential yield improvement.¹²⁷⁸ Example: Rice (Basmati from India/Pakistan) and Coffee (Arabica from Ethiopia) may experience productivity boosts under higher CO₂ levels.

Improved Pest Control in Certain Regions: In some colder areas, higher winter temperatures may reduce frost-related crop damage and improve growing conditions. Example: Olives (Italy, Spain, Greece) might experience fewer frost-induced losses, potentially improving productivity.

New Market Opportunities Due to Altered Product Characteristics: Climate change may lead to variations in taste, aroma, or texture, which can create unique market demands. Example: Some wines (Bordeaux, France) have started showing altered flavor notes due to temperature shifts, making them unique and appealing to different consumer preferences.

11.2 Negative Impacts of Climate Change on GI-Tagged Agricultural Products

Quality Deterioration: Many GI-tagged agricultural products are known for their distinct taste, aroma, and texture. Even slight climatic changes can negatively impact their unique characteristics. Example: Darjeeling Tea (India), known for its unique muscatel flavor, may lose its signature taste due to erratic rainfall and temperature rise.¹²⁷⁹ Kobe Beef (Japan) relies on specific feeding and climatic conditions that may be disrupted by changing weather patterns.

Reduced Yield Due to Extreme Weather Events: Increased instances of droughts, floods, and storms can significantly damage crops, leading to lower productivity and financial losses for farmers. Example: Mangoes (Alphonso from India) are sensitive to unseasonal rain and temperature fluctuations, which can reduce fruit quality and size. Basmati Rice (India/Pakistan) is affected by extreme heat, which can lower yield and grain quality.

Pest and Disease Spread: Warmer temperatures and increased humidity create favorable conditions for pests and fungal diseases, threatening crops that were once resistant. Example: Coffee (Colombian, Ethiopian, and Indian GI varieties) is increasingly threatened by coffee rust disease due to warmer and wetter conditions. Grapes (Napa Valley, Bordeaux, Tuscany wines) face rising risks of fungal infections due to unpredictable rainfall patterns.

Soil Degradation and Nutrient Loss: Rising temperatures and erratic rainfall can lead to

¹²⁷⁷ Food & Agric. Org. of the U.N. (FAO), *Climate Change: Unpacking the Burden on Food Systems* 11 (2021), <https://www.fao.org>.

¹²⁷⁸ Intergovernmental Panel on Climate Change (IPCC), *Climate Change and Land: Summary for Policymakers* 7 (2019), <https://www.ipcc.ch/srccl/>.

¹²⁷⁹ Tea Board of India, *Impact of Climate Change on Darjeeling Tea Quality* (2021), <https://www.teaboard.gov.in>

soil erosion, loss of organic matter, and decreased soil fertility.¹²⁸⁰ This directly impacts crop yields and sustainability. Example: Black Pepper (Malabar, India), which requires nutrient-rich soil, is at risk due to soil degradation. Tuscany Olive Oil (Italy) production may suffer if soil conditions deteriorate due to extreme droughts.

Loss of Unique Geographic Identity: If climatic conditions change too drastically, some crops may no longer exhibit their distinctive qualities, threatening their GI status and market reputation. Example: Champagne (France) requires a specific cool climate for ideal sparkling wine production. Rising temperatures might force producers to shift to higher altitudes or different regions, endangering the traditional GI tag. Darjeeling Tea (India) might lose its distinctiveness if the climate mimics that of non-GI tea-growing regions.

Water Scarcity and Irrigation Challenges: Many GI crops require specific water levels. Changes in rainfall patterns, prolonged droughts, and reduced groundwater levels threaten these crops. Example: Saffron (Kashmir, India) cultivation relies on precise moisture levels, making it highly vulnerable to water shortages. Alphonso Mangoes (India) need a specific pattern of wet and dry seasons, which may be disrupted due to erratic monsoons.

12. Adaptation and Policy Responses

The changing climate poses a formidable threat to the sustainability of Geographical Indication (GI) agricultural products. As these products are deeply connected to specific geographical, environmental, and cultural conditions, even minor disruptions in climate patterns can severely impact their production, quality, and market viability. Therefore, addressing this vulnerability requires a blend of adaptation strategies and proactive policy measures tailored to the unique needs of GI farming communities.

Adaptation begins at the grassroots level with climate-resilient agricultural practices. Farmers must be equipped to respond to erratic weather conditions by using drought-tolerant and flood-resistant crop varieties.¹²⁸¹ The adoption of agroecological systems, such as agroforestry and integrated pest and nutrient management, offers a sustainable path forward. In Kerala, for example, Navara Rice growers are experimenting with early-maturing and resilient strains in response to shifting monsoon patterns.

Water management is another critical area. Given the increasing unpredictability of rainfall, efficient irrigation techniques like drip and sprinkler systems are essential for conserving water.¹²⁸² In many GI regions, especially those with water-stressed crops such as saffron in Kashmir, rainwater harvesting and farm ponds are becoming common strategies to ensure moisture availability during dry spells.

Equally important is the role of knowledge dissemination and community-level capacity building. Extension services must train farmers in climate-smart practices, and real-time climate information services should be made accessible to even the most remote farming areas.¹²⁸³ Successful examples include partnerships between agricultural universities and Darjeeling Tea estates, where ongoing research and seasonal guidance help manage the impact of climate variability on tea quality.

Traditional agricultural knowledge is also a powerful tool for adaptation. Practices like lunar-based irrigation schedules, the use of organic pest repellents, and mixed cropping systems have long supported sustainable agriculture in GI zones. Documenting, preserving, and reviving these indigenous methods can improve long-term resilience, especially when integrated with modern innovations.

¹²⁸¹ Food & Agric. Org. of the U.N. (FAO), *Climate-Smart Agriculture Sourcebook* 37 (2d ed. 2017), <https://www.fao.org/3/i3325e/i3325e.pdf>.

¹²⁸² Ministry of Jal Shakti, Government of India, *Pradhan Mantri Krishi Sinchayee Yojana (PMKSY): Guidelines on Micro-Irrigation* (2021), <https://pmksy.gov.in>.

¹²⁸³ World Bank, *Agricultural Innovation Systems: An Investment Sourcebook* 14 (2012), <https://openknowledge.worldbank.org>.

¹²⁸⁰ United Nations Environment Programme (UNEP), *Global Environment Outlook* 6 289 (2019), <https://www.unep.org>.

On the policy front, the existing framework of GI protection in India, governed by the GI Act of 1999, does not explicitly recognize the challenges posed by climate change. There is a pressing need to amend the law to incorporate sustainability standards and resilience criteria within the registration and renewal process. Climate-dependence should be acknowledged as a key feature of GI identity.

At the national and state levels, the inclusion of GI products in the National Action Plan on Climate Change (NAPCC) and State Action Plans on Climate Change (SAPCCs) is vital. Programs such as the National Mission on Sustainable Agriculture (NMSA) must be leveraged to provide targeted support—through pilot projects, insurance coverage, and adoption subsidies—for farmers cultivating GI crops.

Institutional support mechanisms must also evolve. Dedicated funding streams and cluster-based development programs for GI zones can help build infrastructure and local capacity. Collaboration with research institutions, the Indian Council of Agricultural Research (ICAR), and banks like NABARD will be essential in scaling adaptation projects.

Moreover, international cooperation should not be overlooked. Countries that share or recognize GI frameworks, such as those under WTO or WIPO, should develop common climate guidelines. Cross-border technical exchanges—like those between vineyards in France and grape growers in India—can drive innovation and sustainability.

Lastly, market-based interventions can amplify the impact of adaptation. Labelling GI products as “climate-resilient” can create awareness and potentially open premium market segments. Certification systems that emphasize eco-friendly practices will not only safeguard product identity but also encourage consumers to support sustainable farming traditions. Public education and targeted campaigns can reinforce the importance of climate-conscious purchasing, aligning consumer choice with the

preservation of cultural and environmental heritage.

13. Conclusion

The consequences of climate change on Geographical Indication (GI) agricultural products are both immediate and long-term. Rising temperatures, erratic rainfall, increased pest infestations, and water scarcity directly undermine the production cycles, quality, and market value of these products. From Darjeeling Tea losing its iconic aroma to saffron fields in Kashmir facing water stress, the threats are concrete and growing. However, the pathway forward lies in recognizing these vulnerabilities and responding with climate-resilient farming systems, region-specific adaptation frameworks, and strong legal protection of GI identities. Policymakers, researchers, and local farming communities must collaborate to embed sustainability into GI agricultural practices. This paper concludes that protecting GI products is more than a commercial obligation—it is a cultural, ecological, and generational duty. Preserving their integrity in the face of climate change will require a unified response that combines scientific innovation, traditional knowledge, and climate-conscious governance to preserve both ecological balance and cultural identity.

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