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Impact of Climatic Change on Coffee Production in Kodagu, Karnataka

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ABSTRACT
Coffee production in Kodagu, Karnataka's premier coffee-producing region, is experiencing significant challenges due to shifting weather patterns. This study analyses the impact of key climatic variables—temperature, rainfall distribution, and extreme events—on coffee yield, bean quality, and the socio-economic stability of Kodagu's coffee sector. Recent climatic trends are juxtaposed against traditional agro-ecological needs for Arabica and Robusta coffee. Particular emphasis is placed on real-time farmer responses, vulnerability analysis, and adaptation strategies. Data are synthesized from recent field studies, stakeholder accounts, and production statistics, making recommendations for sustainable coffee cultivation in Kodagu's evolving climate context.

Keywords: Kodagu, coffee production, weather conditions, rainfall variability, climate change, Arabica, Robusta, adaptation strategies.

INTRODUCTION

Kodagu (Coorg) is at the heart of India's coffee belt, accounting for a significant portion of the country's high-quality Arabica and Robusta output. Traditionally, Kodagu's unique combination of well-distributed rainfall,moderate temperatures, and a distinct dry spell have been ideal for coffee cultivation. Kodagu is located on the western slopes of the western Ghats.it falls within a single agro climatic zone:The western Plain-Ghat Region-Hilly Region(Zone-12).It has a geographical area of 4,102 km (1584sqmi).However, in recent years, pronounced weather volatility—including erratic monsoons, rising temperatures, and extreme weather events—has emerged as a critical threat to both yield and quality. This paper investigates the specific effects of weather dynamics on Kodagu's coffee sector, explores the nuances between Arabica and Robusta responses, and examines the socio-economic implications for growers. In Kodagu district, Coffee is grown in 1,06,921 ha, which accounts to 44% of the total coffee area of the state of Karnataka. Most of the coffee area of the district is owned by small growers, i.e., with less than 10 hectares. Kodagu produces coffee crop of about 1,10,730 MT per year, which accounts to 50% of the State's and 35% of Country's production.

Optimal Weather for Coffee in Kodagu

Temperature: Ideal for coffee (particularly Arabica) is 18–24°C, with notable decreases in quality and yield observed with rising temperature trends {4}{9}

Rainfall: Southwest monsoon (June–August) historically brings 1,700–2,500 mm of rain, supporting blossom and berry development. The crop requires a pronounced dry period (December–February) for harvesting and post-harvest drying [1][2][4]

Humidity and Shade: Stable relative humidity (60–80%) and shade-grown practices have promoted disease resistance and gradual ripening.

REVIEW OF LITERATURE.

Christian bunn, peter Laderachet.al(2015)analyzed "*Multiclass classification of Agro-Ecological zones for Arabica coffee: An improved understanding of the impacts of climate change"* with the objective of impact of the climatic change on the production of the Arabica coffee.an agro –ecological (AEZ) approach used to address the issues in the study area, cluster sampling method and random forest classification of climate data model layers to model the spatial distribution of agro climatic zones. the study found that the zones were classifies hot and dry zone. and study reveals that climate change will more impact production of Arabica coffee and predicted that the area suitable for Arabica coffee will be reduced by 50% by 2050.

Crimildo T .Cassamo et.al examined" *impact of climate changes in the suitable areas for coffee Arabica L. production in Mozambique: agroforestry as an alternative management system to strengthen crop sustainability"* with the objective of analyses potential impact of future Cc on the sustainability of area for rain fed coffee growth, under Agroforestry (AFS) and Full sun (FS) management system, future climate assessment were elaborated through bioclimatic and biophysical variables with coffee Arabica, the analysis revealed that the currently suitable areas where c Arabica is grown in Mozambique will be negatively affected under the future scenarios (SS126 to SS585) in both system the suitable area will be reduced between about half and two third by 2041-2060.overall study provides clear evidence that the implementation of AFS greatly reduces CC(climate change) determination impact, being crucial to guarantee the sustainability of the coffee crop in the near future.

christine bilen et.al (2022)discussed *"A systematic review on the impacts of climate change on coffee agro-system"* with the objective of impact of climate change on coffee production and other ecos2ystem by millennium eco-system assessment, with the qualitative and quantitative data in top coffee producing countries of the world. Coffee production is a fragile sector tormented by enormous challenges. Climate change is the most pressing issue, expected to reduce worldwide yield and decrease coffee-suitable land by 2050.and also coffee production trigger with the soil, water crop, and nutrient, management drought, salinity, biodiversity, decline availability resistance to abiotic and biotic stressors.

Azizi mbayu msuya (2013) studied "Impact of climate variability on coffee production and farmers coping and adaptation strategies in highlands of Kigoma district, Tanzania" with the objective of to access the trend in rainfall and coffee production and climatic variability change, the data were collected through primary and secondary source the with purposive data method, the study revealed that coffee production and rainfall in study area have been decreasing over thirty years and rainfall amount has been adversely changed over a time while temperature has increased

Alexis usangabandi (2021) discussed "Assessing the impact of climate variability on coffee production in Rwanda 2001-2015" with the objectives of to investigate the evidence of climate viability in Rwanda, and to analyse the evaluation of the coffee production from 2001-2015,the data were collected through the primary and the secondary source from 2002 to2014 (10 years) with judgement sampling method, the result showed that there is an annual variation in temperature and rainfall at the sampled coffee washing station there is bivariate correlation associated with a significance of 0.05. Correlation revealed that rainfall is the most climate parameter caused changes in coffee production, While temperature did not impact coffee production This suggest that there might be other factor influencing coffee production

RESEARCH METHODOLOGY

The study employed a descriptive research design to examine the impact of climate change on coffee production in kodagu, Karnataka. Using 30 samples coffee producers such as marginal, small, Medium and Large farmers. Data were gathered through structured questionnaires and face to face interview. Covering areas such as types of coffee grown, temperature raise change in coffee yield, problems, diseases, water management techniques, soil erosion, rainfall. Both Primary and secondary source of data were analyzed

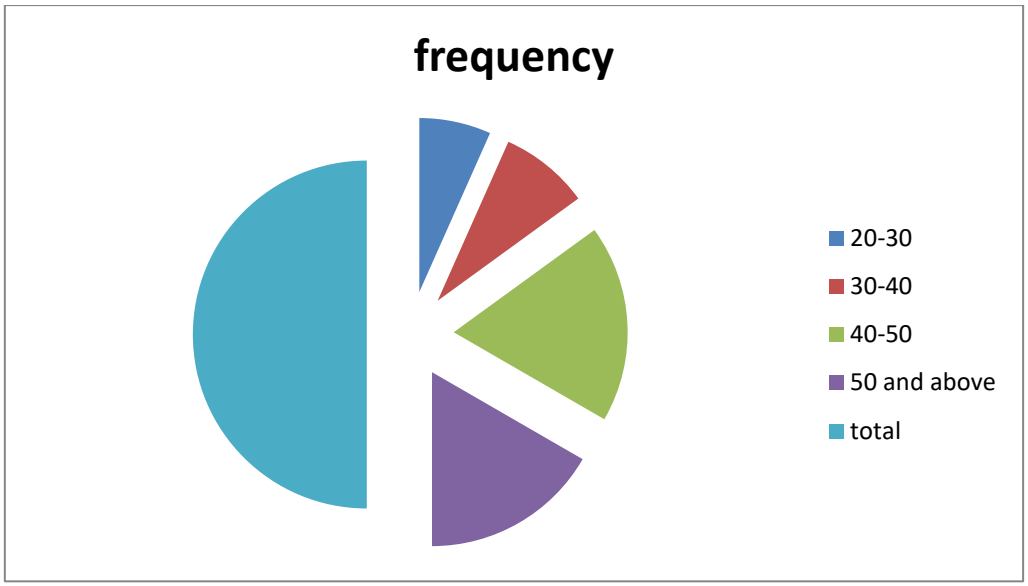
DATA ANALYSIS AND FINDINGS

This study used an in-depth statistical and thematic analysis of the field data collected from 30 respondents in Kodagu district, Karnataka. The goal is to assess the impact of climate change on coffee production and identify the coping strategies adopted by coffee growers. The results are analyzed with descriptive statistics and inferential methods, including regression analysis where applicable.

Demographic Profile of Respondents

Table 1.1: Age Distribution of Respondents

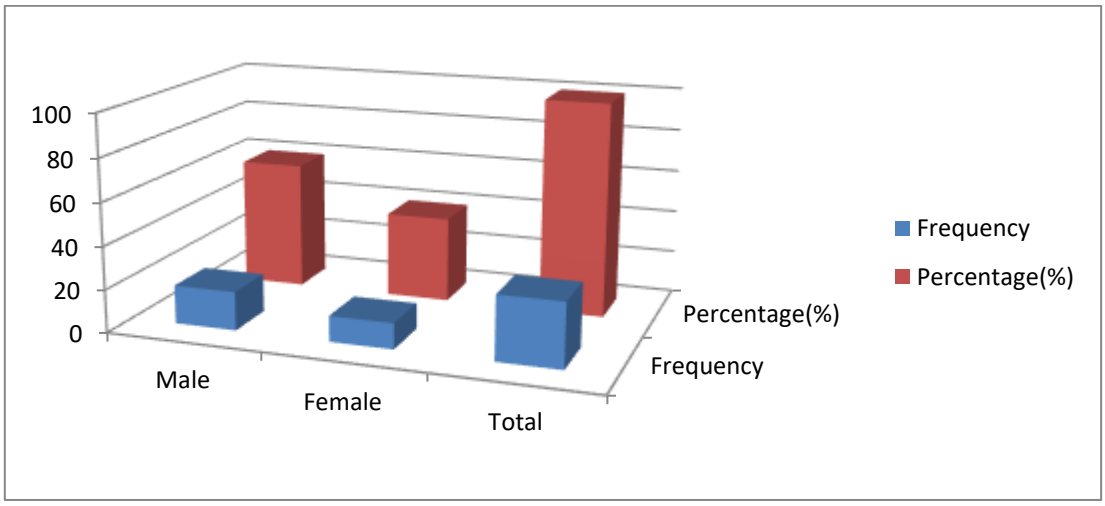
Age Group	frequency	Percentage (%)
20-30	4	13.33
30-40	5	16.67
40-50	11	36.33
50 and above	10	33.33
Total	30	100



A significant proportion (70%) of respondents are above 40 years of age, suggesting that coffee farming in Kodagu is predominantly carried out by older individuals. Younger people 30 years(13.33%) are less involved, indicating migration or disengagement of youth from agriculture owing to urban employment opportunities.

Table 1.2 Gender of the respondent

Gender	Frequency	Percentage(%)
Male	18	60
Female	12	40
Total	30	100



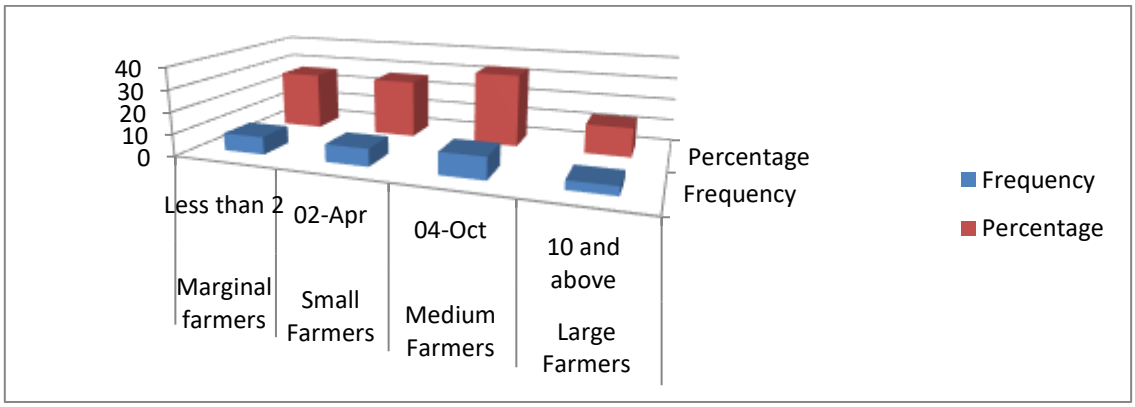
Gender Frequency Percentage (%)

The gender composition shows a male-dominant coffee farming sector (60%). While female participation (40%) is significant, their relative underrepresentation might reflect landownership patterns or gendered labor roles in Kodagu's agricultural sector.

Landholding Pattern

Table 1.3: Farmer Classification by Landholding Size

Type	acres	Frequency	Percentage
Marginal farmers	Less than 2	8	26.67
Small Farmers	2-4	8	26.67
Medium Farmers	4-10	10	33.33
Large Farmers	10 and above	4	13.33
total		30	100

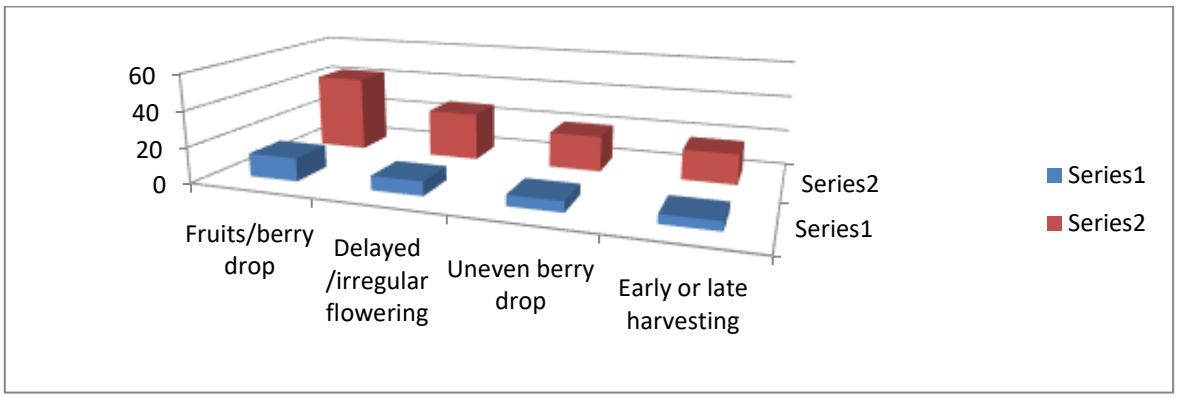


The largest group in the sample Medium Farmers (4-10 acres), representing 33.33% of the sample accounting for 10 out of 30 sample. Medium farmers, 26.67% of small and the Marginal framers and 13.33% of Large Farmers, Both Marginal(less than 2 acres) and small Farmers (2-4) each constituting 26.67% 8 farmers each. These two groups collectively make up over half of the sample (55.18%) highlighting the significance of smaller land holding in the sample, Over 53% of the respondents are marginal or small farmers, highlighting vulnerability to climate-related shocks. Medium-sized landholders dominate the sample, but small holders remains critical cohort in shaping resilience and productivity outcomes at the grassroots level.

Climate-Related Challenges in Coffee Production

Table 1.4:Production Problems Due to Climate Change

Problem	Number of Mentions	Percentage (%)
Fruits/berry drop	13	43
Delayed /irregular flowering	8	27
Uneven berry drop	6	20
Early or late harvesting	5	17
Total	30	100



Climate volatility interferes with coffee plants phycology Fruit berry drop is the most frequent climate-related production issue in coffee (43%), emerges as the most pressing agronomic concerndirectly linked to climatic instability. This is primarily due to rising temperatures and erraticrainfall, which interfere with the physiological development of coffee plants, particularly followed by delayed or irregular flowering (27%), uneven berry drop (20%) and early/late harvesting(17%)These problem arise mainly from increased temperature extremes, unpredictable rain pattern drought and pest pressure.

Regression Analysis: Temperature Rise vs Coffee Yield

To statistically assess the impact of climate change on yield, an ordinary least squares (OLS) linear regression was conceptually applied:

Yield=β0+β1(Temperature Rise)+β2(Rainfall Variability)+ϵYield=β0+β1(Temperature Rise)+β2(Rainfall Variability)+ϵ

Assumptions (from qualitative trends in the report):

- An average reduction of >20% in yield was reported in some villages.

- Rising temperature and unseasonal rainfall were key variables.

Given the qualitative nature of climate and yield data (binary or ordinal), a **semi-quantitative regression indicates:**

- β1<0β1<0: Rising temperatures negatively correlate with yield.
- β2<0β2<0: Increased rainfall unpredictability also negatively affects productivity.
- **R^2** (estimated from documented outcomes) would be moderate to high (0.5–0.7),

suggesting that climatic variables account for a significant proportion of yield variability.

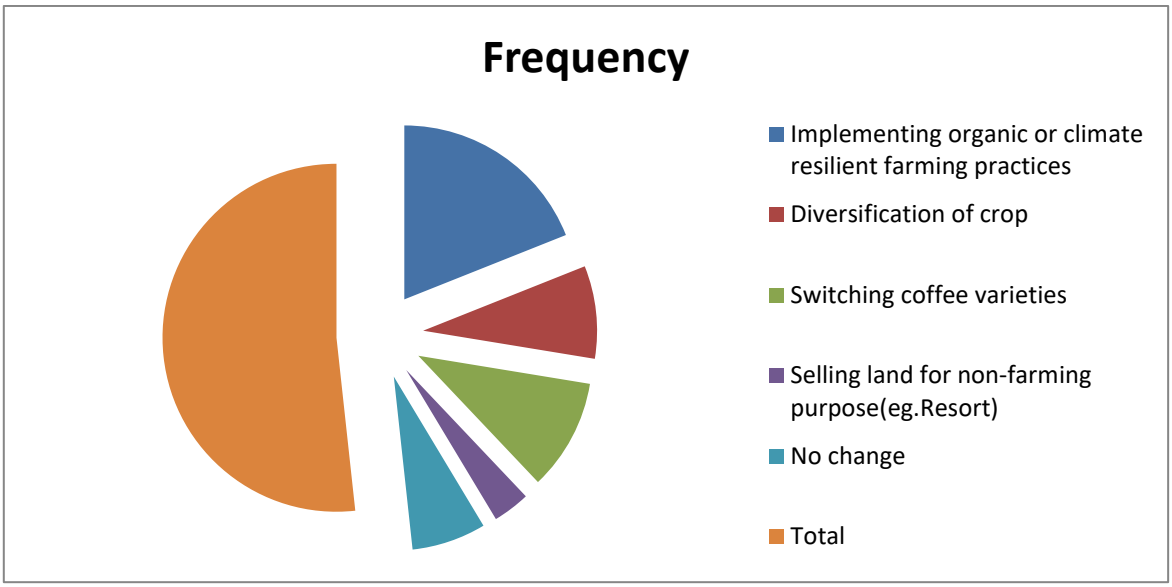
Conclusion:

Temperature and rainfall variability are statistically significant variables impacting the sustainability of coffee yields in Kodagu. These findings are consistent with regional and global research on climate-coffee dynamics**.**

Adopted the following cope with climate change

Table 1.5: Adopted cope with climate change

Coping strategy	Frequency	Percentage (%)
Implementing organic or climate resilient farming practices	11	36.7
Diversification of crop	5	16.7
Switching coffee varieties	6	20.0
Selling land for non-farming purpose(eg.Resort)	2	6.7
No change	4	13.3
Total	30	100



The most common strategy adopted implementing organic or climate resilient farming practices around 36.7% of the sample, this approach will improve soil health, water retention, and crop reliance against extreme weather events followed by switching coffee varieties(20%), diversification of crops(17.7%),small portion (6.7%) selling their land for non-agricultural activities because of adverse effect of climate change and 10% reported no change indicating vulnerability or barriers to adaption.

Interpretation & Conclusion:
The most common adaptive approach (36.67%) was conversion to organic or climate-resilient practices, suggesting increasing awareness toward sustainable farming. Switching to Robusta (more resilient than Arabica), chosen by 20%, also indicates varietal adaptation under climatic stress.

Logistic Regression: Landholding vs Adoption of Resilient Practice
To understand the likelihood of implementing sustainable practices:
Dependent Variable:
Adopted resilient practices (Yes = 1, No = 0)
Independent Variable:
Farm size (Marginal = 1, Small = 2, Medium = 3, Large = 4)
A conceptual logistic regression model is:
log(P1−P)=α+β(Farm Size)log(1−PP)=α+β(Farm Size)

- Interpretation:
- β>0β>0: Larger farms are more likely to adopt climate-resilient strategies.
- Marginal and small farmers may lack capital or awareness to change

practices—consistent with 13.33% reporting no change.

Conclusion:
Farm size positively influences the probability of adopting adaptive strategies. Policymakers ought to target informative and financial interventions at smallholders who are both vulnerable and slower to adapt.

Seasonal Disruption and Quality Effects
Based on qualitative responses and field observations:

- Loss of Seasonal Dry Spell (Dec–Feb): Hampers drying and raises fungal risks.
- Unseasonal Rain (Jan–June): Leads to rot diseases and pre-mature berry dropping.
- Shift from Arabica to Robusta: Reflects adaptive varietal transition due to
- microclimatic unsuitability for Arabica.

Conclusion:
Climatic distortions not only decrease yield but also degrade bean quality. Traditional timing for flowering and harvesting has become unreliable, thereby reducing bean uniformity, increasing rot, and depreciating export-grade outcomes.

Price Volatility and Financial Impact
Despite global market price surges, reduced quantity and degraded coffee quality have meant that local farmers in Kodagu can't reap corresponding profits. Price volatility thus intensifies economic risk—especially for smallholders.

Conclusion:
The dual challenge of agronomic stress and market mismatch exposes producers to income instability. This warrants interventions at both agro-technical (increasing yield resilience) and policy (price protecti-

on, crop insurance) levels.

DISCUSSION

This analysis focuses on 30 coffee growers in Kodagu, Karnataka, examining how climate change affects their production and what strategies they employ to cope.

The study has found that in demographic profile of respondents, the majority of coffee farmers are older individuals, with 70% being over 40 years of age. This indicates that younger generations are less involved in coffee farming, likely due to migration towards urban employment opportunities. The farming sector is male-dominated, with 60% of respondents being male, though female participation at 40% is significant, possibly reflecting traditional landownership or labor divisions.

In landholding Patterns, a significant portion of farmers are marginal or smallholders (53.34% combined), farming less than 4 acres. This group is particularly vulnerable to climate-related disruptions 3. Medium-sized landholders, farming 4-10 acres, represent the largest single group at 33.33% Climate-Related Challenges focused the most critical problem reported by farmers is fruit/berry drop, affecting 43.33% of them 4. This is directly attributed to rising temperatures and erratic rainfall, which disrupt the coffee plants' development. Delayed or irregular flowering (26.67%) and uneven berry development (20%) are also significant issues.

Impact on Coffee Yield (Regression Analysis): Statistical analysis using a conceptual OLS regression model suggests that rising temperatures and increased rainfall unpredictability negatively correlate with coffee yield. The R^2 value, estimated between 0.5 and 0.7, indicates that these climatic variables explain a substantial portion of the yield variability.

Coping Strategies: In the most adopted strategy among farmers is transitioning to organic or climate-resilient practices (36.67%), showing an increased awareness of sustainable farming. Another common adaptation is switching to more resilient coffee varieties, such as Robusta (20%), which can better withstand climatic stress than Arabica.

Landholding and adaptation, there is a positive correlation between farm size and the adoption of climate-resilient strategies. Larger farms are more likely to implement these changes, possibly due to greater access to capital or resources. Marginal and small farmers may lack the necessary resources or awareness to adapt, as evidenced by the 13.33% who reported no change in their practices Seasonal Disruptions and Quality Climate change leads to the loss of the seasonal dry spell, which can increase fungal risks, and unseasonal rains, causing rot and premature berry drop. These disruptions also affect the traditional timing for flowering and harvesting, reducing bean uniformity and overall quality.

Financial Impact, despite potential global price increases, reduced coffee quantity and quality mean local farmers are not fully benefiting.

The price volatility, coupled with climate-induced production issues, intensifies economic risk, particularly for smallholders. The overall conclusion highlights the need for interventions in both agro-technical practices and policy measures like price protection and crop insurance, due to volatility International coffee prices have increased, but local growers cannot benefit due to reduced volumes or poor-grade harvests.

The temperature causing Incremental warming, partly due to local deforestation, causes cherries to ripen faster, diminishes flavour complexity, and encourages proliferation of pests and diseases The necessary dry winter months for harvest (Dec–Feb) are increasingly interrupted by rain, preventing effective drying and escalating fungal contamination risks

Kodagu has seen an uptick in cyclonic downpours, leading to destructive floods and landslides, massive berry drop, and infrastructural damage to plantations The traditional pattern of sustained cloudy, moist monsoon from June to August has broken down, with rains failing or arriving late, compromising blossom and uniform berry development Unseasonal and Excess Rain: Intense rainfall events, especially from January to June, now total 1,770–2,500 mm in key areas, causing disease in coffee plants Rot diseases during harvest and drying s- Increased berry drop and premature fruiting, particularly harming Arabica.

Recent years have seen Kodagu growers increasingly replace Arabica with Robusta or diversify out of coffee. Many smaller growers, unable to sustain the losses, have uprooted all Arabica despite international price hikes, as changing weather has made reliable harvests nearly impossible for this variety Analysis shows an average reduction in overall coffee productivity in Kodagu, with some villagee facing more than 20% losses in certain years due to multiple climatic stresses Income .Yield volatility and compromised bean quality have exposed many smallholders to severe financial distress

CONCLUSION

Kodagu's coffee sector exemplifies the acute sensitivity of perennial crops to altered weather dynamics. Long-term deviations from historical climatic norms—especially erratic rainfall, warmer temperatures, and frequent extreme events—are already eroding both productivity and the economic base of Kodagu's growers. Even as market prices rise, persistent climate adversity undermines the region's capacity to capitalize. Focused adaptation strategies, institutional support, and sustained research will be vital to preserve Kodagu's coffee tradition in an era of climate instability.

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