Indian Journal of Agricultural Economics 79: 3 (2024):420-429
DOI:10.63040/25827510.2024.03.007

Battling Climatic Shifts: Vulnerability of Coffee-Based Farm Households and Resilient Practices in Coffee Farms, Wayanad, Kerala[@]

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ABSTRACT

The study examines the vulnerability of coffee-based farm households in Kerala's Wayanad district, focusing on the panchayats of Vythiri, Ambalavayal, and Noolpuzha. Climate change significantly affects these regions, mainly due to altered rainfall patterns and temperature fluctuations impacting coffee production. The study uses data from 120 farmers and secondary climate information from 1991 to 2022 to analyze the vulnerability of Arabica and Robusta coffee varieties, which are highly sensitive to these climatic changes. Coffee, along with black pepper and areca nut, forms the dominant cropping systems in the region, with coffee being the primary crop. The vulnerability index indicates that Vythiri is the most vulnerable, Ambalavayal is moderately vulnerable, and Noolpuzha is the least vulnerable. Factors such as low literacy, excessive use of inorganic fertilizers, minimal subsidies, and water scarcity exacerbate the vulnerability of these households. To address these challenges, the study suggests improving irrigation infrastructure, developing weather-based crop insurance, providing localized weather information, promoting disease-resistant black pepper varieties, and encouraging soil-based fertilizer applications. The findings emphasize the need for adaptive strategies and targeted policy interventions to reduce the vulnerability of small and marginal farmers in the coffee-based systems of Wayanad.

Keywords: Coffee-based farm households, Vulnerability, climatic variability,

JEL codes: Q01, Q18, Q54, Q57

I

INTRODUCTION

Coffee is among the most widely consumed beverages globally and the most traded commodities. Originating in Africa, coffee plants are tropical evergreen shrubs or small trees. The two primary species of coffee plants are Coffea arabica (Arabica) and Coffea canephora (Robusta), both belonging to the Rubiaceae family. India ranks as the world's fifth-largest producer of Robusta coffee, following Vietnam, Brazil, Indonesia, and Uganda. Regarding production, India's Arabica coffee output is significantly lower than that of Robusta coffee. Karnataka is India's leading coffee cultivation state, accounting for over 50 per cent of the country's total coffee-growing area, followed by Kerala and Tamil Nadu. While Karnataka and Kerala predominantly grow Robusta coffee, Tamil Nadu mainly produces Arabica coffee. In 2022-23, Kerala produced 72,425 million tonnes of coffee, representing 21 per cent of India's total

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[@]The authors acknowledges Kerala Agricultural University (Research Fund for Master Studies) for the financial support provided throughout the research.

coffee production. Wayanad is particularly significant, contributing 79 per cent of the coffee cultivation area and 84 per cent of the state's output, mainly due to its unique climate conditions (Coffee Board, 2023).

Recently, climatic conditions in Wayanad have changed drastically, with a significant rise in minimum temperatures compared to a slight increase in maximum temperatures (Jayakumar et al., 2017). Identified as one of the most vulnerable districts in Kerala (GoK, 2023), Wayanad has faced a series of environmental challenges, including a flood in 2018 and a landslide in 2019. As a climate-sensitive crop, coffee experiences yield reductions under these changing conditions, affecting household income and increasing vulnerability to climate variability. Temperature variations primarily impact arabica coffee, while rainfall variability affects robusta coffee. Given that robusta is the major cultivated variety in Wayanad, the lack of summer showers, which are crucial for blooming and berry setting, poses a significant challenge. In this context, the study was conducted to assess the vulnerability of coffee-based farm households and the driving factors of this vulnerability. The study focused on three panchayaths, Vythiri, Ambalavayal, and Noolpuzha, one from each of three Agro ecological units in Wayanad (AEU No.15, AEU No.20, AEU no.21 respectively).

II

MATERIALS AND METHODS

Vulnerability, when considered as a characteristic of a system, includes both sensitivity and adaptive capacity. It indicates the system's propensity to suffer adverse effects independent of its exposure to external influences.

Socio-Economic Vulnerability Index (SeVI)

The vulnerability index is a metric that defines the vulnerability of a system (IPCC, 2014). Although vulnerability is a non-measurable and non-observable state, it can be quantified using proxy indicators. The computation of SeVI involved five steps.

Step I – *Selection of Indicators*

Vulnerability is a function of sensitivity and adaptive capacity; therefore, indicators for both components were identified. These indicators were chosen through various methods, including literature review, stakeholder consultation, and expert judgment. The selected indicators and the reasoning behind their selection are presented in Table 1.

TABLE 1 - INDICATORS SELECTED FOR THE STUDY

Major component (1)	Sub-component (2)	Explanation of sub-component (3)	Source (4)
Socio-demographic profile	Household head literacy (-)	Scoring is followed for household head literacy	Developed for this study
	Dependency ratio (+)	Ratio of population under 18 and over 65 years of age to the population between 19 and 64 years of age	ICF International (2011)
	Farm size (-)	Farmers with operational land area less than 2.5 acres or one hectare	Developed for this study
	Credit indebtedness (+)	Debt-Equity ratio Ratio of total liability to owner's equity	Reddy *et al*. (2019)
Livelihood strategies	Average livelihood diversification index (+)	The inverse of the (number of livelihood activities of a household + 1)	World Bank (1997) Sam *et al*. (2016)
	Household with migrant members (-)	Household that reported migration as a source of income	Joarder and Miller (2003)
	Crop diversification index (+)	Herfindhal index (HI) $HI = \sum_{i=1}^{N} P_i^2$ N= total number of crops P= proportion of area under each individual crop area to total cropped area	Shiyani and Pandya (1998), Mathew (2022)
Social networking	Household with assistance from NGO/SHG (-)	Number of NGOs or SHGs to a household is connected	Developed for this study
	Household availed subsidy (-)	Households that reported they have received subsidy for farm operations	Developed for this study
	Household exposure to training (-)	Households that attended various training programs	Developed for this study
Crop health	Households reported low yield due to climate variability (+)	Households reported lower yields than in previous years	Developed for this study
	Households with coffee age greater than economic age (+)	Households reported age of coffee higher than 30 years	Developed for this study
	Household reported black pepper and areca nut loss due to disease (+)	Households reported greater than 50% black pepper and areca nut loss due to disease	Anseera (2018)
Soil health	Households shifting to organic farming (-)	Households reported zero application of pesticides or fungicides and lower consumption of inorganic fertilizers	Developed for this study
	Households reported soil erosion (+)	Households reported significant soil erosion	Developed for this study
	Households consuming NPK greater than optimum NPK consumption (+)	Households reported NPK usage higher than 958 kg/ha (KAU, 2016)	Developed for this study
Water	Average no: of water resources (-)	No: of active water resources, a household possess	Developed for this study
	Per cent of gross irrigated area to total cropped area (-)	$\left[\frac{Gross\ irrigated\ area}{Gross\ cropped\ area}\right] 100$	Varghese (2012)
	Drought during summer months for drinking purpose (+)	Households reported drought during summer months for drinking purpose	Developed for this study
	Drought during summer months for irrigation (+)	Households reported drought during summer months for irrigation	Developed for this study

Step II

Data for the indicators were gathered using various methods, such as secondary data sources and household surveys. Consequently, the raw data collected from households were converted into suitable measurement units.

Step III – *Normalization of indicators*

The selected indicators for the assessment were measured in various units, rendering direct aggregation impractical. Therefore, a normalization procedure is suggested to convert all values into dimensionless units. Before endorsing this normalization process, a thorough understanding of the functional relationships between the indicators and vulnerability was obtained. Two types of relationships were identified: positive and negative. In a positive relationship, vulnerability increases with rising indicator values, whereas in a negative relationship, vulnerability decreases as indicator values increase. The mathematical formula for both types of relationships is provided below. For positive relationship –

$$X_{ij}^{p} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})} \qquad \text{.. eqn (6)}$$

Where,

X_{ij}^{p} - Normalised value of the indicator i^{th} indicator for the j^{th} household

X_{ij} - Value of the i^{th} indicator for the j^{th} household

For negative relationships –

$$X_{ij}^{n} = \frac{Max(X_{ij}) - X_{ij}}{Max(X_{ij}) - Min(X_{ij})} \qquad \text{.................................eqn(7)}$$

Thus, normalized indicator values range from 0 to 1. Sign of the relationship of the selected indicators is provided in Table 1.

Step IV – *Assigning weights to indicators*

Various indicators have varying impacts on vulnerability. Therefore, weights are assigned to these indicators to represent their relative contributions to the overall vulnerability of the system. The methodology for assigning these weights followed the index-making approach outlined by Iyengar and Sudarshan (1982). The overall weight values range from 0 to 1. The weights for each performance indicator were calculated using the formulas provided below.

$$w_{ij} = \frac{c}{\sqrt{var(X_{ij}^{p})}}$$

……………………..eqn(6)

Where,

$$c = \frac{1}{\sum_{j=1}^{20} \frac{1}{\sqrt{var\,(X_{ij}^{p}\,)}}}$$

Step V – *Aggregation of indicators and development of vulnerability index*

The vulnerability index of each selected indicator is obtained by multiplying its normalized value by the corresponding assigned weight. These normalized, weighted indicator values are then aggregated to derive the overall vulnerability index of a household.

$$VI = \left[\Sigma_j \; w_{ij}X_{ij}^{p} + \; \Sigma_j \, w_{ij}X_{ij}^{n}\right]$$

………………………………..eqn (7)

Where,

X_{ij}^{p} & X_{ij}^{n} - normalized value of positive and negative indicators

III

RESULTS AND DISCUSSION

The composite vulnerability index (VI) was computed for 120 randomly selected farmers across three panchayats in the district. VI ranges from a minimum value of zero to a maximum of one, where zero indicates low vulnerability and one indicates high vulnerability. In the study area, VI values ranged between 0.26 and 0.70. These values were categorized into low, medium, and high vulnerability groups based on mean and standard deviation criteria. Each category contained 120 farmers, and the findings were subsequently presented (Table 2).

TABLE 2: SOCIO-ECONOMIC VULNERABILITY OF FARM HOUSEHOLDS OF SELECTED PANCHAYATHS IN WAYANAD

Vulnerability (1)	Ambalavayal (2)	Noolpuzha (3)	Vythiri (4)	Total (5)
Low vulnerable	5 (12.50)	10 (25.00)	6 (15.00)	21 (17.50)
Medium vulnerable	30 (75.00)	25 (62.50)	23 (57.50)	78 (65.00)
Highly vulnerable	5 (12.50)	5 (12.50)	11 (27.50)	21 (17.50)
Total	40 (100)	40 (100)	40 (100)	120 (100)

The data shows that the highest percentage of highly vulnerable farmers was observed in Vythiri (27.5 per cent), followed by Noolpuzha and Ambalavayal, each with 12.5 per cent. Similarly, the highest proportion of low-vulnerability farmers was found in Noolpuzha (25 per cent), followed by Vythiri (15 per cent) and Ambalavayal (12.5 per cent), which had the least. Despite the presence of low and highly vulnerable farmers in each panchayat, most farmers fall into the medium vulnerability category. Sixty-five per cent of the total 120 farmers were moderately vulnerable to climate variability.

Drivers of Vulnerability

The vulnerability index can be depicted in various forms, including ranking, classification into low, medium, and high vulnerability categories, spatial representation through maps and charts, and identifying key drivers influencing vulnerability (Sharma et al., 2018). Since this study focused on a coffee-based farming community, categorizing farmers into low, medium, and high-vulnerability groups provided a more generalized representation. Specifically, the study identified and presented the significant factors contributing to higher vulnerability among farmers in each panchayat.

Prioritizing adaptation strategies involves a critical process of identifying the factors that contribute to vulnerability. This includes assessing the impact of each indicator on vulnerability. The drivers of vulnerability, depicted as percentages in Figure 1, highlight the factors influencing the vulnerability index of the highly vulnerable category in Ambalavayal. Due to the inclusion of numerous indicators (20 in total), each driver's contribution as a percentage was generally lower, typically less than 10 per cent. Priority drivers, which contribute more than 7 per cent and are positioned towards the outer edge of the spider diagram, were considered significant for prioritization.

Drivers of Vulnerability in Ambalavayal Panchayath

From the figure, the priority drivers identified for Amabalavayal panchayath were crop diversification index (9.61), Average number of water resources (9.51), Household head literacy (8.73), Subsidy availed (8.73)**,** Assistance from Non-Governmental Organizations (NGO)/Self-Help Group (SHGs) (8.12)**,** Nitrogen, Phosphorous, potassium consumption (7.93).

Farmers identified as highly vulnerable were either illiterate or had only primary or upper primary education. Education is crucial for addressing climate variability as it equips farmers with strategies for risk management and practices aligned with climate-smart agriculture. Additionally, these farmers depended on community panchayat wells for their household needs, making it unfeasible to establish their irrigation infrastructure. A few benefited from the Karappuzha irrigation project in the district but had to pay a substantial annual fee for water. Consistent irrigation during the summer months is vital to maintaining economic yields in coffee plantations amid climatic variability. Therefore, establishing irrigation systems, particularly sprinkler irrigation, is essential.

Despite diversifying their coffee farms with black pepper and areca nut, some farmers failed to maintain an optimal crop stand. The prevalence of foot rot disease in black pepper necessitated replanting vines every six years. Additionally, areca nut crops suffered significantly from yellowing, and the recurrence of diseases made it challenging to maintain ideal crop density. Social networking and integration are critical for raising awareness and encouraging the adoption of measures to address natural disasters, as highlighted by Dundappa (2019). The study also noted that highly vulnerable farmers, particularly those not affiliated with NGOs like WSSS or Perfetto Naturals, face a higher climate variability risk. This emphasizes the importance of organizational support and community networks in enhancing resilience among vulnerable farmers. These NGOs played a significant role in promoting organic farming among coffee farmers in Wayanad. However, those not aligned with these organizations continued to use higher rates of inorganic fertilizers in their fields.

Drivers of Vulnerability for Noolpuzha Panchayath

Noolpuzha panchayat had the highest number of low-vulnerability farmers compared to the other two panchayats. According to the figure, the priority drivers identified in Noolpuzha were nitrogen, phosphorus, and potassium consumption (7.93), household head literacy (7.84), subsidy availed (7.84), farm size (7.73), and the average number of water sources (7.51). Despite having more educated individuals than Vythiri and Ambalavayal, some households in Noolpuzha had low literacy levels. Highly vulnerable farmers were either illiterate or had education levels below upper primary. Higher household education is negatively correlated with the risks of natural disasters and climate variability (Brody et al., 2008). In Noolpuzha, 60 per cent of highly vulnerable farmers were from female-headed households. Female-headed households are particularly vulnerable to weather extremes due to poor literacy and lack of social networks (Sam et al., 2016). Among the highly vulnerable farmers, only 20 per cent were connected to NGOs and adhered strictly to organic farming; the rest used higher amounts of inorganic fertilizers.

The Agriculture Officer at Noolpuzha Krishibhavan mentioned that, since there is a dedicated Coffee Board for coffee, there are no schemes or subsidies available for coffee farmers through the Department of Agriculture and Farmers' Welfare, Government of Kerala. All highly vulnerable farmers had marginal land areas. Larger farm sizes are associated with higher asset values, which can act as a buffer against various stresses, including climate variability and economic challenges. Highly vulnerable farmers rely on panchayat wells for water, exposing them to critical water stress, especially in the Kuppadi area of Noolpuzha. Even moderately vulnerable farmers in that locality face drought-related challenges, but their diverse income sources allow them to have more water resource structures. Despite having more water resources, many moderately vulnerable farmers struggle with irrigation. Tube wells drilled to 500 meters often fail to supply water for even one hour.

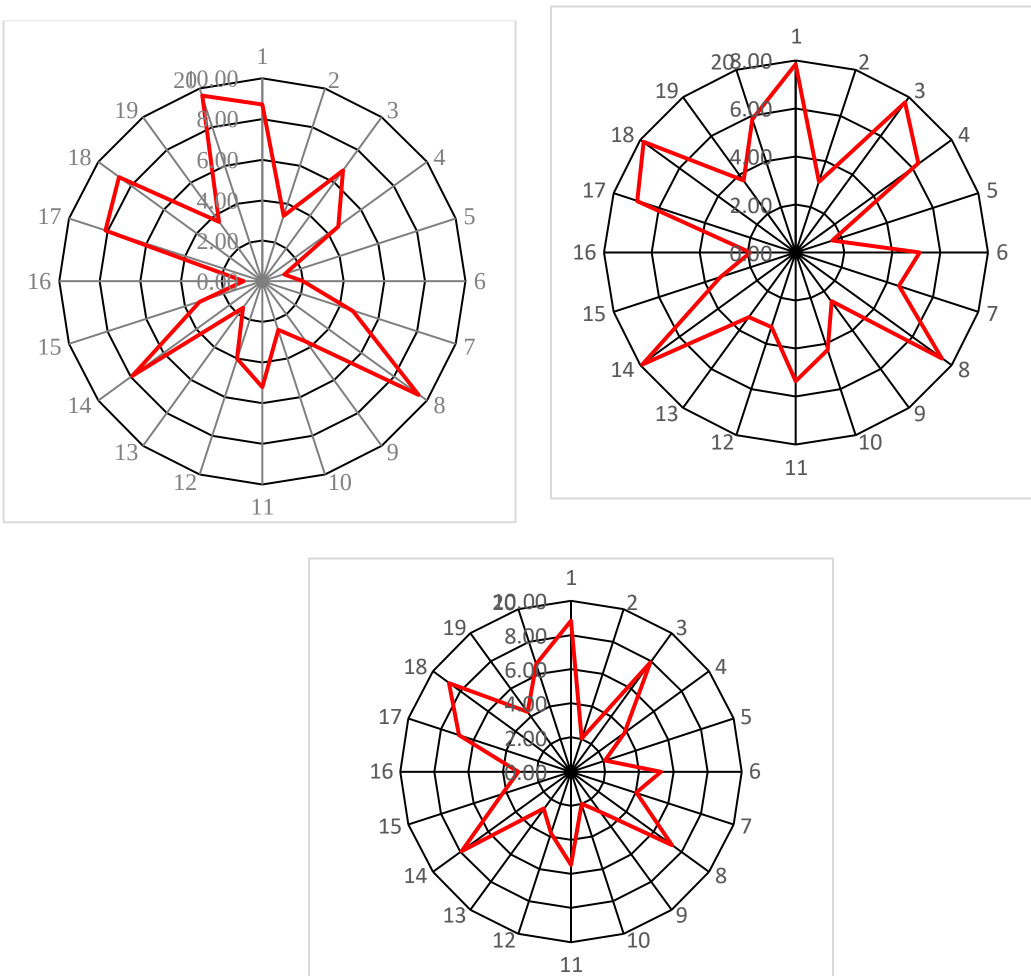

Figure 1. Drivers of Higher Vulnerability in Ambalavayal Panchayath, Noolpuzha Panchayath, Vythiri Panchayath

1	Household head literacy	11	With migrant members as a source of income
2	Dependency ratio	12	Coffee with age greater than economic age
3	Farm size	13	Black pepper and areca nut losses more than 50% due to disease
4	Livelihood Diversification Index	14	Nitrogen, Phosphorous, Potassium consumption
5	Credit indebtedness	15	Shifting to organic farming
6	Lower yield due to climate change	16	Households with soil erosion
7	Per cent irrigated area	17	Assistance from NGO/SHGs
8	Average number of water sources	18	Subsidy availed
9	Water stress for drinking water	19	Exposure to training
10	Water stress for irrigation water	20	Crop diversification index

Drivers of Vulnerability in Vythiri Panchayath

Vythiri, the gateway to Wayanad from Kozhikode, falls under Agro Ecological Unit number 15 (Northern High Hills) and has the highest percentage of highly vulnerable farmers (27.5 per cent). According to the figure, the priority drivers identified for Vythiri panchayat were household head literacy (8.83), subsidy availed (8.83), nitrogen, phosphorus, and potassium consumption (7.93), farm size (7.88), and the average number of water sources (7.32). The key factors contributing to farmers' vulnerability in Vythiri are similar to those in Noolpuzha and Ambalavayal. In all three panchayats, the average number of water sources ranged from 1 to 2, posing a significant challenge for irrigation. Vythiri experienced less water stress compared to Noolpuzha and Ambalavayal. Water stress was reported by farmers near the Pookode Lake region, especially during the summer months. The primary concern was the limited availability of water sources for agriculture, with highly vulnerable households relying on only one water source for domestic purposes. Unlike drought, flood-affected households were more prevalent in Vythiri. During the 2018 flood, 50 per cent of highly vulnerable households were in relief camps. Despite this, many farmers noted that their coffee plants survived the flood without damage, although the yield was affected. After the flood, the Government enacted the Integrated Coffee Development Scheme to rejuvenate coffee farms, benefiting approximately 25 per cent of farmers with financial support ranging from Rupees 1500 to 8000, depending on their farm size and expenses incurred in the 2021-2022 farming year.

In contrast to the other panchayats, crop diversification was a priority indicator in Ambalavayal, while in Noolpuzha and Vythiri, it was the lack of assistance from NGOs/SHGs driving vulnerability (6.88 per cent). Most farmers in Vythiri are not registered under such organizations, leading to a higher application of PPCs. Farmers typically lease their areca nut, and the lessee would carry out chemical spraying.

The livelihood diversification index also emerged as a notable indicator in Noolpuzha, while farm size was a key indicator in Ambalavayal. The farmers in Ambalavayal were predominantly marginal compared to those in the other two panchayats. Farmers in Vythiri exhibited greater livelihood diversification, attributed to the growth of agri-tourism through farm visits and homestays, providing substantial returns beyond farm income. Furthermore, many farmers in Vythiri had established shops or other self-entrepreneurial units, contributing to a secondary income source.

IV

CONCLUSION

Vulnerability assessment helps to identify highly vulnerable farmers and the primary drivers of their vulnerability. A higher number of highly vulnerable farm households were present in Vythiri panchayath, and a higher number of low vulnerable households were present in Noolpuzha panchayath. Compared with the other two panchayaths, the recurrence and impact of climatic events were higher in the Vythiri panchayath. This study also identified the primary factors contributing to the increased vulnerability of farmers in the three panchayats. Key drivers of higher vulnerability included low household head literacy, lack of subsidy availability, fewer water sources, and a higher rate of inorganic fertilizer application. However, this does not imply that their vulnerability is unaffected by elements like reduced yield, the proportion of irrigated area, and losses due to pests and diseases. All these factors contribute equally to the vulnerability of all the farmers.

Recognizing that weather is inherently unpredictable, a major transition from rainfed to irrigation-based farming was necessary to guarantee steady and favourable harvests. Encouraging programs like the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) or other similar initiatives could be helpful since they improve water use efficiency and encourage farmer participation. Consequently, in the face of climate variability, this would provide additional irrigation support, particularly for sprinkler irrigation during critical crop stages.

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