

Shocks, strategies and socio-economic determinants of rural households coping mechanisms: Case study of Kakamega Forest, Kenya

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Osewe I., Coman C., Hălălișan A.-F., Osewe E., Abrudan I.V., Popa B., 2026. Shocks, strategies and socio-economic determinants of rural households coping mechanisms: Case study of Kakamega Forest, Kenya. Ann. For. Res. 69(1): 79-102.

Abstract Rural forest communities in developing countries face multiple and compounding shocks that increase their vulnerability and reliance on limited coping options. While many studies have examined how socio-economic factors shape coping strategies, few have explored the combined and interacting effects of these factors on strategy selection across diverse shock types. This study investigates the types of shocks experienced by communities surrounding the Kakamega Forest Ecosystem (KFE) in western Kenya, the coping strategies employed, and how socio-economic characteristics and their interactions influence these responses. Using participatory approaches, primary data were collected from 453 households through focus group discussions, key informant interviews, and a structured household survey. Data were analysed using Chi-square tests, ANOVA, poisson, and negative binomial regression models. Economic distress and illness emerged as the most widely acknowledged shocks. Significant differences were found across wealth categories and Community Forest Association (CFA) membership for illness, unemployment, animal disease outbreaks, and economic shocks. Only animal disease shocks varied significantly by gender of household head. Forest harvesting was the most frequently adopted coping strategy, used in response to 78% of shocks, underscoring the forest's buffering role. Consumption reduction was common among poor households during unemployment and economic distress, while productive asset sales were triggered by economic and health-related shocks. Rich CFA members and male headed households were less likely to adopt costly or asset-depleting strategies. The paper demonstrates that forest resources serve primarily as short-term safety nets, underscoring the importance of reducing socio-economic disparities and enhancing forest governance to avoid poverty traps and foster resilient, context-specific policies.

Keywords: forest-dependent communities, coping strategies, socio-economic vulnerability, multiple shocks, ecosystems.

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Manuscript: received August 01, 2025; revised June 01, 2026; accepted June 09, 2026.

Introduction

Rural communities in developing countries are highly vulnerable to shocks unexpected events that disrupt livelihoods and well-being due to their limited resources and adaptive capacity (Scoones 1998, Ellis 2000, McSweeney 2004, Ansah et al. 2021, Gautam et al. 2021, Nguyen et al. 2023). These shocks can be classified as *idiosyncratic*, affecting individual households (e.g., illness, death, unemployment, asset loss, wildlife predation, or costly social ceremonies), or *covariate*, impacting entire communities or regions (Fisher & Shively 2005, Pradhan & Mukherjee 2018, Mbiba et al. 2019, Paumgarten et al. 2020).

To cope with shocks, rural households adopt strategies that are broadly categorized as *ex-ante* (preventive) or *ex-post* (reactive) (Abid et al. 2020). This study focuses on *ex-post* strategies, which households employ after a shock to manage its impacts and maintain livelihoods. Common *ex-post* responses include borrowing, selling productive assets or livestock, reducing food consumption, depleting savings, and taking on casual work (Coulibaly et al. 2015, Heltberg et al. 2015, Tongruksawattana & Wainaina 2019). Forest-dependent communities also turn to harvesting wood, charcoal, or non-timber forest products (NTFPs) as coping mechanisms (Wunder et al. 2014, Mulungu & Kilimani 2023). Other social coping mechanisms, such as governmental relief, formal insurance, and informal support networks, are less common due to underdeveloped social protection systems in much of Sub-Saharan Africa (Mills & del Ninno 2015, Burchi et al. 2018, Gao & Mills 2018, Janzen & Carter 2019).

Socio-economic characteristics play a critical role in shaping how forest-dependent households cope with shocks, as they influence access to resources, information, and opportunities (Paumgarten & Shackleton 2011, Gao & Mills 2018). Factors such as

wealth, education, household size, gender, age, and social capital determine the range and effectiveness of coping strategies. Wealthier and better-educated households tend to adopt less harmful and more sustainable strategies, drawing on savings, assets, or diversified income (Meher et al. 2016, Bonfrer & Gustafsson-Wright 2017). Larger households have more labour but greater consumption needs, while gender and age shape access to resources and networks (Meher et al. 2016, Paumgarten et al. 2020). Social capital, including Community Forest Association membership, provides informal safety nets and reduces vulnerability (Paumgarten & Shackleton 2011). Understanding these socio-economic influences is essential for designing targeted policies and interventions that support resilient and equitable coping strategies (Gao & Mills 2018).

Despite extensive research on shocks and coping mechanisms, few studies have examined how socio-economic factors interact to shape coping strategies under multiple, compounding shocks. This study addresses this gap by investigating rural households in the Kakamega Forest Ecosystem (KFE), exploring how they respond to diverse shocks and how their socio-economic characteristics influence their adaptive strategies.

Theoretical framework

This study is grounded in the Sustainable Livelihoods Framework (SLF), which integrates concepts of adaptation and vulnerability to understand coping strategies in forest-dependent communities (Scoones 1998). The SLF explains how households manage shocks and stress by mobilizing various livelihood assets to sustain and improve their well-being over time. A livelihood is considered sustainable if it can recover from shocks while maintaining or enhancing its resource base and capabilities for future generations.

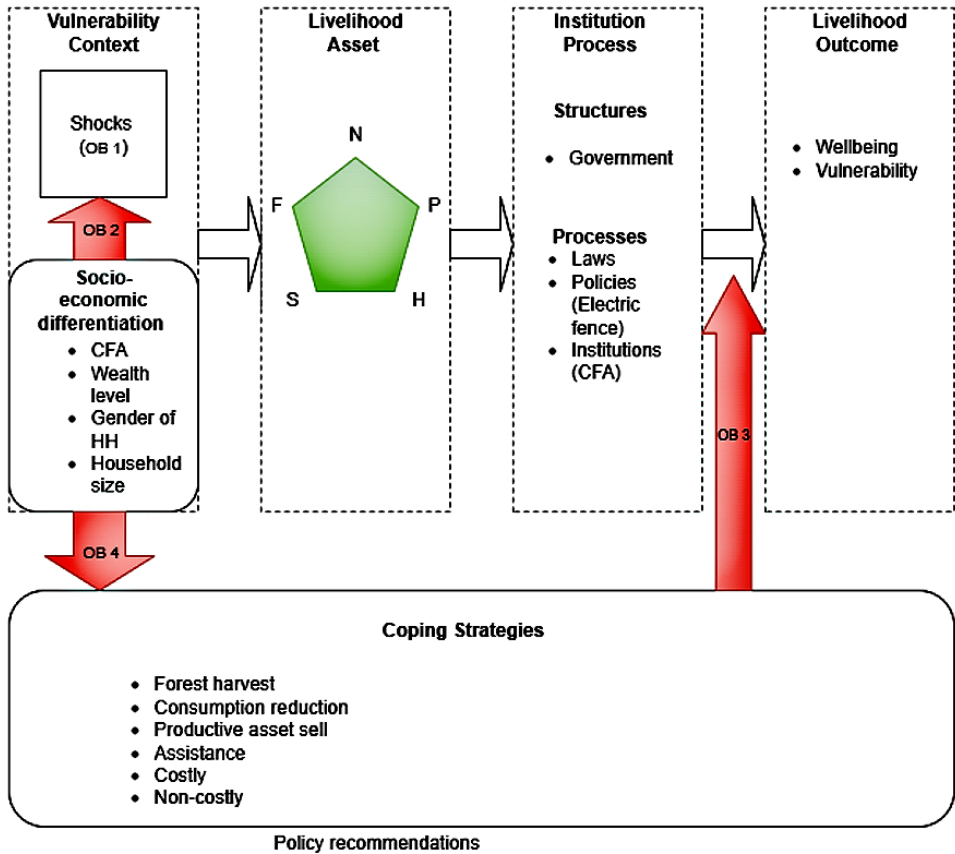


Figure 1 Applied theoretical framework adapted from (Scoones 1998). OB = Objective, N = Natural capital, F = Financial capital, S = Social capital, H = Human capital, P = Physical capital, CFA = Community Forest association, HH = Household head.

The framework comprises five key components: (1) the *vulnerability context*, which includes external factors such as shocks, trends, and seasonality that affect livelihoods; (2) *livelihood assets*, categorized into human, social, natural, physical, and financial capital, which determine households’ ability to cope; (3) *institutions and processes*, referring to the formal and informal rules, policies, and organizations that shape access to assets and opportunities; (4) *livelihood strategies*, or the activities households undertake to make a living; and (5) *livelihood outcomes*, such as improved food security, reduced vulnerability, and sustainable resource use. The SLF thus provides a holistic lens to examine how socio-economic factors influence coping strategies in response to shocks.

Literature review

Typologies of Shocks

Existing literature distinguishes between *idiosyncratic* shocks, which affect individual households (e.g., illness, death, unemployment, asset loss, wildlife predation, animal disease outbreaks, or costly social ceremonies), and *covariate* shocks, which impact entire communities or regions (e.g., economic crises or flooding) (Bonfrer & Gustafsson-Wright 2017, Paumgarten et al. 2020, Nguyen et al. 2022, Mulungu & Kilimani 2023, Yang et al. 2024). However, most studies examine these categories in aggregate, often overlooking the distinct effects of specific shocks, such as unemployment or illness, on household

outcomes. This gap limits our understanding of how households respond to different types of shocks, particularly in contexts where multiple shocks may occur simultaneously (Wunder et al. 2014, Nguyen et al. 2020).

Coping strategies

Forest-dependent rural households employ a range of coping strategies in response to shocks, which vary in their costs and long-term consequences. *Consumption reduction* such as eating fewer meals, cutting spending, or selling food stocks offers immediate relief but is unsuitable for urgent health-related shocks that require cash (Yilma et al. 2014). *Borrowing* from formal or informal lenders and *selling productive assets* (land, livestock, or labour services) can also provide short-term liquidity but often jeopardize future income and deepen vulnerability (Dercon 2004, Paumgarten et al. 2020). *Assistance-based strategies*, such as support from NGOs, religious groups, and social networks, draw on social capital and play an important role where formal safety nets are weak (Dercon 2002, Roy et al. 2005, Were et al. 2006). *Harvesting forest resources* valued for their accessibility, cultural familiarity, and risk-buffering role is particularly critical for forest-dependent households (Takasaki et al. 2004, Völker & Waibel 2010, Osewe et al. 2025b). Other *low-cost strategies* include harvesting wild resources outside forests, casual labour, drawing on savings, diversifying crops or livestock, and starting small enterprises, as these do not significantly erode household assets or long-term resilience (Coulibaly et al. 2015, Eklund et al. 2017, Mulungu & Kilimani 2023, Dey & Nath 2024).

Among coping strategies, *consumption reduction* is widely observed, particularly under multiple shocks. In China and South Africa, it is a common short-term response to food insecurity and financial strain, often accompanied by increased reliance on forest resources (Paumgarten et al. 2020, Yang et al. 2024). However, it carries negative consequences, including malnutrition and

reduced investment in health and education, which erode human capital over time (Paumgarten & Shackleton 2011). Similarly, costly strategies such as *borrowing and asset liquidation* provide immediate liquidity but undermine long-term productivity and can trap households in poverty (Pradhan & Mukherjee 2018, Mulungu & Kilimani 2023). In contrast, households generally prefer non-costly strategies that preserve future resilience, such as additional casual labour, drawing on insurance, or adjusting agricultural practices, which are more sustainable under repeated shocks (Yilma et al. 2014, Heltberg et al. 2015, Janzen & Carter 2019, Nguyen et al. 2023).

Productive asset sales are widely regarded as a costly or “negative” coping strategy due to their long-term harm to household welfare and their potential to entrench poverty (Heltberg et al. 2015, Gao & Mills 2018, Abid et al. 2020, Gautam et al. 2021). Liquidating land, livestock, or tools diminishes future income-generating capacity and is generally adopted only as a last resort after less harmful options are exhausted (Yilma et al. 2014, Bonfires & Gustafsson-Wright 2017, Paumgarten et al. 2020). However, some evidence suggests this classification may be context-specific: in Malawi, for example, Mulungu & Kilimani (2023) found that households perceived asset sales as relatively non-costly, likely reflecting the replaceability of assets or availability of alternative income sources.

Assistance-based coping strategies are often classified as non-costly, as they do not deplete household assets or productive capacity (Mulungu & Kilimani 2023, Dey & Nath 2024). These external forms of support provided by relatives, friends, religious groups, NGOs, or government programs are most commonly employed in response to idiosyncratic shocks, particularly illness or death (Yilma et al. 2014, Nguyen et al. 2020). In contrast, their use during covariate shocks, such as economic crises or natural disasters, is limited because community-wide impacts reduce the availability of help (Wunder et al. 2014, Nguyen et al. 2020). In the

context of this study, however, such strategies may not always be truly non-costly, as the structure of social ties and interdependence can limit their effectiveness and sustainability (Röhss 2012). Moreover, little empirical evidence exists on how households use these strategies under multiple, overlapping shocks, highlighting a gap in literature.

Forest-dependent communities often turn to *forest harvesting* as both a livelihood diversification strategy and an ex-post coping mechanism. Forest products provide readily available resources that can be consumed or sold to offset income or food losses following a shock, functioning as a form of natural insurance, particularly for poorer households (Kalaba et al. 2013, Coulibaly et al. 2015). In this study, focusing on rural communities surrounding Kenya's KFE, forest harvesting is treated as a distinct coping strategy due to its direct link to the local environment, its ecological and cultural significance, and its policy and conservation implications (Ojunga et al. 2023, Osewe et al. 2025a).

Socio-economic determinants

The choice and effectiveness of coping strategies are shaped by diverse, context-specific socio-economic factors. Household wealth is one of the most consistently cited determinants, as it expands the range of available options. Wealthier households, for example, often smooth consumption by selling livestock or liquidating other assets with less risk to future income (Paumgarten & Shackleton 2011, Janzen & Carter 2019). They are also more likely to draw on savings, access formal credit, or rely on social networks for assistance, as documented by Paumgarten et al. (2020) and Mulungu & Kilimani (2023). In contrast, poorer households tend to reduce food consumption or cut essential expenditures to protect their limited assets (Janzen & Carter 2019). When faced with severe shocks, they often rely on costly strategies such as distress asset sales and high interest borrowing (Heltberg et al. 2015, Gao & Mills 2018). As a last resort, poor households

frequently turn to forest harvesting, extracting NTFPs for subsistence or income (Paumgarten & Shackleton 2011, Wunder et al. 2014).

The gender of the household head significantly influences coping strategies, with female-headed households consistently found to be more vulnerable to shocks than male-headed ones. This disparity stems largely from limited access to productive assets, which constrains women's ability to respond effectively to both shocks and opportunities (Paumgarten & Shackleton 2011). Paumgarten et al. (2020) highlight systemic barriers female heads face in accumulating and liquidating assets, as well as in accessing NTFPs, further diminishing their coping capacity. Heltberg et al. (2015) report that female headed households experience higher exposure to health and environmental shocks and tend to rely more on savings and the sale of durable assets (Tongruksawattana & Wainaina 2019). However, in some contexts, women are less likely to sell assets, likely reflecting constraints in ownership and decision-making (Paumgarten et al. 2020). By contrast, male headed households in Malawi and India more often adopt consumption reducing strategies (Heltberg et al. 2015, Mehar et al. 2016) and benefit more from forest based coping through NTFP extraction in South Africa and Zambia (Paumgarten & Shackleton 2011, Kalaba et al. 2013). Gender also shapes access to external assistance: in Zambia, women more often received aid from faith based organizations (Kalaba et al. 2013), while in Kenya, they were more likely to borrow from financial institutions during droughts (Tongruksawattana & Wainaina 2019). These patterns underscore the need for gender sensitive policies that address inequalities in resources, decision-making, and support networks.

The age of the household head is another key socio-demographic factor shaping coping strategies, though its effects are complex and context-dependent. Older household heads often have more accumulated financial capital and

savings, enabling them to rely on these resources during shocks (Paumgarten et al. 2020). In Kenya, for example, they are more likely to sell productive assets in response to health shocks, reflecting a reliance on tangible wealth (Tongruksawattana & Wainaina 2019). In Malawi, older individuals favour assistance-based strategies, such as support from kin and community networks, while participating less in forest harvesting, likely due to physical limitations (Fisher & Shively 2005). Similarly, research from India shows older households are less likely to engage in additional casual labour, citing age-related constraints on physical work and market access (Mehtar et al. 2016). In China, older household heads adopt fewer and more familiar strategies, with less diversification compared to younger counterparts (Yang et al. 2024). These patterns suggest that age influences both the type and diversity of coping responses, highlighting the need for age-sensitive interventions that account for lifecycle capacities and constraints.

Household size influences coping strategies by shaping both labour availability and resource constraints. Larger households often benefit from a greater pool of working-age members, enabling them to pursue labour-based strategies such as seeking employment or engaging in additional casual work (Fisher & Shively 2005). However, this advantage is not universal: in Malawi and Nepal, larger households are less likely to migrate or take on additional labour during shocks, as low per capita asset ownership limits their ability to finance such strategies (Coulibaly et al. 2015, Gautam et al. 2021). Larger households also tend to sell fewer assets (Heltberg et al. 2015, Nguyen et al. 2020), borrow less (Coulibaly et al. 2015), and receive less assistance (Bonfrer & Gustafsson-Wright 2017). Instead, they are more likely to rely on forest-based coping, leveraging household labour to harvest firewood, wild foods, and other non-timber forest products (Mbiba et al. 2019). This suggests that forest resources serve as an important buffer for larger households when other options are constrained. Evidence on the role of social capital, such as Community

Forest Association (CFA) membership, remains mixed; in Malawi, for example, CFA membership had no significant influence on household coping behaviour, underscoring the context-specific nature of institutional support (Senganimalunje et al. 2022).

Research gap and objectives

Despite substantial research on the socio-economic factors shaping household coping strategies, a critical gap remains in understanding how these factors and their interactions influence coping choices in the face of multiple, overlapping shocks. Most existing studies examine individual shocks or isolated socio-economic variables, offering limited insight into decision-making in more complex shock environments. This study addresses this gap by investigating the multi-dimensional nature of coping strategies among forest-dependent communities in KFE, Kenya. Specifically, it aims to: (1) identify the shocks experienced and recognized by forest-local communities; (2) assess how perceptions of these shocks vary across socio-economic groups; (3) document the coping strategies employed in response to specific shocks; and (4) analyse how socio-economic factors, and their interactions, influence coping choices under multiple shocks.

By providing nuanced empirical evidence on the interplay between socio-economic vulnerability and adaptive behaviour, this study seeks to inform more targeted policies and interventions to strengthen resilience in forest-dependent communities.

Material and methods

Study area description

KFE is the only remnant of the once expansive Guineo-Congolian tropical forest located in the western Kenya (Fashing et al. 2004). Geographically, the forest is situated between latitudes 0° 15' S and 0° 21' S, and longitudes 34° 40' E and 34° 57' 30" E, with an elevation ranging from 1,250 to 2,000 meters above sea level (Obonyo et al. 2023). KFE experiences a warm,

humid climate characterized by bimodal rainfall patterns. The dry season typically spans from July to October, while the long rainy season occurs between March and June. Annual precipitation ranges from approximately 1,500 to 2,000 mm (Fashing et al. 2012). The forest is surrounded by a high population density of more than half a million people with an average household size of 5 (KNBS 2019). KFE covers an area of 133 km², the forest is officially protected and subdivided into four management zones designed to balance conservation and sustainable use (KWS 2012). The forest consists of planted and natural forest with tea plantation at the forest edge. The KFE is noted for its high-quality hardwood and softwood species (Fashing 2001).

Forest governance is shared between two national agencies: the Kenya Forest Service and the Kenya Wildlife Service. First one administers the forest through a participatory

forest management approach, involving CFAs as stipulated in the Forest Conservation and Management Act of 2016 (GoK 2016). The CFAs oversee a range of user groups engaged in activities such as firewood and timber harvesting, sand collection, honey production, livestock grazing, medicinal plant gathering, ecotourism, recreational use, and the Plantation Establishment and Livelihood Improvement Scheme (PELIS) (Laura et al. 2020).

Due to population growth, local communities have become increasingly reliant on forest resources (Osewe et al. 2023a). The forest supports various livelihood activities, including ecotourism, sand harvesting, farming under the PELIS program, bushmeat hunting, tea picking, and small scale entrepreneurship (Saalu et al. 2020). This research encompassed all the four sub-counties adjacent to the Kakamega forest: Lurambi, Navakholo, Shinyalu, and Malava (see Figure 2).

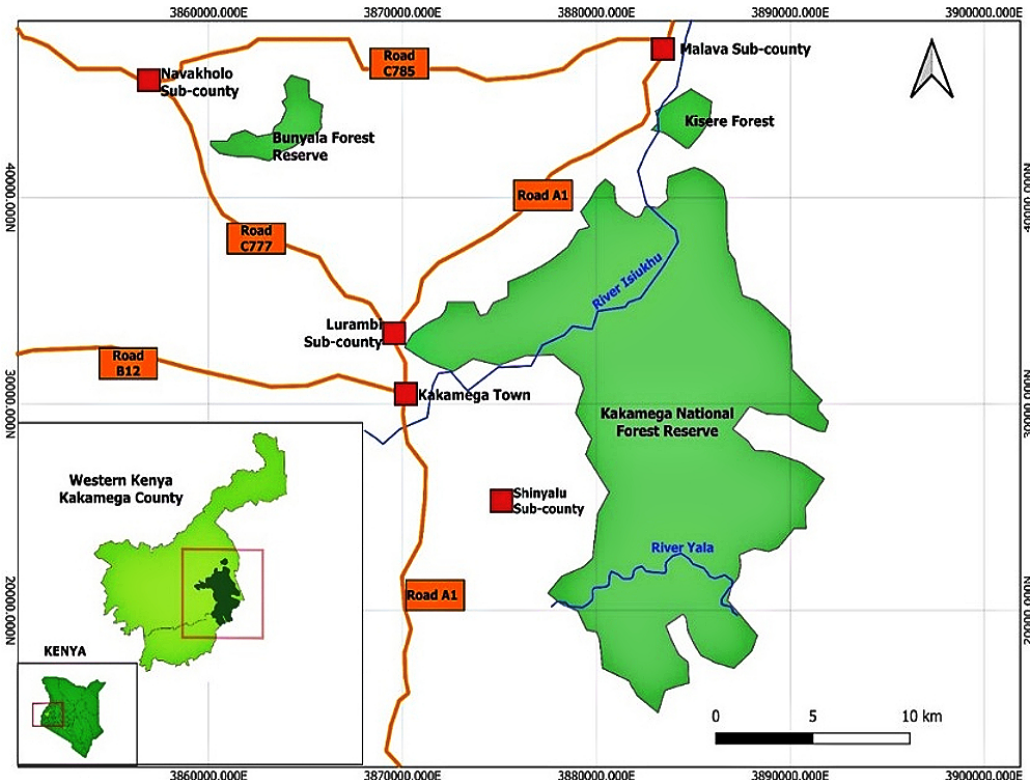


Figure 2 Map of the study area sites (Osewe et al. 2025b).

Methods

This research employed a mixed methods approach, integrating both qualitative and quantitative techniques to provide a comprehensive understanding of the research objectives. The qualitative component was designed to explore and interpret social phenomena through participants' perceptions, lived experiences, and the meanings they assign to various aspects of their lives. This approach emphasizes contextual understanding and relies on the identification of descriptive themes and patterns by the researcher (Leavy 2014). The study adhered to ethical research standards, with informed consent obtained from all participants and confidentiality of responses maintained.

Focus Group Discussions (FGDs): FGDs were conducted in three sub-counties Navakholo, Shinyalu, and Malava each comprising 8 to 10 participants selected through snowball sampling. Lurambi was excluded due to overlapping representation within the CFA. The discussions included both CFA and non-CFA members, with attention to gender balance and age diversity. The primary objectives of the FGDs were to identify the types of shocks experienced by households over the previous two years and to examine the coping strategies adopted in response to these shocks. Each session lasted between 30 and 90 minutes and yielded valuable insights that informed the design of the subsequent questionnaire. The selection and categorization of coping strategies were adapted from the Center for International Forestry Research questionnaire developed for the Poverty and Environment Network project countries (CIFOR 2008).

Key informant Interviews (KII): KIIs were conducted to explore themes similar to those discussed in the FGDs (see Figure 3). Interviews included forest managers from Malava and Shinyalu, three executive CFA members, and three forest rangers representing all four study locations. Each interview lasted approximately 30 to 45 minutes. The KIIs

provided in-depth information on the coping mechanisms employed by forest-dependent communities, particularly those related to the utilization of forest products.

Wealth ranking focus group: This exercise was conducted in all four research locations. Five participants were selected for each location using snowball sampling. Participants first identified local indicators of wealth, which were later finalized through a joint discussion involving the same participants (Osewe et al. 2025b).

A weighted scoring system was then used to categorize households into wealth groups through the following steps:

-(1) each of the four indicators like education, wall material, income, and land ownership was assigned an equal weight of 25%;

-(2) households were scored on each indicator based on predefined criteria, with scores of up to 10 points per indicator (e.g., education levels scored 1.25 per level, wall material 1.67 points, income 2 points, land ownership 2 points; see Supplementary Information (SI) 5);

-(3) total scores were calculated as the weighted sum across indicators; and (4) households were classified into three categories based on total scores: rich (10–7), middle-income (6.9–4.2), and poor (4.1–1.7).

Household Survey: The questionnaire for the household survey was grounded in insights from the FGDs and KIIs. It was piloted in Lurambi with CFA members before full deployment. The questionnaire was administered in English and Kiswahili (see SI 1). KFE has 145,324 surrounding households (KNBS 2019). A target sample of 463 households was calculated using a 5% margin of error and a 95% confidence level. The transect method, following roads and footpaths in a zigzag pattern, was used to select households from different sections of each community (Awuah et al. 2017). Households were chosen at set intervals and informed about the study; willing participants completed the questionnaire, while unwilling households were replaced. SI 2 represents households' socio-economic status.

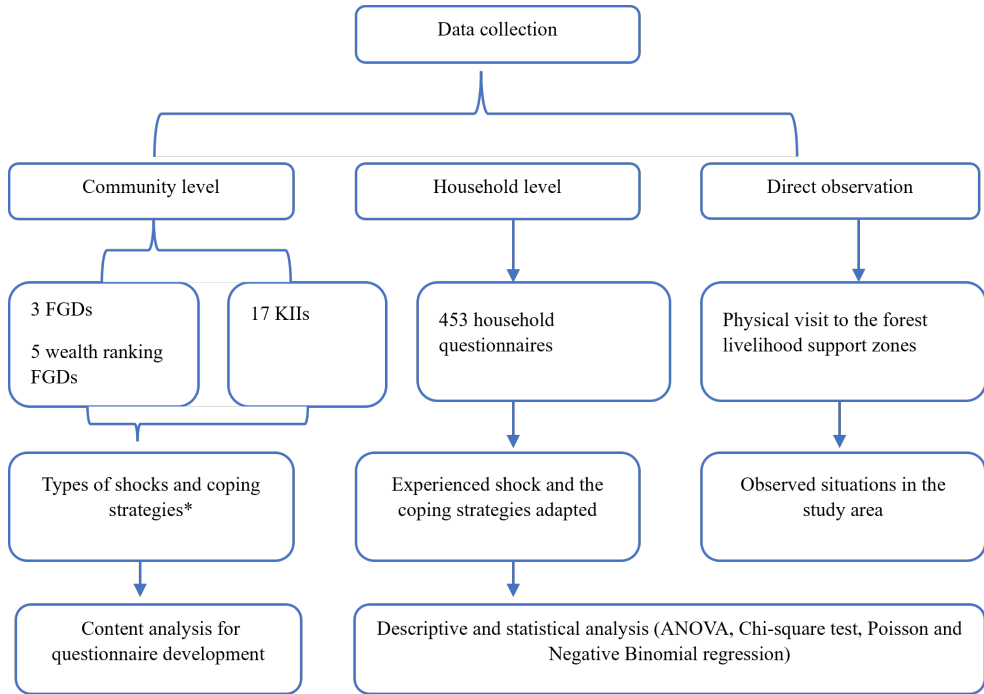


Figure 3 Flow chart of the utilized methodology.

Analysis of data

Questionnaire data were coded with binary values (1 = selected, 0 = not selected) for each identified shock and coping strategy. Data were entered into Microsoft Excel and imported into SPSS version 22 for statistical analysis. Descriptive statistics (percentages) were used to summarize the proportion of households reporting specific shocks, disaggregated by socio-economic variables. Chi-square tests assessed differences in shock acknowledgment between CFA members and non-members, and between male- and female-headed households, with statistical significance set at $p < 0.05$.

For analyses involving wealth categories, one-way Analysis of Variance (ANOVA) tested for significant differences between groups. Levene’s test assessed homogeneity of variances; if the assumption held ($p > 0.05$), Tukey’s Honest Significant Difference (HSD) post hoc test identified pairwise differences. If heterogeneity was detected ($p < 0.05$), Welch’s

ANOVA was applied, followed by the Games-Howell post hoc test when significant.

Since households often employed multiple coping strategies in response to a single shock, Poisson regression was used to estimate the likelihood of adopting each coping strategy category in relation to specific shocks. To facilitate analysis, individual strategies were grouped into five broader categories: 1) *Assistance-based*: support from friends, relatives, NGOs, religious institutions, or community-based organizations; 2) *Consumption reduction*: reducing meals, limiting expenditures, selling food stocks; 3) *Costly strategies*: borrowing from formal or informal lenders; 4) *Productive asset sales*: selling or renting land and livestock; 5) *Non-costly strategies*: harvesting wild fruits outside forests, increasing agricultural production, harvesting immature crops, changing cropping patterns, using savings, engaging in casual labour, starting a business, shifting livestock, or taking no action.

Separate Poisson regression models were estimated for each coping strategy category (count data as the dependent variable), with identified shocks as independent variables. Model fit was assessed using the Pearson Chi-square Goodness-of-Fit test; a non-significant result ($p > 0.05$) indicated no overdispersion and satisfactory fit. The Omnibus Test of Model Coefficients was used to confirm that predictors improved model performance over the null model ($p < 0.05$). Poisson regression was also applied to assess the influence of socio-economic factors on the likelihood of adopting each coping strategy category. Each strategy outcome was modeled separately, with CFA membership, wealth category, and gender of the household head entered as categorical predictors, and household size as a continuous covariate. Main effects and interaction terms were included to capture both individual and combined effects of the socio-economic factors. If overdispersion was detected ($p < 0.05$), models were re-estimated using Negative Binomial regression with a log-link function.

Results were presented in tables with explanatory notes to clarify relationships among variables. Data visualization was conducted using Microsoft Excel and R Studio to support interpretation and improve the presentation of findings.

Results and discussions

The interview elicited more details regarding the choice of shocks and reasons for preference of the coping strategies. Economic distress shock was the most recognized shock during the focus group discussion and household survey. While forest harvest was the most important coping strategy by the local forest community, primarily due to ease of access. We had 46 respondents for the interviews, and 453 households for the survey. The socio-economic profile of the respondents is in SI 1.

Shocks acknowledgement

During the focus group discussions, nine major types of shocks were identified. These were subsequently included in the household survey, where the most commonly acknowledged was *economic distress*, reported by the highest proportion of households (Figure 4).

Economic distress was the most widely reported shock. This likely reflects the combined impact of high inflation, rising fuel prices (Hassan et al. 2023), and stagnating income-generating activities in forest-adjacent communities. FGD participants noted that inflation had stalled local CFA-linked projects such as eco-camps supported by the county government and had led to increased reliance on forest resources like charcoal and NTFPs for supplementary income.

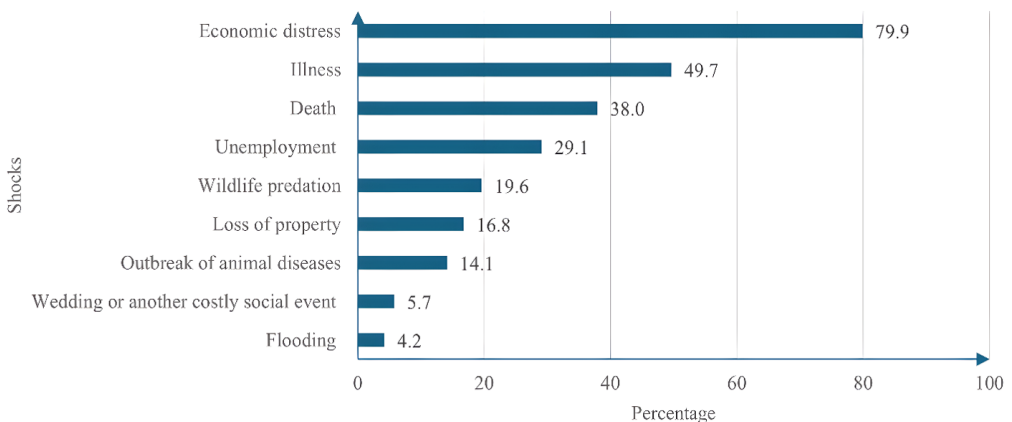


Figure 4 Proportions acknowledged from the households.

Illness was the second most acknowledged shock. This may be linked to weak implementation of Kenya's revised national health insurance scheme, which imposes a flat monthly contribution (KES 300 \approx USD 2.32) that many forest households find unaffordable (Kazungu et al. 2024). FGD participants reported that they often resort to traditional medicine before seeking formal healthcare services, primarily due to cost constraints. *Death* was cited by 38% of households. In western Kenya, high funeral-related expenditures driven by strong cultural norms around dignified burials can exceed even health care costs, placing significant financial strain on families (Kes et al. 2015).

Unemployment was reported by 29.1% of respondents. This may reflect a combination of structural and systemic challenges including macroeconomic stagnation (Okuom et al. 2023), corruption (Onchari 2019), and mismatches between educational training and labor market demands (Khakina 2024). *Wildlife predation* was acknowledged by 19.6% of households, especially on PELIS lands and forest-adjacent farms. Participants cited damage from guerezas and birds, as well as predation of poultry by small carnivores such as genets and civets (Fashing 2001).

Loss of property was reported by 16.8% of households. Cases included theft of goods and, more notably, loss of ancestral land due to inheritance disputes following the death of a male head of household. These cases underscore persistent gender inequities in land tenure systems. *Animal disease outbreaks* were acknowledged by 14.1% of households. Specific cases mentioned included anthrax in Malava (originating in Likuyani) and foot-and-mouth disease in Shinyalu and Lurambi in early 2025 (Kalekye 2023, KNA 2025).

Costly social events, including weddings, bride price payments, and circumcision ceremonies particularly among the Tiriki community were acknowledged by 5.7% of respondents. These expenses may be buffered through community

support, possibly explaining the lower reporting rate. *Flooding*, despite a documented March 2024 event affecting over 1,000 households in Kakamega County (OCHA 2024), was the least acknowledged shock (4.2%). This may reflect its geographically uniform impact across the area, which diluted individual perceptions of severity.

Shocks across socio-economic variables

Wealth categories

Analysis revealed that while *death* was the third most commonly acknowledged shock, it did not vary significantly across wealth groups (Figure 5), consistent with evidence from Zambia (Kalaba et al. 2013). In contrast, *illness* showed a statistically significant difference between poor and middle-income households (Figure 5 and SI 3). Poor households were more likely to report this shock, potentially due to limited access to formal employment and health insurance conditions that may reduce the financial burden of illness for middle-income households. Interestingly, this contrasts with findings in Zambia, where no such difference was observed (Kalaba et al. 2013).

Wildlife predation also differed significantly between poor and middle-income households. This may reflect greater access to PELIS land among the middle-income group, where exposure to crop and livestock predation is more pronounced consistent with patterns of elite capture noted by (Ongugo 2007). A significant difference in *unemployment* acknowledgment was found between rich and poor households, and between rich and middle-income groups. This may relate to income diversification; richer households likely benefit from multiple income streams, a pattern also reported in higher-income contexts (Christelis et al. 2015).

While *property loss* did not vary significantly across wealth groups, poor households reported the lowest incidence. This may reflect fewer assets to lose or challenges in securing land tenure and starting businesses. Similarly, *costly social events* (e.g., weddings) showed no significant variation, though again poor

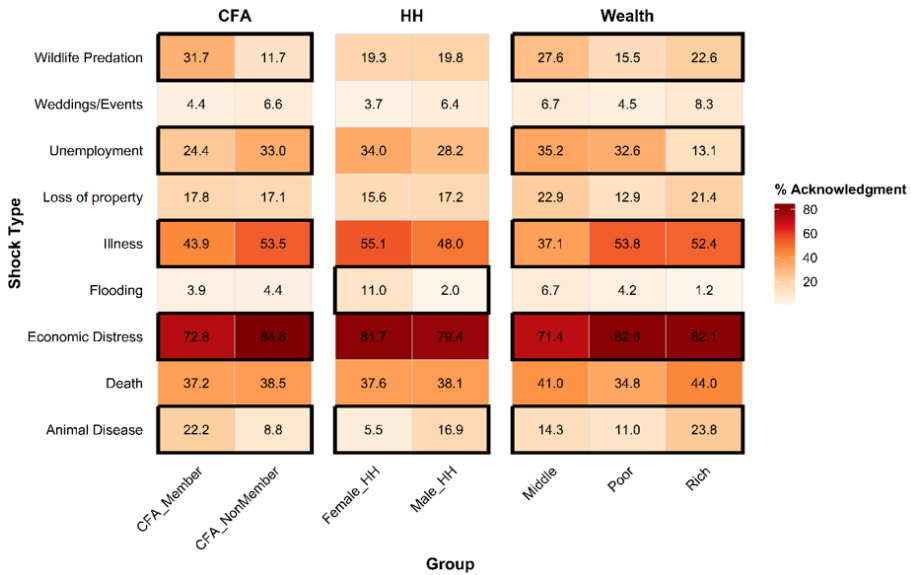


Figure 5 Stratification of shocks across the socio-economic factors. (rows with bold black edges have significant difference at $p < 0.05$).

households reported lower acknowledgment possibly due to lower bride prices or support from extended families. The *outbreak of animal disease* was significantly more acknowledged by richer households. This may stem from their greater livestock ownership, increasing their vulnerability to such shocks unlike patterns reported in Zambia (Kalaba et al. 2013).

Lastly, *economic distress* differed significantly between poor and middle-income households. Middle-income groups may be more buffered by diversified livelihoods, making them less sensitive to economic volatility.

Community Forest Association membership

Significant differences in shock acknowledgment were observed between CFA members and non-members for several shock types.

Illness was reported less frequently among CFA members. This may reflect greater access to traditional medicinal knowledge and forest-based remedies facilitated through user groups, reducing sensitivity to health-related shocks.

Unemployment also differed significantly, with CFA members less likely to report this shock. Participation in forest user groups such as beekeeping, sand harvesting, firewood collection, and grass grazing likely provides supplementary

income, cushioning against job loss.

A significant difference was also noted in *wildlife predation*, more frequently acknowledged by CFA members. This may be due to their greater access to PELIS lands and cultivation near forest edges, which increases exposure to crop and livestock predation by wildlife.

Differences in *animal disease outbreaks* may stem from the fact that livestock grazing within the forest is generally restricted to CFA members. As a result, they may own more livestock or graze them in higher-risk areas, increasing the likelihood of encountering disease outbreaks. Lastly, *economic distress* was significantly more acknowledged among non-members. CFA members may experience greater income diversification through forest-based enterprises, offering some protection against broader economic shocks.

Gender of the household head

Statistically significant gender-based differences were observed for two shocks: *flooding* and *animal disease outbreaks*. *Flooding* was more frequently reported by female-headed households, indicating heightened vulnerability. This may be linked to gendered caregiving responsibilities, reduced mobility, and limited access to recovery resources. Similar patterns were observed in

Ghana, where Gaisie et al. (2022) reported lower flood resilience among female-headed households due to structural inequalities and care burdens. *Animal disease outbreaks* were more commonly acknowledged by male-headed households. This likely reflects their more active involvement in livestock management, especially the ownership of larger herds. The finding aligns with evidence from South Africa, where male heads were found to be more affected by livestock-related shocks due to their central role in animal husbandry (Oruganti et al. 2020).

Ex-post strategy of shocks

Forest harvesting

Households that experienced shocks were significantly more likely to engage in forest harvesting as an ex-post coping strategy (Figure 6, SI 4). Specifically, households reporting *illness* were 87% more likely to harvest forest resources than those who did not experience this shock (SI 4). This likely reflects limited access to health insurance in the study area, where forest resources serve as a last-resort income or medicinal substitute (Kazungu et al. 2024). Those who experienced *unemployment* were 55% more likely to turn to forest harvesting. This finding echoes prior research in Zambia (Kalaba et al. 2013), and may relate to increased engagement in informal income activities such as charcoal production or firewood sales. *Death* as a shock increased the likelihood of forest harvest by 35%. During key informant interviews, a forest manager in Shinyalu noted that bereaved households were permitted to collect logs for economic relief highlighting an institutional dimension that may explain this association. Comparable patterns have been observed in Cambodia (Nguyen et al. 2020). Households facing *loss of property* and *wildlife predation* were 63% and 86% more likely, respectively, to rely on forest harvesting. In these cases, households may turn to collecting NTFPs like wild vegetables and mushrooms to replace lost food or income sources.

Experiencing *flooding* increased the odds of forest harvesting by more than 2.4 times, consistent with findings from Vietnam (Völker

& Waibel 2010). Flood-affected households in Kakamega may harvest timber for use in rebuilding semi-permanent homes, a common construction practice in the area. The effect of *costly social events* was marginally significant (55% increase, $p=0.059$), suggesting a possible trend without conclusive evidence. Finally, households affected by *economic distress* were 48% more likely to harvest from forests. In times of macroeconomic instability, reduced formal employment opportunities may push households toward forest-based livelihood strategies such as charcoal sales and commercial NTFP collection.

In Figure 3, if a shock's vertical line crosses the horizontal line at 1, the effect is not significant. Line length shows confidence intervals i.e. longer means less precision, shorter means more. A point left of 1 indicates a negative effect; right of 1, a positive effect.

Overall, 78% of shock-affected households reported forest harvesting as a coping response. These findings reinforce the role of forest resources as a reactive, short-term insurance mechanism rather than a sustainable livelihood strategy. This reliance may increase household vulnerability in the context of tightening forest access particularly given the erection of an electric fence around Kakamega Forest in 2023 (Osewe et al. 2025b). The findings underscore the importance of complementing forest-based coping with formal safety nets such as financial inclusion and targeted social protection systems.

Consumption reduction

Households employed consumption reduction as a coping strategy in response to several shocks, though statistical significance varied across shock types (Figure 6, SI 4).

A significant relationship was found between *unemployment* and consumption reduction: affected households were 83% more likely to reduce food consumption compared to those not experiencing this shock. This aligns with studies from India (Nath et al. 2024), and may reflect the lack of alternative income streams to meet daily needs during job loss. *Economic distress* was also strongly associated with consumption reduction, with affected households being four times more

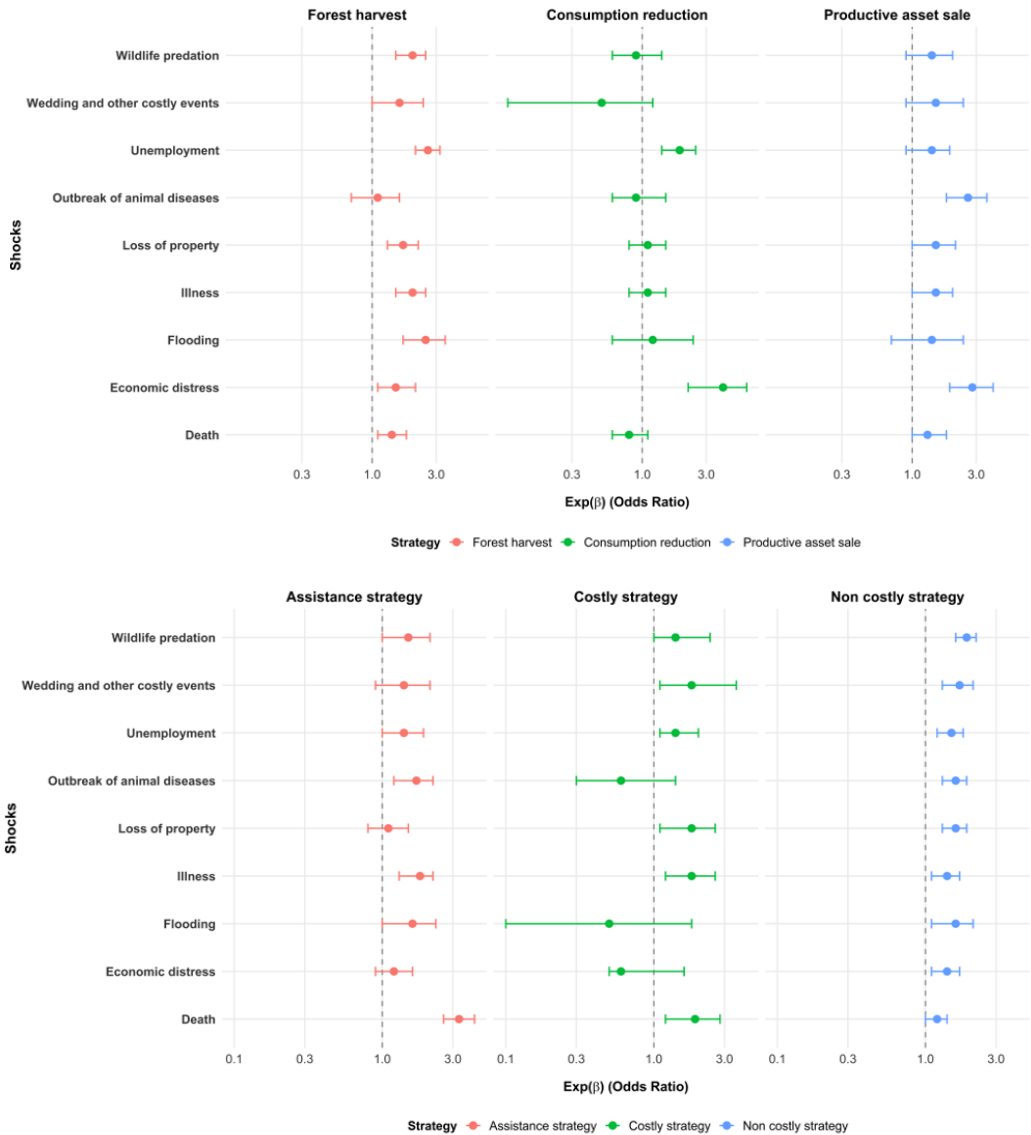


Figure 6 Households self-identified shocks and choice of coping strategies.

likely to adopt this strategy. Unlike findings from Malawi (Mulungu & Kilimani 2023), this suggests that in Kakamega, households reduce consumption pre-emptively possibly to build precautionary savings amid income uncertainty.

For other shocks, no statistically significant associations were found, though some patterns were suggestive. *Illness* showed a positive, though non-significant, association with

consumption reduction. This may reflect a shift in household expenditure from food to healthcare, particularly among those without medical insurance. *Death* was negatively associated with consumption reduction, likely due to increased household spending and food consumption during mourning, consistent with findings from Malawi and China (Mulungu & Kilimani 2023, Yang et al. 2024). *Loss of*

property, *wildlife predation*, and *flooding* all showed weak or mixed associations. In these cases, households appeared more likely to adopt alternative strategies such as forest harvesting or adjusting agricultural practices. *Costly social events* were negatively associated with consumption reduction. This likely reflects increased spending on food to accommodate guests, contrasting with evidence from China (Yang et al. 2024). *Animal disease outbreaks* also had a negative, non-significant association, possibly due to households shifting to different livestock types instead of reducing food intake.

Overall, consumption reduction emerged as a coping strategy primarily for income-related shocks, especially unemployment and economic distress. This behaviour reflects asset-smoothing preferences, where households prioritize preserving productive assets and reduce consumption only when necessary. It also suggests limited access to external assistance and a degree of confidence in short-term recovery, particularly in shocks that directly affect daily sustenance.

Productive asset sale

The use of productive asset sales such as selling livestock or land varied across shocks, with a few clear patterns and several non-significant associations (Figure 3, SI 4).

Households experiencing *illness* were 41% more likely to adopt asset sales as a coping strategy compared to those who did not face this shock. Although not statistically significant, the trend is consistent with findings from Ethiopia (Yilma et al. 2014), where health shocks often prompt urgent asset liquidation due to insufficient savings or insurance. A threefold increase in the likelihood of asset sales was observed among households reporting *animal disease outbreaks*. This mirrors findings from Cambodia (Nguyen et al. 2020), where households resorted to asset liquidation to cover veterinary costs in the absence of livestock insurance. Similarly, *economic distress* also led to a threefold increase in asset sales. This supports earlier research by (Yilma et al. 2014), indicating that in times of

financial uncertainty, households may prefer selling assets over taking out high-interest loans.

Other shocks showed positive but non-significant associations with asset sales. *Death* prompted some households to sell livestock to cover funeral expenses, aligning with findings from South Africa (Paumgarten et al. 2020). However, many also relied on assistance from social networks (40%), reducing reliance on asset sales. *Unemployment* and *loss of property* both showed weak associations. Some households sold assets, while others turned to less erosive strategies, such as reducing spending (4%) or harvesting non-timber forest products (1.8%) (Paumgarten & Shackleton 2011, Mulungu & Kilimani 2023).

Overall, asset sales were most strongly associated with *economic shocks*, *illness*, and *livestock-related losses*, reflecting the severity and immediacy of financial needs in these cases. Their use suggests that households had exhausted fewer damaging options, highlighting the erosive nature of this strategy. While effective in the short term, repeated reliance on asset liquidation can undermine household resilience and exacerbate long-term vulnerability.

Assistance strategies

The likelihood of adopting assistance-based strategies such as support from family, friends, religious groups, or NGOs varied across shock types. Households experiencing *death* were three times more likely to rely on assistance than those not facing the shock. Similarly, *illness* increased the odds of assistance-seeking by 66%. These trends, while not always statistically significant, are consistent with findings from Ghana, Cambodia, and Ethiopia (Yilma et al. 2014, Nguyen et al. 2020, Ansah et al. 2021). In both cases, assistance often took the form of cash gifts, food, labor, or childcare critical during medical emergencies or funerals. Unexpectedly, households affected by *animal disease outbreaks* were 55% more likely to seek assistance. This reflects the vulnerability of livestock-dependent households in the absence of formal insurance schemes. As observed by Nguyen et al. (2020), the death or culling of animals often forces

households to rely on informal social safety nets to meet basic needs and begin recovery.

Conversely, *wildlife predation* showed a negative (though non-significant) association with assistance strategies. This may be due to the widespread nature of the shock many neighboring households face similar challenges and are unable to offer support. The shared burden limits the availability of informal help within the community.

Assistance strategies were most relevant in the face of personal, acute shocks (e.g., death, illness, livestock loss), underscoring the role of strong kinship and social ties in KFE. The positive association with animal disease outbreaks also points to a community-wide response to shared resource risks. These findings highlight the importance of strengthening both informal networks and formal safety nets, particularly where repeated or covariate shocks threaten to overwhelm community-based support.

Costly strategies

Households experiencing *death* and *illness* shocks were 87% and 72% more likely, respectively, to adopt costly coping strategies such as borrowing or taking loans than those not facing these shocks. These findings align with research from China and Ethiopia (Yilma et al. 2014, Yang et al. 2024), though they diverge from studies in India and Cambodia, which found lower reliance on borrowing (Nguyen et al. 2020, Dey & Nath 2024). The likely explanation is that forest-dependent households in KFE have limited access to diverse income sources. While forest products like firewood, charcoal, or NTFPs offer some buffer, they are often low in value and volatile, rendering them insufficient during acute shocks. *Loss of property* also significantly increased the likelihood of turning to costly strategies by 65%, consistent with findings from Malawi (Mulungu & Kilimani 2023). Since land and business assets are key livelihood pillars, their loss often forces households to borrow urgently to replace essential capital.

In contrast, *wildlife predation*, *flooding*, *animal disease outbreaks*, and *economic distress* showed negative but non-significant

associations with costly coping strategies. This suggests a reliance on informal responses, such as assistance from kin or forest-based strategies, particularly in shocks that are recurrent or collectively experienced. For instance, wildlife predation is common in the KFE area, and local households may have developed low-cost, adaptive responses over time.

The use of costly coping strategies in response to *death*, *illness*, and *property loss* suggests that these shocks exceed households' internal coping capacities. The findings point to critical gaps in formal safety nets, including the absence of health, life, and property insurance, and underscore the social and cultural pressures, particularly regarding funerals that may compel borrowing. Strengthening social protection programs and expanding financial inclusion mechanisms (e.g., affordable insurance, microcredit) could reduce reliance on erosive borrowing and improve household resilience in forest-dependent communities.

Non-costly coping strategies

Only *death* shock had a non-significant association with non-costly coping strategy. This outcome conforms with research from India (Dey & Nath 2024). This could be linked to local communities often getting assistance from friends, relatives, communities associations, and religious groups (39.9%). Households experiencing *illness* shock had a 32% increase in the likelihood odds of adapting non-costly coping strategies as opposed to households that didn't experience this shock. This outcome contrasts with Bonfrer's research (Bonfrer & Gustafsson-Wright 2017). This could be ascribed to illness shock being relatively common and households are familiar with them compared to other shocks (flooding, loss of property etc.) and often manage them without needing drastic actions.

Households experiencing *unemployment* and *loss of property* shock had a 44% and 48% increase respectively in the likelihood odds of adopting this coping strategy compared to those that didn't experience the shock. This outcome stems from households resorting to other strategies such as consumption smoothing

such as doing extra casual work. These strategies are preferable over high-risk strategies such as borrowing. Households experiencing *wildlife predation* shock had a 78% increase in likelihood odds of adapting this strategy compared to those that didn't experience this shock. This outcome is consistent with Wunder research on the 24 countries (Wunder et al. 2014). This could be linked to wildlife causing partial loss of agricultural crops, rather than total devastation. Due to this, household resorts to low-cost strategies such as harvesting of premature crops.

Households that experience an *outbreak of animal diseases* had a 54% increase in likelihood odds of adapting these strategies compared to those that didn't experience the shock. This outcome coincides with other research from other parts of the globe (Nguyen et al. 2020, Ansah et al. 2021). This outcome reflects that households resort to spending of cash savings strategy to meet the veterinary cost incurred during the shock. While households experiencing *economic distress* had a 54% increase in likelihood odds of adapting this strategy compared to those that experience the shock. This outcome is consistent with research from China and Ethiopia (Yilma et al. 2014, Yang et al. 2024). This could be attributed to economic distress representing a gradual financial squeeze rather than sudden disaster, this gives households time to adapt incrementally through low cost means such as taking extra casual work (28%), renting out land (6.4%), and starting new small business (11.9%).

The overall pattern suggests that forest-adjacent households strongly prefer non-costly strategies those that preserve long-term assets and income across most types of shocks. These are less erosive and more sustainable in the short term. However, reliance on such strategies may obscure deeper vulnerability, especially when these measures fail to provide sufficient relief during repeated or compounding shocks. For example, strategies like withdrawing children from school to contribute labour (as reported in Ikolomani near Kisere Forest; (Osewe et al. 2025b) may carry hidden long-term costs. The absence of a non-costly strategy in response to

death underscores the unique socioeconomic and cultural weight of bereavement, suggesting a need for formalized social protection interventions tailored to such events.

Socio-economic factors influencing the choice of coping strategies

Forest harvesting

Households headed by males were 35% less likely to rely on forest harvesting as a coping strategy during shocks compared to female-headed households (see Table 1 and SI 5). This aligns with findings from South Africa, where women were more likely to collect NTFPs such as firewood and wild foods (Paumgarten & Shackleton 2011). In Kakamega, this pattern likely reflects gendered labour roles, where women are traditionally responsible for gathering forest resources for household use. Household size also influenced forest harvesting: larger households were 12% more likely to adopt this strategy than smaller ones (SI 5). This result is consistent with research from South Africa and Vietnam (Völker & Waibel 2010, Mbiba et al. 2019), suggesting that increased resource demands and greater labour availability drive forest extraction among larger families.

The interaction between household size and wealth status revealed a negative but non-significant association: middle-income households with large family sizes were less likely to rely on forest harvesting compared to poor households with smaller families. While not statistically robust, this suggests that middle-income households may have alternative coping options, such as formal employment, savings, or insurance, reducing their reliance on forest resources. Similarly, CFA membership was associated with a non-significant reduction in the likelihood of using forest harvest as a coping strategy, compared to non-members. This may be due to stricter monitoring or regulated access for members, while non-members might resort to unauthorized harvesting, including charcoal production, as a commercial coping strategy (Osewe et al. 2025a). Interestingly,

Table 1 Socio-economic factors influence the choice of coping strategy.

	Forest harvest	Consumption reduction	Productive asset sale	Assistance strategy	Costly strategy	Non-costly strategy
Belong to a CFA(Yes)	-	-	+	-	-	-
Gender of the HH (Male)	- sig	-	-sig	+	+	-
Size of the household	+ sig	+	+	-	-	+sig
Wealth category (Rich)	-	- sig	-	-	+sig	+
Wealth category (Middle)	+	-	+	-	+	+
Wealth category (Rich)*Size of the household	+	- sig	+	+ sig	-	-
Wealth category (Middle)*Size of the household	-	+	-	+	-	-sig
Belong to a CFA(Yes)*Size of the household	+	+	+	-	+	-
Wealth category (Rich)*Gender of the HH(Male)	+	+	+	-	-sig	+
Wealth category (Middle)*Gender of the HH(Male)	-	+	+	-	+	-
Wealth category (Rich)*Belong to a CFA(Yes)	+	+	-sig	+	-	+
Wealth category (Middle)*Belong to a CFA(Yes)	+	+	-	+	+	+
Belong to CFA (Yes)*Gender of the household head (Male)	+	+	-	+	-	-
Belong to CFA (Yes)*Size of the households	-	-	+	-	+	-
Gender of the household head (Male)* Size of the household	-	-sig	+	-	+	-

the interaction between CFA membership and household size showed a positive but non-significant relationship with forest harvesting. This may indicate that larger CFA-member households, despite official affiliations, still resort to forest harvest due to greater consumption needs, drawing on resources such as wild vegetables, fruits, and mushrooms.

These findings underscore the gendered and labour intensive nature of forest harvesting in KFE. Women and larger households are more likely to depend on forest resources, reinforcing forest harvest as a feminized and necessity-driven strategy. Although CFA membership is designed to promote sustainable use, its current structure may not fully mitigate forest dependency among larger households. This suggests the need for more targeted interventions, particularly those addressing gender roles and resource needs, to reduce unsustainable forest reliance during times of shock.

Consumption reduction

Rich households were 7% less likely to adopt consumption reduction strategies during shocks compared to poor households. This aligns with findings from South Africa and Malawi (Mulungu & Kilimani 2023, Paumgarten & Shackleton 2011), and likely reflects disparities in baseline consumption levels. While wealthier households may reduce spending on non-essentials (e.g., entertainment or transport), poor households are more likely to cut back on essential food and basic needs, signalling a more erosive form of consumption reduction. Furthermore, the interaction between wealth and household size showed that large, rich households were 23% less likely to adopt consumption reduction than small, poor households. This may be due to greater economic buffers such as savings, credit access, or diversified income enabling wealthier, larger households to absorb shocks without adjusting

basic consumption patterns. Additionally, large male-headed households were 17% less likely to reduce consumption than small female-headed households. This suggests that such households may have higher labour capacity and greater flexibility, such as temporary migration or engagement in casual work, to sustain income and maintain food consumption during shocks.

These findings indicate that wealth and intra-household labour availability significantly influence the likelihood of adopting consumption reduction strategies. For poor households, especially those led by women or with limited labour capacity, consumption smoothing may come at a nutritional and developmental cost. In contrast, wealthier or larger male-headed households are better equipped to absorb shocks without sacrificing essential consumption. This underscores the need for targeted social protection policies that recognize both economic vulnerability and gender-labour dynamics when addressing food insecurity during crisis periods.

Productive asset sale

Male-headed households were 51% less likely to sell productive assets during shocks compared to female-headed households. This finding contrasts with prior research in South Africa (Paumgarten & Shackleton 2011). In KFE, men typically control key productive assets such as land and livestock, which are not only economic tools but also cultural symbols of status and masculine identity. This may lead male heads to avoid asset liquidation, instead preserving long-term economic security and household prestige. In contrast, rich CFA-member households were 53% less likely to adopt asset sales than poor non-CFA households. This suggests that wealth combined with CFA membership provides substantial buffering capacity. Access to forest-based income opportunities such as sand and timber harvesting through user groups supplements financial resilience, reducing pressure to sell off productive assets in times of distress.

Interactions by wealth and household size offered more nuanced, albeit non-significant, patterns. Large rich households showed a

slight increase in likelihood of selling assets compared to small poor households. This may reflect their higher consumption needs (food, healthcare, school fees), which prompt strategic asset liquidation (e.g., older livestock) without compromising future income. Meanwhile, large middle-income households had a slight negative association, likely seeking to preserve long-term productivity by avoiding irreversible coping and turning instead to consumption smoothing or labor-based responses.

These results reinforce themes from earlier sections: forest access (through CFA membership) acts as a critical natural insurance mechanism, particularly for wealthier households. Meanwhile, gendered control of assets shapes household willingness to liquidate them an important consideration for resilience-building programs. As seen in the consumption reduction and forest-harvest sections, households with limited internal buffers are more likely to resort to erosive strategies like asset sales. Thus, policies should promote both asset protection for vulnerable households and expanded income diversification options, especially for female-headed and low-income households without CFA access.

Assistance strategy

CFA membership was not a significant predictor of adopting assistance-based strategies, and the relationship was negatively associated. This contrasts with findings from India (Dey & Nath 2024), where institutional membership increased access to support networks. In the KFE context, this may reflect the fact that CFA members often participate in income-generating activities (e.g., timber harvesting, nursery operations), which buffer them financially during shocks, reducing their need for external help. Additionally, overlapping social networks including churches, neighbours, and family likely blur distinctions between CFA members and non-members in terms of assistance-seeking behaviour.

Household size also showed a non-significant negative association, with larger households less likely to seek assistance compared to smaller ones. This aligns with earlier findings from South

Africa (Paumgarten et al. 2020). The result may stem from larger households having a greater number of working-age members, allowing internal redistribution of labour and income to absorb shocks without external reliance.

Interestingly, rich, large-sized households had a 10% higher likelihood of using assistance-based strategies compared to poor, small-sized households, though this effect was not statistically significant. This could be linked to stronger and more diverse social capital among wealthier households such as professional contacts, cooperative memberships, or local leadership roles which may facilitate easier access to support when needed.

The results suggest that assistance strategies are more likely to complement other coping mechanisms rather than serve as a primary response. Larger and wealthier households, even when better positioned, may still draw on social networks selectively. The limited effect of CFA membership in predicting assistance use highlights the importance of informal networks over formal institutions in some contexts. Programs aimed at strengthening resilience should consider both formal affiliations and existing social ties within communities.

Costly strategy

Rich households were 16 times more likely to adopt costly coping strategies when experiencing a shock compared to poor households. This contrasts with findings from India (Pradhan & Mukherjee 2018), and likely reflects their greater access to savings, credit, and liquid assets that enable borrowing or drawing down savings without jeopardizing long-term welfare. However, when stratified by gender, rich male-headed households were 64% less likely to adopt costly strategies than poor female-headed ones. This may be due to stronger internal buffers among male-headed households and social norms promoting self-reliance, while poor female-headed households often face urgent needs and limited alternatives.

Large CFA-member households showed a positive but non-significant association with costly

strategy adoption, possibly due to their higher expenditure needs (health, food, education), despite having access to forest-derived resources. In contrast, smaller non-member households may lack both the need and capacity to engage in costly strategies. Only in the case of costly strategies did large male-headed households show a positive non-significant association compared to small female-headed ones, potentially due to elevated resource demands that non-costly strategies alone may not cover.

Wealth enables households to engage in costly coping without resorting to asset liquidation or food cuts. In some cases, borrowing appears to be a deliberate financial tool, not a last resort. Gendered differences also point to unequal risk exposure and coping capacity, especially for poor female-headed households.

Non costly strategy

Large households were 9% more likely to adopt non-costly coping strategies when experiencing shocks compared to small households. This contrasts with findings from Nepal (Gautam et al. 2021) and may reflect the availability of additional working-age members in large households, enabling casual labour or minor adjustments in expenditures without resorting to more disruptive strategies.

Middle-income households had a 91% higher likelihood of employing non-costly strategies compared to poor households. This aligns with findings from Southeast Asia (Nguyen et al. 2022), and may be due to buffer resources such as savings, food stockpiles, or diversified livelihoods (e.g., side businesses), which allow households to manage shocks internally. However, large middle-income households were 8% less likely to adopt non-costly coping compared to small poor households. This unexpected trend may relate to higher aggregate needs such as food, education, and healthcare within large families, which could surpass what low-cost strategies can address during shocks.

Large households tend to rely on internal labour and flexibility before resorting to costlier measures, while middle-income

households show stronger capacity to absorb shocks without severe trade-offs. Still, large middle-income households may be especially vulnerable when shocks persist or scale beyond basic coping thresholds, underscoring the need for targeted interventions in such groups.

Overall, the findings highlight that household coping strategies are deeply shaped by gender, wealth, household size, and institutional affiliations such as CFA membership. While women and poorer households tend to rely on more erosive strategies like forest harvesting, consumption reduction, or asset sales, wealthier and larger households draw more heavily on costly and non-costly strategies, often buffered by savings, labour capacity, or diversified income sources. These dynamics demonstrate that resilience is unevenly distributed, calling for policies that recognize the differentiated vulnerabilities and capacities across households, with particular attention to dominant coping responses and socio-economic modifiers. SI 6 shows a matrix of the shock types, coping strategies, and the socio-economic modifiers.

Conclusion and Recommendations

This study examined the types of shocks experienced by forest-adjacent households in KFE, the coping strategies adopted in response, and the role of socio-economic characteristics in shaping these responses. Addressing the research gap identified in (Osewe et al. 2023), the study offered a multidimensional perspective on how gender, wealth, household size, and CFA affiliation influence coping behaviour under multiple and compounding shocks.

The results indicate that economic distress was the most widely acknowledged shock, followed by illness, while flooding had the lowest recognition. Forest harvesting emerged as the most prevalent coping strategy across shocks, especially for vulnerable groups such as female-headed and low-income households, confirming its role as a form of informal insurance. The paper reinforces the role of forest resources as a reactive,

short-term insurance mechanism rather than a sustainable livelihood strategy. This reliance may increase household vulnerability in the context of tightening forest access - particularly given the erection of an electric fence around Kakamega Forest in 2023. In contrast, strategies such as consumption reduction and productive asset sales were more selectively used in response to severe shocks, indicating asset-smoothing behaviour. Costly coping strategies were often adopted during financially urgent situations, while assistance strategies were predominantly associated with illness and death suggesting the enduring role of social capital during culturally sensitive events. Non-costly strategies were common across most shocks, although their sufficiency diminished under high-impact or resource-intensive circumstances. Socio-economic factors significantly shaped these patterns. Larger households were more likely to rely on forest harvesting and low-cost coping options due to increased labour availability and needs. Female-headed households were more dependent on forest resources, while male-headed households prioritized asset preservation, reflecting entrenched gender roles and economic control. Wealthier households, particularly those affiliated with CFAs, were more resilient, showing less reliance on erosive strategies thanks to their diversified income streams and better access to financial buffers.

Based on these findings, several policy recommendations emerge. First, strengthening health and social protection systems particularly by subsidizing the Social Health Insurance Fund for low-income households and reviving community-based health outreach programs can reduce dependence on harmful coping strategies during health-related shocks. Second, expanding financial inclusion through partnerships with cooperatives and SACCOs, alongside promoting financial literacy and savings culture, would improve liquidity and reduce reliance on asset sales or borrowing under duress.

Improved forest governance is also essential. CFA structures should be formalized and

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