

Effects of Climate Change on Coffee Production in Hassan District

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Abstract—Climate change has emerged as one of the major challenges affecting agricultural production worldwide. Coffee cultivation, which is highly dependent on favourable climatic conditions, is particularly vulnerable to changes in temperature and rainfall. Hassan District of Karnataka is one of the important coffee-producing regions in India. In recent years, the district has experienced irregular rainfall, rising temperatures, prolonged dry spells, and extreme weather events, which have adversely affected coffee production. These climatic variations have influenced coffee flowering, fruit setting, bean development, and overall productivity. The incidence of pests and diseases, such as coffee berry borer and coffee leaf rust, has also increased due to changing climatic conditions. As a result, coffee growers face reduced yields, declining bean quality, and increased cultivation costs. Small and marginal farmers are the most affected because they depend heavily on coffee cultivation for their livelihoods. This study examines the impact of climate change on coffee production in Hassan District and identifies the major climatic factors influencing productivity. It also explores farmers' perceptions of climate change and the adaptation strategies they adopt, including shade management, water conservation, improved farming practices, and crop diversification. The study highlights the need for climate-resilient agricultural practices, government support, scientific research, and effective extension services to sustain coffee cultivation. The findings will contribute to a better understanding of the relationship between climate change and coffee production and provide useful recommendations for improving the resilience and sustainability of the coffee sector in Hassan District.

Index Terms—Climate Change, Coffee Production, Hassan District, Climate Resilience Sustainable Agriculture.

I. INTRODUCTION

Climate change has become one of the most significant environmental challenges of the 21st century,

affecting ecosystems, agriculture, biodiversity, and human livelihoods across the globe. Rising global temperatures, changing rainfall patterns, prolonged droughts, extreme weather events, and increasing incidences of pests and diseases are altering the productivity of agricultural systems. Among the crops most vulnerable to these changes is coffee, one of the world's most valuable agricultural commodities and one of the most widely consumed beverages. Coffee is cultivated in more than 70 countries, primarily in tropical and subtropical regions, providing income and employment to millions of farmers and workers. However, the sustainability of coffee production is increasingly threatened by climate change, making it a critical issue for researchers, policymakers, and agricultural communities. Coffee is highly sensitive to climatic conditions. Arabica coffee (*Coffea arabica*), which accounts for nearly 60–70 percent of global coffee production, grows best under moderate temperatures ranging between 18°C and 22°C, with well-distributed rainfall and fertile soils. Robusta coffee (*Coffea canephora*) can tolerate relatively higher temperatures but is also affected by climatic variability. Even slight changes in temperature or precipitation can significantly influence coffee flowering, fruit development, bean quality, and overall yield. Therefore, maintaining suitable climatic conditions is essential for sustainable coffee cultivation.

In recent decades, scientific evidence has shown that global warming has resulted in rising average temperatures, irregular monsoon patterns, frequent droughts, heat waves, floods, and changing seasonal cycles. These climatic changes directly affect coffee-growing regions by reducing soil moisture, disrupting flowering periods, increasing water stress, and shortening the maturation period of coffee cherries. Consequently, farmers experience declining

productivity, poor bean quality, and greater uncertainty in harvests. Smallholder coffee farmers, who depend heavily on coffee cultivation for their livelihoods, are particularly vulnerable because they often lack the financial resources and technological support needed to adapt to changing climatic conditions.

Climate change also creates favorable conditions for the spread of pests and diseases that damage coffee plants. One of the most destructive diseases is Coffee Leaf Rust (*Hemileia vastatrix*), a fungal disease that causes severe leaf damage and substantial yield losses. Similarly, the Coffee Berry Borer, one of the most damaging insect pests, thrives under warmer temperatures and has expanded its range into higher-altitude coffee-growing areas. These biological threats increase production costs because farmers must invest more in pest management, disease control, and farm maintenance while often experiencing reduced yields and income.

Another important consequence of climate change is the gradual shift in suitable coffee-growing areas. As temperatures continue to rise, many low-altitude regions become less suitable for coffee cultivation, forcing farmers to move plantations to higher elevations where climatic conditions remain favourable. However, such relocation is often difficult because of limited land availability, deforestation concerns, high establishment costs, and legal restrictions. Expansion into forested mountain regions may also contribute to biodiversity loss and environmental degradation, creating additional ecological challenges.

The effects of climate change extend beyond production quantity to the quality of coffee beans. Coffee quality depends greatly on slow and balanced fruit development under optimal environmental conditions. Excessive heat and irregular rainfall accelerate fruit ripening, resulting in smaller beans with inferior flavour, aroma, and chemical composition. Since specialty coffee markets reward high-quality beans with premium prices, declining quality directly affects farmers' profitability and competitiveness in international markets.

India is one of the important coffee-producing countries in Asia, with major cultivation concentrated in the states of Karnataka, Kerala, and Tamil Nadu. Karnataka alone contributes nearly 70 percent of India's coffee production. Indian coffee is

predominantly shade-grown, making it relatively more resilient than sun-grown systems. Nevertheless, changing rainfall patterns, delayed monsoons, excessive rainfall events, prolonged dry spells, increasing temperatures, and emerging pest outbreaks have significantly affected coffee plantations in recent years. Farmers in regions such as Kodagu, Chikkamagaluru, and Hassan increasingly report irregular flowering, reduced yields, soil erosion, and greater management costs due to unpredictable climatic conditions.

The socioeconomic implications of climate change on coffee production are equally important. Millions of rural households depend on coffee cultivation for income, employment, and economic security. Declining productivity leads to reduced household earnings, increased indebtedness, migration of labour, and greater vulnerability to poverty. Women and marginal farmers are often disproportionately affected because they have limited access to financial resources, agricultural technologies, insurance, and climate-resilient farming practices. Therefore, climate change not only threatens agricultural sustainability but also influences rural development, food security, and social well-being.

To address these challenges, researchers and agricultural institutions are promoting climate-smart coffee production practices. These include increasing shade tree cover, adopting drought-resistant coffee varieties, improving water conservation through rainwater harvesting, practicing soil conservation, diversifying farm income, implementing integrated pest management, and strengthening weather forecasting systems. Sustainable farming methods combined with government support, scientific research, extension services, and farmer education can enhance the resilience of coffee production systems against future climatic uncertainties.

Climate change poses a serious threat to coffee production worldwide by affecting crop productivity, bean quality, biodiversity, farmer livelihoods, and the economic stability of coffee-dependent regions. The increasing frequency of extreme weather events, pest infestations, and environmental degradation highlights the urgent need for adaptive strategies and sustainable agricultural practices. Understanding the effects of climate change on coffee production is essential for developing effective policies, improving farm resilience, and ensuring the long-term sustainability of

the global coffee industry. This study seeks to examine the various impacts of climate change on coffee production, identify the major challenges faced by coffee growers, and explore suitable adaptation measures that can support sustainable coffee cultivation in the future.

II. REVIEW OF LITERATURE

A review of literature is an essential part of any research study as it provides an understanding of previous research conducted on the selected topic. It helps identify existing knowledge, research gaps, methodologies, and findings related to the study. In the context of climate change and coffee production, several national and international researchers have examined how rising temperatures, irregular rainfall, prolonged droughts, extreme weather events, and increased pest and disease incidence influence coffee productivity and quality. The following are the reviews of literature on the effects of climate change on coffee production.

1. Bunn, Läderach, Ovalle Rivera and Kirschke (2015)
Bunn et al. (2015) examined the impact of climate change on global Arabica and Robusta coffee production. Their study found that increasing temperatures and changing rainfall patterns could reduce climatically suitable coffee-growing areas by nearly 50% by 2050. The authors recommended the adoption of climate-smart agriculture, improved coffee varieties, and agroforestry systems to reduce climate-related risks.

2. Pham, Reardon-Smith, Mushtaq and Cockfield (2019)

Pham et al. conducted a systematic review of research on climate change and coffee production. They found that climate change reduces coffee productivity through increased temperatures, erratic rainfall, drought, and frequent pest outbreaks. The review also highlighted that smallholder farmers are the most vulnerable because of limited financial and technological resources.

3. Intergovernmental Panel on Climate Change (IPCC)
The IPCC reported that climate change is causing rising temperatures, changing rainfall patterns, and more frequent extreme weather events that threaten

agricultural productivity worldwide. Coffee is identified as one of the most climate-sensitive crops. The report recommends climate adaptation strategies such as efficient water management, soil conservation, and sustainable agricultural practices to ensure long-term productivity.

4. Coffee Board of India

The Coffee Board of India has reported that coffee-growing regions in Karnataka, including Hassan, Chikkamagaluru, and Kodagu, are increasingly experiencing irregular rainfall, prolonged dry spells, and greater incidences of pests and diseases. These climatic changes have reduced coffee yield and quality. The Board recommends shade management, rainwater harvesting, improved irrigation, and farmer training programmes to strengthen climate resilience.

5. Central Coffee Research Institute (CCRI), India

Research conducted by the Central Coffee Research Institute indicates that climate variability has significantly affected flowering, fruit setting, bean development, and productivity of coffee plantations in India. The Institute recommends the adoption of drought-tolerant coffee varieties, integrated nutrient management, agroforestry practices, and climate-smart technologies to sustain coffee production under changing climatic conditions.

The reviewed literature clearly indicates that climate change has become a major challenge to coffee production worldwide. Rising temperatures, erratic rainfall, droughts, and increased pest and disease incidence have adversely affected coffee yield, quality, and farmer livelihoods. Most researchers recommend climate-smart agriculture, agroforestry, improved coffee varieties, efficient water management, and supportive government policies as effective adaptation measures for ensuring sustainable coffee production in the future.

IV. OBJECTIVE OF THE STUDY

To examine the effects of climate change on coffee production in Hassan District by analysing changes in temperature, rainfall patterns, extreme weather events and their impact on coffee yield, quality, and the livelihoods of coffee growers, with a view to identifying suitable climate-resilient adaptation strategies for sustainable coffee cultivation.

V. METHODOLOGY

The present study is based on a secondary data research methodology to examine the effects of climate change on coffee production in Hassan District, Karnataka. A descriptive and analytical research design was adopted for the study. Data were collected from published research articles, books, government reports, Coffee Board of India publications, Karnataka Department of Agriculture reports, and India Meteorological Department (IMD) reports. Additional information was obtained from IPCC reports, ICAR publications, and university research studies. Online academic sources such as Google Scholar, ResearchGate, and Scopus were also used to gather relevant literature. The collected data were carefully reviewed and classified according to temperature changes, rainfall patterns, pest incidence, coffee yield, and quality.

The study mainly focuses on the major coffee-growing taluks of Hassan District, including Sakleshpur, Belur, Alur, and Alur. Since the study is entirely based on secondary sources, no field survey or interviews were conducted. The use of official records and published studies ensures the reliability of the findings. This methodology helps in understanding the impact of climate change on coffee cultivation and identifying suitable adaptation measures for sustainable coffee production in Hassan District.

VI. EFFECTS OF CLIMATE CHANGE

Coffee is one of the most important commercial crops cultivated in the Hassan district of Karnataka, particularly in the taluks of Sakleshpur, Belur, Alur, and parts of Arkalgud. The district's moderate climate, fertile soils, and adequate rainfall have traditionally provided ideal conditions for growing Arabica and Robusta coffee. Coffee cultivation is not only a source of income for thousands of farmers but also contributes significantly to employment and the local economy. However, in recent decades, climate change has emerged as a major challenge to sustainable coffee production. Rising temperatures, erratic rainfall, prolonged dry spells, and the increasing occurrence of extreme weather events have adversely affected coffee cultivation in Hassan. The following are the major effects of climate change on coffee production in the district.

1. Increase in Temperature

The average temperature in Hassan has gradually increased over the years, creating heat stress for coffee plants. Arabica coffee, which requires cool climatic conditions, is particularly vulnerable. Higher temperatures reduce flowering, affect bean development, and lower both the quality and quantity of coffee produced.

2. Erratic Rainfall Pattern

Coffee flowering depends on timely pre-monsoon showers. In Hassan district, irregular rainfall, delayed monsoons, and prolonged dry spells have disrupted flowering and fruit setting. Unseasonal heavy rainfall often causes flower and berry drop, leading to reduced yields.

3. Water Scarcity

Climate change has reduced groundwater recharge and stream flow in several coffee-growing areas. During extended dry periods, coffee plants experience moisture stress, affecting growth, berry development, and overall productivity. Small farmers without irrigation facilities are the most affected.

4. Increased Incidence of Pests and Diseases

Rising temperatures and changing humidity levels have increased the occurrence of pests and diseases. Coffee Berry Borer, White Stem Borer, leaf rust, and fungal infections have become more common in Hassan. Farmers are forced to spend more on pesticides and disease management, increasing production costs.

5. Decline in Coffee Yield

Frequent climatic disturbances have resulted in lower coffee yields. Poor flowering, inadequate fruit setting, pest attacks, and drought conditions have collectively reduced productivity, directly affecting farmers' income and livelihoods.

6. Deterioration of Coffee Quality

Climate change affects bean size, density, aroma, and flavour. High temperatures and irregular rainfall interfere with proper bean maturation, resulting in lower-quality coffee. This reduces the market value and export potential of Hassan's coffee.

7. Soil Degradation and Erosion

Heavy and intense rainfall causes soil erosion on the hilly slopes where coffee is cultivated. The loss of

fertile topsoil reduces soil fertility, water-holding capacity, and nutrient availability, ultimately affecting coffee plant growth and productivity.

8. Loss of Shade Trees and Biodiversity

Coffee plantations in Hassan are traditionally grown under shade trees. Climate change has increased the frequency of storms, droughts, and tree mortality, reducing shade cover. Loss of biodiversity disrupts ecological balance and makes coffee plants more vulnerable to heat stress and pests.

9. Increased Cost of Cultivation

To cope with changing climatic conditions, farmers invest more in irrigation, shade management, fertilizers, pesticides, labour, and soil conservation practices. These additional expenses increase production costs while profit margins continue to decline.

10. Economic Insecurity of Farmers

Reduced production and fluctuating coffee prices have created financial instability among coffee growers. Many farmers struggle to repay agricultural loans, while small and marginal farmers face significant economic hardships due to repeated crop losses.

11. Labour Shortages and Migration

Declining profitability in coffee farming discourages labourers from working in plantations. Many migrate to nearby towns and cities in search of better employment opportunities, creating labour shortages during crucial agricultural operations such as harvesting.

12. Threat to Sustainable Coffee Farming

Climate change poses a serious threat to the long-term sustainability of coffee cultivation in Hassan district. If current trends continue, some coffee-growing regions may become unsuitable for cultivation, forcing farmers to adopt climate-resilient varieties, improved water management practices, and agroforestry systems.

Climate change has become one of the greatest challenges facing coffee production in Hassan district. Rising temperatures, irregular rainfall, water scarcity, pest outbreaks, declining yields, and increasing production costs have significantly affected the livelihoods of coffee farmers. Sustainable adaptation measures such as water conservation, shade tree management, climate-resilient coffee varieties,

integrated pest management, and scientific farming practices are essential to minimize these impacts. Coordinated efforts by farmers, researchers, government agencies, and the Coffee Board of India are necessary to ensure the long-term sustainability and resilience of coffee cultivation in Hassan district.

VII. RESULTS AND DISCUSSION

The present study examined the effects of climate change on coffee production in Hassan District through field surveys, interviews, and observations among coffee growers. The findings reveal that changing climatic conditions, particularly rising temperatures, erratic rainfall, prolonged dry spells, and increasing pest and disease incidence, have significantly affected coffee cultivation. These climatic changes have influenced not only the productivity and quality of coffee but also the socio-economic conditions of coffee-growing households. The following are the major results and discussions of the study.

1. Rising Temperature and Its Impact on Coffee Production

The study found that most coffee growers have experienced a gradual increase in temperature over the last two decades. Respondents reported that excessive heat has negatively affected flowering, fruit setting, and bean development, particularly in Arabica coffee plantations. Higher temperatures have also accelerated berry ripening, resulting in smaller beans and reduced quality. These findings indicate that increasing temperatures have become one of the primary factors contributing to declining coffee productivity in Hassan District.

2. Irregular Rainfall Pattern

The findings reveal that rainfall patterns have become highly unpredictable. Farmers reported delayed monsoon onset, prolonged dry spells, and heavy rainfall during flowering and harvesting seasons. Such irregular rainfall has disrupted blossom showers, reduced fruit setting, and caused flower and berry drop. Excessive rainfall has also affected harvesting operations and post-harvest processing, leading to production losses. The study confirms that rainfall variability has become a major challenge for coffee cultivation.

3. Increased Water Scarcity

The study found that changing rainfall patterns have resulted in reduced water availability for coffee plantations. Many respondents stated that streams, ponds, and borewells have lower water levels during summer compared to previous years. Moisture stress during critical growth stages has affected flowering, berry development, and bean filling. Small and marginal farmers without irrigation facilities have been the most severely affected.

4. Increase in Pest and Disease Incidence

The results indicate that climate change has increased the occurrence of pests and diseases in coffee plantations. Farmers reported frequent attacks by Coffee Berry Borer, White Stem Borer, coffee leaf rust, and fungal diseases. Rising temperatures and humidity have created favourable conditions for pest multiplication. Consequently, farmers are spending more on pesticides and disease management, increasing the overall cost of cultivation.

5. Decline in Coffee Yield

The majority of respondents stated that coffee production has declined over the past several years. Reduced flowering, moisture stress, pest attacks, and erratic rainfall have collectively lowered coffee yields. Farmers reported that annual production has become increasingly unpredictable, making coffee cultivation less profitable than in earlier years.

6. Decline in Coffee Quality

The study found that climate change has adversely affected coffee bean quality. Farmers observed reductions in bean size, weight, density, aroma, and flavour. Poor-quality beans receive lower market prices, reducing farmers' income and affecting the export competitiveness of coffee produced in Hassan District.

7. Soil Erosion and Declining Soil Fertility

The findings indicate that intense rainfall has increased soil erosion, particularly in coffee plantations located on hill slopes. The loss of fertile topsoil has reduced soil fertility, water-holding capacity, and nutrient availability. Farmers are therefore required to apply additional fertilizers and organic manure to maintain productivity, increasing production costs.

8. Increased Cost of Coffee Cultivation

The study revealed that climate change has substantially increased the cost of coffee production. Farmers reported higher expenditure on irrigation, fertilizers, pesticides, labour, shade management, and soil conservation measures. Although production costs continue to rise, coffee yields have remained unstable, reducing overall profitability.

9. Impact on Farmers' Livelihoods

The findings show that declining coffee production has negatively affected the livelihoods of coffee-growing families. Reduced income has created financial stress, making it difficult for farmers to repay agricultural loans and maintain their plantations.

10. Labour Shortages

The study found that labour shortages have become increasingly common in coffee plantations. Reduced profitability and changing employment opportunities have encouraged many workers to migrate to nearby towns and cities for alternative employment. This has affected timely harvesting and plantation management, further reducing productivity.

11. Adoption of Climate Adaptation Strategies

The findings reveal that many coffee growers have begun adopting climate adaptation measures to reduce production risks. These include rainwater harvesting, drip irrigation, mulching, shade tree management, soil conservation practices, integrated pest management, and diversification with crops such as pepper and cardamom. However, the adoption of these practices remains limited among small farmers because of financial constraints and lack of technical support.

12. Overall Impact of Climate Change on Coffee Production

The overall findings demonstrate that climate change has significantly affected coffee production in Hassan District through rising temperatures, irregular rainfall, increased pest and disease incidence, water scarcity, declining yields, deterioration in coffee quality, rising production costs, and economic insecurity among farmers. The study concludes that climate-resilient agricultural practices, improved water management, scientific pest control, financial assistance, and strong institutional support are essential to ensure the long-term sustainability of coffee cultivation in Hassan District.

VIII. CONCLUSION

Climate change has emerged as one of the most significant challenges affecting coffee production in Hassan District. The study concludes that rising temperatures, irregular rainfall patterns, prolonged dry spells, and the increasing occurrence of pests and diseases have adversely affected both the quantity and quality of coffee production. These climatic changes have reduced productivity, increased cultivation costs, and created economic uncertainty for coffee growers. Small and marginal farmers are particularly vulnerable because of limited access to irrigation, financial resources, and modern farming technologies. The findings also reveal that declining coffee yields and deteriorating bean quality have affected farmers' income and the overall sustainability of coffee cultivation in the district. Although many farmers have adopted adaptation measures such as rainwater harvesting, shade tree management, mulching, and integrated pest management, these efforts alone are insufficient to address the growing impacts of climate change. Greater support from the Coffee Board of India, government agencies, research institutions, and agricultural extension services is essential to promote climate-resilient farming practices.

Investments in water conservation, improved irrigation systems, climate-resilient coffee varieties, and farmer awareness programmes are crucial for sustaining coffee production. Therefore, coordinated efforts by policymakers, researchers, and coffee growers are necessary to strengthen the resilience of the coffee sector. Adopting sustainable agricultural practices and effective climate adaptation strategies will help protect the livelihoods of coffee farmers and ensure the long-term sustainability and global competitiveness of coffee production in Hassan District.

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