Journal of Wildlife and Conservation (JWC)

ISSN: 3070-3689 (ONLINE)

VOLUME 2 ISSUE 1 (2026)

PUBLISHED BY
E-PALLI PUBLISHERS, DELAWARE, USA

Journal of Wildlife and Conservation (JWC)

Volume 2 Issue 1, Year 2026
ISSN: 3070-3689 (Online)
DOI: https://doi.org/10.54536/jwc.v2i1.7477
https://journals.e-palli.com/home/index.php/jwc

Socio-Ecological Determinants of Community Vulnerability to Indirect Effects of Human-Elephant Interactions Around Mikumi National Park,Tanzania

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Article Information

Received: February 05, 2026

Accepted: April 14, 2026

Published: August 11, 2026

Keywords

Conflict Severity, Conflict Vulnerability, Demographic Factors, Human-Elephant Conflict, Socio-Ecological Factors

ABSTRACT

Human–elephant interactions (HEI) pose significant challenges to communities living adjacent to protected areas in Tanzania, generating not only direct effects such as crop loss, property damage and human deaths but also indirect effects such as fear, psychosocial stress and disrupted livelihoods. Despite these profound consequences, the socio-ecological and demographic factors shaping the vulnerability to these effects remain poorly understood, limiting the effectiveness of mitigation strategies. This study investigates the determinants of community vulnerability to the indirect effects of Human-elephant interactions in 10 villages surrounding Mikumi National Park (MNP). Demographic and socio-ecological data were collected from 405 households through structured questionnaire surveys and analyzed using ordinal logistic regression to identify predictors of conflict severity and household vulnerability. Results indicate that distance to park boundary and seasonal variations, female headed households, widowed individuals, education levels, crop farming and household size significantly influence vulnerability to indirect HEI effects. These findings underscore the importance of understanding socio-ecological determinants to inform participatory, context-sensitive conflict management strategies that integrate community education, landscape-level planning, and targeted support for high-risk households, ultimately fostering sustainable human–elephant coexistence.

INTRODUCTION

Human–elephant interactions, often conceptualized as human–elephant conflict, pose significant challenges in landscapes where humans and elephants coexist (Nyirenda *et al.*, 2018; Thekaekara *et al.*, 2021). While the direct effects of these interactions such as crop loss, property damage, and injury or death are well documented and readily observable (Hariohay *et al.*, 2020; Mamboleo *et al.*, 2021), the indirect effects are subtler yet impose substantial burdens on affected communities (Barua *et al.*, 2013; Mayberry *et al.*, 2017). These indirect effects include fear, disruption of daily activities, opportunity costs from time spent guarding crops and loss of livelihood opportunities, psychosocial stress, restricted movements and social engagement (Barua *et al.*, 2013; Mayberry *et al.*, 2017). Understanding factors influencing communities' vulnerability for indirect consequences of human-elephant interactions is therefore crucial for developing effective mitigation strategies and fostering sustainable coexistence between humans and elephants.

The severity of psychosocial effects from human–elephant interactions is influenced by a combination of biophysical and socio-ecological factors that increase vulnerability among different social groups (Barua *et al.*, 2013). For instance, the death or injury of the primary breadwinner—often a male in low-income country contexts shifts household responsibilities onto women or children, exacerbating family debts and pre-existing poverty (Jadhav & Barua, 2012; Barua *et al.*, 2013). Similarly, when a female household member is killed or injured, children often assume domestic and caregiving roles, leading to reduced school attendance, disrupted parent–child relationships, and impaired child development (Lamarque *et al.*, 2009; Barua *et al.*, 2013). These examples illustrate how demographic and socio-ecological factors shape the severity of indirect effects, emphasizing the need to understand why some individuals or communities are more vulnerable.

Studies examining socio-ecological and demographic drivers of human–elephant interactions have been conducted in multiple landscapes across Africa and Asia, providing insights into factors that shape community vulnerability towards elephant impacts. In Sri Lanka, Köpke *et al.* (2024) applied statistical models to assess household-level vulnerability to human–elephant conflicts demonstrating that spatial exposure, dependence on agriculture, and socio-demographic characteristics strongly influenced conflict severity. Similarly, in Hwange, Zimbabwe, Guerbois *et al.* (2012) revealed that vulnerability to elephant crop raiding was determined by proximity to protected areas, investment in mitigation, and collective action among neighboring households. Comparable findings were reported by Nyirenda *et al.* (2018) in Zambia, where subsistence farmers with limited adaptive capacity were more severely affected by elephant incursions. Pereira *et al.* (2024) further highlighted that livelihood vulnerability mediates how communities experience human–wildlife interactions across protected areas. In Tanzania,

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Hariohay *et al.* (2020) observed strong seasonal patterns of elephant incursions in central Tanzania, consistent with seasonal effects noted around MNP.

While these studies provide important insights into direct effects of elephant interactions, few have explicitly quantitatively linked indirect effects such as psychosocial stress, restricted mobility, and livelihood disruption to household socio-demographic and spatial predictors. This study addresses this gap by assessing the factors influencing the severity and vulnerability of indirect effects of human–elephant interactions in ten villages surrounding MNP.

LITERATURE REVIEW

Human–Elephant Interactions and Human–Wildlife Conflict

Human–elephant interactions (HEI) are a specific and highly consequential form of human–wildlife conflict (HWC), arising when elephants and humans share landscapes and compete for limited resources such as land, water, and crops. These interactions are driven by the overlap between elephant habitats and human settlements, agricultural expansion, and landscape fragmentation (Santiapillai, 2004; Sitati *et al.*, 2005). In many African contexts, HEI is exacerbated by habitat loss due to deforestation, conversion of land for agriculture, and encroachment into wildlife corridors, which forces elephants to venture into farmland in search of food i.e. (Sitati *et al.*, 2005; Gross *et al.*, 2022).

In Tanzania, particularly around protected areas like MNP, HEI is a persistent challenge for rural communities. Studies have documented recurring crop raiding, property destruction, and human injuries or fatalities, often resulting in significant economic and social stress for households dependent on subsistence farming (Sitati & Walpole, 2006; Gross *et al.*, 2022). Crop raiding typically peaks during periods when natural forage in the park is scarce, such as dry seasons, causing elephants to target high-yield agricultural fields in surrounding villages. This seasonal behavior highlights the spatial and temporal variability of HEI, which complicates mitigation efforts and necessitates context-specific strategies (Sampson *et al.*, 2021).

Beyond direct physical and economic losses, HEI can generate profound indirect social and psychological impacts. Households may experience reduced labor availability as members guard fields, diminished school attendance, and heightened anxiety about potential encounters with elephants (Santiapillai, 2004; Sampson *et al.*, 2021). Moreover, repeated interactions can strain community cohesion and trust in local governance structures if mitigation measures are perceived as inadequate or inconsistently applied (Kolinski & Milich, 2021). Such indirect effects often persist long after individual incidents of crop raiding or property damage, highlighting the multi-dimensional vulnerability of communities in human-elephant landscapes. This study aligns with evidence from Mount Galim-Tignère National Park, Cameroon, where human–wildlife interaction effects extend beyond direct damage to significant indirect costs, central to vulnerability, while local adaptations signal resilience, underscoring the need for integrated socio-ecological management approaches (Ngnaniyyi *et al.*, 2026).

Research further indicates that HEI is not uniform across villages. Factors such as proximity to park boundaries, settlement density, agricultural practices, and elephant movement patterns produce spatial differences in the frequency and severity of conflict (Sitati *et al.*, 2005; Gross *et al.*, 2022). Understanding these socio-ecological drivers is critical for designing effective conflict mitigation strategies and for predicting which communities are most vulnerable to both direct and indirect effects of HEI.

Conceptual framework for Human-elephant interactions

To guide the empirical focus of this study, a conceptual framework integrating Human–Wildlife Conflict (HWC) theory and Social–Ecological Systems (SES) theory is adopted to examine how socio-ecological factors shape human–elephant interactions (HEI) (Fig. 1). The framework links ecological processes, human wellbeing, institutional governance, community resilience, and adaptive capacity to both direct and indirect effects of HEI, emphasizing feedback loops through which repeated interactions influence community attitudes, governance responses, and long-term coexistence outcomes (Barua *et al.*, 2013; Shaffer *et al.*, 2019; Zang *et al.*, 2024). Indirect effects, including loss of safety, psychosocial stress, disrupted routines, and food insecurity, accumulation over time, affecting household and community wellbeing (Jadhav & Barua, 2012; Mayberry *et al.*, 2017).

Central to the framework are ecological and landscape drivers such as elephants and human population densities, shared access to water and forage, and land-use patterns around protected areas. Habitat fragmentation, agricultural expansion, and settlement growth increase spatial overlap between farms and elephant movement routes, triggering crop raiding, property damage, night-time guarding, and household tensions (Barua *et al.*, 2013; Shaffer *et al.*, 2019; Zang *et al.*, 2024). In Tanzanian landscapes like Mikumi, these factors strongly influence the spatial-temporal distribution of elephant foraging into human-dominated areas (Sampson *et al.*, 2021; Tripathy *et al.*, 2022).

HEI produces direct effects, including crop loss, property and livestock damage, and occasional human injury, which in turn generate indirect effects such as psychosocial stress, disrupted routines, reduced productivity, food insecurity, and economic vulnerability (Sitati *et al.*, 2003; Nyumba *et al.*, 2020; Sampson *et al.*, 2021). Psychosocial impacts include fear, anxiety, and sleep disruption, affecting household dynamics and mental wellbeing (Barua *et al.*, 2013;

Mayberry *et al.*, 2017). Institutional interventions, including compensation, fencing, chili-based deterrents, and community engagement, moderate HEI outcomes. However, perceived inefficiencies may erode trust in governance and reduce tolerance for elephants (Naughton-Treves *et al.*, 1999; Ogra & Badola, 2008; Zang *et al.*, 2024). Household and community factors, such as wealth, livelihood options, social networks, and farm location, further shape vulnerability (Barua *et al.*, 2013; Nyumba *et al.*, 2020). Overall, the framework links ecological drivers, socio-economic vulnerabilities, and governance responses to both direct and indirect HEI impacts, emphasizing feedback loops that influence community wellbeing and conservation outcomes, providing a foundation for evidence-based interventions in Mikumi and similar landscapes.

Guided by conceptual framework model of human–elephant interactions, the current study situates indirect effects within the causal pathway initiated by direct effects of HEI. By linking demographic and socio-ecological factors to the framework, the analysis is expected to reveal why some households bear disproportionate vulnerability and severity of impacts. This ensures that predictors are interpreted not just statistically, but in the context of established theories on human–elephant coexistence and community resilience. This study explores how such factors influence community vulnerability to the indirect effects of human–elephant

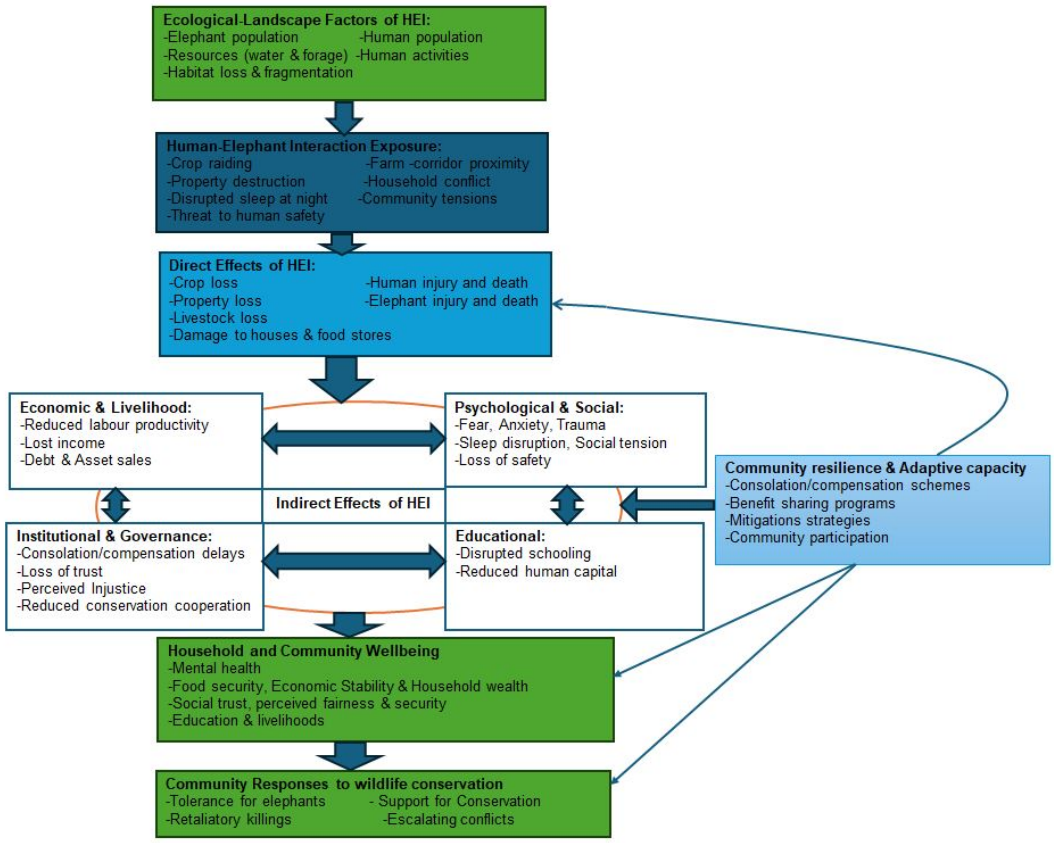

Figure 1: Conceptual framework model for human-elephant interactions illustrating how socio-ecological factors interact to produce direct and indirect effects (Adopted from Human–Wildlife Conflict theory & Social–Ecological System theory)

interactions in villages adjacent to MNP.

MATERIALS AND METHODS

Study area

The study was conducted in ten villages adjacent to MNP in southeastern Tanzania: Mikumi, Ihombwe, Kitunduweta, Mhenda, Mbamba, Kiduhi, Kilangali, Mkata, Doma, and Maharaka (Gunn *et al.*, 2013; Fig. 2). These villages lie within the broader Nyerere–Mikumi–Selous landscape, which supports one of Tanzania's largest elephant populations, estimated at approximately 15,217 individuals (Lohay *et al.*, 2020). Human–elephant interactions in this region have led to conflicts over crops, property, and human safety, including injuries, fatalities, and retaliatory killings of elephants (Gunn *et al.*, 2013; Mayengo *et al.*, 2017).

The landscape features mixed woodland mosaics, an average annual rainfall of 860 mm, and a mean temperature of 25.5 °C (Gunn *et al.*, 2013), creating ecological conditions that influence elephant movements and interactions with human settlements. Livelihoods in these communities are predominantly crop farming and pastoralism. The combination of environmental, ecological, and socio-demographic factors forms the

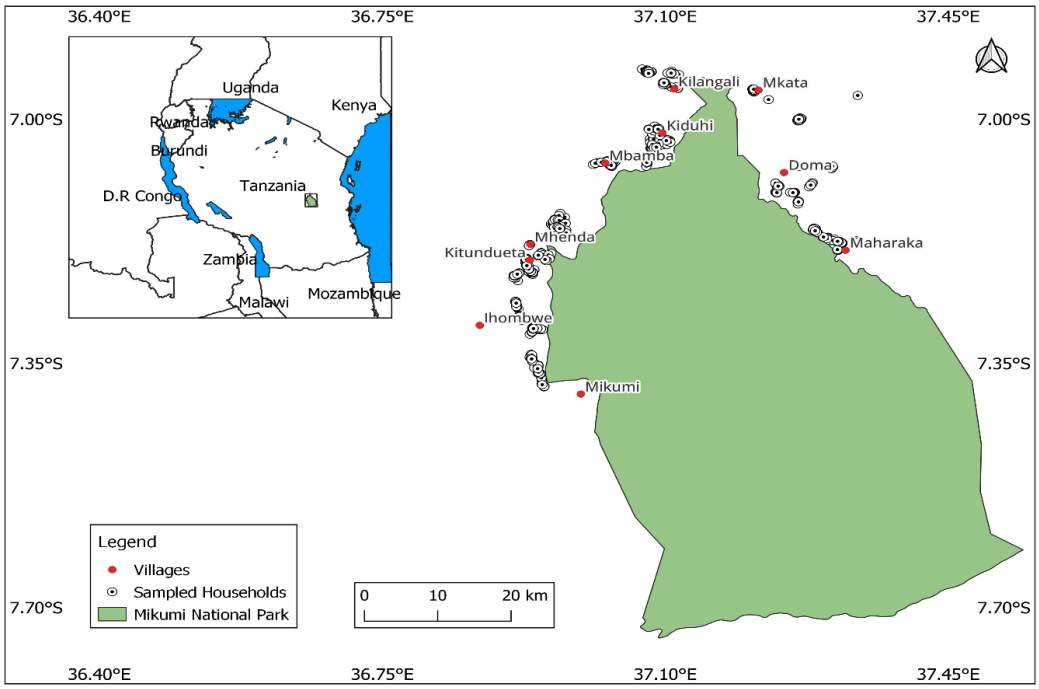

Figure 2: Figure 2 Locations of sampled households in villages adjacent to MNP (January-December 2023)

backdrop for understanding the vulnerability and severity of indirect effects of human–elephant interactions.

Study design and sampling strategy

The study employed a repeated cross-sectional observation design to collect primary data using closed and open-ended questionnaires through household surveys during wet and dry seasons of 2023, Primary data on household surveys were conducted to 405 households from Ten (10) villages (roughly 40 households per village) directly bordering MNP, purposely selected considering history of presence of elephant conflicts, and accessibility. The sample size was determined using Cochran's formula 1977 shown in equation (1) to ensure statistical representativeness.

Where is the required sample size, corresponds to the 95% confidence level, is the estimated population

$$n_0 = \frac{Z^2 \cdot P \cdot Q}{e^2} \ldots\ldots\ldots (1)$$

proportion to maximize sample size, , and represents the 5% margin of error.

Household selection followed a systematic sampling approach. The first household was selected from the one nearest the village office, and subsequent households were chosen using a sampling interval calculated by dividing the total number of households in each village by 40. Only 1 respondent from each household was interviewed from either household heads, spouses, or any other adult aged 18 years older who had resided in the household for at least 12 months. Questionnaires were translated into Kiswahili and pretested on 20 households in Sewe and Mangae villages neighboring villages. These pretested villages did not participate in the survey.

Furthermore, prior to data collection, ethical clearance and research permits were obtained from relevant national institutions and local government authorities. Study objectives were clearly explained to respondents, and verbally informed consent was secured, with participation being entirely voluntary and without financial incentives. Strict confidentiality and anonymity were maintained throughout the research. Also, interviews with households affected by severe elephant-related losses, including injury or death of family members, were conducted sensitively to minimize emotional distress.

Data collection methods

We collected data on households' demographics and socio-ecological data and linked them with indirect effects of human-elephant interactions through household questionnaire surveys, where respondents were asked to rate how presence of elephants indirectly affected their well-being on 5 points Likert scales from 1= Not affected at all to 5= Extremely affected. Household demographics (Table 1), and socio-ecological data including distance from household to park boundaries, position of household with respect to wildlife corridors, and seasonality and socio-ecological variables were assessed to predict their contribution towards communities' vulnerability to indirect effects of human-elephant interactions as in Köpke *et al.* (2024). GPS coordinate positions for each of the households with indirect effects were further recorded to enable estimations of distance

of the households to the park boundary.

Data analysis

Ordinal logistic regression analysis was conducted in RStudio version 4.3.1 (R Core Team, 2020) to examine the association between ordinal response categories of severity and selected predictor variables. The proportional odds model was implemented using the polr () function in the R package MASS. The dependent variable (severity of indirect effects of human–elephant interactions) was explicitly coded as an ordered factor to satisfy the assumptions of ordinal logistic regression. Explanatory variables included distance from the nearest park boundary, position relative to wildlife corridors, seasonality, gender, marital status, education level, respondent occupation, and household size, consistent with approaches used by Köpke *et al.* (2024). Model fitting was performed using maximum likelihood estimation, and the argument Hess = TRUE was specified to obtain the Hessian matrix for reliable estimation of standard errors.

Model outputs were processed and organized using the tidy () function from the broom package, which generated log-odds coefficients, standard errors, and corresponding z-statistics. Statistical significance of predictors was assessed at conventional thresholds, enabling identification of key socio-ecological determinants influencing the severity of indirect effects associated with human–elephant interactions.

RESULTS AND DISCUSSION

Demographic and livelihood characteristics of respondents

The demographic and livelihood characteristics of the participants of this survey are detailed in table 1. Males constituted 54.6% (221) of respondents, while females accounted for 45.4% (184), for age distribution, most respondents were in the economically active age group (26–55 years), totaling 258 individuals (63.6%). For education status, 96 respondents (23.7%) had no formal education, while 23 (5.7%) were primary school dropouts. The majority, 259 respondents (64.0%), had completed primary education. Only 22 (5.4%) had secondary education, 3 (0.7%) had tertiary education, and 2 (0.5%) had university education. While in terms of occupation, most respondents were primarily farmers. A total of 333 respondents (82.2%) depended solely on farming. Others combined farming with pastoralism (39 respondents, 9.6%) or farming with business (28 respondents, 6.9%). Only 5 respondents (1.2%) were exclusively pastoralists.

These results indicate the dominance of respondents in the 26–55 age range implying that community members dealing with agricultural production bear the greatest burden of indirect effects, including disrupted farming schedules, increased labor demands, and income instability. Also, low education levels limit access to diversified livelihoods, formal employment, and information on effective mitigation strategies. Finally, the overwhelming reliance on farming (over 90% engaged in agriculture in some form) makes households highly exposed to crop raiding, likely to intensify indirect effects such as food insecurity, reduced income, increased opportunity costs, and psychological stress.

The predominance of young to middle-aged respondents suggests that the study captured perspectives from individuals actively engaged in farming, thereby providing relevant insights into how elephant presence generates

Table 1: Socio-demographic characteristics of surveyed households around MNP

Characteristic	Characteristic variable	Frequency (%)
Gender	Male	221 (54.6%)
	Female	184 (45.4%)
Age category	18-25 Years	36(9%)
	26-35 Years	83(20.5%)
	36-45 Years	89(21.9%)
	46-55 Years	86(21.2%)
	56-65 Years	58(14.3%)
	65+ Years	53(13.1%)
Education status	No formal education	96(23.7%)
	Primary school drop-out	23(5.7%)
	Primary education	259(64%)
	Secondary education	22(5.4%)
	Tertiary education	3(0.7%)
	University education	2(0.5%)
Occupation	Farming	333(82.2%)
	Farming & Business	28(6.9%)
	Farming & Pastoralist	39(9.6%)
	Pastoralist	5(1.2%)

opportunity costs in agricultural livelihoods (Shokirov *et al.*, 2021). The higher representation of males is consistent with their greater involvement in farm cultivation, crop guarding, and confronting elephants, which likely enabled more direct observations of human–elephant interactions. This aligns with Liendekiye *et al.* (2022), who found that men are often more affected by human–wildlife conflict because they are typically the first to confront problem animals like elephants. Low education levels among respondents may constrain awareness of formal procedures for reporting damages and accessing compensation for elephant-related losses, supporting findings by Xu *et al.* (2020). Finally, the strong dependence on farming increases household exposure to crop-raiding elephants, consistent with Laverty *et al.* (2019), who noted that agricultural activities near protected areas heighten the likelihood of human–wildlife conflict.

Overall, study was dominated by respondents who are economically active, low-educated, and farming-dependent members who are more exposed to elephant-related risks while having limited capacity to adapt or access consolation mechanisms. Gender roles shape how indirect effects of HEI are experienced, with men facing greater physical risks and women bearing greater livelihood and food security burdens from crop losses.

Socio-Ecological Factors

Results of the ordinal logistic regression (OLR) analysis identified several factors influencing households' vulnerability to the indirect effects of human–elephant interactions (Appendix 1). Distance from the park boundary to farm/household had a small but significant effect (Estimate = −0.00009, z = −2.57), indicating that households located far from the park boundaries generally reported less severe effects. For seasonality, wet season has significant impact on the severity of indirect effects than dry season (Estimate = 1.347, z = 12.521).

For gender disparity, male-headed households were less likely to experience severe effects (Estimate = −0.071, z = −2.10) compared to female-headed ones. For marital status, widowed households were slightly more likely to report severe impacts (Estimate = 0.015, z = 1.99). By contrast, separated (Estimate = −0.057, z = −35.98) and single households (Estimate = −0.488, z = −184.69) were much less likely to experience more effects compared to married individuals (Estimate = 0.029, z = 0.95, not statistically significant). Education level was particularly strong factor. Households with only primary education were somewhat more likely to report severe impacts (Estimate = 0.487, z = 16.81), while those with secondary (Estimate = 0.643, z = 1,016), tertiary (Estimate = 1.332, z = 14,614), and university education (Estimate = 1.429, z = 14,357) reported much higher severity. In contrast, households that dropped out of primary school reported much lower severity (Estimate = −0.362, z = −228.35). This suggests that having education might increase awareness and reporting of indirect effects.

Occupation also mattered, compared to farming as a reference group, households who diversified in both farming and business (Estimate = −0.688, z = −122.04), farming and pastoralism (Estimate = −0.600, z = −593.49), or pastoralism alone (Estimate = −0.286, z = −172.47) reported lower severity. This indicates that households who practiced only crop farming were much more vulnerable to effects to other groups, this literally means local communities diversify to different means of production as coping strategies adapted to elephant/wildlife-related impacts. Being located within a wildlife corridor (Estimate = 0.002, z = 0.097) did not significantly change severity, nor did the number of household members (Estimate = −0.021, z = −1.01).

Distance from Park Boundaries

Distance from the park had significant influence indirect effects of human-elephant interactions, that being closer to park borders exposed more elephant encounters leading to increased stress and anxiety. These findings align with the conceptual framework of HEI, wherein proximity to the park boundary acts as a key spatial driver that increases exposure to direct encounters and thus intensifies the severity of associated impacts on affected individuals.

The proximity to park boundaries is consistently associated with increased elephant encounters and heightened indirect costs, wherein households closer to Masai Mara National Reserve, Kenya and Mikumi National Park in Tanzania, spend more time guarding fields, experience chronic fear, and restrict nighttime activities, leading to productivity losses and social stress (Sitati *et al.*, 2003; Chang'a *et al.*, 2016).

These findings are in line with results demonstrated by Mamboleo *et al.* (2021) where in villages adjacent to Serengeti National Park and Grumeti Game Reserve, most of the elephant incidents decreased along increased distance from the protected areas. However, Guerbois *et al.* (2012), investigated the relationship between elephant interactions with humans in Hwange Rural District in Matabeleland North, Zimbabwe, was an interplay of numerous sociological and ecological factors including human settlements and farmers' investment on mitigations and neighbors' combined efforts which decreased proportions of damages. This study villages within corridors like Ihombwe, Mkata, and Kilangali practices intensive farming including irrigation, such large-scale farming would prompt investing on mitigation measures for deterrence of elephants.

Further studies have shown that crop damage by elephants and other wildlife tends to be higher where farms and settlements are closer to protected area boundaries, as elephants venture outside park borders to access agricultural foods and water sources (Graham *et al.*, 2010). The study in northern Tanzania that mapped crop damage concentrated near park boundaries within 1 kilometer, showing spatial clustering of raids close to protected areas (Hariohay *et al.*,2025). Also, a study in the Masai Mara region of Kenya has shown that elephant cropraiding is spatially concentrated near the protected

area boundary, with farms closer to park edges and adjacent forest patches experiencing higher risk of raids (Tiller *et al.*, 2021).

Overall, the evidence demonstrates that distance from park boundaries plays a critical role in shaping the socio-ecological dynamics of human–elephant interactions. Households located closer to protected areas experiencing greater exposure to elephants, resulting in heightened psycho-social stress. Consequently, achieving sustainable human–elephant coexistence requires integrated approaches that consider spatial planning, community livelihoods, and collaborative mitigation strategies rather than relying solely on park-based conservation.

Seasonal variations

Seasonal variation shapes both elephant behavior and human livelihood activities, which together determine how vulnerable households are exposed to direct elephant encounters, ultimately leading to the indirect effects of human–elephant interactions (fear, lost labor time, crop guarding, disrupted mobility, and psychological stress). Communities experienced severe elephant invasions during wet seasons compared to dry seasons, because it is a peak for crops in the farms. Further, seasonal variation significantly influences the availability and distribution of water and forage, driving elephants to seek resources outside protected areas, often into agricultural landscapes where they encounter people and increasing conflicts. Furthermore, Seasonality influence resource availability, elephant movement patterns, agricultural cycles, and human livelihood activities. Understanding these elephant-seasonal dynamics is critical for forecasting potential conflict hotspots and designing targeted mitigation strategies responsive to seasonal variations in risk and prioritizing support to vulnerable communities.

Studies across Asia and Africa consistently show that the timing and frequency of elephant incursions into human landscapes are strongly seasonal. In Thailand, study revealed that conflict peaks during the rainy season from July to October, likely linked to crop phenology and increased attractiveness of agricultural fields to elephants (Supanta *et al.*,2025). Whereas seasonal distribution study in Ethiopia demonstrated that during the dry season, water scarcity concentrates elephants near limited water sources and irrigated crops, while natural forage quality declines, elephants disperse widely during wet periods but become concentrated near water sources during dry months, increasing overlap with human fields (Temesgen, 2025). Also, In Zimbabwe's Eland Sanctuary Park, findings indicated that seasonality enhanced forage availability by promoting the growth of highly palatable regrowth, which in turn significantly influences wildlife diet composition and selective habitat use (Mahakata & Chikara, 2024). Further, Hariohay *et al.* (2020), indicated that elephant invasions in Central Tanzania were higher during the wet season, because rainfall promote growth of crops attracting elephants to farms and/or near homesteads as opposed to dry seasons. On contrary, Sydney *et al.* (2021), reported that, elephant invasions in the Western Serengeti, Tanzania occurred most frequently at the end of the rainy season and throughout the dry season.

Gender

Gender shapes exposure, sensitivity, and adaptive capacity to the indirect effects of human–elephant interactions. Men and women experience different vulnerabilities due to division of labor, social roles, and differential access to resources, which influence how they are affected by crop raiding, guarding responsibilities, restricted mobility, and psychosocial stress. In this context, male-headed households were generally less vulnerable to indirect effects compared to female-headed households, as women often have limited access to financial resources, information, and institutional support, increasing their susceptibility to livelihood disruptions and stress.

The study highlights that, gendered roles and responsibilities, coupled with access to resources, critically determine how individuals experience and respond to human–elephant conflicts, ultimately shaping both their risk exposure and adaptive capacity. These aligns with findings reported by Rutta, (2023) in Mikumi which demonstrated that rural women in villages around MNP are vulnerable to elephant conflicts because on top of having less access to resources for investing in mitigation measures, still compelled to take on more of tasks (fetching firewood, water, walking through risky paths) that expose them to elephant risks leading to increased exposure to fear, harassment, injury and/or fatalities from elephants. These results concur with findings from Northeastern India where female-headed households have less access to resources, labor or credit, smaller landholdings to enable absorbing elephant losses like food shortages, and repair damaged properties which result in severe effects like working extra work to compensate for food, and missed school attendance to pupils who have to help their mothers (Banerjee & Sharma, 2022).

Overall, gender significantly influences vulnerability, risk perception, participation in mitigation, and adaptive capacity in the context of human–elephant interactions. Understanding these gender disparities is essential for designing equitable, effective interventions that reflect the lived realities of both men and women in elephant-coexisting landscapes.

Marital Status

Marital status is a key socio-demographic shaping vulnerability to the indirect effects of human–elephant interactions through their influence on household composition, labor allocation, resource access, social support networks, and decision-making dynamics. Findings from this study have indicated that widowed respondents slightly reported severe effects compared to separated and single individuals compared to married individuals.

These findings are in line with a study on gender

dynamics and human–wildlife conflict in the Maasai Mara, Kenya which found that marital status shape how people perceive and cope with conflict impacts such as crop damage and livelihood losses one; this is a socio-demographic factors associated with how households experienced conflict, along with household roles, agricultural activities, income loss, and land ownership (Omed & Majale, 2022). Further, another study in Chyulu Hills, Kenya, on human–wildlife and social conflicts found that households led by women experienced higher levels of social conflict and insecurity than those led by men, and that women-headed households implemented fewer mitigation strategies than men-headed households. This implies that marital status and household headship affect adaptive capacity and indirect vulnerability to wildlife impacts (Donatti *et al.*, 2025).

Moreover, a study in Northern Tanzania indicates that household composition influence vulnerability to human-wildlife conflict impacts and food insecurity in communities adjacent to protected areas (Salerno *et al.*, 2016). Also, results from similar area of Mikumi demonstrated that married couples collaborate, men guard farms women stay home with children, also in cases of food scarcity from elephant damage they can help each other to counter food shortages and even repair damaged properties (Rutta, 2023).

Overall, evidence from this study aligns with findings from Kenya and Tanzania, which show that household composition and headship significantly influence how people experience, perceive, and respond to human–wildlife conflict. Married households are better positioned to share responsibilities such as crop guarding, childcare, and recovery from crop losses, thereby enhancing their adaptive capacity. In contrast, households with limited social and labor support, particularly widowed or single-headed households are more exposed to livelihood disruption, psychosocial stress, and reduced capacity to mitigate conflict impacts.

Education level

Education plays a critical role in shaping a household's vulnerability and adaptive capacity to the indirect effects of human–elephant interactions. Post primary and primary respondents reported much more severe effects compared to primary school dropouts and informal education, highlighting that education increases awareness and access to information, capacity to engage in decision making and mitigation strategies to enhance resilience on consequences of elephants to humans. Individuals with higher levels of education often have better access to information, awareness of risks, and knowledge of mitigation strategies, which can reduce exposure and improve their ability to cope with the indirect impacts of HEI. Conversely, individuals with lower education levels may face greater vulnerability due to limited awareness of elephant behavior, seasonal movement patterns, and effective mitigation techniques, as well as reduced ability to participate in community-based conflict management initiatives.

Evidence from the Masai Mara landscape, Kenya demonstrate that households' experiences of human–elephant conflict vary with educational background: education level significantly differed between households experiencing conflicts and those that did not, indicating that education is correlated with how households perceive and report impacts of elephant interactions, which include indirect effects on wellbeing (Nyumba *et al.*, 2020).

A recent study by (Mbise, 2025), on locals' perceptions of elephant crop raiding and conservation support near Lake Manyara National Park and Swagaswaga Game Reserve in Tanzania found that education level was a significant determinant of conservation support. Wherein individuals with lower education (primary or less) were less likely to understand or support elephant conservation initiatives, likely due to lower awareness of longterm benefits and mitigation strategies compared to those with higher education. This suggests that education influences how people view and respond to HEI, which in turn affects their exposure to indirect effects of HEI.

Similar situation was reported by Nguyen *et al.* (2023) that education enhances understanding of the importance and willingness to participate in human-elephant management programs. However, in the Kashmir Division of Jammu and Kashmir state in India; education levels of household members did not influence human-elephant conflicts mitigation management (Mir *et al.*, 2015).

Overall, the findings indicate that education level is a key determinant of vulnerability and adaptive capacity to the indirect effects of human–elephant interactions. Individuals with higher education tend to have greater awareness of elephant behavior, seasonal movement patterns, and effective mitigation strategies, enabling them to anticipate risks, participate in community-based management, and reduce exposure to indirect impacts such as crop loss, time spent guarding, and psychosocial stress. While some global contexts, such as the case of Kashmir, suggest that education alone may not always predict conflict management outcomes. Collectively, these findings underscore the importance of integrating educational interventions and awareness programs into human–elephant conflict mitigation strategies to enhance community resilience and reduce vulnerability to indirect effects.

Occupation

Occupation is a critical component of socio-demographic variable in shaping household exposure, sensitivity, and adaptive capacity to the indirect effects of human–elephant interactions. The type of occupation determines where and how individuals spend their time, the nature of their daily activities, and their interaction with elephant-prone areas, all of which influence vulnerability to indirect impacts such as crop loss, reduced productivity,

psychosocial stress, and disruption of daily routines. Households practicing solely crop farming or pastoralism were much more vulnerable to indirect effects than other occupations. Diversification of occupations seems to be coping mechanisms against elephant conflicts.

Nguyen *et al.* (2023), demonstrated that crop farmers in communities adjacent to Dong Nai Biosphere Reserve, Vietnam were motivated to participate in human-elephant mitigation programs with the hope of reducing conflict occurrences and damages compared to non-crop-farmers, while livestock farming and other non-forest related occupations in communities adjacent to Paratharia Hills Reserve Forest- Assam, India; were less likely to engage in wildlife conservation activities indicating negative perception of such occupations with conservation (Talukdar & Choudhury, 2020).

Rutta, (2023) demonstrated that, subsistence farming is the dominant occupation for communities adjacent to MNP and other protected areas in Tanzania. Wherein most households rely on crops for both food and income. Elephants regularly raid these farms, resulting in crop loss, reduced household food supply, and increased time spent guarding fields threatening livelihoods and food security. Further, Mayengo, (2013) affirms that pastoralism is another key occupation around Mikumi and other rural areas of Tanzania. The presence of elephants and other wildlife alters grazing patterns and access to water and pasture, which indirectly affects pastoral productivity. In areas where farmers and pastoralists coexist, competition over land and water can escalate conflicts, increasing vulnerability of pastoralists to livelihood disruption and resource scarcity.

While formal employment like teaching, small business, and service work may reduce direct exposure to elephant interactions, non-farm workers can still suffer indirect effects due to the occupation's connection with local economies: Evidence from household survey in Mikumi shows that while farming dominates income portfolios, other income sources such as seasonal labour, small businesses, and local shops are also present; yet, farming still contributes the largest share of household income, making other occupations indirectly affected when farming productivity falls.

Occupation significantly shapes the vulnerability of individuals and households to the indirect effects of human–elephant interactions in human-elephant landscapes. Those engaged in subsistence agriculture or pastoralism face the highest exposure and indirect costs, including crop loss, time spent guarding, routines disruptions, and psychological stress, because their workplaces them directly within elephantprone areas. Even nonfarm occupational groups feel the ripple effects through reduced household productivity and economic instability. Recognizing these occupation-linked vulnerabilities is crucial for designing targeted mitigation strategies such as livelihood diversification support, community earlywarning systems, and conflict management training that reduce indirect effects and improve resilience among affected communities around Mikumi and other protected areas.

CONCLUSION

This study demonstrates that vulnerability to the indirect effects of human–elephant interactions in villages surrounding MNP is shaped by a dynamic interplay of spatial exposure, seasonal- ecological processes, and household socio-demographic characteristics. While proximity to park boundaries and wet-season conditions elevate exposure to direct elephant encounters, demographic factors like gender, marital status, education level, and occupation mediate how direct encounters translate into psycho-social stress, livelihood disruption, and long-term vulnerability. Female-headed and widowed households experience disproportionately severe indirect effects, underscoring that human–elephant interactions are not solely ecological processes but deeply embedded within social structures. By situating these findings within the conceptual framework of human–elephant interactions, the study confirms that indirect effects of HEI arise through cumulative pathways initiated by direct encounters and amplified by socio-ecological inequalities. Importantly, the results reveal that awareness and perception shaped by education further influence reported severity, highlighting that vulnerability is not only a function of exposure but of capacity, agency, and resilience. Addressing human–elephant interactions in Mikumi therefore requires moving beyond reactive conflict mitigations toward integrated strategies that simultaneously reduce encounter risks and strengthen household adaptive capacity.

Based on the study findings, the following recommendations are proposed to enhance sustainable human–elephant coexistence in the Mikumi landscape:

i. Strengthening community-based monitoring and early-warning systems by empowering village wildlife committees to track elephants and coordinate rapid responses, prioritizing high-risk households near park boundaries.

ii. Target education and awareness initiatives should focus on vulnerable groups, particularly women and low-resource households to improve understanding of elephant behavior, risk periods, and safe mitigation strategies.

iii. Integrate social vulnerability into conflict management: Mitigation programs should explicitly target female-headed and widowed households through tailored support mechanisms, including access to labor, credit facilities, and community-based guarding arrangements.

iv. Integrating socio-demographic insights into policy and conservation interventions, including psychosocial support, compensation mechanisms for indirect effects, and adaptive strategies informed by ongoing monitoring and community feedback.

v. Promoting livelihood diversification and adaptive land-use planning to reduce household vulnerability, integrating socio-ecological factors such as distance to

park boundaries, seasonal patterns, and corridor locations.

REFERENCES

Banerjee, S., & Sharma, S. (2022). En-gendering human-wildlife interactions in Northeast India: Towards decolonized conservation. *Journal of Political Ecology, 28*(1). https://doi.org/10.2458/jpe.5217

Barua, M., Bhagwat, A.S., & Jadhav, S. (2013). The hidden dimensions of human wildlife conflict: Health impacts, opportunity and transaction costs. *Biological conservation 157* (2013):309-316. https://doi.org/10.1016/j.biocon.2012.07.014

Caro, T., Jones, T. & Davenport, T. R. B. (2009). Realities of documenting wildlife corridors in tropical countries. *Biological Conservation, 142*(11), 2807–2811. https://doi.org/10.1016/j.biocon.2009.06.011

Chang'a, A., de Souza, N., Muya, J., Keyyu, J., Mwakatobe, A., Malugu, L., Ndossi, P.H., Konuche, J., Omondi, R., Mpinge, A., Hahn, N., Palminteri, S., & Olson, D. (2016). Scaling-up the use of chili fences for reducing human–elephant conflict across landscapes in Tanzania. *Tropical Conservation Science, 9*(2), 921–930. https://doi.org/10.1177/194008291600900220

Donatti, C. I., Moraga-Lewy, N., Nyongesa, J., Mwanzia, M., Edmond, J., & Fedele, G. (2025). Grassland restoration impacts human-wildlife and social conflicts in the Chyulu Hills, Kenya. *Frontiers in Environmental Science, 12,* 1431316. https://doi.org/10.3389/fenvs.2024.1431316

Gara, W.T., Wang, T., Dube, T., Ngene, M.S., & Mpakairi, K. (2021). African elephant (Loxodonta africana) selects less fragmented landscapes to connect core habitats in human-dominated landscapes. *African Journal of Ecology, 59*(2)370-377. https://doi.org/10.1111/aje.12839

Giliba, R. A., Fust, P., Kiffner, C., & Loos, J. (2022). Multiple anthropogenic pressures challenge the effectiveness of protected areas in western Tanzania. *Conservation Science and Practice, 4*(6), e12684. https://doi.org/10.1111/csp2.12684

Giliba, R. A., Kiffner, C., Fust, P., & Loos, J. (2023). Modelling elephant corridors over two decades reveals opportunities for conserving connectivity across a large, protected area network. *PLoS One, 18*(10), e0292918. https://doi.org/10.1371/journal.pone.0292918

Graham, M. D., Notter, B., Adams, W. M., Lee, P. C., & Ochieng, T. N. (2010). Patterns of crop-raiding by elephants, Loxodonta africana, in Laikipia, Kenya, and the management of human–elephant conflict. *Systematics and Biodiversity, 8*(4), 435-445. https://doi.org/10.1080/14772000.2010.533716

Granados, A., Weladji, B. R., & Loomis, R. M. (2012). Movement and occurrence of two elephant herds in a human-dominated landscape, the Bénoué Wildlife Conservation Area, Cameroon. *Mongabay.com Open Access Journal - Tropical Conservation Science,5*(2):150-162. https://doi.org/10.1177/194008291200500205

Gross, E. M., Pereira, J. G., Shaba, T., Bilério, S., Kumchedwa, B., & Lienenlüke, S. (2022). Exploring routes to coexistence: Developing and testing a human–elephant conflict-management framework for African elephant-range countries. *Diversity, 14*(7), 525. https://doi.org/10.3390/d14070525

Guerbois, C., Chapanda, E., & Fritz, H. (2012). Combining multi-scale socio-ecological approaches to understand the susceptibility of subsistence farmers to elephant crops raiding on the edge of a protected area. *Journal of Applied Ecology, 49*(2012):1149–1158. https://doi.org/10.1111/j.1365-2664.2012.02192.x

Gunn, J., Hawkins, D., Barnes, R.F.W., Mofulu, F., Grant, R.A., & Norton, G.W. (2013). The Influence of lunar cycles on crop raiding elephants; Evidence for risk avoidance. *African Journal of Ecology 52*(2):129-137. https://doi.org/10.1111/aje.12091

Hariohay, K.M., Munuo, W.A., & Røskaft, E. (2020). Human-elephant interactions in areas surrounding the Rungwa, Kizigo, and Muhesi Game Reserves, Central Tanzania. *Oryx 54*(5): 612-620. https://doi.org/10.1017/S003060531800128X

Hariohay, K. M., Shabani, Z. M., Shoo, R. A., Mfanga, S. H., & Katunzi, T. (2025). *Elephant crop raiding in northern Tanzania: Spatio-temporal trends and damage assessment in villages adjacent to Mkomazi National Park.* https://doi.org/10.21203/rs.3.rs-7093604/v1

Hossen, A., & Røskaft, E. (2023). A case study on conflict intensity between humans and elephants at Teknaf Wildlife Sanctuary, Cox's Bazar, Bangladesh. *Frontiers in Conservation Science, 4*(1067045):11. https://doi.org/10.3389/fcosc.2023.1067045

Jadhav, S., & Barua, M. (2012). The Elephant Vanishes: Impact of human–elephant conflict on people's wellbeing. *Health & place, 18*(6), 1356-1365. https://doi.org/10.1016/j.healthplace.2012.06.019

Jones, T., Banford, A. J., Ferrot – Schulte, D., Hieronimo, P., McWilliam, N., & Rovero, F. (2012). Varnishing wildlife corridors and options for restoration: A case study from Tanzania. *Tropical Conservation Science, 5*(4): 463 – 474. https://doi.org/10.1177/194008291200500405

Köpke, S., Withanachchi, S. S., Chinthaka Perera, E. N., Withanachchi, C. R., Gamage, D. U., Nissanka, T. S., & Thiel, A. (2024). Factors driving human–elephant conflict: statistical assessment of vulnerability and implications for wildlife conflict management in Sri Lanka. *Biodiversity and Conservation, 33*(11), 3075-3101. https://doi.org/10.1007/s10531-024-02903-z

Kolinski, L., & Milich, K. M. (2021). Human-wildlife conflict mitigation impacts community perceptions around Kibale National Park, Uganda. *Diversity, 13*(4), 145. https://doi.org/10.3390/d13040145

Lamarque, F., Anderson, J., Fergusson, R., Lagrange, M., Osei-Owusu, Y., & Bakker, L. (2009). *Human–Wildlife Conflict in Africa: Causes, Consequences and Management Strategies.* Food and Agriculture Organization of the United Nations, Rome, Pp. 112

Laverty, T. M., Teel, T. L., Thomas, R. E., Gawusab,

A. A., & Berger, J. (2019). Using pastoral ideology to understand human-wildlife coexistence in arid agricultural landscapes. *Conservation Science and Practice 1*(5):14. https://doi.org/10.1111/csp2.35

Liendekiye, A. I., Mahenge, F. Y., & Makupa, E.E. (2022). Implication of Consolation scheme in reducing Human-Wildlife Conflict near the Rungwa-Muhesi-Kizigo Game Reserve in Singida, Tanzania. *Journal of Research in Forestry, Wildlife & Environment 14*(3):56-64.

Lohay, G.G., Weathers, T.C., Estes, A.B., McGrath, B.C., & Cavener, D.R. (2020). Genetic connectivity and population structure of African savanna elephants (Loxodonta africana) in Tanzania. *Ecology and Evolution 10*(2020):11069-11089. https://doi.org/10.1002/ece3.6728

Mamboleo, A.A., Doscher, C., & Paterson, A. (2021). A computational modelling approach to human-elephant interactions in the Bunda District, Tanzania. *Ecological Modelling 443*(2021) 109449. https://doi.org/10.1016/j.ecolmodel.2021.109449

Mahakata, I., & Chikara, M. (2024). Forage Availability and the Effects of Dry Season Patch Burning on Diet and Habitat Selection by the Common Eland in Eland Sanctuary Park, Zimbabwe. *Journal of Wildlife and Conservation, 1*(1), 10-17. https://doi.org/10.54536/jwc.v1i1.2341

Mayberry, L.A., Hovorka, J.A., & Evans, E.K. (2017). Well-being impacts of human elephant conflict in Khumaga, Botswana: Exploring visible and hidden dimensions. *Conservation and Society 15*(3): 280-291. http://dx.doi.org/10.4103/cs.cs_16_132

Mayengo, G., Bwagalilo, F., & Kalumanga, E., V. (2017). Human Wildlife Conflicts to communities surrounding Mikumi National Park in Tanzania. A case of selected villages. *International Journal of Environment, Agriculture and Biotechnology. 2*(4):1777-1784. http://dx.doi.org/10.22161/ijeab/2.4.40

Mayengo, G. (2013). *Assessment of natural resources conflicts in some selected villages surrounding Mikumi National Park* (Master's thesis, University of Dodoma). University of Dodoma Institutional Repository. https://repository.udom.ac.tz/bitstream/20.500.12661/1531/1/MAYENGO%20GABRIEL.pdf

Mbise, F. P. (2025). Determinants of locals' perceptions of elephant crop raiding and support for conservation in two distinct protected areas in Tanzania. *Discover Global Society, 3*(1), 1-13. https://doi.org/10.1007/s44282-025-00143-2

Mir, Z.R., Noor, A., Habib, B., & Veeraswami, G.G. (2015). Attitudes of local people toward wildlife conservation: a case study from Kashmir Valley. *Mt Res. Dev. 35*(4):392–400. https://doi.org/10.1659/MRD-JOURNAL-D-15-00030.1

Naughton-Treves, L., Treves, A., Chapman, C., & Wrangham, R. (1998). Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. *Journal of Applied ecology, 35*(4), 596-606. https://doi.org/10.1046/j.1365-2664.1998.3540596.xNgnaniyyi,

A., Stéphanie, P., Housseini, M. D., Rick, T. T., & Akwanjoh, S. R., (2026). Beyond Crop Raids: Socio-Ecological Resilience and Hidden Costs of Human-Monkey Conflict In Vervets around Mount Galim-Tignère, Cameroon. *Journal of Wildlife and Conservation, 2*(1), 10-19. https://doi.org/10.54536/jwc.v2i1.6251

Nguyen, H. T. T., Phan, T. T. T., & Lee, C. H. (2023). Determinants of locals' willingness to participate in human–elephant conflict management: evidence from Dong Nai Biosphere Reserve, Vietnam. *Trees, Forests and People, 14*(100435):10. https://doi.org/10.1016/j.tfp.2023.100435

Nyirenda, V.R., Nkhata, B.A., Tembo, O., & Siamundele, S. (2018). Elephant Crop Damage: Subsistence Farmers' Social Vulnerability, Livelihood Sustainability and Elephant Conservation. *Sustainability.* 2018; 10 (3572):19. https://doi.org/10.3390/su10103572

Nyumba, T. O., Emenye, O. E., & Leader-Williams, N. (2020). Assessing impacts of human-elephant conflict on human wellbeing: An empirical analysis of communities living with elephants around Maasai Mara National Reserve in Kenya. *PLoS One, 15*(9); 14. https://doi.org/10.1371/journal.pone.0239545

Omed, M. A., & Majale, C. (2022). Gender Dynamics and Human-Wildlife Conflicts in Maasai Mara Game Reserve, Kenya. *East African Journal of Environment and Natural Resources, 5*(1);161-173

Ogra, M. V., & Badola, R. (2008). Compensating human–wildlife conflict in protected area communities: Ground-level perspectives from Uttarakhand, India. *Human Ecology, 36*(5), 717–729. https://doi.org/10.1007/s10745-008-9189-y

Pereira, J. G., Rosalino, L. M., Ekblom, A., & Santos, M. J. (2024). Livelihood vulnerability and human-wildlife interactions across protected areas. *Ecology and Society, 29*(1):13. https://doi.org/10.5751/ES-14605-290113

R Core Team. (2020). *R: A language and environment for statistical computing.* R Foundation for Statistical Computing. https://www.R-project.org/

Rutta, W.E. (2023). Rural women vulnerability to human wildlife conflicts: lessons from villages near Mikumi National Park, Southeast Tanzania. *International journal of Biodiversity and Conservation. 15*(3)92-105. http://www.academicjournals.org/IJBC

Salerno, J., Mulder, M. B., Grote, M. N., Ghiselli, M., & Packer, C. (2016). Household livelihoods and conflict with wildlife in community-based conservation areas across northern Tanzania. *Oryx, 50*(4), 702-712. https://doi.org/10.1017/S0030605315000393

Sampson, C., Rodriguez, S.L.; Leimgruber, P., Huang, Q., & Tonkyn, D. (2021). A quantitative assessment of the indirect impacts of Human elephant conflict. *PLOS ONE 16*(7):19. https://doi.org/10.1371/journal.pone.0253784

Santiapillai, C. (2004). Review of The living elephants: Evolutionary ecology, behavior, and conservation, by R. Sukumar. *Oryx, 38*(4), 463–468.

Shaffer, J.L., Khadka, K., Van den Hoek, J. & Naithani, K. J. (2019). Human elephant conflicts: A review of current management strategies and future directions. *Frontiers in ecology and evolution 6*(235),12. https://doi.org/10.3389/fevo.2018.00235

Shokirov, Q., Backhaus, N., & Bartmess, J. (2021). Community perceptions of co-managing Tajik National Park. *Central Asian Survey, 40*(3), 420 – 437. https://doi.org/10.1080/02634937.2021.1942787

Sitati, N. W., Walpole, M. J., Smith, R. J., & Leader-Williams, N. (2003). Predicting spatial aspects of human–elephant conflict. *Journal of Applied Ecology, 40*(4), 667–677. https://doi.org/10.1046/j.1365-2664.2003.00828.x

Sitati, N. W., Walpole, M. J., & Leader-Williams, N. (2005). Factors affecting susceptibility of farms to crop raiding by African elephants: using a predictive model to mitigate conflict. *Journal of applied ecology, 42*(6), 1175-1182. https://doi.org/10.1111/j.1365-2664.2005.01091.x

Sitati, N. W., & Walpole, M. J. (2006). Assessing farm-based measures for mitigating human-elephant conflict in Transmara District, Kenya. *Oryx, 40*(3), 279-286. https://doi.org/10.1017/S0030605306000834

Supanta, J., Poolkhet, C., Yindee, M., Manatchaiworakul, W., & Wongtawan, T. (2025). Human–Elephant Conflict in Thailand over the Past Decade (2014–2023): Occurrence, Geographical Distribution, and Temporal Trends. *Animals, 15*(9), 1304. https://doi.org/10.3390/ani15091304

Sydney, D. K., Mneney, P., Mkilindi, P.B.B., & Mbise, N. (2021). Seasonal and spatial vulnerability to agricultural damage by elephants in the western Serengeti, Tanzania. *Oryx, 55*(1):139-149. https://doi.org/10.1017/S0030605318001382

Talukdar, N. R., & Choudhury, P. (2020). Attitudes and perceptions of the local people on human–elephant conflict in the Patharia Hills reserve Forest of Assam, India. *In Proceedings of the zoological society (Vol. 73, No. 4*, pp. 380-391). New Delhi: Springer India

Temesgen, F., & Warkineh, B. (2025). Human-elephant conflicts and attitude of the local communities toward African elephant (*Loxodonta africana*) conservation in Kafta Sheraro National Park, Tigray region, Ethiopia. *PeerJ, 13,* e19428. https://doi.org/10.7717/peerj.19428

Thekaekara, T., Bhagwat, S. A., & Thornton, T. F. (2021). Coexistence and culture: understanding human diversity and tolerance in human-elephant interactions. *Frontiers in Conservation Science, 2*(735929):17. https://doi.org/10.3389/fcosc.2021.735929

Tiller, L. N., Humle, T., Amin, R., Deere, N.J., Lago, B. O., Leader-Williams, N., Sinoni, K.F., Sitati, N., Walpole, M., & Smith, R. J. (2021). Changing seasonal, temporal and spatial crop-raiding trends over 15 years in a human-elephant conflict hotspot. *Biological Conservation, 254,* 108941. https://doi.org/10.1016/j.biocon.2020.108941

Tripathy, B. R., Liu, X., & Ranga, V. (2022). Demographic circumstances and people's sentiments towards elephants in the Human–Elephant Conflict Hotspot Villages of Keonjhar Forest Division in Eastern India. *Diversity, 14*(5), 311. https://doi.org/10.3390/d14050311

Xu, L., Ao, C., Mao, B., Cheng, Y., Sun, B., Wang, J., and Ma, J. (2020). Which is more important, ecological conservation or recreational service? Evidence from a choice experiment in wetland nature reserve management. *Wetlands, 40*(6): 2381 – 2396. https://doi.org/10.1007/s13157-020-01348-8

Zang, H., Guo, S., Ma, L., Su, K., Lobora, A., Hou, Y., & Wen, Y. (2024). Living with elephants: Analysing commonalities and differences in human-elephant conflicts in China and Tanzania based on residents' perspectives. *Global Ecology and Conservation 53*(2024):14. https://doi.org/10.1016/j.gecco.2024.

Appendix

Ordinal Logistic Regression Model Results of factors influencing communities' Vulnerability to indirect effects of human-elephant interactions

Table 1: Socio-demographic characteristics of surveyed households around MNP

Predictor(s)	**Level**	**Estimate (log-odds)**	**Std. Error**	**z – value(s)**
Distance from park	−0.00009	0.00004	−2.56783	
Position with respect to wildlife corridor	within corridor	0.00182	0.01874	0.09688
Seasonal variations	Wet season	1.347	0.0087	12.521
Gender	Male	−0.07143	0.03401	−2.10007
Marital status	Married	0.02916	0.03080	0.94671
	Separated	−0.05679	0.00158	−35.97745
	Single	−0.48798	0.00264	−184.69388
	Widowed	0.01454	0.00731	1.98906
Education level	Primary School	0.48721	0.02898	16.80916
	Primary School drop-out	−0.36166	0.00158	−228.35464
	Secondary School	0.64347	0.00063	1,016.06818
	Tertiary Education	1.33186	0.00009	14,613.99329
	University Education	1.42919	0.00010	14,357.32211
Occupation	farming & business	−0.68798	0.00564	−122.03662
	farming & pastoralist	−0.59971	0.00101	−593.48650
	Pastoralist	−0.28570	0.00166	−172.47489
Number of household members	−0.02053	0.02040	−1.00667	