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Household socio-agricultural profiles and the adoption of crop protection strategies in human-wildlife conflict contexts: Insights from western Côte d'Ivoire around mount Sangbé National Park

Koffi Kouamé Christophe*[1], Ouffoue Affoué Eugénie Naomie[1], Gagbé Dalié Sylvestre[1], Beda Alex[2]

[1]*Université de Man, Département d'Agronomie et de Foresterie, Man, Côte d'Ivoire*

[2]*Office Ivoirien des Parcs et Réserves, Abidjan, Côte d'Ivoire*

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ABSTRACT

In rural sub-Saharan Africa, proximity to protected areas and habitat fragmentation intensify human-wildlife conflicts, particularly through crop-raiding. This study examines how household socio-agricultural profiles influence the adoption of protection strategies against wildlife incursions. The study took place near mount Sangbé national park in Côte d'Ivoire and involved surveying 121 farming households from three villages through structured interviews, complemented by field observations and expert consultations. Nineteen wildlife species were identified as crop raiders, with granivores and rodents, especially the grass cutter, red-headed quelea, and patas monkey, causing significant damage to rice, cassava, and cocoa. A hierarchical classification revealed four distinct household clusters, differentiated by landholding size, education level, age structure, and proximity to the park. Binary indicators were constructed for each method to evaluate protection practices and visualized by cluster. Strategies were grouped into physical deterrents, agroecological measures, and community-based interventions. A bias-reduced multinomial logistic regression was conducted using adjusted score equations to obtain stable estimates. Results show that field guarding is the most widely used strategy, especially among educated households with smaller landholdings, while traditional hunting and trapping are more common among older, less educated households with larger farms. Passive tolerance was positively associated across all clusters, suggesting widespread reliance on non-confrontational coping mechanisms. Scarecrows and trapping methods showed low or negative adoption rates, indicating limited perceived effectiveness. These findings underscore the need to tailor mitigation strategies to household-specific capacities and spatial contexts. The study advocates for agroecological and community-based approaches to enhance resilience and sustainability in buffer zones near protected areas.

***Corresponding Author:** Koffi Kouamé Christophe ✉ christophe.koffi@univ-man.edu.ci

* https://orcid.org/0009-0008-8516-1781

INTRODUCTION

In rural regions of sub-Saharan Africa, agricultural systems are increasingly subjected to ecological and social pressures resulting from habitat fragmentation, expansion of cultivated areas, and proximity to protected zones. These factors exacerbate human-wildlife conflicts, particularly via wildlife encroachments into subsistence crops, a phenomenon extensively documented in buffer zones adjacent to natural reserves (Dibloni *et al.,* 2020; Chepkwony *et al.,* 2025). Such crop-raiding events jeopardize food security, economic stability, and the psychological well-being of farming households (Barua *et al.,* 2013; Nyhus, 2016). Crop-raiding, defined as the incursion of wild animals into cultivated fields, results in direct economic losses and indirect effects on the mental health and social cohesion of farmers (Hill, 2005; Galley and Anthony, 2024). These conflicts are further aggravated by land pressure, habitat degradation, and inadequate compensation or prevention mechanisms (Asaye *et al.,* 2024).

While forest ecosystems provide essential services that enhance rural resilience to climate change, their proximity also increases exposure to crop-raiding, especially in low-diversity farming systems. This paradox highlights the need for integrated approaches that balance conservation and agricultural productivity. Agroecology is a theoretically grounded and operational framework to address this dual challenge. Rooted in ecological principles and local knowledge, agroecology promotes crop diversification, sustainable soil management, and landscape-level planning. It offers practical strategies such as vegetative barriers, agroforestry, and community-based surveillance systems that can mitigate wildlife incursions while enhancing ecosystem services (Altieri, 1995; Bommarco, 2024; Dickman, 2010; Wezel *et al.,* 2009).

Despite growing recognition of crop-raiding impacts, existing research remains fragmented and overly focused on direct economic losses. It often neglects the socio-territorial and behavioral dimensions that shape household responses and rarely incorporates agroecological or resilience-based perspectives. Moreover, the socio-agricultural typologies of farming households and their influence on the adoption of mitigation strategies are insufficiently characterized. This study fills these gaps by analyzing the complex interactions between household socio-agricultural profiles, crop-raiding dynamics, and protection strategies. It adopts a differentiated and sustainability-oriented approach to managing human-wildlife conflicts in rural areas adjacent to protected zones. Specifically, the study identifies the plant and animal species involved in crop-raiding events, characterizes the socio-agricultural profiles of affected households, evaluates the protection strategies adopted based on household profiles and geographic location, and statistically models the influence of household characteristics on mitigation methods.

MATERIALS AND METHODS

Study site

The study was conducted in rural areas surrounding Mount Sangbé National Park (MSNP), where human-wildlife conflicts are particularly prevalent (Koffi *et al.*, 2024). A random sampling technique was employed to select households across three villages, as depicted in Fig. 1.

Fig. 1. Location of the study area

The sampling frame was based on household census data provided by the Ivorian Office of Parks and Reserves (OIPR), which conducted demographic surveys in the target villages in 2021. According to OIPR records, 214 households were identified in Toulo, 196 in Sorotonan, and 221 in Kokialo. From these populations, a random sample of 40 households was selected in both Toulo and Sorotonan, and 41 households in Kokialo, resulting in sampling rates of

18.69% in Toulo, 20.41% in Sorotonan, and 18.55% in Kokialo that are consistent with recommended practices for rural household surveys in sub-Saharan Africa, where sampling rates between 15% and 25% are commonly used to ensure representativeness while maintaining feasibility (Awuah *et al.,* 2017; UNHCR, 2024; United Nations, 2005).

The inclusion criterion required that selected households actively engage in agricultural activities; non-agricultural households were excluded and replaced through an additional random selection process. Prior to data collection, informed consent was obtained from all participating households. The survey covered 121 households across the three villages surrounding the protected area. This multi-village approach was intentionally adopted to capture a broader diversity of cropping systems and crop-raiding species, rather than limiting the analysis to a single territorial context. Data collection took place from February to April 2022.

Mount Sangbé National Park, designated as a "classified forest" in 1945 and a national park since 1976, is located in the Man region, within a forest-savanna transition zone. Covering 95,000 hectares, it is the fourth largest national park in Côte d'Ivoire. The Bafing River traverses the park and hosts rich biodiversity, with 69 mammal species, 12 reptile species, and 60 bird species recorded (Lauginie, 2007). Approximately 40% of its area is mountainous, with a peak of 1,052 meters at the Mount Sangbé massif. Between 1995 and 2001, the park received financial support from the European Union for its development.

Local populations inhabit a peripheral zone of 200,000 hectares surrounding the park, comprising four ethnic groups: Yacouba, Toura, Mahou, and Worodougou. The regional economy is based on cash crops such as cocoa (*Theobroma cacao* L.), coffee (*Coffea canephora* Pierre ex A. Froehner), and cashew (*Anacardium occidentale* L.), complemented by traditional subsistence farming including rice (*Oryza sativa* L.), maize (*Zea mays* L.), cassava (*Manihot esculenta* Crantz), yam (*Dioscorea sp.*), okra (*Abelmoschus esculentus* L.), sweet potato (*Ipomoea batatas* L.), chili pepper (*Capsicum* sp.), and eggplant (*Solanum melongena* L.).

The park operates as an integrated natural reserve, open to visitors and researchers, but prohibits resource exploitation by local communities (Gueneau and Jacobee, 2005). In return, these communities' benefit from targeted subsidies and employment opportunities linked to tourism development.

Conceptual framework

To guide the analysis, the following conceptual framework (Fig. 2) illustrates the relationships between socio-agricultural profiles, risk perception, response strategies, and risk management outcomes in human-wildlife conflict. The conceptual framework guiding this study integrates four interrelated dimensions to analyze household-level responses to crop-raiding in rural landscapes adjacent to protected areas. It begins with the socio-agricultural profile of farming households-encompassing farm size, crop diversity, and proximity to forested zones-fundamentally shaping their risk perception. Risk perception, influenced by the perceived frequency of wildlife incursions, informs the selection of response strategies.

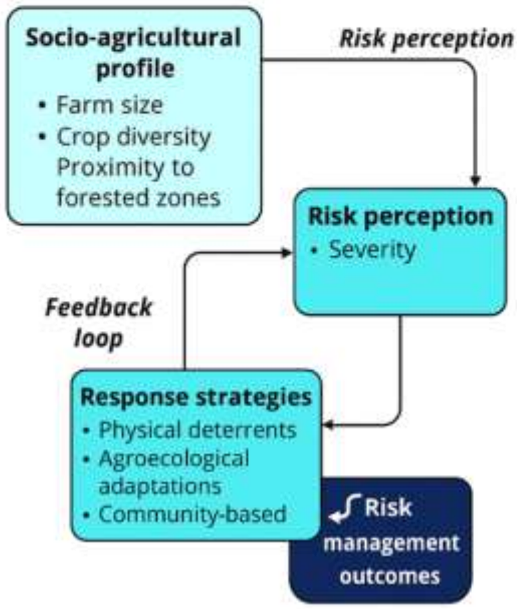

Fig. 2. A conceptual framework illustrating the interrelationships among socio-agricultural profiles, risk perception, response strategies, and risk management outcomes within human-wildlife conflict

These strategies range from physical deterrents and agroecological adaptations to community-based interventions. The effectiveness, sustainability, and ecological compatibility of these responses determine risk management outcomes, particularly in household resilience and biodiversity conservation. A feedback loop is embedded within the framework, whereby the outcomes of implemented strategies influence future risk perceptions and adaptive behaviors, reinforcing or weakening the resilience of farming systems over time.

Data collection

The methodology adopted was based on semi-structured interviews conducted with household heads, aimed at collecting information on cultivated crops, farmed areas, the distance of these fields from the park boundary, animal species identified as crop raiders, the frequency of incursions by crops and species, protection methods used, and the socio-demographic characteristics of households (size, age, education level, and location). Farmers are well-informed about the size and location of their fields due to regular surveys conducted by the Ministries of Agriculture and Environment. Most plots are georeferenced, enabling household heads to accurately report field area and distance from the park without difficulty.

Farmers were invited to report on the animal species responsible for crop damage, based on direct field observations rather than assumptions. Only species visually identified or encountered by the farmers in their fields were considered. The local names of the animals were recorded in their native language and subsequently identified by ecologists affiliated with OIPR, who were part of the survey team. These ecologists, selected from within the local communities, have been working with OIPR for over five years and possess extensive knowledge of the regional fauna and flora. In each surveyed village, two such ecologists assisted in species identification. Once the vernacular and/or scientific names were provided, species validation was conducted using morphological identification guides (Hilary Fry and Keith, 2020; Kingdon *et al.,* 2024; 2013; Kingdon and Happold, 2024). This validation process was crucial in ensuring taxonomic accuracy and minimizing the risk of misidentification bias. It also strengthened the ecological relevance of the data by aligning local knowledge with standardized scientific references.

Data analysis

Crop–raider interactions

A contingency matrix was constructed to investigate the interactions between cultivated plant species and crop-raiding animal species, cross-tabulating crop types with raider species.

Incursion events were systematically recorded, and absent combinations were coded as zero to ensure matrix completeness. A heatmap was then generated using the ggplot2 package in R software, where each tile represented a crop–raider pair, with color intensity indicating the percentage of raids and embedded labels showing exact values. This visualization provided a comprehensive overview of wildlife pressure across agricultural systems, highlighting the most vulnerable crops and the most frequent raiders.

Classification of socio-agricultural profiles

Socio-agricultural profiles were defined based on operationalized variables including farm size, crop diversity, proximity to forest, household size, and education level. A Hierarchical Ascending Classification (HAC) was performed using a Gower distance matrix to accommodate mixed data types (numerical and categorical), with Ward.D2 linkage used to construct the dendrogram. The optimal number of clusters was determined via silhouette analysis, comparing average silhouette widths for solutions ranging from 2 to 6 clusters.

Nonparametric tests were applied to compare clusters across numerical indicators such as the number of crops, cultivated area, average field distance to the park, and household size due to non-normal distributions and unequal variances. Shapiro-Wilk and Levene's tests assessed assumptions, followed by Kruskal-Wallis tests and Dunn's post-hoc comparisons with Benjamini-Hochberg correction. Boxplots with jittered points were used to visualize these distributions. Categorical attributes such as village of residence, age group, and education level were analyzed using cross-tabulations and grouped bar plots to reveal socio-demographic patterns.

Analysis of crop protection strategies

Binary indicators were constructed for each method to evaluate crop protection practices, and their relative frequencies within clusters were visualized using stacked bar charts. Response strategies were categorized into physical deterrents, agroecological measures, and community-based interventions. In line with the conceptual framework, which posits that socio-agricultural profiles shape risk perception and influence strategy selection, a bias-reduced multinomial logistic regression was conducted using the brglm2 package of R software. Household-level method counts were collapsed into a single multinomial response by selecting the most frequently used method per household; households with no recorded method were excluded. The model was fitted using brmultinom (type = "AS_mean"), which applies adjusted score equations (Kosmidis and Firth, 2009) to mitigate issues of quasi-complete separation and ensure finite, stable estimates. All analyses were performed in R (version 4.4.3).

RESULTS

Species-specific patterns of crop raiding

Surveys of 121 households identified 15 crop species frequently targeted by 19 wild animal species (Fig. 3). Incursion intensity varied markedly by crop and raider species. Within cereals, rice was the most heavily impacted: the grass cutter (*Thryonomys swinderianus*, Temminck 1827) accounted for 90.1% of reported incursions on rice, the red-headed quelea (*Quelea erythrops*, Hartlaub 1848) for 82.6%, and the patas monkey (*Erythrocebus patasc*, Schreber 1774) for 23.1%. Cereals such as rice and maize, therefore, predominantly attract granivores and small to medium-sized rodents. Primates and large rodents were dominant in tree crops. For cashew, the patas monkey represented 48.8% of incursions, and the northern giant pouched rat (*Cricetomys gambianus*, Waterhouse 1840) 19.8% and the Green Bush Squirrel (*Paraxerus poensis,* Andrew Smith 1830), with the African Savanna Hare (*Lepus victoriae*, Oldfield Thomas 1893) and the Striped Ground Squirrel (*Xerus erythropus*, Étienne Geoffroy Saint-Hilaire 1803) also showing substantial shares (33.9% each in certain modalities). For cacao, the Green Bush Squirrel contributed 28.9% of incursions and the northern giant pouched rat 12.4%. These patterns indicate heightened vulnerability of perennial orchard crops to arboreal and semi-arboreal species. Among tuber crops, cassava experienced strong pressure from the grass cutter and the warthog (*Phacochoerus africanus*, Gmelin 1788): the grass cutter accounted for 21.5% of cassava incursions and the warthog for 19.8%, consistent with targeted predation on starch-rich roots. Across most crop types, the straw-colored fruit bat (*Eidolon helvum*, Kerr 1792) acted as a secondary raider, except for coffee, representing 10.7% of observed incursions.

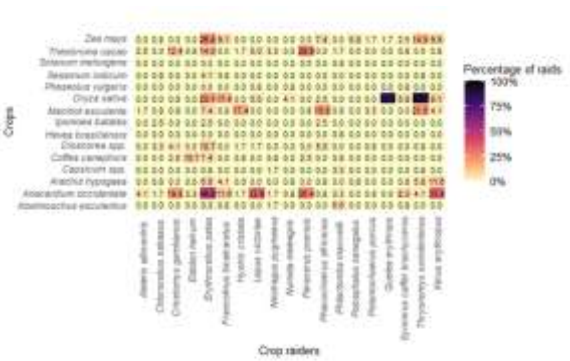

Fig. 3. Distribution of wildlife pressure on cultivated crops

Optimal household typologies using silhouette-based cluster validation

The evolution of average silhouette widths observed for different values of k indicates a progressive improvement in partition quality up to k= 5. The recorded values were 0.1700 for k= 2, 0.1902 for k = 3, 0.1938 for k = 4, and a peak of 0.1939 for k= 5, followed by a slight decline to 0.1896 for k= 6. This peak at k= 5 suggests an optimal configuration in terms of intra-cluster cohesion and inter-cluster separation. However, the marginal difference between silhouette indices for k= 4 and k= 5 (< 0.001) justifies the choice of a four-cluster solution, balancing statistical robustness, analytical parsimony, and operational clarity.

The analysis of silhouette widths associated with the 121 households distributed across four clusters confirms an overall satisfactory partition quality (Fig. 4). The identified groups consist of 27, 24, 30, and 40 households, representing approximately 22%, 20%, 25%, and 33% of the sample, respectively. This relatively balanced distribution, despite a slight predominance of Cluster 4, ensures adequate representativeness of socio-economic profiles.

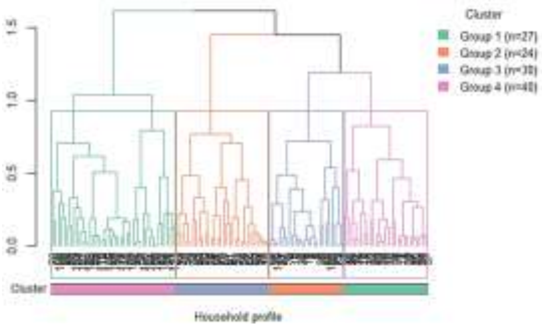

Fig. 4. Silhouette-based determination of optimal cluster number using Ward.d2 hierarchical clustering Brief cluster descriptions: Group 1: Diversified Mid-Sized Households in Peripheral Zones; Group 2: Diversified Large Households with High Labor Capacity and Low Formal Education; Group 3: Proximal, Mid-Sized Households with Moderate Resources; Group 4: Small, Educated Households in Remote Zones.

Moreover, the moderate and homogeneous size of the groups reinforces the robustness of the typology, avoiding excessive dominance of any single profile and ensuring a balanced interpretation of the results.

Socio-agricultural profiles of households

The clustering analysis reveals four distinct household profiles that differ significantly in spatial location, household size, cultivated area, age structure, and educational level (Fig 5 and 6). While crop diversity remains statistically similar across groups (Kruskal–Wallis χ^2= 1.156, df = 3, p= 0.764), proximity to the park and landholding size emerge as key discriminating factors. The strong association between clusters and village location (χ^2= 170.74, df= 6, p < 2.2e-16) underscores the influence of local ecological and socio-institutional contexts. Age (χ^2= 104.1, p ≤ 5e-05) and education (χ^2= 21.77, p= 0.0076) also contribute significantly to cluster differentiation.

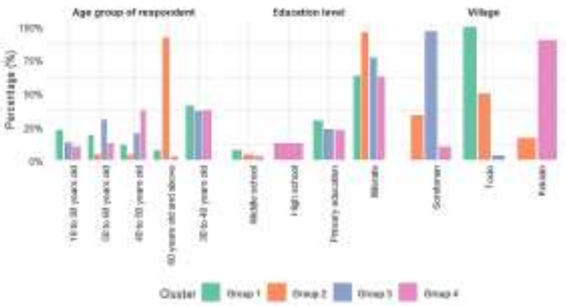

Fig. 5. Distribution of village, education level, and age group across household clusters

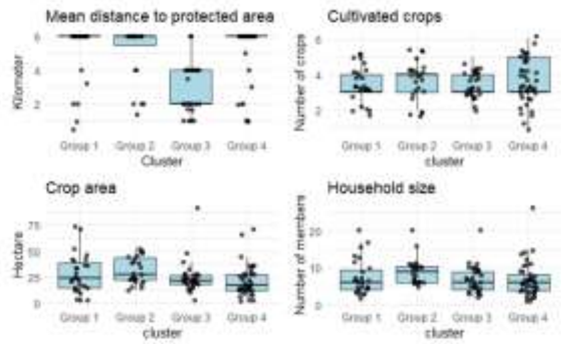

Fig. 6. Descriptive statistics of farming profiles: cultivated area, crop number, and household size by cluster

Cluster 1- Diversified Mid-Sized Households in Peripheral Zones- regroups households exclusively located in the village of Toulo (100 %), indicating a strong spatial anchoring.

These households are characterized by moderate household sizes (mean = 7.96), average cultivated areas (mean = 26.91 ha), and a relatively balanced age distribution, with a predominance of respondents aged 30–40 years (40.7 %). The average distance of plots from the park is relatively high (mean = 5.14 km), suggesting a peripheral location with potentially lower exposure to wildlife incursions. The educational profile shows a high illiteracy rate (63.0 %), though less extreme than in other clusters. Statistically, this group does not differ significantly from Clusters 2 and 4 regarding distance or cultivated area. However, its exclusive localization in Toulo and moderate demographic and agronomic characteristics justify its classification as a mid-range, diversified group with moderate exposure to crop-raiding risks.

This profile reflects a socio-agricultural configuration within the conceptual framework, characterized by moderate operational capacity and peripheral location, likely resulting in moderate risk perception and conventional response strategies.

Cluster 2- Diversified Large Households with High Labor Capacity and Low Formal Education is the most spatially dispersed, with households distributed across Toulo (50 %), Sorotonan (33 %), and Kokialo (17 %), indicating a cross-village profile. It is distinguished by the largest household sizes (mean= 9.04 members) and the highest average cultivated area (mean = 31.60 ha), suggesting strong labor capacity and land access. Age distribution is heavily skewed toward older respondents (91.7% aged 60+), and the illiteracy rate is the highest among all clusters (95.8%), indicating limited formal education. Despite its spatial dispersion, Cluster 2 stands out statistically for its significantly larger household and land sizes (Kruskal–Wallis $p < 0.05$). However, it does not differ significantly regarding crop diversity or average plot distance to the park. This profile reflects a group of experienced, resource-rich households with potentially greater capacity for implementing labor-intensive protection strategies, albeit with limited formal education. Within the framework, this cluster represents households with high exposure potential and labor capacity constrained by limited formal education.

Cluster 3- Proximal, Mid-Sized Households with Moderate Resources - is almost entirely composed of households from Sorotonan (97 %), and is uniquely characterized by its proximity to the protected area (mean distance = 2.89 km; median= 2 km), a statistically significant difference from all other clusters (Kruskal–Wallis $\chi^2 = 38.49$, $p < 0.001$, $\eta^2 = 0.303$). This proximity suggests a higher potential exposure to crop-raiding. Households in this cluster have moderate household sizes (mean = 7.07), average cultivated areas (mean = 24.83 ha), and a relatively young to middle-aged respondent profile (notably 30–40 and 50–60 age groups). The illiteracy rate is high (76.7 %), though not as extreme as in Cluster 2.

Despite similarities in crop diversity with other clusters, this group's spatial and demographic distinctiveness, particularly its proximity to the park, positions it as a high-risk profile for human-wildlife conflict. This has implications for targeted mitigation strategies. Within the framework, this cluster reflects households with moderate resources but elevated risk perception, likely requiring more active or adaptive response strategies.

Cluster 4- Small, Educated Households in Remote Zones - is predominantly located in Kokialo (90 %), with households situated at relatively greater distances from the park (mean = 5.14 km), similar to Clusters 1 and 2. It is characterized by the smallest household sizes (mean = 6.73 members) and the lowest average cultivated area (mean = 21.45 ha), both statistically significant (Kruskal–Wallis $p < 0.05$). The age distribution is concentrated in the 30–50 age range, and the educational profile is the most diverse: while 62.5% of respondents are illiterate, 22.5% have primary education, and 12.5% have completed secondary school, representing the highest proportion of educated respondents among all clusters. This profile suggests a group of relatively smaller, more educated households with limited land resources but potentially greater openness to knowledge-based or community-driven crop protection strategies. Within the framework, Cluster 4 represents households with limited land and labor resources but potentially greater openness to knowledge-based and community-driven protection strategies.

These findings, interpreted through the conceptual framework, support the need for differentiated, context-sensitive approaches to human-wildlife conflict mitigation tailored to each household profile's specific capacities, vulnerabilities, and spatial realities. The feedback loop embedded in the framework further suggests that the effectiveness of response strategies will influence future risk perception and resilience outcomes.

Household profiles and the heterogeneity of crop protection responses

The analysis of crop protection method usage reveals significant disparities across household clusters (Fig. 7), reflecting the differentiated socio-agricultural configurations outlined in the conceptual framework. These disparities are shaped by variations in household size, landholding, proximity to the protected area, age structure, and educational level—factors that influence risk perception and the selection of response strategies.

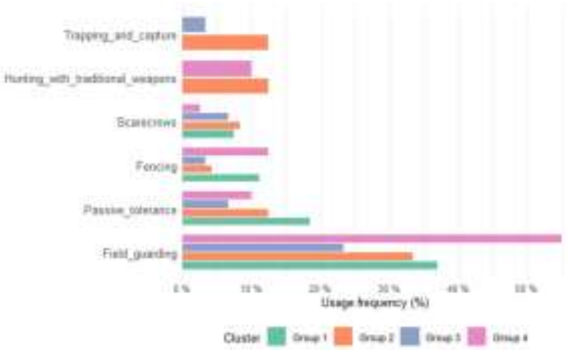

Fig. 7. Heterogeneity of crop protection strategies across household clusters

Field guarding emerges as the most commonly adopted strategy across all clusters. However, its frequency varies considerably: it is least used by Cluster 3 (23.3%), composed of mid-sized households located near the park with moderate resources and limited education, and most prevalent in Cluster 4 (55.0%), which includes smaller, more educated households in remote zones. This pattern suggests that better-educated households may favor structured and proactive protection strategies, consistent with the framework's emphasis on the role of human capital in shaping response behavior.

Cluster 1, composed of diversified mid-sized households in peripheral zones, shows a relatively high reliance on passive tolerance (18.5%) and fencing (11.1%), indicating a minimalist or low-intensity approach to risk management. This may reflect moderate risk perception due to greater distance from the park and limited exposure to wildlife incursions.

In contrast, Cluster 2, which includes large, elderly households with extensive landholdings and low education levels, adopts a diversified strategy. Usage rates are evenly distributed across trapping, traditional hunting, and guarding (12.5% each), suggesting an adaptive approach rooted in experience and labor availability, despite limited access to formal knowledge systems.

Cluster 3, despite its spatial cohesion and proximity to the park, shows the lowest overall adoption rates for all methods except guarding. This may reflect operational constraints, resource limitations, or differing priorities in managing crop-raiding risks. The low engagement with alternative strategies could also indicate a reactive rather than proactive posture, shaped by limited educational capital and moderate landholding.

Finally, the use of scarecrows remains marginal across all clusters (<8.3%), suggesting low perceived effectiveness or cultural disinterest in this method. These findings underscore the importance of integrating territorial, demographic, and educational dimensions into differentiated and context-sensitive mitigation strategies. Within the conceptual framework, they illustrate how socio-agricultural profiles shape risk perception and response behavior, ultimately influencing household resilience and the sustainability of human-wildlife conflict management.

Effects of household profiles on the adoption of protection strategies: results from the multinomial regression

Using Cluster 1 characterized by diversified, mid-sized households in peripheral zones—as the reference category, the model reveals differentiated behavioral patterns across clusters (Table 1). Notably, Clusters 2 and 4 households exhibit a higher propensity to adopt "Hunting with traditional weapons" (log-odds coefficients: +1.72 and +0.96, respectively). This tendency may reflect the influence of extensive farming experience in Cluster 2 and the emerging agency of more educated households in Cluster 4.

Table 1. Multinomial modeling of response strategy adoption across household profiles

Response strategy	Cluster 1 (Ref)	Cluster 2	Cluster 3	Cluster 4
Hunting with traditional weapons	−2.56	+1.72	+0.62	+0.96
Passive tolerance	+0.87	+0.74	+1.12	+1.87
Scarecrows	−0.96	+0.11	−0.99	−0.65
Trapping and capture	−0.37	+0.03	+0.03	−1.24

The strategy of "Passive tolerance" shows consistently positive associations across all clusters, with the strongest effect observed in Cluster 4 (+1.87), followed by Cluster 3 (+1.12), Cluster 1 (+0.87), and Cluster 2 (+0.74). This pattern may indicate a behavioral orientation toward non-confrontational or adaptive coping mechanisms, particularly among households with higher educational attainment or limited operational capacity.

In contrast, using "Scarecrows" and "Trapping and capture" presents more heterogeneous and often negative associations. For instance, Cluster 4 shows a notably negative coefficient for "Trapping and capture" (−1.24), suggesting a lower likelihood of adopting this method, potentially due to a preference for less labor-intensive or more knowledge-based strategies.

Similarly, "Scarecrows" are negatively associated with Clusters 1 (−0.96) and 3 (−0.99), and only marginally positive in Cluster 2 (+0.11), indicating limited appeal or perceived effectiveness across profiles.

After 23 Fisher scoring iterations, the model converged and yielded an AIC of 196.16, indicating acceptable model stability and fit. These results reinforce the conceptual framework's proposition that household-level characteristics particularly education, landholding, and proximity to risk play a critical role in shaping the selection of crop protection strategies. The observed heterogeneity in strategy adoption underscores the need for tailored interventions that align with each household profile's specific capacities, perceptions, and constraints.

DISCUSSION

This study provides a nuanced understanding of the complex interactions between wildlife species and agricultural systems in rural landscapes adjacent to the Mont Sangbé National Park (MSNP), Côte d'Ivoire. The findings confirm that crop-raiding is not a uniform phenomenon but is shaped by species-specific behaviors, crop types, and the socio-agricultural profiles of farming households. The high incidence of incursions by species such as the grass cutter, the red-headed quelea, and the patas monkey on strategic crops like rice, cassava, and cocoa aligns with broader patterns observed across sub-Saharan Africa, where granivores and rodents are primary agents of crop damage (Lahm, 1996; Mamo *et al.,* 2021; Naughton-Treves and Treves, 2005; Walker, 2010).

The vulnerability of perennial crops such as cashew and cocoa to arboreal and semi-arboreal species (the patas monkey, the Green Bush Squirrel) highlights the need for crop-specific and species-specific mitigation strategies. These findings support ecological studies emphasizing the role of feeding preferences and spatial foraging behavior in shaping wildlife incursions (Hill, 2000; Tavolaro *et al.,* 2022).

The household typology derived from silhouette-based clustering revealed four distinct socio-agricultural profiles, each with unique demographic, spatial, and educational characteristics.

This segmentation is consistent with frameworks that emphasize the heterogeneity of rural households in shaping agricultural decision-making and adaptive capacity (Manono *et al.,* 2025; Pacini *et al.,* 2014). The spatial distribution of clusters such as Cluster 3's proximity to the park and Cluster 4's educational diversity correlates strongly with the observed variation in crop protection strategies.

The adoption of field guarding as the dominant strategy across all clusters reflects its perceived reliability and cultural embeddedness. However, its higher prevalence in Cluster 4 (55.0%) composed of smaller, more educated households suggests that education may enhance the uptake of structured and proactive responses, even in resource-constrained settings. This is consistent with findings from (Chang'a *et al.,* 2016) and (Mnukwa *et al.,* 2025), which showed that education and access to information significantly influence the adoption of non-lethal and innovative practices.

Conversely, the diversified use of traditional methods (hunting, trapping) in Cluster 2, composed of large, elderly households with low education levels, reflects a reliance on experiential knowledge and labor availability. This aligns with (Blench, 2017) and (Conteh *et al.,* 2022), who emphasized the role of age and traditional ecological knowledge in shaping adaptive behavior in rural contexts.

The multinomial regression analysis further confirms that household socio-economic characteristics significantly influence the likelihood of adopting specific strategies. For instance, the positive association between Clusters 2 and 4 and the use of traditional hunting suggests that both experience (Cluster 2) and emerging agency (Cluster 4) can drive similar behavioral outcomes, albeit through different pathways. The strong positive effect of "Passive tolerance" in Cluster 4 (+1.87) may reflect a strategic choice rooted in risk perception and a preference for non-confrontational approaches, possibly influenced by higher education levels and lower exposure to wildlife.

In contrast, the negative coefficients for "Trapping and capture" in Cluster 4 (−1.24) and "Scarecrows" in Clusters 1 and 3 (−0.96 and −0.99, respectively) suggest either a lack of perceived effectiveness or cultural disinterest in these methods. These findings are consistent with (Hajdu, 2022) and (Burudi *et al.,* 2025), who report low adoption of scarecrows due to limited efficacy and symbolic associations.

Importantly, the model's convergence (23 iterations, AIC = 196.16) and the significance of selected coefficients reinforce the robustness of the analysis. The results support the conceptual framework's proposition that socio-agricultural profiles defined by landholding, education, and spatial exposure shape risk perception and, consequently, the selection of response strategies. The feedback loop embedded in the framework is also evident: households' experiences with specific strategies likely influence future perceptions and adaptations, contributing to dynamic resilience trajectories.

CONCLUSION

This study identified 19 wildlife species responsible for crop-raiding, with granivores and rodents—particularly the grass cutter, red-headed quelea, and patas monkey causing severe damage to rice, cassava, and cocoa. Perennial crops were especially vulnerable to arboreal species. Cluster analysis revealed four distinct household profiles whose socio-agricultural characteristics significantly influenced the adoption of protection strategies. Field guarding emerged as the most common method, while traditional hunting and trapping were more prevalent among older, less educated households. Passive tolerance was consistently associated across all clusters, whereas scarecrows and trapping showed low adoption rates. These findings highlight the need for tailored mitigation strategies that account for household diversity and species-specific crop-raiding patterns.

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REFERENCES

Altieri MA. 1995. Agroecology: The Science of Sustainable Agriculture (2nd Ed.). Intermediate Technology Publications Ltd (ITP), WESTVIEW PRESS, Estados Unidos de América. https://www.sidalc.net/search/Record/KOHA-OAI-UAAAN:31703/Description

Asaye B, Tekalign W, Dobamo T. 2024. Livestock predation, crop raiding, and community attitudes towards sustainable wildlife conservation in and around Mankira Forest, Southwest Ethiopia. BMC Ecology and Evolution **24**(1), 85. https://doi.org/10.1186/s12862-024-02279-2

Awuah R, Douglass R, Agyepong S, Kuwornu E. 2017. An adaptive household sampling method for rural African communities. African Journal of Food, Agriculture, Nutrition and Development **17**(1), 11477 11496.

Barua M, Bhagwat SA, Jadhav S. 2013. The hidden dimensions of human–wildlife conflict: Health impacts, opportunity and transaction costs. Biological Conservation **157**, 309 316. https://doi.org/10.1016/j.biocon.2012.07.014

Blench R. 2017. Fencing agricultural land in Nigeria: why should it be done and how can it be achieved? Field investigations on pastoralist-farmers' crises areas and enhancement of MISEREOR's partners interventions in Nigeria, Phase 3. MISEREOR. https://www.misereor.org/fileadmin/user_upload_misereororg/publication/en/foodsecurity/fencing-agricultural-land-in-nigeria.pdf

Bommarco R. 2024. Ecological redesign of crop ecosystems for reliable crop protection. A review. Agronomy for Sustainable Development **44**(6), 51. https://doi.org/10.1007/s13593-024-00987-z

Burudi JW, Kovács ET, Katona K. 2025. Wildlife fences to mitigate human–wildlife conflicts in Africa: A literature analysis. Diversity **17**(2), 87. https://doi.org/10.3390/d17020087

Chang'a A, Souza De N, Muya J, Keyyu J, Mwakatobe A, Malugu L, Ndossi HP, Konuche J, Omondi P, Mpinge A, Hahn N, Saibulu J, Kioko J, Kiffner C. 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

Chepkwony MC, Lyakurwa GJ, Sabuhoro E. 2025. Human–wildlife conflicts, household livelihood security, and conservation support among residents adjacent to the Maasai Mara National Reserve in Kenya. Wild **2**(1), 6. https://doi.org/10.3390/wild2010006

Conteh AMH, Gebge B, Kallon S. 2022. Using multinomial logistic regression model (MLRM) to assess the factors influencing the selection of farming business by cassava and rice farmers in Bombali District, Sierra Leone. International Journal of Advanced Research and Publications **5**(11), 103-108.

Dibloni OT, Ouoba D, Zoman YS, Yameogo S, Kabré BG. 2020. Caractérisation des conflits hommes-faune dans la Réserve de Biosphère de la Mare aux Hippopotames en zone sud soudanienne du Burkina Faso. Afrique Science **17**(2), 115 127.

Dickman AJ. 2010. Complexities of conflict: the importance of considering social factors for effectively resolving human–wildlife conflict. Animal Conservation **13**(5), 458 466.

Fry HC, Keith S. 2020. The Birds of Africa: Volume VII. Vol. 7. Bloomsbury Publishing. Londres.

Galley W, Anthony BP. 2024. Beyond crop-raiding: Unravelling the broader impacts of human-wildlife conflict on rural communities. Environmental Management **74**(3), 590 608. https://doi.org/10.1007/s00267-024-02018-9

Gueneau S, Jacobee F. 2005. Conservation de la biodiversité forestière tropicale en Afrique centrale: dépassionner les débats. Idées pour le débat, N°14. Institut du développement durable et des relations internationales.

Hajdu I. 2022. Top Five Strategies to Protect Crops from Wild Animals. AGRIVI, 31 mars. https://www.agrivi.com/blog/top-five-strategies-to-protect-crops-from-wild-animals/

Hill CM. 2000. Conflict of interest between people and baboons: Crop raiding in Uganda. International Journal of Primatology **21**(2), 299 315. https://doi.org/10.1023/A:1005481605637

Hill CM. 2005. People, crops and primates: A conflict of interests. Commensalism and Conflict: The Human-Primate Interface **4**, 40 59.

Kingdon J, Butynski T, Kalina J. 2024. Mammals of Africa: Volume II. Vol. 2. Bloomsbury Publishing. Londres. (p 784)

Kingdon J, Happold D, Butynski T, Hoffmann M, Happold M, Kalina J. 2013. Mammals of Africa: Volume VI. Vol. 3. Bloomsbury Publishing. Londres. 560p.

Kingdon J, Happold D. 2024. Mammals of Africa: Volume III. Vol. 3. Bloomsbury Publishing. Londres. 704p.

Koffi KC, Kouakou HB, Kouakou NK, Kouakou AB, Beda A. 2024. Phenological stage of the destruction of crops by wild animals around Mont Sangbé National Park, Western Côte d'Ivoire. International Journal of Agriculture & Biology **33**(3), 1-6.

Kosmidis I, Firth D. 2009. Bias reduction in exponential family nonlinear models. Biometrika **96**(4), 793 804. https://doi.org/10.1093/biomet/asp055

Lahm S. 1996. A nationwide survey of crop-raiding by elephants and other species in Gabon. Pachyderm **21**, 69 77.

Lauginie F. 2007. Conservation de la nature et aires protégées en Côte d'Ivoire (NEI/Hachette et Afrique Nature). Abidjan. 668p.

Madden F. 2004. Creating coexistence between humans and wildlife: global perspectives on local efforts to address human–wildlife conflict. Human Dimensions of Wildlife **9**(4), 247 257. https://doi.org/10.1080/10871200490505762

Mamo A, Lemessa D, Diriba OH, Hunde D. 2021. Pattern of crop raiding by wild large mammals and the resultant impacts vary with distances from forests in Southwest Ethiopia. Ecology and Evolution **11**(7), 3203 3209. https://doi.org/10.1002/ece3.7250

Manono BO, Khan S, Kithaka KM. 2025. A Review of the Socio-Economic, Institutional, and Biophysical Factors Influencing Smallholder Farmers' Adoption of Climate Smart Agricultural Practices in Sub-Saharan Africa. Earth **6**(2), 48. https://doi.org/10.3390/earth6020048

Mnukwa ML, Mdoda L, Mudhara M. 2025. Assessing the Adoption and Impact of Climate-Smart Agricultural Practices on Smallholder Maize Farmers' Livelihoods in Sub-Saharan Africa: A Systematic Review. Frontiers in Sustainable Food Systems **9**, 1543805. https://doi.org/10.3389/fsufs.2025.1543805

Naughton-Treves L, Treves A. 2005. Socio-ecological factors shaping local support for wildlife: crop-raiding by elephants and other. People and Wildlife, Conflict or Co-existence? 9, 252.

Nyhus PJ. 2016. Human–Wildlife Conflict and Coexistence. Annual Review of Environment and Resources **41**(1), 143 171. https://doi.org/10.1146/annurev-environ-110615-085634

Pacini GC, Colucci D, Baudron F, Righi E, Corbeels M, Tittonell P. 2014. Combining multi-dimensional scaling and cluster analysis to describe the diversity of rural households. Experimental Agriculture **50**(3), 376 397. https://doi.org/10.1017/S0014479713000529

Tavolaro F, Woodgate Z, Brown C, Redpath S, O'Riain JM. 2022. Multispecies study of patterns and drivers of wildlife impacts on human livelihoods in communal conservancies. Conservation Science and Practice **4**(7), e12773. https://doi.org/10.1111/csp2.12773

UNHCR. 2024. Sampling for household surveys. UNHCR Assessment and Monitoring Resource Centre.

United Nations. 2005. Designing Household Survey Samples: Practical Guidelines. Studies in Methods, Series F No. 98. Department of Economic and Social Affairs, Statistics Division.

Walker, Kendra L. 2010. Moving Away from Prescriptive Pachyderm Palliatives: Toward an Integrated Assessment of Farmer-Elephant Conflict in Gabon. PhD Thesis in Natural Resources and Environment, University of Michigan. https://deepblue.lib.umich.edu/handle/2027.42/75922.

Wezel A, Bellon S, Doré T, Francis C, Vallod D, David C. 2009. Agroecology as a Science, a Movement and a Practice. A Review. Agronomy for Sustainable Development **29**(4), 503 515. https://doi.org/10.1051/agro/2009004

Woodroffe R, Thirgood S, Rabinowitz A. 2005. People and wildlife, conflict or co-existence? Vol. 9. Cambridge University Press. Cambridge. 452p.