

Forest Ecosystem Services, Resource Utilization, and Household Livelihood Sustainability in the Kakamega Tropical Rainforest Ecosystem

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ABSTRACT

Forest ecosystems provide essential provisioning, regulating, supporting, and cultural services that sustain rural livelihoods while maintaining ecological integrity. However, increasing pressure from unsustainable resource utilization threatens biodiversity and the long-term sustainability of forest-dependent communities. This study examined the relationship between forest ecosystem services, resource utilization, and household livelihood sustainability in the Kakamega Tropical Rainforest Ecosystem, Kenya. Guided by the pragmatism research philosophy, the study adopted a convergent mixed-methods design that integrated quantitative and qualitative approaches. Data were collected from 384 households using structured questionnaires, complemented by key informant interviews, focus group discussions, and field observations to provide contextual understanding. Quantitative data were analyzed using descriptive statistics, while qualitative data were subjected to thematic analysis. The findings revealed that local communities highly value the forest's provisioning services, including timber, firewood, herbal medicine, fodder, and food, as well as regulating services such as flood control, storm prevention, catchment protection, cloud formation, and greenhouse gas regulation. More than 89% of respondents acknowledged the significant contribution of these ecosystem services to household livelihoods. Non-timber forest products, particularly honey, medicinal plants, mushrooms, wild fruits, and fuelwood, were found to play a critical role in income generation, food security, healthcare, and livelihood diversification, especially during periods of agricultural and economic uncertainty. The study further established that respondents were highly aware of the environmental consequences of unsustainable forest resource utilization, including soil erosion, forest degradation, biodiversity change, species redistribution, and climate variability, although forest fires were perceived as a less significant threat within the rainforest ecosystem. The study concludes that the sustainability of household livelihoods in the Kakamega Tropical Rainforest Ecosystem is intrinsically linked to the conservation and sustainable utilization of forest ecosystem services. It recommends strengthening participatory forest management, promoting sustainable harvesting and commercialization of non-timber forest products, integrating indigenous ecological knowledge into forest governance, and enhancing community awareness of sustainable resource utilization to simultaneously improve rural livelihoods and conserve biodiversity.

Keywords: Forest ecosystem services, resource utilization, household livelihoods, non-timber forest products, biodiversity conservation and sustainable livelihoods.

BACKGROUND TO THE STUDY

Forests are among the most valuable natural ecosystems globally, supporting ecological stability, economic development, and human well-being through the provision of diverse ecosystem services. These services include provisioning services such as timber, fuelwood, food, medicinal plants, and freshwater; regulating services including climate regulation, carbon sequestration, soil conservation, and water purification; cultural services that support recreation, spirituality, and indigenous knowledge systems; and supporting services such

as nutrient cycling and biodiversity conservation. Together, these ecosystem services underpin the livelihoods of more than one billion people worldwide, particularly in rural areas where dependence on natural resources remains high. Increasing environmental degradation, climate change, and unsustainable resource exploitation, however, have diminished the capacity of forest ecosystems to continue providing these essential services, thereby threatening sustainable development and the achievement of the Sustainable Development Goals (SDGs), especially Goals 1, 13, and 15 (Osewe et al., 2025; United Nations, 2024).

Globally, there has been a paradigm shift from viewing forests primarily as sources of timber to recognizing them as multifunctional ecosystems that generate ecosystem services essential for human well-being and sustainable livelihoods. Recent ecosystem service research increasingly emphasizes the integration of natural capital into development planning and policy formulation through ecosystem service valuation and payment for ecosystem services (PES). Such approaches seek to balance biodiversity conservation with socioeconomic development by assigning measurable value to ecosystem benefits that have traditionally been overlooked in conventional economic accounting. Consequently, sustainable forest management has become central to international environmental frameworks, including the Kunming–Montreal Global Biodiversity Framework and the United Nations Decade on Ecosystem Restoration, both of which advocate ecosystem restoration alongside livelihood improvement.

In Sub-Saharan Africa, forests constitute an indispensable component of rural livelihood systems. Forest-dependent households derive food, fuelwood, medicinal plants, fodder, construction materials, honey, bushmeat, and numerous non-timber forest products from forest ecosystems. These resources supplement household incomes, enhance food security, provide safety nets during periods of crop failure, and strengthen resilience to climate-related shocks. However, rapid population growth, agricultural expansion, illegal logging, charcoal production, mining, and infrastructure development have accelerated forest degradation across the continent. The resulting decline in ecosystem services disproportionately affects vulnerable rural communities that rely heavily on forests for their daily subsistence. Recent studies therefore recommend integrated forest governance approaches that combine biodiversity conservation, community participation, and sustainable livelihood strategies to reduce pressure on forest ecosystems while improving household welfare (Achieng et al., 2023).

In Kenya, forests occupy approximately 8.8% of the national land area and play a strategic role in biodiversity conservation, water catchment protection, climate regulation, and socioeconomic development. Forest ecosystems contribute significantly to national food security, renewable energy, tourism, and climate change mitigation while supporting millions of rural households through the provision of timber and non-timber forest products. Kenya has strengthened forest governance through the Forest Conservation and Management Act (2016), participatory forest management initiatives, and ongoing landscape restoration programmes aimed at increasing national tree cover. Nevertheless, many forests continue to experience increasing anthropogenic pressure arising from illegal harvesting, agricultural encroachment, charcoal production, and settlement expansion. These pressures reduce biodiversity and ecosystem resilience while simultaneously undermining the sustainability of forest-dependent livelihoods. Consequently, there is growing recognition that forest conservation policies must adequately address the livelihood needs of adjacent communities if conservation objectives are to be achieved sustainably (Osewe et al., 2025).

The Kakamega Tropical Rainforest Ecosystem is Kenya's only remaining tropical rainforest and the easternmost remnant of the Guineo–Congolian rainforest belt. The ecosystem is internationally recognized for its exceptional biological diversity, harbouring hundreds of indigenous tree species, numerous endemic flora and fauna, rare birds, butterflies, reptiles, amphibians, and primates. Besides its ecological significance, Kakamega Forest provides multiple ecosystem services that sustain surrounding communities. These include fuelwood, medicinal plants, fruits, mushrooms, fodder, timber, clean water, carbon sequestration, soil protection, pollination, ecotourism, cultural heritage, and spiritual values. Thousands of households living around the forest rely on these ecosystem services for subsistence and income generation, making the forest an important component of local livelihood systems (Osewe et al., 2025).

Despite its ecological and socioeconomic importance, the Kakamega Tropical Rainforest Ecosystem continues to face increasing environmental pressures associated with high population density, agricultural encroachment,

overharvesting of forest products, illegal logging, habitat fragmentation, invasive species, and climate variability. These pressures have contributed to declining biodiversity, degradation of ecosystem services, and increasing vulnerability of forest-dependent households. Recent empirical studies in Kakamega indicate that local communities place the greatest value on provisioning ecosystem services such as firewood, medicinal plants, fruits, vines, and timber, while also acknowledging the importance of regulating and cultural ecosystem services. These studies further demonstrate that household characteristics such as education, land ownership,

Community Forest Association membership, and livelihood diversification significantly influence patterns of ecosystem service utilization and conservation attitudes. Such findings underscore the need for socially inclusive forest management strategies that simultaneously improve livelihoods and conserve ecosystem integrity (Osewe et al., 2025).

Although considerable research has examined biodiversity conservation, carbon sequestration, forest cover change, and valuation of individual ecosystem services within the Kakamega Tropical Rainforest Ecosystem, relatively few studies have comprehensively analyzed the interrelationships among forest ecosystem services, patterns of resource utilization, environmental effects of resource extraction, and household livelihood sustainability. Existing studies have largely focused on ecological or economic dimensions in isolation, leaving limited understanding of how these factors interact to influence the long-term sustainability of livelihoods among forest-dependent households. This knowledge gap limits the development of integrated policies capable of simultaneously promoting biodiversity conservation, sustainable resource utilization, and resilient livelihoods.

It is against this background that the present study examined the relationship between forest ecosystem services, resource utilization, and household livelihood sustainability in the Kakamega Tropical Rainforest Ecosystem. By analyzing the ecosystem services utilized by local communities, the environmental implications of resource use, and their influence on household livelihood sustainability, the study seeks to provide empirical evidence to support integrated forest governance, community-based conservation, and sustainable livelihood interventions in Kenya's only tropical rainforest.

LITERATURE REVIEW

Forest Biodiversity and Household Livelihoods

Forest biodiversity provides multiple provisioning, regulating, supporting, and cultural ecosystem services that directly influence rural livelihoods. Beyond timber production, forests supply numerous non-timber forest products (NTFPs) that serve as sources of food, medicine, income, and household energy. These products often function as safety nets during periods of agricultural failure or economic hardship, thereby strengthening household resilience (Baskent et al., 2024). Empirical studies across tropical regions demonstrate that households living adjacent to forests derive substantial livelihood benefits from wild edible plants, medicinal herbs, mushrooms, honey, fodder, and fuelwood (Yasin et al., 2024). Such resources diversify livelihood portfolios and reduce vulnerability to climate-related shocks. Consequently, biodiversity conservation is increasingly viewed not only as an ecological imperative but also as a prerequisite for sustainable rural development (Persha et al., 2023).

Recent studies indicate that forest biodiversity contributes significantly to livelihood security through the provision of ecosystem services that support agriculture, water regulation, soil fertility maintenance, and climate stabilization (Waiswa et al., 2026). Biodiverse forests enhance ecosystem resilience, enabling communities to withstand environmental disturbances such as droughts, floods, pests, and diseases. Forest ecosystems with higher species richness are generally more productive and resilient, thereby ensuring a continuous supply of resources upon which local communities depend (Persha et al., 2023). Furthermore, forest restoration and conservation initiatives have been shown to generate simultaneous benefits for biodiversity conservation, climate mitigation, and community livelihoods when local populations are actively involved in management processes (Waiswa et al., 2026).

Non-timber forest products remain particularly important for rural households in developing countries. A

recent systematic review found that NTFPs contribute substantially to household incomes and poverty alleviation by providing both subsistence goods and marketable products (Sibanda et al., 2025). Forest-dependent communities frequently engage in harvesting and selling products such as honey, fruits, medicinal plants, resins, mushrooms, and fibres, thereby diversifying income sources and reducing dependence on agriculture alone. However, the extent of livelihood benefits depends on governance structures, market access, resource availability, and sustainable harvesting practices (Baskent et al., 2024; Sibanda et al., 2025).

Participatory forest management has emerged as an effective approach for balancing biodiversity conservation with livelihood improvement. Evidence from community-managed forests indicates that local participation enhances forest regeneration, biodiversity conservation, and ecosystem service provision while simultaneously promoting income diversification and poverty reduction (Mekonnen et al., 2024). Communities involved in forest governance often develop stronger stewardship of forest resources, resulting in improved conservation outcomes and more equitable distribution of benefits (Persha et al., 2023).

In the Kenyan context, studies conducted around Kakamega Forest reveal that local communities derive a wide range of ecosystem services from forest biodiversity, including fuelwood, medicinal plants, food resources, water regulation, and cultural benefits (Osewe et al., 2025). These services contribute directly to household welfare and livelihood sustainability. Community perceptions further indicate that conservation efforts are more likely to succeed when local livelihood needs are integrated into forest management strategies (Osewe et al., 2025). The valuation of ecosystem services in Kakamega Forest has also demonstrated the significant economic contribution of biodiversity to rural households, highlighting the need for policies that simultaneously support conservation and livelihood enhancement (Osewe et al., 2025).

Moreover, emerging evidence suggests that forest biodiversity plays a critical role in building resilience to climate change. Diverse forest ecosystems provide alternative livelihood opportunities during periods of environmental stress and contribute to long-term adaptive capacity through the sustained provision of ecosystem goods and services (Waiswa et al., 2026). As climate variability intensifies across tropical regions, maintaining forest biodiversity is increasingly recognized as a key strategy for enhancing livelihood resilience, reducing rural poverty, and achieving sustainable development goals (Persha et al., 2023; Waiswa et al., 2026).

Contribution of Forest Ecosystem Services to Household Livelihoods

Forest ecosystem services (FES) are fundamental to the sustainability of rural livelihoods because they provide ecological, economic, and social benefits that enhance household well-being and resilience. The Millennium Ecosystem Assessment classifies forest ecosystem services into provisioning, regulating, cultural, and supporting services, all of which contribute directly or indirectly to human welfare. Recent studies indicate that these ecosystem services form the natural capital upon which many rural households depend for food security, income generation, climate adaptation, and poverty reduction (Osewe et al., 2025).

Provisioning ecosystem services constitute the most visible contribution of forests to household livelihoods. These services include fuelwood, timber, medicinal plants, wild fruits, mushrooms, honey, fodder, construction materials, and clean water. Rural households rely on these resources for domestic consumption and commercial purposes, thereby reducing household expenditure while generating supplementary income. In many developing countries, forest products also function as safety nets during periods of crop failure, unemployment, and climatic shocks. Recent research in the Kakamega Forest Ecosystem found that firewood, medicinal plants, timber, fruits, and poles were among the most highly valued ecosystem services because of their direct contribution to household subsistence and income generation (Osewe et al., 2025).

Beyond the direct provision of forest products, regulating ecosystem services play a critical role in sustaining agricultural productivity and household resilience. Forest ecosystems regulate local climate, sequester atmospheric carbon, protect watersheds, reduce soil erosion, moderate floods, and enhance water quality. These ecological functions improve crop production, reduce vulnerability to climate change, and lower the costs associated with environmental degradation. Consequently, regulating services contribute to long-term livelihood sustainability by maintaining the ecological conditions necessary for agriculture and other rural economic activities (Osewe et al., 2025).

Supporting ecosystem services—including nutrient cycling, soil formation, primary productivity, habitat provision, and biodiversity conservation—form the ecological foundation upon which all other ecosystem services depend. Although these services are often less visible to local communities, they sustain forest productivity and ensure the continued availability of provisioning and regulating services. Degradation of biodiversity and ecosystem processes ultimately reduces the capacity of forests to support rural livelihoods, highlighting the importance of conserving ecological integrity alongside resource utilization (Achieng et al., 2023).

Cultural ecosystem services also contribute significantly to household livelihoods by strengthening social cohesion, preserving indigenous knowledge, supporting ecotourism, and maintaining cultural and spiritual values. Sacred forests, traditional medicinal practices, and ecotourism opportunities provide both tangible and intangible benefits to local communities. Recent studies in Kakamega Forest demonstrate that communities recognize cultural ecosystem services as important sources of identity, recreation, education, and tourism income, although these benefits are often undervalued in conventional forest management policies (Osewe et al., 2025).

Across Sub-Saharan Africa, forests continue to function as important livelihood assets, particularly for poor rural households. Forest ecosystem services supplement agricultural production, diversify income sources, improve nutrition, and enhance resilience to economic and climatic shocks. However, increasing population pressure, agricultural expansion, illegal logging, charcoal production, and climate change have accelerated forest degradation, reducing the availability and quality of ecosystem services. This decline disproportionately affects forest-dependent communities, emphasizing the need for integrated forest governance that balances conservation objectives with local livelihood needs (Achieng et al., 2023).

In Kenya, forest ecosystems contribute substantially to household livelihoods through the provision of both timber and non-timber forest products, while simultaneously supporting water catchment protection, biodiversity conservation, tourism, and climate regulation. Community participation through Participatory Forest Management (PFM) and Community Forest Associations (CFAs) has enhanced local involvement in forest conservation and sustainable resource utilization. Nevertheless, unsustainable harvesting, agricultural encroachment, and increasing demand for forest resources continue to threaten the long-term provision of ecosystem services, making sustainable management essential for livelihood security (Osewe et al., 2025).

The Kakamega Tropical Rainforest Ecosystem represents one of the most important forest landscapes for livelihood support in Kenya. As the country's only tropical rainforest, it provides numerous ecosystem services that sustain adjacent communities. Recent empirical studies reveal that households bordering Kakamega Forest derive significant livelihood benefits from fuelwood, medicinal plants, wild vegetables, mushrooms, timber, poles, water resources, and ecotourism opportunities. Furthermore, household dependence on forest ecosystem services varies according to socioeconomic characteristics such as education level, household income, gender, land ownership, and Community Forest Association membership. These factors influence both the utilization of ecosystem services and community participation in forest conservation initiatives (Osewe et al., 2025).

Despite the recognized contribution of forest ecosystem services to rural livelihoods, existing studies have primarily focused on the valuation of individual ecosystem services or biodiversity conservation. Comparatively fewer studies have examined how multiple ecosystem services interact with patterns of resource utilization to influence household livelihood sustainability. In addition, limited attention has been given to the environmental trade-offs associated with increasing dependence on forest resources. Addressing these knowledge gaps is essential for developing integrated forest management strategies that simultaneously conserve ecosystem integrity and improve household livelihoods within the Kakamega Tropical Rainforest Ecosystem (Osewe et al., 2025).

Environmental effects of forest resource utilization in Kakamega Tropical Rainforest Ecosystem

Forest resource utilization provides essential livelihood benefits to millions of people living adjacent to tropical forests. However, increasing demand for timber, fuelwood, medicinal plants, poles, and other non-timber forest products has intensified pressure on forest ecosystems, resulting in significant environmental

consequences. Environmental degradation resulting from unsustainable resource extraction threatens biodiversity, ecosystem resilience, and the long-term provision of ecosystem services that support human well-being. Recent studies emphasize that balancing conservation with livelihood needs remains one of the greatest challenges facing tropical forest management in Africa (Achieng et al., 2023; Osewe et al., 2025).

One of the most visible environmental effects of forest resource utilization is deforestation and forest degradation. According to Osewe, Niță, and Abrudan (2022), Kakamega Forest has experienced progressive canopy loss and fragmentation due to agricultural encroachment, settlement expansion, illegal logging, and infrastructure development. Forest fragmentation reduces habitat connectivity, exposes forest edges to disturbance, and limits the movement of wildlife, thereby reducing ecosystem resilience. Similarly, Obonyo et al. (2023) reported that degradation of indigenous forest stands has reduced above-ground biomass and carbon stocks, weakening the forest's role in climate regulation and carbon sequestration.

Biodiversity loss is another major consequence of unsustainable forest resource utilization. Kakamega Tropical Rainforest is recognized as a biodiversity hotspot supporting numerous endemic plants, birds, primates, insects, amphibians, and reptiles. Nevertheless, continuous harvesting of timber, fuelwood, medicinal plants, and other forest products has altered vegetation structure, reduced habitat quality, and affected species composition. Achieng et al. (2023) argue that biodiversity loss across Afrotropical ecosystems is accelerating because of habitat destruction, weak monitoring systems, and inadequate conservation investments. In Kakamega Forest specifically, Obonyo et al. (2023) found a strong positive relationship between tree species diversity and above-ground carbon storage, implying that biodiversity degradation also diminishes ecosystem functioning and climate regulation.

Unsustainable forest resource utilization also contributes to soil degradation and hydrological changes. Removal of vegetation exposes soils to erosion, reduces litter accumulation, lowers soil organic matter, and increases sediment transport into rivers and streams. Forest degradation consequently reduces infiltration, alters streamflow, and affects water quality for downstream users. These environmental changes have direct implications for agricultural productivity because forest ecosystems regulate water availability and maintain soil fertility within surrounding landscapes. Studies conducted in East African tropical forests consistently demonstrate that intact forest cover enhances watershed protection and reduces the risks of floods and droughts affecting rural communities (Obonyo et al., 2023; Osewe et al., 2025).

Forest degradation also weakens the capacity of tropical forests to mitigate climate change. Tropical forests function as major carbon sinks by storing carbon in vegetation and soils while regulating local temperature and rainfall. When forests are degraded through logging, charcoal production, and agricultural expansion, stored carbon is released into the atmosphere while future carbon sequestration potential declines. Obonyo et al. (2023) demonstrated that indigenous forest stands in Kakamega possess significantly greater carbon storage capacity than disturbed areas, highlighting the importance of conserving mature forests for climate change mitigation. Likewise, recent reviews indicate that maintaining forest integrity remains one of the most cost-effective nature-based solutions for reducing greenhouse gas emissions and enhancing ecosystem resilience.

Human-induced disturbances associated with forest resource utilization have further increased the spread of invasive plant species within the Kakamega ecosystem. Mukhwana, Mutavi, and Oindo (2025) found that activities such as fuelwood collection, livestock grazing, footpaths, and repeated disturbance create favourable conditions for invasive plant species, which suppress indigenous vegetation and interfere with natural forest regeneration. Their findings suggest that ecological disturbances resulting from resource extraction significantly influence invasive species diversity and long-term ecosystem health.

Fire hazards have also emerged as an important environmental consequence of increasing human activity within Kakamega Forest. Wepukhulu (2024) reported that climate variability combined with anthropogenic activities, including illegal resource extraction and human encroachment, has increased the frequency and intensity of forest fires. Besides destroying vegetation, forest fires alter soil properties, reduce biodiversity, increase greenhouse gas emissions, and slow natural forest regeneration, thereby compounding the effects of other forms of environmental degradation.

Recent community-based studies indicate that households living around Kakamega Forest increasingly recognize environmental changes associated with forest resource utilization. Osewe et al. (2025) found that local communities perceive declining forest cover, decreasing availability of fuelwood and medicinal plants, biodiversity loss, and changing rainfall patterns as major environmental challenges affecting both ecosystem services and household livelihoods. The study further established that perceptions of environmental degradation vary according to wealth status, education, gender, and access to forest resources, underscoring the importance of integrating local ecological knowledge into sustainable forest management.

Although substantial progress has been made in understanding forest degradation in Kakamega, existing studies remain fragmented. Some have concentrated on forest cover change and fragmentation (Osewe et al., 2022), others on carbon dynamics (Obonyo et al., 2023), invasive species (Mukhwana et al., 2025), ecosystem service valuation (Osewe et al., 2025), or community perceptions (Osewe et al., 2025). Few studies have integrated these environmental dimensions with household livelihood sustainability to examine how patterns of forest resource utilization simultaneously influence ecosystem integrity and community well-being. This gap highlights the need for an integrated assessment of forest ecosystem services, resource utilization, environmental effects, and household livelihood sustainability in the Kakamega Tropical Rainforest Ecosystem.

RESEARCH METHODOLOGY

Research Philosophy

The study was guided by the pragmatism research philosophy, which recognizes that no single method is sufficient for understanding complex socio-ecological systems. Pragmatism supports the integration of quantitative and qualitative approaches to provide comprehensive insights into environmental and livelihood issues (Creswell & Creswell, 2023; Saunders et al., 2023). Since forest ecosystem services involve ecological, economic, and social dimensions, the pragmatic approach was appropriate because it enabled the researcher to combine household survey data with qualitative information from community members, forest managers, and local leaders.

Research Design

The study adopted a convergent mixed-methods research design, combining descriptive, analytical, and cross-sectional survey approaches. Quantitative data was collected through structured household questionnaires to determine patterns of forest resource utilization and livelihood outcomes, while qualitative data was obtained through key informant interviews, focus group discussions, and field observations to provide contextual understanding.

The mixed-methods approach allows triangulation of findings, thereby enhancing the validity and credibility of the results (Creswell & Plano Clark, 2024).

Population of the Study

Western Kenya is large and widespread, but the study focused on communities surrounding Kakamega Tropical Rainforest, which comprises of a large variety of ecosystems (Pittock et al. 2012) and its natural ecosystem is one of the most vulnerable sector to climate change (Smith & Ash, 2011). Under the latest climate change projections (IPCC, 2014), the ecosystem services supply from forested landscapes is likely to be under more pressure. However, the trend is yet to be explored for most terrestrial forest ecosystems, particularly for remaining areas of tropical rainforest.

Sampling

Using the Morgan & Krejcie (1970), formula for sample estimation, 384 cases were selected using stratified simple random sampling for questionnaire administration to the general population. Sixteen focus group discussions were planned and held in communities, 8 in each of the 2 ethnic groups. Participants in each FGD

were recruited purposively using convenience sampling. In addition, 12 direct and structured observations were made, 6 in each ethnic set up. Finally, 10 purposively enlisted key informants were interviewed in each set up to offer a total of 20 key informants. Key informants were enlisted using purposive sampling, based on objectives of the interviews.

Methods of Data Collection

- a) **Questionnaire:** The quantitative tools were administered to a sample of 384 respondents enlisted from the general population, to determine resource utilization of Kakamega Tropical rainforest on sustainability household livelihoods. The tools were administered to the general population to elicit perspectives of forest utilization. These tools were therefore to draw information from men and women about forest utilization and sustainability of livelihoods. The questionnaire was undoubtedly the best survey method of collecting quantitative data from the general population. A researcher administered semi-structured questionnaire employed.
- b) **Key Informant Interviews (KII):** The KII guides were administered to 20 key informants. Davis Silverman (2000), extols the importance of interviews in guided extraction of information from respondents and we believe that KII were justified here since culture experts were asked to offer details they have experienced over forest utilization and sustainability of household livelihoods.
- c) **Focus Group Discussion:** The tools were deployed to obtained data from discussions lending varied views and consensus formations over structures that predispose effective forest utilization and management. The moderator ensured discussions end up with analytical consensus of nexus between forest ecosystem services, utilization and sustainability of household livelihoods. According to Harvey Bernard Russell (2006), focus group discussions are the best means by which we can obtain qualitative data from many people within a short time and in a way that the group forms analytical consensus over a topic of discussion.
- d) **Observation:** Researchers used a structured direct observation checklist to document presence or absence of forest ecosystem services, utilization and household livelihoods.

DISCUSSION OF THE FINDINGS

Contribution of Forest Ecosystem Services to Household Livelihoods

Forest ecosystems constitute one of the most important forms of natural capital available to rural communities, providing a wide range of provisioning, regulating, supporting, and cultural ecosystem services that underpin sustainable livelihoods and human well-being. In the context of Kakamega Tropical Rainforest, ecosystem services extend beyond the extraction of tangible products such as timber and fuelwood to include ecological functions such as climate regulation, watershed protection, flood mitigation, and biodiversity conservation. Understanding local perceptions of these ecosystem services is critical because community appreciation of forest values often determines the level of participation in conservation and sustainable management initiatives. The study sought to assess respondents' perceptions regarding the contribution of Kakamega Tropical Rainforest to household livelihoods through the provision of ecosystem services. The findings, presented in Table 1, reveal overwhelming recognition of the multiple ecological and socio-economic benefits derived from the forest ecosystem.

Table 1. Perceived contribution of forest ecosystem services to household livelihoods

Ecosystem service	SA n (%)	A n (%)	D n (%)	SD n (%)
Timber	250 (65.1)	100 (26.0)	20 (5.2)	14 (3.7)
Firewood	254 (66.1)	90 (23.4)	30 (7.8)	10 (2.6)
Herbal medicine	244 (63.5)	100 (26.0)	20 (5.2)	20 (5.2)
Fodder	284 (74.0)	80 (20.8)	15 (3.9)	5 (1.3)

Food	100 (26.0)	200 (52.1)	50 (13.0)	34 (8.9)
Storm prevention	284 (74.0)	90 (23.4)	8 (2.1)	2 (0.5)
Flood control	300 (78.1)	50 (13.0)	20 (5.2)	14 (3.7)
Cloud formation	70 (18.2)	294 (76.6)	10 (2.6)	10 (2.6)
Catchment protection	50 (13.0)	320 (83.3)	10 (2.6)	4 (1.1)
Greenhouse gas regulation	50 (13.0)	300 (78.1)	24 (6.3)	10 (2.6)

The findings reveal a remarkably high level of awareness among respondents regarding the contribution of forest ecosystem services to household livelihoods and environmental sustainability. For virtually all ecosystem services examined, more than three-quarters of respondents either agreed or strongly agreed that Kakamega Tropical Rainforest provides essential ecological and livelihood benefits, demonstrating that local communities perceive the forest as a multifunctional resource rather than merely a source of extractive products.

With respect to timber provision, 91.1% of respondents (65.1% strongly agree and 26.0% agree) acknowledged the forest as an important source of timber for construction and household use. Only 8.9% expressed disagreement. This finding highlights the continuing importance of forest-derived construction materials in rural livelihoods and suggests that timber remains a valuable economic resource despite increasing conservation regulations.

Similarly, 89.5% of respondents recognized the forest as a major source of firewood, reflecting the continued dependence of rural households on biomass energy. Given the limited access to alternative energy sources in many rural areas, fuelwood remains indispensable for cooking, heating, and small-scale processing activities. The findings underscore the close relationship between forest conservation and household energy security.

The importance of herbal medicine was equally evident, with 89.5% of respondents agreeing that the forest serves as a critical source of medicinal plants. This reinforces the central role of traditional ecological knowledge in maintaining community healthcare systems and demonstrates that biodiversity conservation has direct implications for public health and primary healthcare accessibility.

The strongest consensus was observed regarding the provision of fodder, where 94.8% of respondents acknowledged the forest's contribution to livestock production. This finding illustrates the close interdependence between forestry and agricultural systems, particularly within mixed farming economies where livestock productivity depends partly on forest-derived forage resources.

Although perceptions regarding the forest as a direct source of food were comparatively lower, 78.1% of respondents still agreed that forest foods contribute significantly to household nutrition. Wild fruits, edible vegetables, mushrooms, honey, and other non-timber forest products supplement agricultural production and enhance dietary diversity, particularly during periods of seasonal food shortages.

Beyond provisioning services, respondents demonstrated strong awareness of the forest's regulating ecosystem services. An overwhelming 97.4% agreed that the forest contributes to storm prevention, while 91.1% recognized its role in flood control. These findings indicate that local communities appreciate the protective ecological functions of forests in reducing environmental hazards and safeguarding agricultural production and human settlements.

The highest levels of agreement were recorded for cloud formation (94.8%) and catchment protection (96.3%), suggesting that respondents possess considerable indigenous understanding of hydrological processes and the relationship between forests and regional water cycles. This ecological awareness reflects generations of observation and interaction with the forest ecosystem and demonstrates that local knowledge encompasses sophisticated understandings of ecosystem functioning.

Similarly, 91.1% of respondents acknowledged the role of forests in greenhouse gas regulation, indicating increasing public awareness of the relationship between forests and climate change mitigation. Although

scientific terminology such as greenhouse gas regulation may not traditionally form part of indigenous discourse, environmental education programmes and community conservation initiatives appear to have enhanced local understanding of the broader global significance of forest ecosystems.

The findings demonstrate that communities surrounding Kakamega Tropical Rainforest perceive the forest as a multifunctional socio-ecological system that simultaneously supports livelihoods, food security, environmental stability, and climate regulation. Rather than viewing forests solely as sources of extractable commodities, respondents recognized a diverse range of ecosystem services that contribute directly and indirectly to household well-being. The strong appreciation of provisioning services such as timber, fuelwood, fodder, medicinal plants, and food confirms that forests continue to constitute an indispensable livelihood asset for rural households. These findings are consistent with Baskent et al., (2024) whose studies across tropical Africa demonstrated that forest-dependent communities derive substantial livelihood benefits from non-timber forest products and ecosystem services that often remain undervalued in conventional economic accounting. Forest products diversify income sources, reduce household expenditure, and provide critical safety nets during periods of agricultural failure and economic hardship.

Equally significant is the high level of recognition accorded to regulating ecosystem services, including flood control, storm prevention, catchment protection, cloud formation, and climate regulation. This confirms Waiswa et al., (2026) assertions that forest biodiversity contributes significantly to livelihood security through the provision of ecosystem services that support agriculture, water regulation, soil fertility maintenance, and climate stabilization. This suggests that indigenous communities possess sophisticated ecological knowledge developed through long-term interaction with forest ecosystems. Such knowledge enables communities to recognize the functional relationships between biodiversity conservation, hydrological stability, agricultural productivity, and human well-being. The findings further agree with Persha et al., (2023) who implied that local support for biodiversity conservation may be strengthened when conservation programmes emphasize the tangible livelihood and ecological benefits that forests provide. Communities that understand the multifunctional value of forests are more likely to participate actively in sustainable management initiatives and resist practices that degrade ecosystem integrity.

Non-Timber Forest Products and Household Livelihoods

Non-timber forest products (NTFPs) constitute one of the most significant pathways through which forest biodiversity contributes to rural livelihoods, poverty reduction, and household resilience. Unlike timber resources, NTFPs encompass a diverse array of biological products harvested from forests without requiring the destruction of tree cover, thereby offering opportunities for sustainable resource utilization while maintaining ecosystem integrity. These products include edible fruits, medicinal plants, mushrooms, honey, fibres, fodder, fuelwood, gums, resins, and construction materials, all of which contribute to household consumption, income generation, cultural practices, and social well-being. For forest-dependent communities, NTFPs represent a critical livelihood asset that enhances economic diversification and reduces vulnerability to environmental and economic shocks.

The findings of this study indicate that households surrounding Kakamega Tropical Rainforest derive substantial livelihood benefits from a wide variety of non-timber forest products. Respondents identified honey, wild fruits, mushrooms, fuelwood, fodder, medicinal plants, fibres, and construction materials as the principal forest products supporting household livelihoods. These resources serve multiple functions by providing food, medicine, livestock feed, household energy, raw materials for domestic use, and commodities for local markets. Qualitative interviews revealed that the collection and utilization of NTFPs occur throughout the year, although availability varies according to seasonal cycles and ecological conditions. Community members explained that these products are particularly important during periods of agricultural uncertainty, drought, crop failure, and declining household incomes. Women and youth were reported to play particularly active roles in collecting edible plants, mushrooms, fuelwood, and medicinal herbs, while men were more involved in harvesting construction materials and larger forest products. This gendered division of labour reflects the complementary roles that household members play in sustaining livelihoods through forest resource utilization.

One participant noted: "When our maize harvest is poor or prices fall in the market, we depend on honey, mushrooms, medicinal plants and firewood from the forest to survive. The forest helps us when agriculture fails." Another respondent observed: "Forest products reduce the money we spend because we collect medicine, vegetables, fodder and fuel instead of buying them. Without the forest, many families would struggle to meet their daily needs." These narratives illustrate that NTFPs function not only as sources of income but also as mechanisms for reducing household expenditure and strengthening livelihood resilience.

The findings demonstrate that non-timber forest products constitute an essential component of household livelihood strategies among communities surrounding Kakamega Tropical Rainforest. Rather than depending exclusively on agriculture, households diversify their livelihood portfolios by utilizing forest resources that supplement income and household consumption. Such diversification enhances economic stability by reducing dependence on a single livelihood source and increasing adaptive capacity in the face of climatic and economic uncertainty. The diversity of products identified by respondents highlights the multifunctionality of forest ecosystems. Honey and wild fruits contribute directly to nutrition and income generation, while mushrooms provide seasonal food and market opportunities. Fuelwood remains the principal source of domestic energy for many households, reducing expenditure on commercial fuels. Medicinal plants lower healthcare costs by providing accessible treatment alternatives, whereas fodder supports livestock production and contributes indirectly to household food security and income. Fibres and construction materials supply essential raw materials for housing and household infrastructure, reducing the need for purchased goods. This agrees with Yasin et al., (2024) who asserted that empirical studies across tropical regions demonstrate that households living adjacent to forests derive substantial livelihood benefits from wild edible plants, medicinal herbs, mushrooms, honey, fodder, and fuelwood

An equally important finding is that NTFPs serve as livelihood safety nets during periods of crisis. Respondents consistently described forest products as fallback resources that cushion households against crop failure, market fluctuations, unemployment, and other livelihood shocks. This buffering function demonstrates that forests contribute not only to routine livelihood activities but also to long-term household resilience. The findings also reveal the close relationship between biodiversity conservation and poverty alleviation. The availability of diverse plant and animal species within Kakamega Tropical Rainforest increases the range of products accessible to local communities, thereby expanding livelihood opportunities and strengthening household adaptive capacity. This confirms Baskent et al., (2024) assertion that These products often function as safety nets during periods of agricultural failure or economic hardship, thereby strengthening household resilience.

The dependence on non-timber forest products observed in this study underscores the central role of biodiversity in supporting sustainable rural livelihoods. Forest ecosystems provide a continuous flow of resources that complement agricultural production and reduce vulnerability among resource-constrained households. In many cases, NTFPs represent the difference between economic security and poverty, particularly during periods when agricultural productivity is compromised by climatic variability or declining soil fertility. The findings further suggest that the economic significance of forests extends far beyond commercial timber production. Conventional measures of forest value often underestimate the substantial contribution of NTFPs because many products are consumed directly by households rather than entering formal markets. Consequently, the true economic and social value of biodiversity is frequently overlooked in policy and development planning. This confirms Sibanda et al., (2025) findings that NTFPs contribute substantially to household incomes and poverty alleviation by providing both subsistence goods and marketable products.

The role of women in collecting and utilizing many non-timber forest products deserves particular attention. Women's involvement in gathering medicinal plants, edible vegetables, fuelwood, and mushrooms contributes directly to household nutrition, health, and welfare. Supporting women's access to forest resources and strengthening their participation in community forest governance may therefore enhance both conservation outcomes and household well-being. The findings also indicate that sustainable harvesting practices are essential for maintaining the long-term availability of NTFPs. Excessive extraction, habitat degradation, and biodiversity loss could undermine the resource base upon which rural livelihoods depend. Conservation strategies should therefore balance livelihood needs with ecological sustainability through community-based

resource management and participatory governance.

The findings corroborate the work of Shackleton, Delang, and Angelsen (2011), who argue that non-timber forest products play a vital role in supporting rural livelihoods by providing food, medicine, income, and employment opportunities while contributing to poverty reduction. The diversity of products identified in the present study reflects similar patterns documented across tropical forest landscapes in Africa, Asia, and Latin America. The results are also consistent with Angelsen et al. (2014), whose global comparative analysis demonstrated that environmental income derived from forests constitutes a substantial proportion of total household income among rural populations. Their findings emphasize that forests function as important livelihood assets that reduce vulnerability and strengthen resilience, particularly among poorer households. Similarly, Arnold and Pérez (2001) observed that NTFPs contribute significantly to livelihood diversification and can simultaneously support biodiversity conservation when harvested sustainably. The reliance on honey, medicinal plants, mushrooms, and wild fruits documented in this study illustrates how biodiversity conservation can generate socio-economic benefits without necessitating destructive resource extraction.

The findings further align with Ellis (2000), who emphasizes livelihood diversification as a critical strategy for managing risk and enhancing household resilience. By combining agriculture with forest-based resource utilization, households increase their capacity to cope with climatic shocks, fluctuating markets, and environmental uncertainty. In addition, the results reinforce studies by FAO (2022) highlighting the importance of forests in supporting inclusive rural economies and strengthening food systems through the sustainable utilization of non-timber forest products. The contribution of NTFPs to food security, healthcare, livestock production, and income generation demonstrates the multidimensional value of forest ecosystems within sustainable development pathways.

The findings strongly support the Sustainable Livelihoods Approach (SLA), which conceptualizes livelihoods as dependent upon access to diverse forms of capital that interact to enhance household resilience. Within this framework, forest biodiversity represents a critical form of natural capital, while knowledge regarding the collection, processing, and marketing of non-timber forest products constitutes human and cultural capital. Community networks facilitating resource sharing and collective management represent social capital, and together these assets contribute to improved livelihood outcomes. The diversity of NTFPs identified in this study demonstrates how households transform natural capital into food security, income, health, and adaptive capacity. The results also reinforce Firey's Theory of Resource Use (1960), which posits that resource utilization is influenced by ecological conditions, economic needs, and cultural values. The collection of honey, medicinal plants, wild fruits, and other forest products is not solely motivated by economic necessity but is embedded within cultural traditions, indigenous knowledge systems, and customary rules governing sustainable harvesting. These cultural dimensions encourage responsible resource use while reinforcing community stewardship of biodiversity. From the perspective of Social-Ecological Systems Theory, NTFPs represent a tangible manifestation of the reciprocal relationship between ecological integrity and human well-being. Healthy forest ecosystems sustain livelihood opportunities, while community dependence on these resources creates incentives for conservation and sustainable management. However, ecological degradation disrupts this relationship by reducing biodiversity, limiting livelihood options, and increasing household vulnerability.

The findings demonstrate that non-timber forest products should no longer be regarded as secondary or peripheral forest resources but rather as strategic livelihood assets that sustain household economies, strengthen food security, support public health, and enhance resilience against socio-economic and climatic shocks. Their contribution extends beyond subsistence to encompass poverty alleviation, livelihood diversification, and community adaptation to environmental change. In the author's view, forest conservation policies that prioritize timber production while undervaluing non-timber forest products fail to recognize the true socio-economic significance of biodiversity for local communities. Sustainable forest management should therefore adopt a people-centred approach that promotes the conservation and sustainable commercialization of NTFPs, strengthens community tenure rights, supports women's participation in forest enterprises, and integrates indigenous ecological knowledge into resource governance. Such an approach would enable biodiversity conservation and rural development to reinforce one another, ensuring that Kakamega Tropical Rainforest continues to serve as both an ecological sanctuary and a foundation for sustainable household

livelihoods.

Perceived Environmental Effects of Forest Resource Utilization

The sustainability of forest ecosystems depends largely on the balance between resource extraction and the regenerative capacity of ecological systems. While forests provide indispensable ecosystem services that support human livelihoods, unsustainable patterns of utilization can compromise ecosystem integrity, reduce biodiversity, alter ecological processes, and diminish the capacity of forests to continue providing essential goods and services.

In tropical forest ecosystems such as Kakamega Tropical Rainforest, increasing population pressure, agricultural expansion, illegal harvesting, and changing land-use practices have intensified pressure on biodiversity and ecosystem functioning. Understanding community perceptions of these environmental changes is therefore critical for informing sustainable conservation strategies and strengthening community participation in forest governance. The study sought to examine respondents' perceptions regarding the environmental consequences of forest resource utilization. The findings presented in Table 2 indicate widespread awareness among local communities that unsustainable exploitation of forest resources contributes to ecological degradation and biodiversity loss.

Table 2. Perceived environmental effects of forest resource utilization (N = 384)

Statement	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)
Increased soil erosion	78.1	13	5.2	3.7
Forest degradation	75.5	15.6	6.3	2.6
Biodiversity composition change	39	52.1	8.9	0
Species redistribution	54.7	26	16.7	2.6
Increased fire frequency	1.1	7.8	78.1	13
Climate variability	0	91.1	6.3	2.6

The findings reveal a remarkably high level of environmental awareness among communities surrounding Kakamega Tropical Rainforest. Respondents clearly recognized that unsustainable forest resource utilization has significant ecological consequences that extend beyond the depletion of individual resources to affect broader ecosystem functions and biodiversity conservation. The strongest concern related to soil erosion, with 91.1% of respondents (78.1% strongly agreeing and 13.0% agreeing) indicating that excessive forest exploitation contributes to increased erosion. Only 8.9% disagreed with this statement. This finding reflects local observations that the removal of vegetation cover exposes soils to rainfall impact and surface runoff, resulting in declining soil fertility, sedimentation of rivers, and reduced agricultural productivity. Communities living adjacent to the forest have likely experienced these environmental changes firsthand, explaining the high level of consensus. Similarly, 91.1% of respondents perceived forest degradation as a major consequence of unsustainable resource extraction. The high proportion of respondents recognizing degradation suggests widespread awareness of declining forest quality, reduced canopy cover, habitat fragmentation, and loss of ecological integrity. Such degradation threatens the long-term sustainability of ecosystem services upon which local livelihoods depend.

The findings further indicate that 91.1% of respondents acknowledged changes in biodiversity composition, implying that unsustainable harvesting alters species abundance, ecological interactions, and community structure within the forest ecosystem. Local communities appear to recognize that some plant and animal species have become less common while others have increased or disappeared altogether, reflecting ecological shifts associated with habitat disturbance. Regarding species redistribution, 80.7% of respondents agreed that forest utilization contributes to changes in species distribution patterns. This perception suggests that community members have observed alterations in the occurrence and spatial distribution of wildlife and plant species, possibly resulting from habitat fragmentation, human encroachment, and changing climatic conditions. Such observations demonstrate a sophisticated understanding of biodiversity dynamics grounded in

long-term interaction with the forest environment.

An interesting finding concerns perceptions of fire frequency. Only 8.9% of respondents agreed that forest resource utilization has increased fire occurrence, whereas 91.1% disagreed. This pattern reflects the ecological characteristics of Kakamega Tropical Rainforest, which is characterized by high humidity, dense vegetation cover, and relatively low susceptibility to large-scale wildfires compared with drier forest ecosystems. The responses suggest that local ecological knowledge accurately distinguishes between the dominant environmental threats affecting the rainforest. Finally, respondents overwhelmingly associated forest utilization with climate variability, with 91.1% agreeing that environmental degradation contributes to changing climatic conditions. This finding demonstrates increasing community awareness of the relationship between forest ecosystems and climate regulation. Respondents linked deforestation and forest degradation to irregular rainfall patterns, prolonged dry periods, changing temperatures, and declining agricultural productivity, indicating an appreciation of the role of forests in maintaining local and regional climatic stability. The findings demonstrate that communities surrounding Kakamega Tropical Rainforest possess substantial ecological awareness regarding the environmental consequences of unsustainable forest resource utilization. Their perceptions extend beyond immediate resource depletion to encompass broader ecological processes such as soil conservation, biodiversity maintenance, hydrological regulation, and climate stability.

The strong concern regarding soil erosion and forest degradation illustrates recognition of the interconnected nature of ecosystem functions. Forest vegetation protects soils from erosion through canopy interception, root stabilization, and organic matter accumulation. When vegetation is removed, these ecological functions are disrupted, leading to land degradation and declining agricultural productivity. Consequently, biodiversity conservation directly supports both environmental sustainability and rural livelihoods. The widespread perception of biodiversity composition change and species redistribution further indicates that local communities possess detailed observational knowledge of ecological transformations occurring within the forest. Such knowledge represents an important component of traditional ecological knowledge and can provide valuable insights for biodiversity monitoring and adaptive forest management.

Community observations may serve as early indicators of ecological change before such changes become evident through formal scientific assessments. The low concern regarding increased fire frequency is equally informative. Rather than responding uniformly to all environmental threats, respondents differentiated among ecological processes based on local environmental realities. This finding demonstrates that indigenous ecological knowledge is context-specific and grounded in empirical observation, reinforcing its value for environmental governance and conservation planning. The perceived relationship between forest degradation and climate variability reflects growing awareness of global environmental change within local communities. Forests regulate microclimates by influencing evapotranspiration, moisture recycling, carbon sequestration, and local rainfall formation. Respondents' recognition of these relationships suggests that conservation initiatives emphasizing climate resilience may receive strong community support because they align with local experiences of environmental change.

The findings are consistent with the Millennium Ecosystem Assessment (2005), which concluded that ecosystem degradation resulting from unsustainable resource use reduces the capacity of ecosystems to provide essential services such as soil protection, water regulation, climate regulation, and biodiversity conservation. The respondents' perceptions closely reflect these documented ecological consequences. The results also corroborate Lambin and Geist (2006), who argue that deforestation and land-use change contribute significantly to soil degradation, habitat fragmentation, and biodiversity loss in tropical ecosystems. The widespread recognition of erosion and forest degradation among respondents supports evidence that local communities directly experience the environmental impacts of ecosystem disturbance.

Similarly, the findings align with IPBES (2019), which identifies habitat destruction and unsustainable exploitation as primary drivers of global biodiversity decline. The observed perceptions of changing species composition and redistribution mirror scientific assessments documenting shifts in species distributions resulting from habitat modification and climate change. The respondents' views regarding climate variability are further supported by the Intergovernmental Panel on Climate Change (IPCC, 2023), which emphasizes the critical role of forests in carbon sequestration, rainfall regulation, and climate stabilization. Deforestation and

forest degradation contribute to altered hydrological cycles and increased climatic variability, affecting both ecosystems and human livelihoods. The findings also reinforce Ostrom's (2009) Social-Ecological Systems Framework, which highlights the reciprocal relationship between human activities and ecological outcomes. Unsustainable resource use degrades ecosystem services, while ecological degradation subsequently undermines the livelihoods and well-being of communities dependent on those ecosystems.

The findings strongly reinforce Firey's Theory of Resource Use (1960), which argues that resource utilization outcomes emerge from the interaction of ecological conditions, economic demands, and socio-cultural values. Respondents recognized that excessive exploitation driven by livelihood needs can generate unintended ecological consequences, including erosion, biodiversity loss, and ecosystem degradation. This illustrates the importance of culturally informed resource management practices that balance utilization with conservation. The results also strongly support the Sustainable Livelihoods Approach (SLA). The degradation of forest ecosystems represents a decline in natural capital, thereby weakening the capacity of households to generate food, income, medicine, and other livelihood benefits. As natural capital deteriorates, household vulnerability increases, reducing resilience to environmental and economic shocks. Sustainable management of biodiversity is therefore essential for maintaining long-term livelihood security.

Furthermore, the findings align with Social-Ecological Systems Theory, which conceptualizes human societies and ecosystems as interconnected adaptive systems. The respondents clearly recognized that environmental degradation negatively affects ecosystem functioning and, consequently, household well-being. This reciprocal relationship underscores the necessity of integrated conservation approaches that simultaneously address ecological integrity and human development. The findings also resonate with the concept of ecosystem resilience, which emphasizes the capacity of ecosystems to absorb disturbances while maintaining essential functions. Unsustainable resource utilization reduces resilience by simplifying ecological communities, diminishing biodiversity, and weakening ecosystem processes that support long-term sustainability. The findings reveal that local communities are not passive users of forest resources but informed environmental observers capable of recognizing the ecological consequences of unsustainable exploitation. Their perceptions of soil erosion, biodiversity change, forest degradation, and climate variability reflect a sophisticated understanding of ecosystem dynamics developed through generations of interaction with Kakamega Tropical Rainforest.

In the author's view, these findings challenge conventional conservation narratives that portray local communities primarily as drivers of environmental degradation. Instead, they demonstrate that communities possess valuable ecological knowledge that can strengthen biodiversity monitoring, adaptive management, and sustainable forest governance. Conservation policies should therefore move beyond exclusionary approaches and actively integrate indigenous ecological knowledge into environmental planning and decision-making. Ultimately, the long-term sustainability of Kakamega Tropical Rainforest depends on recognizing that healthy ecosystems and healthy communities are mutually reinforcing. Protecting biodiversity safeguards ecosystem services, strengthens food security and public health, enhances climate resilience, and sustains the cultural knowledge systems that have historically enabled communities to coexist with the forest. An integrated socio-ecological approach that values both biological and cultural diversity offers the most promising pathway toward sustainable conservation and improved household well-being.

CONCLUSION OF THE STUDY

A rising from the research findings, it can be concluded that; ecosystem services of Kakamega tropical rainforest affects household livelihoods in Western Kenya in the following ways; makes it a source of timber, source of firewood, source of herbal medicine, source of fodder for livestock, source of food, prevents storms, flood control, cloud formation, catchment protection, and greenhouse gas regulation for household livelihood in Western Kenya.

The effects of utilization of forest ecosystem services of Kakamega tropical rainforest on household livelihoods in Western Kenya include; leads to increased erosion, degradation and loss of forest cover, functional trait composition, species extinction or range redistribution, increased fire frequency and changes

in precipitation and warming.

RECOMMENDATIONS

The households living around the Kakamega tropical rainforest should be encouraged to explore the ecosystem services of Kakamega tropical rainforest in moderation as a way of maintaining and conserving the forests.

The households living around the Kakamega tropical rainforest should be sensitized on the negative effects of utilizing the ecosystem services of Kakamega tropical rainforest.

Non-timber forest products contribute significantly to household livelihoods but remain underdeveloped economically. Policies should support sustainable harvesting, value addition, certification, and market development for products such as honey, medicinal plants, mushrooms, indigenous fruits, fibres, and edible insects. Community enterprises and cooperatives should be strengthened to enhance income generation while ensuring sustainable resource use.

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