**Original Research Article**

**Economic Vulnerability of Tribal Households in Southern India: The Role of Medicinal Non-Timber Forest Products.**

**ABSTRACT**

 The study analysed the economic vulnerability of tribal communities in Kerala's Wayanad district, India, in terms of its reliance on medicinal Non-Timber Forest Products (NTFPs). Through a survey of 90 families, quantifying economic vulnerability using Economic Vulnerability Index (EVI), with exposure, sensitivity, and adaptive capacity.The Economic Vulnerability Index (EVI) was estimated based on three dimensions: exposure, sensitivity, and adaptive capacity. Both female-headed households (FHHs) and male-headed households (MHHs) obtained significant proportion of their income from NTFPs, with MHHs obtaining 75% and FHHs 70% respectively. Female heads, bear the burden of household expenditure with less resource base, reduced overall income, and lower capacity to adjust, especially to climate change and environmental degradation. Female-headed households (FHHs) also showed a lack of preparedness and recovery skills. Economic vulnerability was found to be significantly influenced by a number of factors, including gender, the presence of chronic illness in the household, asset ownership, and monthly per capita. The proportion of households that were not warned of an upcoming natural disaster was the most influencing indicator for exposure while the average livelihood diversification index influenced the sensitivity of medicinal plant collectors. The average livelihood diversification index followed by annual income status was found to be contributing to adaptive capacity. Additionally, MHHs were marked by higher social networks and better access to productive assets, which relatively reduced their vulnerability. FHHs, on the other hand, faced income uncertainty and lack of diversification. By filling findings showed the research gap between MHHs and FHHs, the study reaffirms the critical role of medicinal NTFPs in building resilience among vulnerable families.

**KEYWORDS**: Economic vulnerability; medicinal Non-Timber Forest Products (NTFPs); tribal livelihood; gender analysis; livelihood diversification index; climate adaptation; Wayand; adaptive capacity.

**1.INTRODUCTION**

India’s diverse ecosystems, ranging from tropical rainforests to semi-arid woodlands, support a vast array of Non-Timber Forest Products (NTFPs) that hold both domestic and global significance. NTFPs play a crucial role in the livelihoods of millions of people, both in rural and urban areas worldwide (Shackleton et al., 2015). They provide essential resources such as food, shelter, medicine, fibres, energy, and cultural artifacts, benefiting not only some of the world’s poorest populations but also a substantial portion of relatively wealthier populations (Saha and Sundriyal, 2012). NTFPs also serve as a crucial safety net for dependent communities, offering sustenance during periods of scarcity and even famine. Indigenous forest and rural communities continue to depend on NTFPs for their livelihood. This reliance stems from economic marginalization, a lack of recognition and limited participation in their own socioeconomic development (Alex et al., 2016).

Kerala’s forests are a home to a variety of NTFPs such as bamboo, medicinal herbs, and aromatic plants, which have long served as sources of food, medicine and income. A livelihood consists of capabilities and assets that enable individuals to recover from stress and shocks, and create sustainable livelihood opportunities for the future generations. Additionally, it contributes net benefits to other livelihoods at both local and global levels, in both the short and long term (Chambers and Conway, 1992). It focuses on enhancing people’s economic power and empowering them. It involves facilitating asset creation, capacity building, and access to opportunities and aims to build livelihood security. Occupation serves as the basis of generating income to sustain livelihoods. The remote and isolated nature of the study area, combined with inadequate infrastructure and limited accessibility, had contributed to its overall underdevelopment (Daneji and Suleiman, 2011). A large number of family members involved in collection led to increased resource gathering, thereby improving income and livelihood sustainability. Larger family sizes tend to have a higher dependency on these resources, utilizing all available family labour for collection (Endamana et al., 2016).

Wayanad district of Kerala is considered highly vulnerable due to its heavy dependence on agriculture, plantation crops, and Non-Timber Forest Products (NTFPs) (Nikhil, 2024). The economic vulnerability of forest-dwelling tribal communities and medicinal plant collectors is further intensified by restrictive forest regulations and ongoing biodiversity loss. The combined impacts of erratic rainfall, declining forest cover, and soil degradation present serious challenges to sustainable agriculture in the region. Given its high susceptibility to climate change, there is an urgent need to implement sustainable development strategies that ensure livelihood security (Sundaran et al., 2024).

Tribal households in Wayanad exhibit a high dependency on NTFPs, which they rely on almost exclusively for their livelihoods. Many of these families also face financial constraints, rising debt levels, and poor infrastructure, further exacerbating their economic vulnerability.

This study identifies the key medicinal NTFPs collected by tribal communities and assesses their contribution to household income. Notable species include *Sida rhombifolia* (Kurunthotti), *Solanum torvum* (Chunda), *Acacia sinuata* (Cheenikkaya), *Cyclea peltata* (Padakkizhangu), and *Parmelia dilatata* (Kalpasam), which contributed significantly to household earnings (Tables 2 and 3). The Economic Vulnerability Index (EVI) was constructed using three dimensions- exposure, sensitivity, and adaptive capacity and determinants of vulnerability were further analyzed through logistic regression.

**2.MATERIALS AND METHODS**

**2.1. STUDY AREA**

The present study was conducted in the tribal settlements of Wayanad district, located in the state of Kerala, India. Wayanad covers a geographical area of 2,132 square kilometres and comprises one revenue division, three taluks, 49 villages, 25 Gram Panchayats, three Block Panchayats, and one municipality. Geographically, the district lies between 11°27′ and 11°58′ North latitude and 75°47′ and 76°27′ East longitude. Wayanad is bordered by the Nilgiri Hills and Mysuru district of Karnataka to the east, Kodagu (Coorg) district to the north, Malappuram district to the south, and Kozhikode and Kannur districts to the west.



 Fig.1.Map of the study area

**2.2. SAMPLING METHOD**

Three taluks Vythiri, Mananthavady, and Sulthan Bathery were selected for the study due to their high concentration of tribal populations and the rich diversity of medicinal plants found in Wayanad’s forested regions. One panchayat was chosen from each taluk based on the highest number of tribal residents, using population data obtained from the Kalpetta office of the Integrated Tribal Development Project (ITDP). Accordingly, Meppadi (Vythiri), Thirunelli (Mananthavady), and Noolpuzha (Sulthan Bathery) were selected.A pre-tested, well-structured questionnaire was used to purposively survey 90 households—30 from each selected panchayat. The head of the household was identified as the individual primarily responsible for domestic and financial decision-making. Households were classified as female-headed if the woman was widowed, separated, or had been the sole caretaker in the absence of a male partner for more than six months. Most tribal families in Kerala follow a patriarchal social structure; however, widowed women typically over 40 years of age—who lived with their sons, performed physical labor, and relied solely on Non-Timber Forest Products (NTFPs) for income, were often the de facto heads of their households.Primary data on the collection, utilization, and income contribution of medicinal NTFPs were gathered directly through household surveys, while supplementary secondary data were obtained from official sources.

**3. QUANTIFYING HOUSEHOLD ECONOMIC VULNERABILITY**

 Economic vulnerability refers to the likelihood that a country’s or household’s economic development is hindered by the occurrence of unforeseen external shocks (Guillaumont, 2009). In this study, the economic vulnerability of households was assessed using a modified version of the ASPIRES (Accelerating Strategies for Practical Innovation & Research in Economic Strengthening) Economic Vulnerability Tool, originally developed by FHI 360 in collaboration with a consortium of 20 organizations in the United States. The components of this tool are detailed in Table 1. In addition, the Economic Vulnerability Index (EVI) developed by the Intergovernmental Panel on Climate Change (IPCC) was adopted as the overall framework for vulnerability assessment. This framework is structured around three core dimensions: exposure, sensitivity, and adaptive capacity. Within this context, exposure captures the magnitude and frequency of external shocks and the extent of losses incurred; sensitivity reflects the degree to which a household or system is affected by these shocks; and adaptive capacity represents the system’s ability to cope with, recover from, or adjust to such disruptions. For this study, four indicators were used to measure exposure, six indicators were included under sensitivity, and five indicators were used to assess adaptive capacity. A detailed presentation of the components and indicators used in the economic vulnerability assessment is provided in Table 1.

**Table 1. Major components and sub-components of the Economic Vulnerability Index (EVI).**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Major component | Subcomponent | Explanation of subcomponent | Survey question | Source | Potential limitation |
| Exposure | Number of natural disasters affected in past 6 years | Total number of landslides, storms, cyclones, and wildfires that hit the households during 2019–2024. The number of events is divided by 10 to lower the value so that they come under a smaller range | How many times was your household affected by landslides/storms/ cyclones/wildfires. | Adapted from [27] | Recall bias |
|  | Losses suffered from the disasters that affected the household in past 6 years. | Physical losses suffered from the disasters. | How severe were the losses you suffered from these disasters?a) No loss-0b) < 10,000 – 0.1c) 10,000–50,000 – 0.2d) 50,000–1 lakh – 0.3e) > 1 lakh – 0.4 | Developed to meet the purpose of this study. | Tendency of the household to project greater loss. |
|  | Recovery status of households from the disasters that hit them. | The status of households if they have returned to normalcy from the losses caused by disasters. | Which of the below options best describe the recovery status as what happened? a) Household never recovered – 0.4 b) Household is still recovering – 0.3 c) Household recovered over time – 0.2 d) Household recovered immediately – 0.1 | Adapted from [15] | Tendency to state that the household has not yet recovered. |
|  | Percent of households that did not receive a warning about the pending natural disaster. | Percentage of households who have not received a warning about disasters that hit them in the past 6-year period. | Have you received any warning for the cyclone/flood/storms that hit your area during the 2019–2024 period? | Adapted from [27] | Subjective definition of warning |
| Sensitivity | Percent of households dependent solely on NTFPs medicinal plants and related activities as a source of income | Percent of households that state medicinal plants and NTFP’s related activities as their only income source. | Do any of the family members work outside the medicinal plant collection or NTFP’s related collection or earn income through various means other than from the Medicinal plants collection or NTFP’s? | Modified from [28] | Subjective definition of “solely” |
|  | Average medicinal plants collectors livelihood diversification index. | The number of livelihood activities engaged by the family members in the medicinal plant collection. | List all the livelihood activities undertaken by the family members of the household in the medicinal plant collection. | Modified from [30] | Tendency to ignore activity that yield occasional income. |
|  | Proportion of NTFP’s (medicinal plants) income to annual household income | Proportion of the income from various activities in the NTFP’s (medicinal plants) (drying, processing, selling) to the total annual income (comprising income from other sources as well) of the household. | Can you please mention the income received from each source in a year? | Modified from [31] | Due to lack of trust, people may not reveal the exact income. |
|  | Ability of household to meet its basic needs | How well the household is able to meet its basic needs like food, shelter, education and health care. | Which response most accurately describes your household’s ability to meet its basic needs, including food, shelter, education, and health care? 1. We struggle to pay for food and shelter: 0.4 2. We can usually pay for food and shelter, but we struggle to make lump sum payments for health and education expenses: 0.3 3. We can usually pay for food, shelter, and education and health care expenses. Sometimes we struggle, but we usually make lump sum payments: 0.2 4. We are always able to pay for food, shelter, education, and health care without struggle: 0.1 | Adapted from[15] | Tendency of people to project themselves as poor. |
|  | Income volatility if sudden halt in primary income source | The steps taken by the household when something bad happens and earning from the primary source of livelihood stops. | If something bad happened and you could no longer earn money through your primary livelihood, what would you do? 1. Find a new job: 0.1 2. Rely more on other existing income generating activity: 0.2 3. Rely on family for support or loans: 0.3 4. Rely on charity, I don’t have a livelihood: 0.45) How frequently is this income available throughout the year  | Adapted from[15] | Confusion among the options regarding which one to follow. |
|  | Income volatility in terms of frequency of income availability | The status of income availability of the household based on the regularity in their income earnings. | a)Unpredictable: 0.4 b)Predictable, but changes dramatically depending on the season:0.3c)Predictable, but changes slightly depending on the season:0.2d) Predictable throughout the year: 0.1 | Adapted from[15] |  |
| Adaptive capacity | Productive assets | Productive assets are the resources used to generate income, like livestock, land for agriculture, tools, or equipment for a business. | How would you describe your household’s productive assets? a) We don’t have any productive assets: 0.1 b) We have some productive assets: 0.2 c) We have a lot of productive assets: 0.3 | Adapted from[15] | Confused whether some are productive assets or not. |
|  | Savings | The difference between a household’s disposable income and its consumption on goods and services. | How much money do you have in savings? 1. Nothing or nearly nothing: 0.1 2. Some, but the amount changes a lot during the year: 0.2 3. Some, but the amount changes a little during the year: 0.3 4. We always have a lot of savings: 0.4 | Adapted from[15] | Variability in the amount of savings. |
|  | Annual income status | The annual income of the household | What is the annual income range of your household? a) Less than 50,000: 0.4 b) 50,000 – 1 lakh: 0.3 c) 1 lakh – 2 lakhs: 0.2 d) Above 2 lakhs: 0.1 | Developed to meet the purpose of this study.[15] | Difficult to quantify income from supplementary and informal sources. |
|  | Economic status | Household’s perception about their economic status | Describe your household’s economic status? 1. Destitute: we are barely surviving 2. Struggling to make ends meet: we are surviving, but our economic status is not stable 3. Prepared to grow: our status is mostly stable and we are investing in new opportunities, though we sometimes struggle 4. Not vulnerable: we are stable and secure | Adapted from[15] | Tendency of people to project themselves as poor. |
|  | Liquid assets | Is there anything your household owns that can be turned into cash quickly, such as livestock, food stores, or personal belongings such as gold, silver etc. These are called liquid assets. | What describes your household best? a) We never have many liquid assets: 0.1 b) We have some liquid assets, but the amount changes a lot during the year: 0.2 c) We have some liquid assets, and the amount changes a little during the year: 0.3 d) We always have many liquid assets: 0.4 | Adapted from[15] | Confused whether some are liquid assets or not. |

         EVI is the arithmetic average of all sub-components to its final value even if all the main components are comprised of varying numbers of indicators. To achieve this, a balanced weighted average method, commonly used in vulnerability assessment studies, was applied. This method involves standardizing all sub-components using an equation adapted from the Human Development Index:

Sg  =$\frac{Sg-Smin}{Smax-Smin}$(1)

Where,Sg represents the original sub-component for gender (g), while Smin and Smax denote the minimum and maximum values recorded for each sub-component across both male- and female-headed household groups.

$Mg=\frac{\sum\_{i=0}^{n}indexXSgi}{n}$(2)

Where, Mg= one of the major components of gender g[Exposure(E), Sensitivity (S), Adaptive capacity(A), indexsgi represents the subcomponent indexed by 1, which make up each major component and n is the number of sub-components.

After determining the values for each of the three key components for both male-and female-headed households, the mean was calculated using Eq. (3) to obtain the LVI:

$EVIg=\frac{\sum\_{i=1}^{3}wuMgi}{\sum\_{i=1}^{3}wMi}$(3)

Which can also be expressed as-

$EVIg= $*w*E Eg+wSSg+wADADg

WE +wS+ wAD

Where, EVIg the Economic Vulnerability Index for gender g, equals the weighted average of major components. The weight of each major component (*wMi*) was determined based on the number of sub-components. The weights were assigned to ensure that all sub-components contributed equally to the overall EVI. In this study, the EVI values range from 0 (least vulnerability) to 1 (highest vulnerability).

**3.1. NORMALISATION AND ALIGNMENT**

 Normalization is a technique that scales the range of features to a standard one. Data scaling is required when the dataset has features with different ranges. Different normalization methods are tailored to accommodate different data distributions and model requirements. It is to ensure that negative scores are converted into positive score.

**3.2. DETERMINANTS OF ECONOMIC VULNERABILITY**

**3.2.1 LOGIT REGRESSION**

The determinants of economic vulnerability was analysed using a logit regression. The dependent variable is defined by classifying the respondents into two groups: those with the value of the vulnerability index above 0.35 (high vulnerability) and those with a value below 0.35 (low vulnerability) on a scale of 0 to 0.5. The model equation is as follows and it was estimated using R software.

$$Pi =E (Y = 1|Xi)=\frac{1}{1 + e-\left(α+βiXi\right)}$$

Where,

𝑃𝑖 → probability

𝑋𝑖 → vector of independent variables

𝛽𝐼𝑠 → coefficients to be estimated

Pi  =$\frac{1}{1 + e-Zi}$ =$\frac{ e zi}{ 1 + eZi}$

Where,

𝑍𝑖 → 𝛼 + 𝛽𝑖𝑋𝑖

1-Pi $\frac{1}{1 + e-Zi}$= $\frac{Pi}{1-Pi}$ = ezi

This represents the probability of a respondent being categorized as less vulnerable for a given set of independent variables.

Taking logarithm on both sides,

𝐿𝑖 = ln (𝑃𝑖⁄1 − 𝑃𝑖) = 𝑍𝑖

 = 𝛼 + 𝛽𝑖𝑋𝑖

*L* is called the logit.

In the present study, the model is

𝑌 = 𝛼 + 𝛽1𝑋1 + 𝛽2𝑋2 + 𝛽3𝑋3 + 𝛽4𝑋4 + 𝛽5𝑋5 + 𝛽6𝑋6

Where,

𝛼 → the intercept

𝛽 → coefficient of subsequent variables

**Table 2. Variables used in the logit model.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| Sl No. | Variables | Unit |
|  | Households with NTFPs (Medicinal plants as the only source of income) (X1) | 1-Solely dependent0-Not solely dependent |
|  | Gender (X2) | 1-Male0-Female |
|  | Chronically ill members (X3) | Count in numbers |
|  | Total income generated from NTFPs to annual income (X4) | (₹) Range: 0.1-0.4 |
|  | Monthly per capita consumption expenditure (X5) |  (₹) Range: 0.1-0.4 |
|  | Assets owned by the household(X6) | Range: 0.1-0.4 |
|  | Average household livelihooddiversification index (X7) | Range: 0.1-0.4 |
|  | Economic vulnerability (Y) | 1-High vulnerability0-Low vulnerability |

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**4. RESULTS AND DISCUSSION**

Approximately 25% of respondents did not disclose/answer regarding income volatility. The frequency of income generation remained relatively consistent among the surveyed households. The household's debt status was included earlier as a sub-component. Additionally, the facilities for group credit accessed by households were also considered. Microcredit facilities were less prevalent in the tribal areas of South India. NTFP medicinal plant collectors played a central role in their households, efficiently managing earnings and income generation.

**Table 3. Major medicinal NTFPs collected**

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| --- | --- | --- |
| Sl.No. | Common Name | Botanical name |
| 1 | Kurunthotti | *Sida rhombifolia* |
| 2 | Cheenikkaya | *Acacia sinuata* |
| 3 | Kalpasam | *Parmelia dilatata* |
| 4 | Chunda | *Solanum torvum* |
| 5 | Padakkizhangu | *Cyclea peltata* |

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The collection of medicinal non-timber forest products (NTFPs) varies across species, both in terms of quantity and household participations Table 4.

**Table 4. Major Medicinal Non-Timber Forest Products (NTFPs) and their share.**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| --- | --- | --- | --- | --- | --- |
| Sl. No. | Common name  | Annual quantity collected (Kg) | Sale price per (₹/kg) | Value (₹ lakhs) (% share) | Number of households |
| 1 | Kurunthotti | 198000 | 85 | 168.3 (51.19) | 87 |
| 2 | Cheenikkaya | 183000 | 72 | 131.76(40.07) | 80 |
| 3 | Kalpasam | 49200 | 43 | 21.15(6.43) | 78 |
| 4 | Chunda | 16000 | 42 | 6.72(2.04) | 73 |
| 5 | Padakkizhangu | 1280 | 68 | 0.832 (0.27) | 65 |
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Table 4 shows that *Kurunthotti* and *Cheenikkaya* were the most collected medicinal NTFPs in terms of quantity. *Kurunthotti* accounted for the highest share of total value at ₹168.3 lakhs (51.19%), followed by *Cheenikkaya* with ₹131.76 lakhs (40.07%). In contrast, *Chunda*, *Kalpasam*, and *Padakkizhangu* collectively contributed only ₹28.7 lakhs (8.74%), indicating a strong dependence on a few key species for household income.

Most medicinal NTFP collectors were labourers on tea and coffee estates and belonged to the Below Poverty Line (BPL) category. Their primary roles involved collection, cleaning, grading, chopping, and sun-drying of plant materials. Due to limited knowledge of value addition and packaging, these products were sold immediately to tribal societies in order to preserve shelf life. As a result, many women-headed households faced challenges in generating consistent income. To supplement earnings, some family members sought employment as migrant labourers in neighbouring states such as Tamil Nadu and Karnataka. Sikder et al. (2017) emphasized that remittances offer crucial financial support, enabling families to secure basic needs such as three meals a day. Furthermore, such financial inflows contribute to stronger social resilience, enhancing a household’s capacity to cope with external shocks and disasters.

**4.1. Economic vulnerability of male-headed and female-headed households**

The Economic Vulnerability Index (EVI) of medicinal plant-gathering households was assessed using three core sub-components: **exposure, sensitivity**, and **adaptive capacity**. Table 4 presents a detailed summary of the average scores for each sub-component, along with their respective minimum and maximum values. The analysis revealed that female-headed households exhibited the highest levels of vulnerability across all three dimensions, indicating a greater degree of socio-economic and environmental risk compared to male-headed households.

**4.1.1. Exposure**

 Exposure refers to the presence of people, resources, infrastructure, or assets in hazard-prone areas where they are susceptible to potential losses. In this study, exposure was assessed at the household level based on the frequency and intensity of extreme weather events, the extent of economic losses incurred, and the level of preparedness for such events.

 Female-headed households (FHHs) reported a slightly higher frequency of extreme weather events, averaging 3.0 events per year, compared to 2.9 events for male-headed households (MHHs). However, vulnerability scores showed that MHHs were more affected by disaster-related losses, with a score of 0.48, compared to 0.09 for FHHs. In contrast, FHHs exhibited greater difficulty in recovering from disaster impacts, as reflected in their higher post-disaster recovery vulnerability score (FHHs: 0.25; MHHs: 0.17).

 The overall exposure score was higher for FHHs (0.87) than for MHHs (0.61), indicating that FHHs were more exposed to climate-related risks and were less likely to receive early warnings or take preventive measures. These findings are consistent with previous studies by Sreya et al. (2021) and Aiswarya et al. (2022), which similarly highlighted disparities in household responses to extreme weather events, especially among vulnerable populations.

**4.1.2 Sensitivity**

 **Sensitivity** refers to the degree to which individuals or communities are adversely affected by climate-related disasters, and are shaped by their economic conditions and dependence on vulnerable livelihood sources. In this study, sensitivity was evaluated through indicators such as household income, economic status, and dependence on Non-Timber Forest Products (NTFPs), particularly medicinal plants.

 NTFPs served as the primary source of income for approximately 75% of male-headed households (MHHs) and 70% of female-headed households (FHHs). While livelihood diversification was observed to enhance income stability and reduce risk, MHHs exhibited a slightly higher sensitivity score (0.81) compared to FHHs (0.74), indicating greater economic vulnerability in this dimension.

 The proportion of income derived from medicinal plant collection and related activities was nearly identical for both household types 0.34 for MHHs and 0.33 for FHHs. However, FHHs demonstrated greater economic difficulty in meeting daily household needs, with a higher economic strain score (0.34) compared to MHHs (0.28). Both household types reported income volatility, and the frequency of income generation was used to capture this aspect. The vulnerability scores for income volatility were 0.49 for MHHs and 0.43 for FHHs.

These findings highlight that, although both MHHs and FHHs depend heavily on NTFPs, the nature and extent of their economic sensitivity vary. The results are consistent with earlier studies by Zhang (2024) and Batista (2022), who also reported gender-based disparities in poverty and economic vulnerability among forest-dependent households.

**4.1.3. Adaptive capacity**

 The adaptive capacity score, indicating a household’s ability to cope with shocks, showed that both MHHs and FHHs had low income volatility. MHHs owned more productive assets (0.65) such as livestock and land, while FHHs held more liquid assets (0.70), likely for short-term needs. However, MHHs had greater savings (0.19) compared to FHHs (0.04), reflecting stronger financial resilience. Overall, economic vulnerability was lower in MHHs (0.65) than in FHHs (0.30). Detailed component-wise vulnerability scores are presented in Table 5.

**Table 5. Major components and sub-components of the Economic Vulnerability Index (EVI).**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Major component | Sub-component | Units | MHH | FHH | Max value | Min Value |
| Exposure | 1.Number of extreme weather events affected in past 6 years.2. Losses suffered from the disasters that affected the household in past the 6 years.3. Recovery status of households from the disasters that hit them.4. Percent of households that did not receive a warning about the pending natural disaster. | Count/10Range(0.1–0.4)Range(0.1–0.4)Range(0.1-0.4)Percent | 0.2900.3030.1690.61244.20 | 0.3000.3390.1650.69316.00 | 0.60.40.4100 | 10.10.10 |
| Sensitivity | 1. Percent of households dependent solely on NTFP (medicinal plants) and related activities as a source of income.
2. Average NTFP (medicinal plants) collector’s livelihood diversification index.
3. Proportion of NTFP (medicinal plants) income to annual household income.
4. Ability of the household to meet its basic needs.
5. Income volatility if sudden halt in primary income source.
6. Income volatility in terms of frequency of income availability.
 | Percent1/1+no. of livelihoodsRatioRange (0.1–0.4)Range (0.1–0.4)Range (0.1–0.4)Range(0.1-0.4) | 33.3000.1950.3040.3280.2790.3660.349 | 20.000.6960.1900.250.3350.3390.343 | 1000.510.40.40.40.4 | 00.170.160.10.10.10.1 |
| Adaptive capacity | 1.Productive assets2.Savings3.Annual income status4.Economic status5.Liquid assets | Range (0.1–0.4)Range (0.1–0.4)Range (0.1–0.4)Range (0.1–0.4)Range (0.1–0.4) | 0.3540.0750.3300.3490.440 | 0.2740.3780.3390.3610.339 | 0.40.40.30.40.4 | 0.10.10.10.10.1 |

The three major characteristics – exposure, sensitivity and adaptive capacity the vulnerability status of male and female headed households is presented in figure 2. MHH encountered more extreme natural disasters than the other four indicators. While gathering wild honey, several male heads stated that they experienced difficulties including fall from trees and being attacked by wild animals. Some women climbed trees to gather leaves, fruits, and bark or dug for roots. Majority of the menfolk in tribal region were involved in honey collection while the womenfolk focused on medicinal plants. Significant gender inequalities were noted by Abhishek and Parayil (2024), indicating that men were involved in risky taking and NTFP collecting activities. The study revealed a decreasing interest in NTFP collection as the younger generation increasingly turned to alternative sources of income.

**Table 6. EVI major sub-components**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | Sub-component | MHHs | FHHs | Major component | MHHs | FHHs |
|  |  |  |  |  |  |  |
| 1 | Number of extremeWeather events affected in the past 6 years. | 0.08 | 0.5 | Exposure | 0.24 | 0.52 |
| 2 | Losses suffered from the disasters that affected the household in the past 6 years. | 0.09 | 0.48 |  |  |  |
| 3 | Recovery status of households from the disasters that hit them. | 0.17 | 0.25 |  |  |  |
| 4 | Percent of households that did not receive a warning about the pending natural disaster.  | 0.61 | 0.87 |  |  |  |
|  |  |  |  |  |  |  |
| 1 | Percent of households dependent solely on NTFPs (medicinal plants) and related activities as a source of income | 0.75 | 0.70 | Sensitivity  | 0.63 | 0.58 |
| 2 | Average medicinal plants collector’s livelihood diversification index. | 0.81 | 0.74 |  |  |  |
| 3 | Proportion of NTFPs (medicinal plants) income to annual household income | 0.63 | 0.29 |  |  |  |
| 4 | Ability of household to meet its basic needs | 0.29 | 0.35 |  |  |  |
| 5 | Income volatility if sudden halt in primary income source | 0.63 | 0.70 |  |  |  |
| 6 | Income volatility in terms of frequency of income availability | 0.65 | 0.72 |  |  |  |
| 1 | Productive assets | 0.65 | 0.46 | Adaptation | 0.56 | 0.44 |
| 2 | Savings | 0.19 | 0.04 |  |  |  |
| 3 | Annual income status | 0.67 | 0.70 |  |  |  |
| 4 | Economic status | 0.65 | 0.30 |  |  |  |
| 5 | Liquid assets | 0.64 | 0.70 |  |  |  |
|  | EVI: MHHs | 0.50 |  |  |  |  |
|  | EVI: FHHs | 0.52 |  |  |  |  |

Note: Index values should be interpreted as relative values within the study sample only

 Fig.2. Vulnerability diagram

Employment opportunities are linked to higher education while the tribal women are disproportionately affected by climate change, facing increased water scarcity and health risks, which threaten their livelihoods and well-being (Joseph, 2024). According to Baez, Caruso, and Niu (2020) extreme weather events exacerbated poverty in affected households. Rahman (2013) observed the financial damages resulting from disasters had the greatest impact on economically vulnerable to women. The study revealed that male heads had stronger social networks and connections compared to female heads, which enabled them to access financial assistance. MHHs recovered from the impacts of these disasters more quickly than FHHs, who faced greater difficulties and took longer to overcome their losses. MHHs were able to obtain financial aid more readily than female heads since they had greater social networks and contacts. Chant (2004) reported that female heads tend to maintain their calm in challenging circumstances and were hesitant to avail credit facility (Chant, 1997).

 The MHHs (67) were either actively working, retired, or had transitioned from medicinal plant collection to other occupations. This provided them with stronger social networks and better access to warning messages, which they primarily received via SMS or WhatsApp. In contrast, FHHs had fewer members engaged in other occupations and typically were informed of warnings through television, neighbours, or relatives.

**5.1. Sensitivity**

 NTFPs are deeply embedded in the cultural practices and beliefs of the tribal communities, serving not only as economic resources but also as symbols of identity and heritage. Due to their lower earnings, many female household heads opted to work outside the sector during lean season. They worked for the rest of the year, taking up labour-intensive jobs under Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGA) program. Many tribal households rely entirely on NTFPs collection and had little access to official employment options (Abhishek and Parayil, 2024). Females usually gathered medicinal herbs and were involved in post-harvest processes such as drying and selling of herbs. MHHs earned an income from alternate sources like working as estates labourers in coffee and tea plantations, growing their own black pepper and cardamom, and engaging in agricultural work, and, to some extent, working as contract-based forest guards. A few members from both household groups were employed in salaried work, for example, teachers and caretakers at local Anganwadi centres or nurses at primary health centres in surrounding towns.

 Climate-induced natural disasters have disrupted their livelihood resources, compelling many to migrate from their ancestral lands (Khan et al. 2024). Climate change has worsened the marginalization of women within the tribal community. Hannagan and Morduch (2015) observed that households classified as Below Poverty Line experienced the greatest fluctuations and instability in their monthly income.

**5.2. Adaptive capacity**

The main subsistence activities, productive assets like land and livestock provided additional revenue. However, cultivation was severely hampered by the study area's hilly terrain. Agricultural productivity was hampered by respondents' average land ownership of only five to fifteen cents. Ownership of other productive assets was uncommon, although some households owned livestock, primarily cattle and poultry.

 They provide funds for future investments, savings and are essential for maintaining economic stability. Both female-headed households (FHHs) and male-headed households (MHHs) in the study area reported low savings, despite MHHs being in a better position overall. Most of the households that did save put their money into unofficial programs like chit funds. But these savings frequently ran out quickly, leaving a lack of funds for most of the years.

 Tribal households were more economically disadvantaged than the overall population. Whereas MHH (0.65) were relatively better off than FHH (0.30), both were unable to manage a fair level of living. The loss of medicinal resources and the hope for better economic prospects led them to move to nearby states like Tamil Nadu and Karnataka, as they mostly resided in border regions.

 The assets they owned, mainly gold, were often sold to cope with financial strain caused by health issues or educational expenses of family members. However, FHHs generally held more liquid assets than MHHs. In FHHs, women typically preserved their assets for future needs, whereas in MHHs, assets were more readily used to address fund scarcity as they arose.

 Both male- and female-headed households, classified under the BPL category, had significantly low mean annual incomes (MHHs: USD $1,400; FHHs: USD $947), which were far below the average income of the general population. FHHs were in disadvantaged position, earning substantially less than their male-headed counterparts, despite having diversified income sources.

 FHHs were found to be more vulnerable across all key components of vulnerability assessment, including exposure (FHHs-0.52; MHHs-0.24), sensitivity (MHH-0.53; FHHs-0.67), and adaptive capacity (FHHs-0.44). Women's social responsibilities, household duties, and limited decision-making power further heightened their exposure to disasters. There were notable differences in adaptive capacity scores between MHHs and FHHs. Phan, Jou, and Lin (2019) found that men showed greater adaptive capacity to resist the impacts of climate change. Bhadra (2017) also mentioned that women's higher susceptibility to disasters is attributed to their overall lower socioeconomic status.

Van Aelst and Holvoet (2016) claimed that while societal actions limited women's capacity to respond, they also increased their exposure to climate change. Even though the exposure differences between the two groups were insignificant, EVI revealed that FHHs were economically more exposed (0.52) to extreme climatic events than MHHs (0.50). This increased risk among FHHs was attributed to their poor asset base, income and savings decline, greater vulnerability due to livelihood instability, and higher exposure based on poor capacity for recovery as well as the unreliability of early warning systems access. These conclusions coincided with that of Flatø, Muttarak, and Pelser's (2017) study. Omolo and Mafongoya (2019) as well as by Balikoowa and Nabanoga (2019) also mentioned that female-headed households were more vulnerable to climate change than male-headed households, and this difference was primarily driven by disparities in their adaptive capacity.

**6. KEY INDICATORS INFLUENCING ECONOMIC VULNERABILITY**

**6.1. Exposure**

 The sub components of exposure- strongest predictor for both MHHs and FHHs were the proportion of households that were not warned of an upcoming natural disaster. This was 61% (0.61) for MHHs and 87% (0.87) for FHHs. The second strongest predictor for MHHs was the recovery status of households from previous disasters, with a value of 0.17. For FHHs, the main issue was the damages incurred due to disasters in the last six years, and their value was 0.48, as indicated in the figure 3.

Fig.3. Indicators for economic vulnerability- exposure.

**6.2. Sensitivity**

 In terms of sensitivity, the most influential indicator for MHHs was the average livelihood diversification index of medicinal plant collectors, i.e. 0.81. This was ranked by the percentage of households which relied exclusively on NTFP medicinal plants and their activities for income, i.e., 75% (0.75). For FHHs, the greatest indicator was also the mean livelihood diversification index of medicinal plant collectors (0.81), followed by the volatility of income, and indicated by the frequency of income availability and with a measure of 0.72 as shown in figure 4.

 Fig.4. Indicators for economic vulnerability-sensitivity

**6.3. Adaptive capacity**

The most powerful predictor for MHHs regarding adaptative capacity was annual income status at 0.67, followed by productive assets with the same value of 0.65 for economic status. For FHHs, annual income status and liquid assets had the same power of influence.

Fig.5. Indicators for economic vulnerability- adaptive capacity

**7.Drivers of Economic vulnerability**

Fig.6. Economic vulnerability drivers- MHHs

 Among the 15 indicators assessed, the most critical driver of economic vulnerability for male-headed households (MHHs) was the lack of early warning systems for impending natural disasters (score: 0.61). The absence of such warnings left households unprepared, thereby increasing their vulnerability. Additionally, a low recovery rate from previous disasters (0.17), losses incurred (0.09), and the frequency of natural disasters (0.08) further contributed to income instability and uncertainty. Under the sensitivity component, overdependence on medicinal plants as the sole source of income (0.75) rendered these households highly vulnerable to environmental changes and market fluctuations. Income variation (0.63) and the proportion of income derived from medicinal plants (0.63) reinforced this economic fragility. Moreover, difficulty in meeting basic needs (0.29) indicated fiscal pressure and limited economic capacity. In terms of adaptive capacity, key influencing factors included annual income (0.67), overall economic condition (0.65), ownership of productive assets (0.65), and liquid assets (0.64). These indicators collectively determined a household’s resilience to shocks. Increased asset ownership and financial stability were found to enhance coping mechanisms. However, savings remained low (0.19), indicating the absence of financial buffers to absorb economic shocks. Notably, the Livelihood Diversification Index (0.81) emerged as the most significant determinant, suggesting that households with multiple income sources were considerably less vulnerable. These findings highlight the importance of promoting income diversification and asset accumulation as strategic interventions to strengthen the economic resilience of MHHs.

Fig.7. Economic vulnerability drivers for female headed households (FHH)

The economic vulnerability of FHHs among the chosen indicators was influenced by various factors, as shown in the figure 7. The most dominant driver of vulnerability is percent of households that did not receive a warning about the pending natural disaster (0.86), thus causing pending repayments and outstanding loans. Average medicinal plants collector’s livelihood diversification index (0.74) is also a significant factor, implying that they were less vulnerable when they had diversified sources of income. Income volatility in terms of frequency of income availability (0.72), liquid assets (0.70), annual income status (0.70), income volatility in primary income source (0.70), and medicinal plants as the only source (0.70) emphasizes the need for secure income and income buffers. Low values, including savings (0.04) and recovery status of households from the disasters that hit them (0.24), reflect poor financial resilience and slow recovery from economic shocks. Natural disasters (0.50) and losses (0.47) also increased vulnerability. These conditions demonstrated the precarious economic position of FHHs, with low financial cushions and heavy reliance on individual income sources, making them more vulnerable to economic uncertainty.

**Table 7. Determinants of Economic Vulnerability**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variable | Coefficient | Standard error | Wald statistic | Odds ratio |
|  |  |  |  |  |
|  |  |  |  |  |
|  |  |  |  |  |
| Constant |  0.265  | 3.613 |  0.000 | 0.023 |
| Households with NTFP’s (medicinal as the only source of income (X1) |  0.450  | 0.070 |  0.279 | 1.047 |
| Gender (X2) |  0.034 \* | 0.683 |  0.000 | 0.265 |
| Chronically ill members (X3) |  0.858 | 0.365  |  0.000 | 1.313 |
| Total income generated from NTFP’s to annual income(X4)  |  0.109 | 0.281  |  0.090 | 0.992 |
| Monthly per capita consumption expenditure(X5) | 0.046 \* | 0.006 | 0.0444 | 0.991 |
| Assets owned by the household(X6) | 0.187 | 0.187 |  0.000 | 3.36×1012 |
| Average household livelihood diversification index (X7) |  0.125  | 28.265 |  0.265 | 0.999 |
| No. of observations  | 90 |  |  |  |
| McFadden’s Pseudo R-square  | **0.2**  |  |  |  |

 |

\*\*\*Significance at 0.1% level, \*\*Significance at 1% level, \*Significance at 5% level

8. VARIABLES FOR ESTIMATING ECONOMIC VULNERABILITY

8.1. Households with NTFPs (Medicinal Plants as the Only Source of Income)

 Although the reliance on medicinal NTFPs as the sole source of income (X1) had a positive coefficient (0.45), it was not statistically significant, indicating that while such dependence may contribute to economic vulnerability, its effect is not strong enough to be considered influential. Similarly, the percentage contribution of NTFPs to total income (X4) also lacked statistical significance (odds ratio = 0.992), suggesting that other diversified income sources may play a more crucial role in ensuring household economic stability.

8.2. Gender

 Gender (X2) was found to be a significant predictor of economic vulnerability at the 5% level (p < 0.05), with an odds ratio of 0.265. This implies that female-headed households (FHHs) are significantly more economically vulnerable than male-headed households (MHHs), likely due to structural inequalities and reduced access to productive assets and opportunities.

8.3. Household Health Status and Economic Risk

 The presence of chronically ill members in the household (X3) was positively associated with economic vulnerability, with a coefficient of 0.858 and an odds ratio of 1.313. This finding reflects the increased financial burden resulting from medical expenses and the reduced workforce participation by both the ill member and caregivers. Chronic illness may also limit other household members from seeking employment, thereby reducing overall household income and increasing vulnerability.

8.4. Income Dependency on NTFPs

 Reiterating the findings from section 8.1, both the sole dependence on medicinal NTFPs (X1) and the proportion of total income derived from them (X4) showed no statistically significant impact on economic vulnerability. Although these income sources contribute to household earnings, they are insufficient alone to reduce economic insecurity or enhance resilience.

8.5. Household Spending and Economic Vulnerability

Monthly per capita consumption expenditure (X5) showed a significant negative relationship with economic vulnerability (coefficient = -0.046, significant at the 5% level). This suggests that higher household expenditure is linked with better financial health, improved access to essentials like food, healthcare, and education, and greater resilience to shocks. Stable consumption is often a marker of better financial management and resource availability. Policies aimed at enhancing household consumption—through social safety nets, improved employment, financial literacy, and access to credit—can play a vital role in strengthening economic resilience.

8.6. Asset Holding and Economic Resilience

 Asset ownership (X6) had an exceptionally strong protective effect against economic vulnerability, with an odds ratio of 3.36 × 10¹². This underscores the importance of physical and financial asset accumulation in reducing vulnerability and improving resilience, particularly for households dependent on forest-based resources.

8.7. Livelihood Diversification

 Livelihood diversification (X7) had a positive coefficient (0.125) but was not statistically significant (odds ratio = 0.999). This indicates that diversification alone does not necessarily translate into lower economic vulnerabilityespecially in FHHs, where the presence of chronically ill members and limited income-generating options may diminish its potential benefits.

**CONCLUSION AND POLICY RECOMMENDATIONS**

The study emphasizes the high economic vulnerability of tribal households in Wayanad, particularly focus on their dependence on medicinal non-timber forest products (NTFPs) for livelihood. Among the households surveyed, female-headed households (FHHs) were found to be more economically vulnerable than male-headed households (MHHs) across all key dimensions of vulnerability exposure, sensitivity, and adaptive capacity. Both MHHs and FHHs shows heavy reliance on NTFPs, particularly medicinal plants, as a primary source of income. However, FHHs were more exposed to extreme weather events and had lower levels of disaster preparedness and recovery capacity. Results from logistic regression analysis indicated that gender, chronic illness within the household, asset ownership, and monthly per capita consumption expenditure were significant predictors of economic vulnerability.

 The urgent need for policy interventions aimed at enhancing the resilience of marginalized tribal households. Interventions must focus on strengthening institutional and human capacity, improving access to physical and financial assets, expanding healthcare services, and implementing gender-inclusive economic development strategies. The study further confirms that NTFPs remains a vital source of livelihood for tribal communities, necessitating the formulation of context-specific policies, especially for the upliftment of FHHs who face compounded socio-economic disadvantages.

Policy Recommendations

Based on the findings of the study, the following recommendations are proposed to reduce economic vulnerability and enhance the resilience of tribal households:

1. Livelihood Diversification and Capacity Building

• Promote agroforestry and sustainable farming as alternative income-generating activities alongside NTFP collection.

• Organize skill development programs focused on sustainable harvesting techniques to ensure ecological balance and better market outcomes.

• Support the documentation and transmission of traditional knowledge, which can contribute to both cultural preservation and livelihood security.

2. Financial Inclusion and Entrepreneurship Support

• Develop and implement microfinance and credit schemes specifically designed for tribal communities to encourage entrepreneurial ventures and reduce financial dependence on forest resources.

3. Sustainable Resource Management and Conservation

• Initiate community-based conservation programs to ensure the sustainable extraction of medicinal NTFPs.

• Integrate scientific research with traditional ecological knowledge for evidence-based and culturally appropriate resource governance.

• Establish community-managed seed banks and nurseries for medicinal plants to support biodiversity conservation and sustainable livelihoods.

4. Social Protection and Economic Resilience

• Introduce crop insurance schemes and risk management strategies tailored to forest-based livelihoods to reduce vulnerability to climate and market fluctuations.

• Improve access to healthcare services and enforce occupational safety protocols for NTFP collectors, especially women.

• Recognizing and incorporating traditional medicinal knowledge into the mainstream healthcare system.

• Encouraging the adoption of certification mechanisms, such as the Voluntary Certification Scheme for Medicinal Plant Produce (VCSMPP), to improve product credibility and access to premium markets.

5. Forest Rights and Tenure Security

• Ensuring the effective implementation of the Forest Rights Act (FRA), 2006, to guarantee individual and community rights over forest resources.

• Promoting participatory forest mapping and community forest management practices to strengthen local governance and secure resource access.

• Launching the legal literacy campaigns to raise awareness about rights and entitlements under the FRA, empowering tribal communities to assert their claims and protect their livelihoods.

6. Institutional Support and Policy Coherence

• Strengthening coordination between forest departments, tribal welfare agencies, and research institutions to foster collaborative approaches to livelihood and resource management.

• Aligning forest conservation policies with livelihood development initiatives to ensure policy coherence and sustainability.

• Establishing robust grievance redressal mechanisms to address issues related to NTFP collection, pricing, and market access, thereby ensuring accountability and fairness in forest product value chains.

• Implications for Policy and Practice

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author(s) hereby declares that generative AI technologies such as Large Language Models, etc. have been used during the rephrasing of manuscripts. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

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1.ChatGPT basic model was used to rephrasing.

 2.No AI technology was used in writing.

**COMPETING INTERESTS**

The authors have no conflict of interests to declare. The authors also declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

We certify that the submission is original work and is not under review at any other publication.

**COMPETING INTERESTS DISCLAIMER:**

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

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