

ECOLOGIES OF WELL-BEING: LINKING FOREST BIODIVERSITY, INDIGENOUS KNOWLEDGE AND HOUSEHOLD RESILIENCE IN KAKAMEGA TROPICAL RAINFOREST ECOSYSTEM

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ABSTRACT

Forest biodiversity and indigenous ecological knowledge are interconnected socio-ecological assets that sustain the livelihoods and resilience of forest-dependent communities. However, environmental degradation, biodiversity loss, and socio-economic transformation increasingly threaten these systems and the well-being they support. This study examined the relationship between forest biodiversity, indigenous knowledge, and household resilience among communities surrounding Kakamega Tropical Rainforest, Kenya. Specifically, it explored indigenous knowledge of forest resource use, assessed the contribution of medicinal plants and non-timber forest products to livelihoods and health, evaluated the role of forest-based foods in food security, and examined community participation in biodiversity conservation. Guided by Firey's Theory of Resource Use and the Sustainable Livelihoods Approach, the study employed a mixed-methods cross-sectional design involving 384 households. Quantitative data were collected using structured questionnaires, while qualitative data were generated through key informant interviews, focus group discussions, and field observations. Quantitative data were analyzed using descriptive and inferential statistics, and qualitative data were analyzed thematically. The findings indicate that indigenous ecological knowledge remains central to the sustainable use and conservation of forest biodiversity, supporting household resilience through healthcare, nutrition, income generation, and cultural continuity. Indigenous conservation practices also enhance community stewardship and sustainable forest management. However, declining biodiversity and the erosion of indigenous knowledge pose significant challenges. The study concludes that integrating indigenous knowledge into biodiversity conservation and forest governance can strengthen household resilience and sustainable development. It recommends documenting indigenous knowledge, conserving indigenous plant species, and promoting community-based forest management and participatory conservation policies.

Keywords: Forest biodiversity, indigenous ecological knowledge, household resilience, biodiversity conservation, sustainable livelihoods.

1. INTRODUCTION

Forests are among the world's most valuable ecosystems, providing essential ecological functions while sustaining the livelihoods, health, and cultural identities of millions of people (FAO, 2020; UNEP, 2021). Tropical forests are particularly important because they harbour exceptional biological diversity and supply ecosystem services that underpin food production, climate regulation, water conservation, and human well-being (FAO, 2020; IPBES, 2019). Beyond their

ecological functions, forests represent living repositories of indigenous knowledge accumulated through generations of interaction between local communities and their natural environments (Sinthumule, 2023). Indigenous ecological knowledge has increasingly attracted scholarly attention as an indispensable component of biodiversity conservation and sustainable development (Haq et al., 2023; Sinthumule, 2023). Indigenous communities possess sophisticated knowledge regarding species identification, harvesting techniques, ecological succession, medicinal properties of plants, and sustainable resource management practices (Sinthumule, 2023). Such knowledge systems have enabled forest-dependent societies to utilize natural resources while maintaining ecological balance over extended periods and are increasingly recognized as critical for addressing contemporary environmental challenges (Haq et al., 2023).

In sub-Saharan Africa, indigenous knowledge continues to shape the management and utilization of forest ecosystems despite growing modernization and socio-economic transformation (Sinthumule, 2023). Rural households depend on forests for medicinal plants, wild fruits, edible vegetables, fuelwood, construction materials, fodder, honey, mushrooms, and numerous non-timber forest products that supplement agricultural production and household incomes (FAO, 2020). These resources contribute significantly to food security, nutritional diversity, healthcare access, and resilience against environmental and economic shocks (Oldekop et al., 2023). However, the sustainability of these socio-ecological systems is increasingly threatened by rapid deforestation, agricultural expansion, climate change, population growth, commercialization of natural resources, and changing cultural values (IPBES, 2019; UNEP, 2021). The erosion of biodiversity often coincides with the disappearance of indigenous ecological knowledge, creating a dual crisis that undermines both conservation efforts and community livelihoods (Sinthumule, 2023). Younger generations are increasingly detached from indigenous practices, while formal governance systems frequently overlook local knowledge in forest management policies (IPBES, 2019; Haq et al., 2023).

Kenya provides an important context for examining these dynamics due to its diverse ecological landscapes and strong traditions of indigenous environmental stewardship (Government of Kenya, 2023). Kakamega Tropical Rainforest, the country's only remnant tropical rainforest, represents a globally significant biodiversity hotspot supporting numerous endemic plant and animal species (Kenya Forest Service, 2023). Communities surrounding the forest have historically depended on its resources for subsistence and cultural practices, making the area an ideal setting for investigating the relationships between biodiversity, indigenous knowledge, and household well-being (Kenya Forest Service, 2023). Despite increasing recognition of indigenous knowledge within international conservation frameworks, empirical evidence linking indigenous ecological knowledge, biodiversity conservation, food security, and human health remains fragmented (IPBES, 2019; Sinthumule, 2023). Most previous studies have examined these dimensions separately, limiting understanding of their interconnected nature. There remains insufficient evidence on how indigenous knowledge simultaneously contributes to biodiversity conservation and household well-being within tropical forest landscapes (Oldekop et al., 2023). This study addresses this knowledge gap by examining the contribution of forest biodiversity and indigenous ecological knowledge to sustainable livelihoods among communities adjacent to Kakamega Tropical Rainforest. By integrating ecological, anthropological, and livelihood perspectives, the study contributes to current debates on inclusive conservation strategies that recognize indigenous knowledge as an essential pillar of sustainable development (Haq et al., 2023; Sinthumule, 2023).

2. LITERATURE REVIEW

2.1 Indigenous Ecological Knowledge and Conservation

Indigenous ecological knowledge (IEK) encompasses cumulative understandings, practices, innovations, and beliefs developed through long-term interactions between communities and their environments. Unlike externally imposed conservation models, indigenous knowledge systems are embedded within local cultural institutions that regulate access to natural resources through customary norms and social sanctions. Communities frequently employ seasonal harvesting restrictions, species-specific management practices, sacred groves, and taboos that promote ecological sustainability. These indigenous governance mechanisms contribute to biodiversity conservation while ensuring continued access to ecosystem services (IPBES, 2022; UNESCO, 2023). Integrating indigenous knowledge with scientific management approaches has increasingly been recognized as an effective strategy for strengthening community-based conservation and improving ecosystem resilience under conditions of climate change (IPCC, 2023; Reed et al., 2023).

2.2 Medicinal Plants and Human Health

Medicinal plants constitute one of the oldest forms of healthcare worldwide and remain essential for millions of people, particularly in developing countries. Rural populations often rely on herbal medicine because of its affordability, accessibility, and cultural acceptance (World Health Organization [WHO], 2023). Tropical forests contain a rich diversity of medicinal plant species used to treat infectious diseases, digestive disorders, respiratory illnesses, reproductive health conditions, and chronic ailments. The conservation of medicinal plant diversity therefore has implications extending beyond biodiversity protection to public health, pharmaceutical research, and health equity (WHO, 2023; Kunwar et al., 2024). Declining forest ecosystems threaten both the availability of medicinal species and the indigenous knowledge required for their identification, preparation, and sustainable use (IPBES, 2022; FAO, 2024).

2.3 Forest Foods and Food Security

Forest foods contribute significantly to household nutrition by providing essential vitamins, minerals, proteins, and dietary diversity that complement agricultural production. Wild fruits, leafy vegetables, edible insects, mushrooms, and nuts are particularly important during seasonal food shortages and periods of climatic stress (FAO, 2023; CIFOR-ICRAF, 2024). Such resources enhance nutritional resilience and reduce vulnerability to food insecurity. Recent scholarship recognizes forests as integral components of sustainable food systems rather than merely emergency food sources, emphasizing their role in supporting healthy diets, resilient livelihoods, and sustainable development (FAO, 2023; HLPE, 2023). Consequently, biodiversity conservation contributes directly to achieving food security and nutrition objectives while supporting rural livelihoods. Although previous studies acknowledge the importance of traditional knowledge and forest biodiversity, relatively few have examined their combined contribution to household well-being through integrated analyses of conservation, food security, and health outcomes. Existing evidence often emphasizes ecological dimensions while overlooking the social and cultural processes that sustain biodiversity and strengthen community resilience (IPBES, 2022; Reed et al., 2023). This study responds to this gap by adopting a holistic socio-ecological perspective that links indigenous knowledge systems with biodiversity conservation, food security, human health, and livelihood resilience.

3. THEORETICAL FRAMEWORK AND RESEARCH METHODOLOGY

This study is anchored in Firey's Theory of Resource Use and the Sustainable Livelihoods Approach (SLA). Firey's Theory argues that natural resource use is influenced not only by economic considerations but also by cultural values, social norms, and symbolic meanings (Firey, 1960). Communities utilize natural resources in ways shaped by traditions, beliefs, and collective identities, making cultural institutions central to environmental stewardship. Contemporary studies continue to demonstrate that indigenous knowledge systems, customary institutions, and cultural values play a critical role in biodiversity conservation, sustainable resource governance, and climate adaptation (IPBES, 2022; Reed et al., 2023).

The Sustainable Livelihoods Approach conceptualizes household well-being as dependent upon access to multiple forms of capital, including natural, human, social, physical, financial, and cultural assets (Scoones, 1998). Recent applications of the framework emphasize that sustainable livelihoods increasingly depend on the interaction between ecosystem services, biodiversity conservation, and local knowledge systems, particularly among rural and forest-dependent communities (FAO, 2024; UNDP, 2023). Forest biodiversity constitutes an important form of natural capital, while traditional ecological knowledge represents cultural and human capital that enables effective utilization and sustainable management of environmental resources. Together, these assets strengthen livelihood diversification, adaptive capacity, food security, and resilience to environmental and socio-economic shocks (FAO, 2024; Reed et al., 2023).

The integration of Firey's Theory of Resource Use and the Sustainable Livelihoods Approach provides a comprehensive explanation of how biodiversity conservation and indigenous knowledge interact to support sustainable livelihoods, food security, and health outcomes among forest-dependent communities. The combined frameworks acknowledge that livelihood outcomes are shaped not only by the availability of natural resources but also by the cultural institutions, governance systems, and indigenous knowledge that influence access, management, and sustainable use of those resources (IPBES, 2022; IPCC, 2023).

3.1 Research Methodology

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, 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).

3.2 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 forest biodiversity 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.

3.2.1 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.

3.3 Methods of Data Collection

- a) **Questionnaire:** The quantitative tools were administered to a sample of 384 respondents enlisted from the general population, to determine the link between forest biodiversity, indigenous knowledge and resilience of households. The tools were administered to the general population. These tools were therefore to draw information from men and women. The questionnaire was undoubtedly the best survey method of collecting quantitative data from the general population. A researcher administered semi-structured questionnaire was 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 biodiversity, indigenous knowledge and resilience of households.
- c) **Focus Group Discussion:** The tools were deployed to obtained data from discussions lending varied views and consensus formations. The moderator ensured discussions end up with analytical consensus of nexus between forest biodiversity, indigenous knowledge and resilience of households. 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 a link between forest biodiversity, indigenous knowledge and household resilience.

4. RESULTS AND DISCUSSIONS

4.1 Socio-Demographic Characteristics of Respondents

Understanding the socio-demographic characteristics of respondents is essential for contextualizing patterns of forest resource utilization, traditional ecological knowledge transmission, and household dependence on ecosystem services. Demographic variables such as gender and age influence access to natural resources, participation in conservation activities, decision-making processes, and the intergenerational transfer of indigenous knowledge. Consequently, the characteristics of the respondents provide an important foundation for interpreting the subsequent findings on biodiversity conservation, food security, and household well-being.

Table 1. Socio-demographic characteristics of respondents (N = 384)

Variable	Frequency	Percentage (%)
Gender		
Male	288	75.0
Female	96	25.0
Age group (years)		

Variable	Frequency	Percentage (%)
20–30	50	13.0
31–40	73	19.0
41–50	221	57.6
≥51	40	10.4

A total of 384 household heads participated in the study. As presented in Table 1, majority of respondents were male (75.0%, n = 288), while female-headed households accounted for 25.0% (n = 96). In terms of age distribution, respondents aged 41–50 years constituted the largest proportion (57.6%, n = 221), followed by those aged 31–40 years (19.0%, n = 73), 20–30 years (13.0%, n = 50), and 51 years and above (10.4%, n = 40). The predominance of male respondents suggests that household decision-making concerning forest resource use and natural resource management remains largely patriarchal within communities surrounding Kakamega Tropical Rainforest. In many rural African societies, customary tenure systems and cultural norms assign men primary authority over land ownership, forest access, and resource allocation. Consequently, men are often the principal actors in decisions regarding timber harvesting, fuelwood collection, agroforestry practices, and participation in formal forest governance structures.

However, the relatively substantial proportion of female respondents (25%) should not be underestimated. Women frequently serve as the primary collectors and users of non-timber forest products, including medicinal plants, wild vegetables, fuelwood, mushrooms, and water. Their daily interaction with forest ecosystems provides them with unique ecological knowledge that is often overlooked in conventional forest management frameworks. The findings therefore highlight the need for gender-responsive conservation strategies that recognize both male and female contributions to biodiversity conservation and sustainable livelihood systems.

The age distribution reveals that the majority of respondents belong to the economically active and socially productive age group of 41–50 years. This demographic profile is particularly significant because individuals within this age bracket typically possess extensive practical experience in farming, forest resource utilization, and indigenous ecological knowledge acquired through decades of interaction with the natural environment. Their lived experiences position them as custodians of traditional environmental knowledge and cultural practices that support sustainable biodiversity management. Conversely, the relatively low proportion of respondents aged 20–30 years (13.0%) may indicate declining engagement of younger generations in traditional forest-based livelihoods. Increasing access to formal education, rural-urban migration, changing employment aspirations, and exposure to modern lifestyles may be reducing opportunities for younger people to acquire indigenous ecological knowledge through traditional apprenticeship systems. This demographic trend raises concerns regarding the long-term continuity of traditional knowledge systems that have historically supported biodiversity conservation and sustainable resource use.

The relatively small representation of respondents aged 51 years and above (10.4%) may reflect demographic dynamics such as declining life expectancy or the transfer of household leadership responsibilities to younger family members. Nevertheless, older community members remain important repositories of indigenous ecological knowledge, possessing specialized understanding of medicinal plants, sacred forests, seasonal harvesting practices, and customary conservation institutions. Their limited representation underscores the urgency of documenting indigenous knowledge before it is irreversibly lost.

5. DISCUSSION OF THE FINDINGS

The demographic profile observed in this study aligns with broader patterns reported across forest-dependent communities in sub-Saharan Africa, where men often dominate formal resource governance structures despite women's substantial contribution to everyday forest utilization. Although men generally exercise authority over strategic decisions concerning forest resources, women are frequently responsible for collecting and processing non-timber forest products that directly support household nutrition, healthcare, and energy needs. This apparent gendered division of labour suggests that effective biodiversity conservation requires inclusive governance structures that incorporate the knowledge and experiences of both men and women.

The dominance of middle-aged respondents further suggests that traditional ecological knowledge remains concentrated among mature adults rather than younger generations. Indigenous knowledge is predominantly transmitted orally through observation, participation, and cultural practices embedded within family and community life. When younger people increasingly disengage from traditional livelihoods, opportunities for knowledge transmission diminish, contributing to the gradual erosion of cultural heritage and environmental stewardship practices. Similar concerns have been documented in many tropical forest regions where modernization and globalization have weakened traditional systems of ecological learning.

The findings also have important implications for biodiversity conservation. Communities with experienced and knowledgeable household heads are more likely to recognize the ecological value of forests and adopt sustainable harvesting practices developed over generations. Indigenous management systems often include selective harvesting, seasonal restrictions, sacred groves, and customary sanctions that regulate resource use and maintain ecosystem integrity. The concentration of respondents within the mature age category therefore provides an important foundation for community-based conservation initiatives.

5.1 Theoretical Corroboration

The findings strongly support Firey's Theory of Resource Use (1960), which argues that natural resource utilization is shaped not only by economic rationality but also by cultural values, social norms, and community institutions. The predominance of mature household heads suggests that forest management decisions are embedded within long-standing cultural traditions and accumulated experiential knowledge rather than purely market considerations. Indigenous ecological knowledge functions as a cultural asset that guides sustainable resource utilization through socially accepted norms and practices. The results are equally consistent with the Sustainable Livelihoods Approach (Scoones, 1998), which conceptualizes household well-being as dependent upon multiple forms of capital, including human, social, natural, and cultural capital.

The respondents' age and accumulated experience represent valuable human capital, while their indigenous ecological knowledge constitutes an important form of cultural capital that enhances the productive use of natural capital embodied in forest biodiversity. The interaction among these livelihood assets strengthens household resilience, food security, and adaptive capacity in the face of environmental and socio-economic change. From the perspective of Social-Ecological Systems Theory, the demographic composition of the community reflects the interdependence between human systems and ecological systems. The transmission of knowledge across generations facilitates adaptive management of forest ecosystems, while demographic shifts that weaken knowledge transfer may reduce the resilience of both communities and ecosystems. Thus, conserving biodiversity requires simultaneous investment in conserving the cultural institutions that sustain traditional ecological knowledge.

The demographic characteristics of respondents provide compelling evidence that the future of biodiversity conservation in Kakamega Tropical Rainforest depends not only on protecting biological resources but also on safeguarding the human knowledge systems that govern their sustainable use. The concentration of traditional ecological knowledge among middle-aged and older community members presents both an opportunity and a challenge. While these groups remain invaluable custodians of indigenous conservation practices, the relatively limited participation of younger generations signals a potential discontinuity in knowledge transmission that could undermine long-term conservation efforts.

In the author's view, sustainable forest governance should move beyond conventional protectionist models and embrace intergenerational knowledge conservation as a core component of biodiversity policy. Programmes that facilitate mentorship between elders and youth, integrate indigenous ecological knowledge into formal education, and strengthen the participation of women and young people in community forest management are likely to enhance both ecological sustainability and household well-being. Ultimately, the conservation of Kakamega Tropical Rainforest will be most effective when biological diversity and cultural diversity are recognized as inseparable pillars of resilient socio-ecological systems.

5.2 Indigenous Ecological Knowledge and Household Health

Indigenous ecological knowledge (IEK) constitutes one of the most enduring forms of indigenous knowledge systems among forest-dependent communities and plays a fundamental role in promoting primary healthcare, disease prevention, and household well-being. Embedded within cultural beliefs, intergenerational learning, and long-term interaction with the natural environment, IEK encompasses the identification, harvesting, preparation, and administration of medicinal plants for treating a wide range of ailments. In many rural communities where access to modern healthcare services is constrained by financial limitations, geographical isolation, and inadequate health infrastructure, forest-based traditional medicine remains an indispensable component of community health systems. Consequently, conserving biodiversity also contributes to the preservation of healthcare resources and the cultural knowledge required for their effective utilization. The quantitative findings of this study strongly support the importance of medicinal plants in household healthcare. As presented in Table 2, 89.5% of respondents (63.5% strongly agreed and 26.0% agreed) indicated that Kakamega Tropical Rainforest serves as an important source of herbal medicine, while only 10.4% disagreed with this statement. This overwhelming consensus demonstrates that medicinal plants continue to occupy a central position in local healthcare practices and reinforces the importance of traditional ecological knowledge in sustaining community health and resilience.

The qualitative findings further complement the quantitative evidence by revealing that local communities utilize a wide diversity of medicinal plant species to treat common illnesses affecting household members. Participants reported the widespread use of herbal remedies for managing respiratory infections, gastrointestinal disorders, malaria-like symptoms, skin diseases, reproductive health conditions, fever, stomach ailments, wounds, and childhood illnesses. Traditional healers and elderly respondents explained that knowledge regarding medicinal plant identification, harvesting periods, preparation techniques, dosage, and administration has been transmitted orally across generations and remains an integral component of community identity and survival. One elderly herbal practitioner explained: *"Before hospitals became common, the forest was our pharmacy. Almost every illness had a plant that our parents taught us to use. Even today, many families first use herbs before seeking treatment at health facilities."* Similarly, participants in focus group discussions observed that medicinal plants are often preferred because

they are readily available, affordable, culturally acceptable, and perceived to produce fewer side effects than some synthetic medicines. For many low-income households, traditional medicine provides an accessible healthcare alternative, particularly during periods of financial hardship when conventional medical services may be beyond their reach.

The findings clearly indicate that traditional ecological knowledge remains a critical determinant of household health among communities surrounding Kakamega Tropical Rainforest. The high proportion of respondents recognizing the importance of medicinal plants suggests that biodiversity conservation directly influences community health outcomes by ensuring continued access to indigenous pharmacological resources. The dependence on herbal medicine reflects both necessity and cultural preference. While limited access to healthcare facilities encourages reliance on traditional remedies, respondents also demonstrated confidence in the efficacy of indigenous treatments based on accumulated community experience. This illustrates that traditional medicine functions not merely as a substitute for modern healthcare but as a complementary healthcare system embedded within local cultural and social institutions. This is in agreement with World Health Organization (2023) which averred that rural populations often rely on herbal medicine because of its affordability, accessibility, and cultural acceptance

The findings further suggest that the erosion of forest biodiversity poses a significant threat to household health. Declining populations of medicinal plant species may reduce treatment options for rural communities, increase healthcare costs, and undermine local resilience against disease. Simultaneously, the disappearance of indigenous knowledge holders threatens the continuity of ethnomedical knowledge that has evolved through centuries of observation and experimentation. The interdependence between biodiversity conservation and healthcare therefore extends beyond ecological preservation to encompass human survival, cultural continuity, and social resilience. Protecting medicinal plant diversity safeguards both biological resources and the intellectual heritage associated with their utilization. This confirms Kunwar et al., (2024) assertion that the conservation of medicinal plant diversity therefore has implications extending beyond biodiversity protection to public health, pharmaceutical research, and health equity.

The findings highlight the intimate relationship between forest ecosystems and community healthcare systems in rural Kenya. Medicinal plants represent one of the most tangible examples of ecosystem services directly supporting human well-being. Their continued use demonstrates that biodiversity contributes not only to environmental sustainability but also to disease prevention, healthcare accessibility, and poverty reduction. The reliance on traditional medicine observed in this study reflects broader patterns across many developing countries, where indigenous healthcare systems continue to complement formal biomedical services. In areas characterized by inadequate healthcare infrastructure and limited financial resources, medicinal plants provide affordable and locally accessible treatment options that enhance community resilience. This is in line with IPBES, (2022) and FAO, (2024) who stated that declining forest ecosystems threaten both the availability of medicinal species and the indigenous knowledge required for their identification, preparation, and sustainable use.

The findings also reveal that indigenous ecological knowledge functions as an important form of cultural capital. Knowledge concerning medicinal plants is often concentrated among elders and traditional healers, whose expertise is acquired through prolonged observation, apprenticeship, and cultural transmission. Such knowledge systems embody generations of empirical learning and ecological adaptation, representing valuable intellectual resources for both local communities and scientific research. However, respondents expressed concern regarding declining interest among younger generations in learning traditional medicinal practices. Increased urbanization,

modernization, formal education, and changing cultural values have reduced opportunities for intergenerational knowledge transfer. Unless deliberate efforts are made to document and preserve indigenous healthcare knowledge, both the knowledge and the biodiversity upon which it depends may be irreversibly lost.

The findings corroborate the World Health Organization (WHO, 2023), which estimates that a substantial proportion of the global population, particularly in developing countries, continues to rely on traditional medicine for primary healthcare. The extensive use of medicinal plants documented in this study confirms that indigenous healthcare systems remain highly relevant in improving health accessibility and reducing inequalities in rural settings. The results are also consistent with Berkes (2012), who argues that traditional ecological knowledge represents a cumulative body of knowledge, beliefs, and practices concerning relationships between living organisms and their environment. The ability of respondents to identify medicinal species and appropriate treatment methods illustrates the adaptive nature of indigenous knowledge systems developed through long-term interaction with biodiversity. Similarly, the findings support Gadgil, Berkes, and Folke (1993), who contend that indigenous knowledge contributes simultaneously to biodiversity conservation and sustainable resource utilization. Communities dependent on medicinal plants often develop sustainable harvesting techniques and customary regulations that ensure continued availability of valuable species while minimizing ecological degradation.

The results further align with ethnobotanical studies across tropical Africa demonstrating that forests function as important repositories of pharmaceutical resources. Numerous modern medicines have originated from plant compounds first identified through indigenous knowledge, emphasizing the scientific and economic significance of preserving traditional healthcare systems alongside biodiversity conservation. Moreover, the findings reinforce evidence from Colfer (2008) that forests and human health are intrinsically linked through the provision of medicinal resources, nutritional diversity, clean water, and environmental regulation. Conserving forest ecosystems therefore contributes directly to achieving public health objectives and strengthening community resilience. The findings provide strong empirical support for **Firey's Theory of Resource Use (1960)**, which proposes that natural resource utilization is shaped by ecological conditions, economic needs, and cultural values. The use of medicinal plants reflects not only their economic affordability and ecological availability but also the cultural beliefs.

5.3 Forest-Based Foods and Household Food Security

Food security remains one of the most pressing development challenges facing rural communities in sub-Saharan Africa, where climate variability, declining agricultural productivity, population growth, and environmental degradation continue to threaten household nutritional well-being. Within forest-dependent communities, biodiversity plays a critical role in complementing agricultural production by providing diverse food resources that enhance dietary quality, improve resilience against seasonal food shortages, and reduce household vulnerability. Forest-based foods, including wild fruits, indigenous vegetables, mushrooms, edible insects, honey, nuts, and roots, constitute an important component of traditional food systems that have sustained rural populations for generations. Beyond their nutritional value, these foods embody indigenous ecological knowledge and cultural practices that contribute to sustainable livelihoods and community resilience.

The findings of this study demonstrate that forest biodiversity makes a substantial contribution to household food security among communities surrounding Kakamega Tropical Rainforest. Quantitative results indicate that 78.1% of respondents (26.0% strongly agreed and 52.1% agreed) acknowledged that the forest serves as an important source of food for their households, while only

21.9% expressed disagreement. This high level of agreement underscores the continuing significance of forest foods in supporting household nutrition despite the expansion of agricultural production systems.

The qualitative findings provide deeper insights into the diversity and importance of forest-derived foods. Respondents identified wild fruits, indigenous leafy vegetables, mushrooms, honey, edible insects, medicinal herbs with nutritional properties, and other edible forest products as important dietary supplements that contribute to household food availability throughout the year. Many participants indicated that these resources become particularly valuable during periods of crop failure, prolonged drought, or seasonal food scarcity when agricultural harvests are insufficient to meet household nutritional requirements.

Women participating in focus group discussions emphasized that forest foods play a vital role in improving child nutrition, maternal health, and household dietary diversity. Indigenous vegetables and wild fruits were reported to provide essential vitamins and micronutrients that complement staple cereal-based diets, while mushrooms and edible insects contribute valuable sources of protein. Honey was frequently cited as both a nutritious food and a traditional remedy used to support children's health and strengthen immunity. One female participant explained: *"When vegetables from our farms become scarce, the forest provides indigenous vegetables and fruits that keep our children healthy. Without these foods, many families would experience hunger during the dry season."* Another respondent observed: *"Wild mushrooms and honey are not only food but also a source of income. We eat some and sell the surplus to buy other household necessities."* These narratives demonstrate that forest foods simultaneously support nutrition, income generation, and livelihood diversification, thereby strengthening overall household resilience.

The findings indicate that Kakamega Tropical Rainforest functions as a critical food reserve and nutritional safety net for surrounding communities. The high proportion of respondents acknowledging the contribution of forest foods reflects the continued dependence of rural households on biodiversity for dietary supplementation and food security. Forest-derived foods extend beyond emergency coping mechanisms and constitute regular components of household diets that enhance nutritional quality and cultural food traditions. The diversity of forest foods identified by respondents illustrates the important relationship between biodiversity and dietary diversity. Households with access to a broad range of edible forest species are better positioned to achieve balanced nutrition by supplementing staple crops with fruits, vegetables, mushrooms, and protein-rich foods. Such dietary diversity contributes to improved health outcomes by addressing micronutrient deficiencies and reducing malnutrition among vulnerable populations, particularly women and children. This is in agreement with FAO, 2023 and CIFOR-ICRAF, 2024 who stated that Wild fruits, leafy vegetables, edible insects, mushrooms, and nuts are particularly important during seasonal food shortages and periods of climatic stress.

The findings further demonstrate that forest foods contribute significantly to household resilience during periods of seasonal food insecurity. Climatic variability, crop diseases, fluctuating market prices, and declining agricultural yields frequently undermine rural food systems. Under such conditions, forest biodiversity provides alternative food sources that reduce vulnerability and enable households to withstand temporary production shocks. This buffering function highlights the importance of biodiversity conservation in strengthening adaptive capacity under changing environmental conditions. Another important observation emerging from the qualitative findings is the central role of women as custodians of indigenous food knowledge. Women's expertise in identifying edible plant species, determining harvesting seasons, preparing traditional foods, and preserving indigenous recipes contributes significantly to household nutrition and food sovereignty.

Their knowledge represents an important cultural asset that complements biodiversity conservation and sustainable livelihood strategies. This confirms FAO, (2023) and HLPE, (2023) findings that forests as integral components of sustainable food systems rather than merely emergency food sources, emphasizing their role in supporting healthy diets, resilient livelihoods, and sustainable development.

The findings reinforce the understanding that forests contribute to food security through multiple pathways extending beyond conventional agricultural production. Rather than functioning as isolated ecological systems, forests interact with farming systems to create integrated socio-ecological landscapes capable of supporting diversified livelihoods and resilient food systems. Forest foods supplement cultivated crops, diversify nutrient intake, and reduce dependence on external food markets, particularly among economically vulnerable households. The contribution of wild foods to household nutrition also demonstrates the importance of conserving biodiversity as a strategy for improving public health. Dietary diversity is widely recognized as a key determinant of nutritional status, especially among children and pregnant women. Indigenous fruits and vegetables are often rich in vitamins, minerals, antioxidants, and phytochemicals that contribute to immune function and disease prevention. Consequently, biodiversity loss may have direct nutritional consequences through the disappearance of culturally significant and nutritionally valuable food species. This supports Osewe et al., (2025) that 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

The findings further suggest that traditional ecological knowledge remains fundamental to sustainable food systems. Knowledge regarding the identification of edible species, seasonal availability, harvesting techniques, processing methods, and conservation practices has enabled communities to utilize forest biodiversity sustainably over generations. However, respondents expressed concern that younger generations are increasingly unfamiliar with many indigenous foods due to changing dietary preferences, urbanization, and modernization. This erosion of traditional food knowledge may weaken future food security by reducing dietary diversity and increasing dependence on commercially produced foods. The role of women highlighted in this study also deserves particular attention. As primary food providers and custodians of household nutrition, women play a critical role in linking biodiversity conservation to food security outcomes. Policies promoting women's participation in forest governance and indigenous food conservation may therefore generate significant benefits for both biodiversity protection and household well-being. This confirms the findings of IPBES, (2022) and UNESCO, (2023) who stated that these indigenous governance mechanisms contribute to biodiversity conservation while ensuring continued access to ecosystem services.

The findings corroborate the Food and Agriculture Organization (FAO, 2023), which recognizes forests as integral components of sustainable food systems through their provision of edible plants, fruits, nuts, mushrooms, honey, insects, and wild meat that contribute to food security and nutritional diversity. The diversity of forest foods reported by respondents reflects the multifunctional role of forests in supporting healthy diets and resilient livelihoods. The results are also consistent with Powell et al. (2015), who demonstrated that access to forests is positively associated with improved dietary diversity and micronutrient intake among rural households in tropical regions. Their findings suggest that biodiversity-rich landscapes provide important nutritional benefits that cannot be fully replaced by agricultural production alone. Similarly, the study supports the work of Johns and Sthapit (2004), who argue that biodiversity conservation and nutrition are mutually reinforcing objectives because diverse ecosystems sustain diverse diets that

contribute to human health and resilience. The reliance on indigenous vegetables, wild fruits, and mushrooms documented in this study illustrates the close relationship between ecosystem integrity and nutritional security. The findings further align with Bharucha and Pretty (2010), who emphasize that wild foods continue to provide essential dietary resources for millions of rural households worldwide, particularly during periods of food scarcity and environmental stress. The respondents' characterization of forest foods as seasonal safety nets strongly reflects this global pattern. Moreover, the findings resonate with ethnobiological research demonstrating that indigenous food systems represent valuable repositories of ecological knowledge and cultural identity. Traditional knowledge concerning edible species contributes not only to food security but also to biodiversity conservation through sustainable harvesting practices and local stewardship of ecosystems.

The findings strongly support the Sustainable Livelihoods Approach (SLA) by demonstrating how natural capital, in the form of forest biodiversity, contributes directly to household food security and nutritional well-being. Forest foods complement agricultural production, diversify livelihood options, and strengthen household resilience during periods of environmental and economic stress. Indigenous knowledge regarding edible species represents human and cultural capital, while community sharing of food resources reflects social capital, illustrating the interconnected nature of livelihood assets within rural communities. The results also reinforce Firey's Theory of Resource Use (1960), which argues that natural resource utilization is shaped by the interaction of ecological opportunities, economic needs, and cultural values. The collection and consumption of forest foods are not driven solely by subsistence needs but are embedded within cultural traditions, indigenous knowledge systems, and locally developed resource management practices that promote sustainable harvesting and ecological stewardship.

From the perspective of Social-Ecological Systems Theory, the findings illustrate the reciprocal relationship between ecosystem health and human food security. Healthy forests provide diverse food resources that sustain household nutrition, while community dependence on these resources creates incentives for biodiversity conservation. Conversely, biodiversity loss diminishes food availability, dietary diversity, and community resilience, demonstrating the inseparable relationship between ecological integrity and human well-being. The findings provide compelling evidence that Kakamega Tropical Rainforest functions not merely as a reservoir of biodiversity but as a living food system that underpins household nutrition, dietary diversity, and community resilience. Forest-based foods constitute an often-overlooked component of rural food security strategies, yet their contribution extends far beyond emergency coping mechanisms to encompass year-round nutritional supplementation, cultural continuity, and livelihood diversification. In the author's view, biodiversity conservation should be recognized as an integral component of national food security policy rather than being confined to environmental management frameworks. Conservation strategies that protect indigenous food species, strengthen women's roles as custodians of traditional food knowledge, and promote the sustainable utilization of forest-based foods can simultaneously advance biodiversity conservation, nutritional security, and sustainable rural development. Preserving Kakamega Tropical Rainforest therefore represents an investment not only in ecological sustainability but also in healthier, more resilient, and food-secure communities whose well-being remains intimately connected to the conservation of biological and cultural diversity.

5.4 Community Participation in Biodiversity Conservation

The results demonstrate high levels of community engagement in forest conservation. Approximately 91.2% of respondents agreed that local communities participate in forest

management, while 91.1% reported involvement in biodiversity conservation activities. Participation in rehabilitation programmes was also substantial.

Table 2. Community participation in forest conservation activities (N = 384)

Activity	SA (%)	A (%)	D (%)	SD (%)
Forest management	52.1	39.1	8.9	0.0
Forest rehabilitation	50.5	26.0	15.6	7.9
Conservation activities	26.0	65.1	5.2	3.7

5.5 Perceptions of Government Conservation Strategies

Government policies and institutional interventions play a critical role in shaping biodiversity conservation outcomes and promoting sustainable forest management. Over the past three decades, forest governance has progressively shifted from centralized, command-and-control approaches towards participatory and collaborative management frameworks that recognize the importance of local communities, civil society organizations, and other stakeholders in conserving forest ecosystems. In Kenya, the adoption of Participatory Forest Management (PFM), the establishment of Community Forest Associations (CFAs), promotion of farm forestry, and partnerships with faith-based organizations and non-governmental institutions have transformed conservation from an exclusively state-led function into a shared responsibility. Evaluating community perceptions of these conservation strategies is essential because public acceptance and local support significantly influence the effectiveness and sustainability of conservation interventions. The present study sought to assess respondents' perceptions regarding the effectiveness of selected government and stakeholder-led conservation strategies implemented around Kakamega Tropical Rainforest. The findings presented in Table 3 indicate strong support for participatory and incentive-based approaches to biodiversity conservation.

Table 3. Perceived effectiveness of government conservation strategies (N = 384)

Strategy	Strongly Agree (%)	Agree (%)	Disagree (%)	Strongly Disagree (%)
Incentive-based forestry	26.0	52.1	13.0	8.9
Protectionist approach	0.0	78.1	13.0	8.9
Faith-based incentives	26.0	65.1	4.4	4.4
Community participation	0.0	91.1	2.6	6.3
Farm forestry	65.1	26.0	8.9	0.0

The findings demonstrate that respondents strongly favour participatory and incentive-based conservation strategies over purely regulatory approaches. Among the strategies assessed, community participation emerged as one of the most highly endorsed interventions, with 91.1% of respondents agreeing that it constitutes an effective mechanism for sustainable forest conservation. Only 8.9% expressed disagreement or strong disagreement. This overwhelming support suggests that local communities perceive their active involvement in conservation planning, decision-making, and implementation as fundamental to the long-term sustainability of Kakamega Tropical Rainforest.

Similarly, the promotion of farm forestry received exceptionally high approval, with 91.1% of respondents (65.1% strongly agreeing and 26.0% agreeing) recognizing its effectiveness in reducing pressure on natural forests while simultaneously supporting household livelihoods. Respondents indicated that tree planting on farms provides fuelwood, timber, fodder, fruits, and other ecosystem services that reduce dependence on protected forest areas. The particularly high proportion of respondents who strongly agreed (65.1%) reflects widespread appreciation of farm forestry as both a conservation and livelihood strategy.

The findings also reveal substantial support for faith-based conservation incentives, with 91.1% of respondents acknowledging their positive contribution to biodiversity conservation. Churches and faith-based organizations were perceived as influential institutions in promoting environmental awareness, mobilizing communities for tree planting activities, supporting environmental education, and reinforcing moral responsibility for environmental stewardship. This finding highlights the important role of religious institutions as partners in community-based conservation.

Regarding incentive-based forestry programmes, 78.1% of respondents agreed that incentives implemented through government agencies encourage sustainable forest management. These incentives include access to seedlings, livelihood support programmes, community benefit-sharing arrangements, environmental education, and opportunities for participatory forest management. The findings suggest that positive incentives are viewed as more effective in promoting conservation behaviour than punitive enforcement measures alone.

Although the protectionist approach also received considerable support, with 78.1% of respondents agreeing that it contributes to forest conservation, its level of endorsement was lower than that of participatory and incentive-based strategies. This may indicate recognition of the importance of legal protection while simultaneously reflecting community preference for approaches that integrate local participation and shared benefits rather than relying exclusively on restrictive regulations.

The findings illustrate a clear preference among local communities for inclusive, participatory, and collaborative conservation strategies that recognize communities as partners in biodiversity conservation rather than merely subjects of regulation. Respondents appear to perceive conservation as most effective when local people are empowered to participate actively in decision-making and derive tangible socio-economic benefits from sustainable resource management. The strong support for community participation reflects increasing recognition that local stewardship enhances conservation effectiveness by fostering ownership, accountability, and long-term commitment to environmental protection. Communities living adjacent to Kakamega Tropical Rainforest possess detailed ecological knowledge, cultural values, and practical experience that can complement scientific management and improve adaptive conservation strategies. Their participation also strengthens compliance with conservation regulations because communities are more likely to support policies that they help formulate and implement.

The high endorsement of farm forestry underscores its strategic importance as a mechanism for balancing livelihood needs with biodiversity conservation. By producing timber, fuelwood, fodder, fruits, and other products on private land, farm forestry reduces harvesting pressure on natural forests while generating economic and environmental benefits for rural households. It also contributes to carbon sequestration, soil conservation, watershed protection, and landscape restoration, thereby extending conservation benefits beyond protected areas. The positive perception of faith-based conservation initiatives is particularly noteworthy because it demonstrates that biodiversity conservation extends beyond ecological and economic considerations to encompass ethical, moral, and cultural dimensions. Religious institutions often

possess extensive community networks and moral authority that enable them to influence environmental behaviour and promote stewardship values rooted in spiritual teachings. Their involvement broadens the institutional foundation for conservation and enhances community mobilization. The comparatively lower support for purely protectionist approaches suggests that while communities recognize the necessity of legal regulation and enforcement, they may perceive exclusionary conservation models as less effective in achieving sustainable outcomes.

Conservation strategies that restrict resource access without providing alternative livelihood opportunities or community benefits may generate resistance and undermine local support. The findings therefore reinforce the growing consensus that successful biodiversity conservation requires balancing ecological protection with social equity and livelihood security. The findings strongly corroborate Ostrom (1990), who demonstrated that participatory governance and collective action often produce more sustainable outcomes than centralized resource management systems. The overwhelming support for community participation observed in this study reflects the effectiveness of locally grounded institutions in promoting responsible resource stewardship and biodiversity conservation.

The results are also consistent with Pretty and Smith (2004), who argue that participatory environmental governance enhances conservation by strengthening local ownership, social learning, and collective responsibility. Communities actively engaged in conservation are more likely to develop long-term commitments to ecosystem protection and sustainable resource use. Similarly, the findings align with Agrawal and Gibson (1999), who emphasize that conservation initiatives achieve greater success when local institutions are recognized and communities are empowered to participate in resource governance. The respondents' strong endorsement of participatory approaches reinforces the importance of decentralization and collaborative management within forest conservation policy.

The widespread support for farm forestry corroborates studies by the Food and Agriculture Organization (FAO, 2022) demonstrating that agroforestry systems contribute simultaneously to biodiversity conservation, climate change mitigation, livelihood diversification, and food security. Farm forestry enhances landscape connectivity, reduces pressure on natural forests, and provides sustainable sources of forest products for rural households. The findings also resonate with literature highlighting the role of faith-based organizations in environmental governance. Scholars have increasingly recognized that religious institutions influence environmental ethics, promote stewardship values, and mobilize communities for conservation initiatives through education, advocacy, and collective action. The positive perception of faith-based incentives observed in this study reflects this expanding role of religious organizations in biodiversity conservation. Furthermore, the results support the Convention on Biological Diversity's emphasis on inclusive governance and stakeholder participation as essential principles for achieving effective biodiversity conservation and sustainable use of biological resources.

The findings provide strong empirical support for Firey's Theory of Resource Use (1960), which proposes that resource management decisions are shaped by the interaction of ecological realities, economic incentives, and socio-cultural values. The preference for incentive-based and participatory conservation strategies demonstrates that communities value approaches that integrate livelihood benefits with cultural norms of stewardship and ecological sustainability. Conservation is therefore perceived not merely as regulatory compliance but as a socially embedded process influenced by local values and collective interests. The results equally reinforce the Sustainable Livelihoods Approach (SLA). Community participation, farm forestry, and incentive programmes strengthen multiple livelihood capitals simultaneously. Farm forestry

enhances natural capital through tree cover restoration, increases financial capital through income generation, strengthens human capital through skills development and environmental education, and builds social capital through collective action and institutional collaboration. These interconnected livelihood assets enhance household resilience while promoting biodiversity conservation.

The findings are also highly consistent with Social-Ecological Systems Theory, which conceptualizes conservation as an adaptive process emerging from interactions between ecological systems, governance institutions, and human communities. Participatory governance strengthens feedback mechanisms between ecosystem conditions and community responses, thereby enhancing the resilience of both social and ecological systems. Incentive-based approaches create positive feedback loops that encourage sustainable behaviour while maintaining ecosystem functions essential for long-term well-being. Finally, the results align with the principles of Collaborative Governance Theory, which argues that shared decision-making among governments, communities, civil society organizations, and other stakeholders generates more legitimate, effective, and sustainable environmental outcomes than unilateral regulatory approaches.

The strong endorsement of community participation and faith-based initiatives illustrates the value of multi-stakeholder partnerships in forest governance. The findings provide compelling evidence that the future of biodiversity conservation in Kakamega Tropical Rainforest lies in collaborative rather than coercive governance. While legal protection remains necessary for safeguarding ecologically sensitive areas, conservation strategies that empower communities, promote farm forestry, and utilize locally trusted institutions such as faith-based organizations are likely to generate stronger and more enduring conservation outcomes.

In the author's view, government conservation policy should move beyond traditional protectionist paradigms toward integrated landscape governance that simultaneously addresses biodiversity conservation, household livelihoods, food security, and human health. Expanding participatory forest management, strengthening Community Forest Associations, scaling up farm forestry programmes, institutionalizing incentive-based conservation mechanisms, and fostering partnerships with religious and community organizations would create a more inclusive and resilient conservation framework. Such an approach recognizes that biodiversity conservation is ultimately a social as well as an ecological endeavour, and that sustainable management of Kakamega Tropical Rainforest will be achieved most effectively when local communities are empowered as co-managers and beneficiaries of the ecosystem they have helped sustain for generations.

6. Recommendations

Based on the findings of the study, the following recommendations are proposed for policymakers, conservation agencies, development practitioners, researchers, and local communities.

6.1 Strengthen Documentation and Preservation of Indigenous Ecological Knowledge

Traditional ecological knowledge is rapidly declining due to modernization, urbanization, and changing socio-cultural values. National and county governments, universities, research institutions, and cultural organizations should establish comprehensive programmes for documenting indigenous knowledge relating to medicinal plants, edible forest species, sustainable harvesting practices, and biodiversity management. Community elders and traditional knowledge holders should be actively involved in recording and transmitting this knowledge to younger generations through formal and informal educational platforms.

6.2 Integrate Indigenous Knowledge into Biodiversity Conservation Policies

Forest governance frameworks should move beyond conventional scientific approaches by formally recognizing indigenous ecological knowledge as an important component of biodiversity conservation. Government agencies such as the Kenya Forest Service (KFS), Kenya Wildlife Service (KWS), and county governments should incorporate traditional conservation practices into forest management plans and strengthen collaboration with Community Forest Associations and indigenous knowledge holders.

6.3 Promote Community-Based Forest Management

The study demonstrates that local communities possess strong conservation values and actively participate in biodiversity protection. Participatory Forest Management should therefore be expanded through strengthened Community Forest Associations, inclusive decision-making processes, equitable benefit-sharing mechanisms, and greater community representation in forest governance institutions. Empowering local communities as co-managers will enhance conservation effectiveness while strengthening local ownership and accountability.

6.4 Scale Up Farm Forestry and Agroforestry Programmes

Promotion of farm forestry emerged as one of the most highly supported conservation strategies. National and county governments should increase investments in agroforestry through the provision of quality tree seedlings, technical extension services, financial incentives, and market support for tree-based products. Farm forestry will reduce pressure on natural forests while improving household incomes, food security, carbon sequestration, and climate resilience.

6.5 Strengthen Conservation of Indigenous Medicinal Plants

Given the critical role of medicinal plants in household healthcare, targeted conservation programmes should prioritize threatened medicinal species through community nurseries, botanical gardens, domestication initiatives, and in situ conservation within forest ecosystems. Collaboration between traditional healers, health professionals, universities, and conservation agencies could facilitate scientific validation, sustainable utilization, and preservation of indigenous pharmacological resources.

6.6 Mainstream Forest Biodiversity into Food and Nutrition Security Policies

The findings demonstrate that forest foods significantly enhance dietary diversity and household nutrition. Government food security programmes should recognize indigenous forest foods as strategic nutritional resources by promoting their conservation, domestication, value addition, and inclusion in nutrition education programmes. School feeding initiatives and community nutrition programmes should incorporate indigenous food biodiversity where appropriate to improve dietary quality and cultural food preservation.

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