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Beyond Crop Raids: Socio-Ecological Resilience and Hidden Costs of Human-Monkey Conflict In Vervets around Mount Galim-Tignère, Cameroon

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ABSTRACT

Around Mount Galim in Cameroon and in 113 households, this study on human-vervet monkey (*Chlorocebus pygerythrus*) conflict investigated methods of protection against raids as well farmers' perceptions and food security. The results reveal, first, that raids caused 88, 261 USD in annual losses, or an average of 39.0% of agricultural products looted by monkeys in each of five villages concerned. Among the six protection methods, five crackers were the most popular, with 1.58 firecrackers/household/24 h used, even though this strategy is perceived as moderately ineffective and costly (122, 90/year/h/week). Secondly, farmers' perceptions were dichotomous, with 42.5% negative and 42.5% positive responses, showing no correlation with the duration of the conflict. Thirdly, no households are exposed to food insecurity despite significant agricultural losses. In reality, 49.8% and 58.2% of households derive their livelihood from livestock farming and trade respectively, with agriculture as means of subsistence accounting for only 49.8% of households, which probably explains the surprising socio-ecological resilience observed. The diversity of livelihoods has had a cushioning effect inhibiting the direct collapse of the local food system. In order to ensure sustainable coexistence, an integrated management framework calls for strengthening livelihood diversification, implementing alternative techniques to mitigate raids, and, above all, prioritizing early warning systems.

INTRODUCTION

Feeding a growing population sustainably is a challenge that communities everywhere must address (Naves *et al.*, 2025). In a context where natural habitats are being altered by humans for the intensive extraction of subsistence resources, sharing fragmented territories between wildlife and humans cannot be done without real conflict. This is why Blanco and Canal (2024) have called human-wildlife conflict a conflict of survival, regardless of the protagonists. In sub-Saharan Africa, and in Cameroon in particular, agroecosystems close to biodiversity hotspots are still the areas where human-wildlife conflicts are most widely documented. The Galim region is an example of a permanent hotspots of tension, especially between primates, including communities of vervets' monkeys, and local residents who practice subsistence and commercial agriculture (Gabellone *et al.*, 2025). Vervets' monkeys are primates known for their ability to adapt to humans. Several different groups of this primate have been identified as the main looters in several regions of the Galim-Tignère subdistrict, causing sometimes colossal economic damage with significant nutritional consequences for households (Asmamaw *et al.*, 2025).

Issues surrounding human-wildlife conflict are relatively recent on the continent, but understanding of this phenomenon remains incomplete and complex because there is little credible data on the real causes of daily raids, the effectiveness, cost, and nature of the methods used to counter these attacks. Furthermore, no studies have been conducted to clarify the impact of the damage and the socio-economic stability of local households. This lack of detailed data on all villages inhabiting Mount Galim severely limits the formulation of concrete solutions capable of simultaneously protecting crops and the biodiversity of native primates in the forests of Mount Galim. A holistic methodological approach remains key to understanding this complex ecosystem dynamic, such as that of sustainable human-wildlife coexistence. This is the case in the study conducted by Lopez-Angulo *et al.* (2025), which advocates for the sustainable coexistence of the main species in conflict-prone territories. According to Bruno *et al.* (2025), the gradual fragmentation of mountain primate habitats through agricultural intensification is the primary cause of the current conflict, and these primates are threatened (Galan-diag, 2025). According to Dalam-Diaz (2025), the most appropriate conservation approach

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is one that, above all else, combines local socio-economic realities with urgent conservation priorities. It is therefore urgent for this study to propose a practical integrated management framework to guide the conservation of gray vervet monkeys without compromising the food security of the local populations in the Mont Galim-Tignère region. The field missions carried out in this biodiversity hotspot aimed to assess, among other things, the extent of economic damage inflicted on forest edge crops by monkeys in survival mode. The also sought to evaluate the response system used by farmers to deal with these raids on an economic, social, and even cultural level. With the aim of filling glaring gap in the existing literature, fieldwork was conducted to evaluate the hypothesis that monkeys raids will be damaging to the local economy, including households, in the long and medium term.

LITERATURE REVIEW

Whether in the Americas, Eurasia, or even Africa human-wildlife conflict arises, is perceived, and is managed in more of less different ways. Harmonizing the management framework while taking in to account food security and local economic development without losing sight of the urgent need to conserve endangered species remains an achievable challenge (Angulo *et al.*, 2025). This should guide the theoretical conceptual framework of the current conflict in the Galim-Tignère subdivision, based on a review of the existing literature (Wallace & Hill, 2012; Blanco & Canals, 2024; Naves *et al.*, 2024; Mahadi, 2025). According to studies conducted on primates, gray vervet monkeys are one of the most voracious species and therefore capable of carrying out large-scale daily raids thanks to their intelligent adaptative abilities in relation to humans and their agroecosystems. The widespread poaching that often takes place around Faro National Park, located in the same ecological region, currently poses a double threat to the survival of primates (Dickman, 2010; Wallace & Hill, 2012; Barua *et al.*, 2023; Fuentes-Lamas *et al.*, 2025). Studies such as those conducted by Wallace & Hill (2012) and Barua *et al.* (2013) mention the sometimes-high financial costs of repelling and even killing primates. In addition, Barua *et al.* (2013) revealed that in any humans-wildlife conflict, there is immaterial damage that the authors described as hidden costs, such as significant psychosocial and health costs borne by farmers. König *et al.* (2020) on their study on the perceptions of local residents in conflict areas, point out that negative perceptions among local residents can amplify the crisis, while positive perceptions, that is to say acceptance of wildlife, can facilitate coexistence and thus successful conservation. The resilience of socio-ecological systems is an aspect that has been under estimated until now, especially in the case of human-wildlife conflicts. The work of Fuentes-Lamas *et al.* (2025) emphasizes a particular methodological approach that takes spatial and temporal dynamics into account. The methodology must incorporate simultaneous monitoring of wildlife and the food crops of local habitants. It is

should be added that when livelihoods are diversified through agriculture, livestock farming, and trade, the damage caused by primates is very often mitigated, thus protecting village households from food insecurity, as observed in some regions where the system is not diversity (Miller *et al.*, 2016). For these reasons, it is useful to study the economic and socio-ecological impacts between humans and gray vervet monkeys (*Chlorocebus pygerythrus*) in villages bordering the residual forests of the Mount Galim-Tignère in order to formulate a management framework adapted to the socio-economic and cultural realities of the communities and habitants, as well as to this ecosystem weakened by this conflict.

MATERIAL AND METHODS

Study Sites

The study was conducted in the Adamaoua Region (Figure 1- Fig. b), specifically in the fragmented landscapes of the Faro and Déo Division in Cameroon. Within these fragmented landscapes, there is a mosaic of mountain forest ecosystems at altitudes ranging from 1,033.16 to 1,153 m above sea level. Small agricultural plots are the areas where the habitats of gray vervet monkeys border the fields. The study focuses on five sites located in: Galim-South, Galim-Center, Galim-East, Galim-West and Galim-North (Figure 1-b). The entire study area converted a final area of 22.27 ha, bounded by a pentagon and lying between the latitudes North and South: Specifically, from 7.1027837 to 10.8829 N at 12.45862712 to 4.66199 E. A distance of 583.14 m was used for optimal configuration of the surveyed sites.

Data Collection

Sampling

Fieldwork was conducted in five villages (S1-S5), in which 113 households were sampled using the survey method. To ensure that all socioeconomic situations were represented in their geographical context, simple random sampling was the appropriate technique. This technique ensured statistical robustness, as it captured the diverse experiences of households to the greatest extent possible. The sampling methodology used in this study was inspired by the applied by Kansky *et al.* (2016) in their study modeling conflict between farmers and baboons in the Cape region of South Africa.

Surveys

Semi-structured interview and structured questionnaires were the two surveys techniques combined during the survey phase of this study, based on the suggestions made by Dickman (2020) for studies on humans-wildlife conflicts. The combination of open-ended interviews and standardize questionnaires was necessary to ensure the statistical robustness of the analyses by capturing the key drivers suggested by Kiffner *et al.* (2020). Informal interviews with farmers are appropriate when capturing inter-individual perceptions, which are dynamic variables, as well as defining strategies to counter vervet monkeys

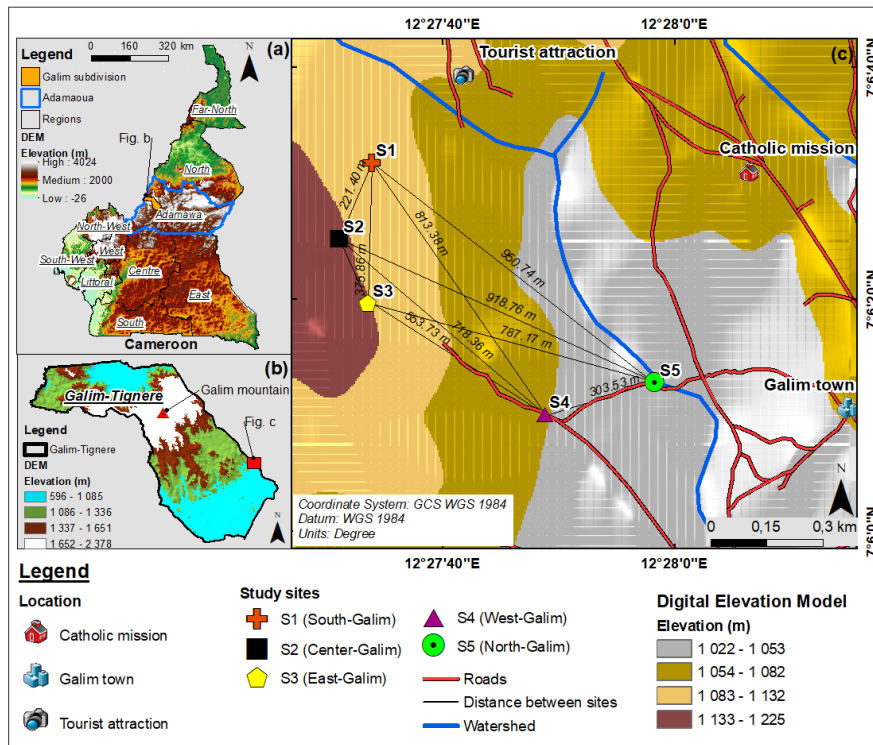


Figure 1: Spatio-ecological context of the human-wildlife conflict in the Galim-Tignère District, Adamaoua, Cameroon. (Fig. a) Location of the Adamaoua Region within the national context. (Fig. b) Details of the Galim subdivision within the Region. (Fig. c) Topographic gradient (596237 m) of the Mount Galim Massif and distribution of study sites (S1-S5). DTM (Digital Terrain Model) base map. Source: Satellite images processing and GPS field surveys (2021-2023).

(Kansky *et al.*, 2016). The work of Barua *et al.* (2013) and Kansky *et al.* (2016) both recommended measuring and estimating crop losses, which were expressed as a percentage of annual production in this study. The quantified losses were then converted into monetary (USD) based on local prices (August, 2023). The crop protection strategies used by farmers were listed with the amount of time (in h) per week allocated to each of these methods. The financial cost and perceived effectiveness of using these protection methods were also assessed. Perceived effectiveness was rated on a Likert scale ranging from 1 (very ineffective) to 5 (very effective). Based on similar scores, households' perceptions of monkey's raiders were also assessed. Scales 1 to 5 corresponded to very negative and very positive scores, respectively. Finally, food security within the households surveyed was assessed according to the scores of Barua *et al.* (2013), where scale 1 corresponds to high security and score 3 to food insecurity.

Statistical Methods and Analytical Pipeline Configuration

The Python program (version 3.x) using standards modules and packages was used via a pipeline to analyze the data in this study. This approach was chosen based on the principles of robustness and reproducibility advocated in the work of Harris *et al.* (2020) and Virtanen

et al. (2020). To gain a visual understanding of the distribution of key variables, including the duration of the conflict and the percentage of agricultural losses, it was necessary to apply the following four descriptive statistical measures. Measures of central tendency (mean and median); measures of dispersion (range, standard deviation, and quartiles); measures of shape (kurtosis, skewness), and measures of relative variability (coefficient of variability). To examine the relationship between variables and compare villages, three inferential statistical tests were applied as recommended by Quin & Keough (2002). For continuous and Gaussian-distributed variables, analysis of variance (ANOVA with Tukey-HSD multiple comparison) was applied to test for differences between villages. For variables that did not follow the reduced centered normal distribution, as well as ordinal variables, the Kruskal-Wallis test was applied. Relationship between categorical variables were measured using Chi-square (χ^2) test which Cramer's calculation. Associations between numerical variables were evaluated using Pearson's correlation test, supplemented by the calculation of 95% confidence of intervals. Effect sizes were also calculated systematically in order to assess the practical significance of the results beyond their statistical significance threshold (Lakens, 2013). The Chi-square (χ^2) was used to measure the magnitude of effects in ANOVA, the epsilon-square (ϵ^2) for the Kruskal-Wallis

test, and Pearson's correlation coefficient (r). For all statistical test, the significance threshold was set at the significant probability threshold, $\alpha=0.05$.

RESULTS AND DISCUSSION

Economic Impact of Monkey Raids and Households' Agricultural Resilience

Figure 2 provides an economic analysis of the damage caused by monkeys to the crop fields. It shows significant agricultural losses, but these are fairly evenly distributed among households. The average economic impact was 39.0% with a median of 38.0%, representing an increase ranging from 20.0% to 60.0% (Coefficient of variation=29.5%). In monetary terms, the losses amounted to USD 88, 261, or an average of USD 781 and 735 per household. In addition, there were significant individual losses (USD 315-475). The homogeneity of economic is illustrated in Figure 2-A, where average losses were similar (Galim-North to Galim-South), at

39.7%, with no significant differences between villages ($F=0.161$; $p=0.957$; ANOVA). Figures 2-B-C describe, respectively, the total economic impact per village and agricultural vulnerability, where the impact is observed across eight crops (with yams being the most affected, with 19 households affected). Figure 2-D shows the distribution of losses rates across the sample, where 39.0%, an average impact rate recorded, is considered high for human-wildlife conflict in Africa, as observed by Hill & Wallace (2012) in Uganda. The homogeneous distribution of economic impact across the five villages surveyed is a remarkable result. This suggests that crop raiding is not an isolated problem, but rather a systemic and even structural challenge, as the phenomenon has affected all agricultural landscape around Mount Galim. The regional dimension of the phenomenon is probably linked to the adaptative ubiquity of gray vervet monkeys on the one hand and the similarity of local agricultural systems on the other.

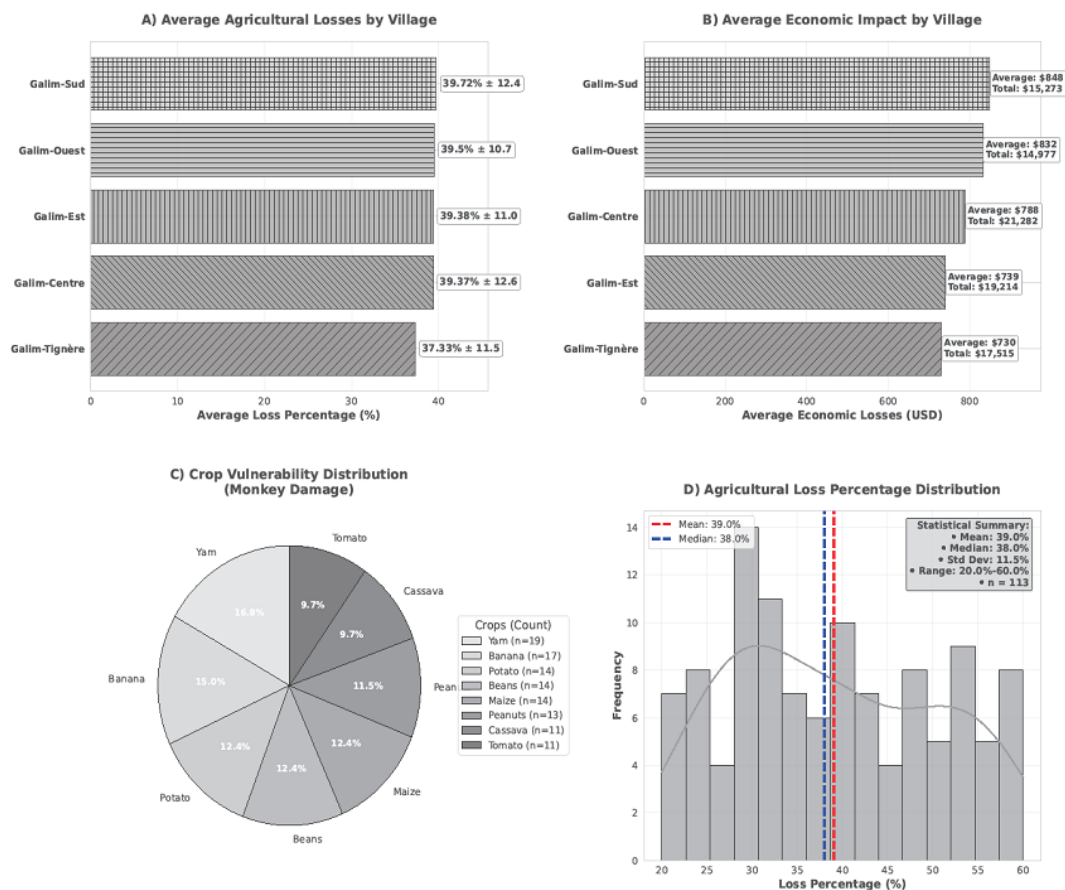


Figure 2: Economic impacts and detailed analysis of vervet raids on fields. (A) and (B) shows the average loss (%) and the total economic impact per village, respectively. (C) The subplot describes the distribution of the most frequently raided crops. (D) The subgraph shows the distribution of the sample (113) according to loss rates, including key metrics.

Perceived Effectiveness and Cost of Protection Methods

Figure 3-A presents the analysis of methods used to protect fields against monkeys' raids. Survey was

conducted in five villages, gathering the perceptions of 113 households. Overall, households were found to use a variety of methods (six types, and often used in combination for enhanced protection), with firecrackers

being the most frequently used (34 out of 113 households, or 30.10%). An averages of 1.58 methods per household used a distinct strategy. Figure 3-B analyzes the perceived effectiveness of these methods. On a scale of 1 (very ineffective) to 5 (very effectiveness), an average score of 2.96 (± 0.79) and median of 3.00 were recorded. Figure 3-C presents the analysis of the economic cost associated with the used of crop protection methods. The average annual cost was USD 122.9 (\pm USD 44.6) with a median of USD 122.0 and average of USD 50.0 to USD 200.0. Finally, Figure 3-D illustrated an analysis of the duration (in h) spent each week by type of method

used. An average of 5.4 h (± 2.0 h)/week is the time spent by each household. The fact that the use of firecrackers is perceived as ineffective, while this firecracker strategy costs an average of more than USD 122.9 and 5.4 h/week, highlights a strategic vicious circle for farmers. Although these acoustic methods are disruptive in the short term, they probably induce habituation in monkeys, thereby reducing their long-term effectiveness. This in ineffectiveness is a phenomenon reported by Yue *et al.* (2023). This perceived ineffectiveness is currently paving the way for alternative and sustainable community-based methods.

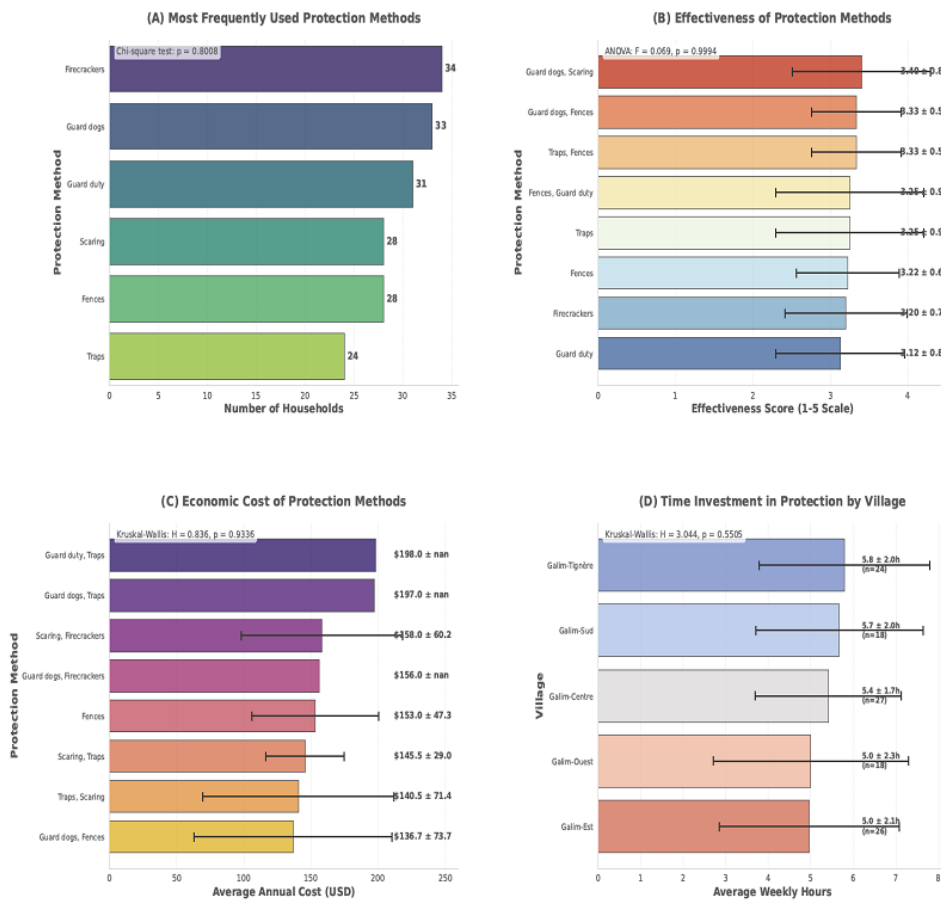


Figure 3: Indicators of methods for protecting fields against vervet raids. (A) indicates the number of households using each method. (B) Indicates the average effectiveness ratings (scale of 1 to 5). (C) The subplot shows the average annual costs (USD). (D) The subgraph shows the average number of hours per week allocated to protection efforts.

Farmers' Perceptions and Temporal Dynamics of The Conflict

A dichotomous perception of responsibility for agricultural damage was observed among the households surveyed, with a mixed average score of 2.96 on a scale of 1 to 5, as shown in Figure 4-A. This dichotomy was marked by divided perceptions, with 42.5% having a negative perception and 42.5% of households not recognizing the responsibility of vervet monkeys. The analysis of the temporal dynamics of the conflict is shown in Figure 4-B. The average duration of the conflict

was 5.7 (± 0.65) years. According to Figure 4-C, there is no statistically significant positive association between the duration of the conflict and farmers' perceptions. Ultimately, the study highlighted seasonality, with a critical period identified as the most damaging. During these seasonal cycles, 43.14% of 100% of agricultural losses were observed. The polarization of perceptions, with an equal proportion of farmers expressing negative and positive views, is the most surprising result of this survey. This dichotomous result challenges the hypothesis of widespread hostility towards gray vervet monkeys. This

evenly split opinion could be explained by motivations for acceptance and socio-cultural appreciation of gray vervet monkeys in villages (Dickman, 2010) on the

one hand, and on the other hand, Dickman (2010) also observed the normalization of looting by farmers when fields bordered the primates' natural habitats.



Figure 4: Analysis of human-vervet monkey conflict perceptions and duration. (A) Distribution of farmer perceptions towards vervet monkeys (scale from 1: Very Negative to 5: Very Positive). (B) Average conflict duration by village. ANOVA indicates a non-significant difference between villages ($F=0.59$, $p=0.6704$). (C) Relationship between conflict duration and perception. The Pearson correlation is weak and non-significant ($r = -0.045$, $p = 0.6333$, ns). (D) Seasonal distribution of critical conflict periods.

Links to Food Security and Multivariate Analysis

Figure 5-A shows the results of the food security analysis. It shows an average food security score of 2.018 ± 0.813 on a scale of 1 to 3, with an almost even distribution between the tree levels of security: high (31.9%), medium (34.5%), and low (33.6%). An average cultivated area of 2.802 ± 1.281 ha and average annual crop losses of $39.02 \pm 11.50\%$ were observed (Figure 5-B). Figure 5-C presents an analysis of income sources. It shows a clear dominance of income from trade (58.23%), followed by agricultural income (49.79%) and income from livestock farming (49.77%). No significant correlation was found between food security and agricultural losses ($r=0.029$; $p=0.755$), cultivated area ($r=-0.707$; $p=0.259$), or distance to the forest ($r=-0.021$; $p=0.824$). Figure 5-D reveals no significant differences between villages ($p<0.05$). In this study, the absence of a correlation between losses

inflicted by monkeys and food security is in itself a paradoxical result. This result therefore refutes the hypothesis put forward on the direct nutritional impact based on the observations of Barua *et al.* (2013). These authors' studies have widely reported on the adaptation mechanisms of communities living with human-elephant conflicts in India. Based on this result, it appears that diversification of livelihoods mitigates and compensates for the losses incurred by households. We can see the agricultural livelihoods account for only 49.8%, with the remainder of needs being met by trade (58.28%) and livestock farming (49.9%). The buffering effect observed in this landscape explains the remarkable resilience of this mosaic of mounting ecosystems. This resilience phenomenon is similar to that observed by Muller *et al.* (2016) and König *et al.* (2020).

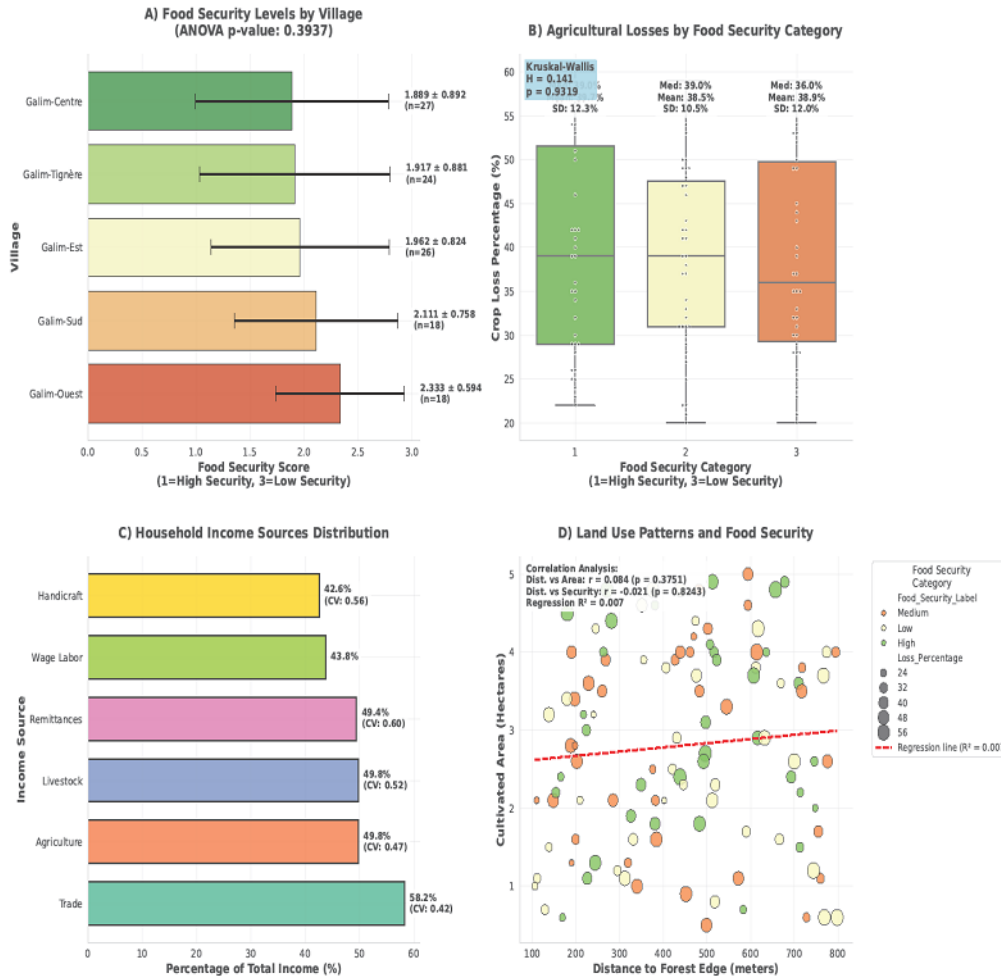


Figure 5: Food security levels by village and associated factors. Data from household surveys in five villages of the Galim subdivision. (A) Mean food security scores (1 = high, 3 = low). No significant difference was observed between villages (ANOVA, $p = 0.394$). (B) Agricultural losses (median $\approx 39\%$) did not vary significantly by food security level (Kruskal-Wallis, $p = 0.932$). (C) The subplot shows the distribution of household income sources. (D) The subfigure shows no significant difference between the variables food security, cultivated area, and distance to the forest ($R^2=0.007$).

Summary by Multidimensional Analysis

A summative multivariate analysis of the dynamics of the conflict between humans and gray vervet monkeys is shown in Figure 6. Two significant statistical links among the eleven analyzed are to be considered in Figure 6-A. The strongest correlation ($r=0.923$; $p=0.000$) was observed between the number of agricultural workers and household size. The other statistically significant correlation is the strong link ($r=0.862$; $p=0.000$) between economic losses (in US Dollars) and loss percentages. A summary table of these two statistically significant correlations is provided in Figure 6-B, as no other correlations were statistically significant apart from these two cases. Figure 7 presents an overview of the descriptive-inferential statistical tests, significant correlations, and effect size metrics. A total of 113 households in five villages (Galim-North to Galim-South) were surveyed. Average agricultural losses in the villages amounted to 39.0% ($\pm 11.5\%$), or USD 88, 261 in monetary terms. The average duration of the conflict was 5.7 years (± 2.9) according to Figure 7-C. Figure 7-A

shows not significant ($p>0.05$) between villages for the eight variables subjected to inferential analysis. Figure 7-E identifies the two positive and significant correlations ($|r| > 0.5$, $p < 0.05$). The strongest positive correlation is that observed between the number of households members and farmers. The other significant positive correlation observed was between the variables of agricultural loss rates and their local monetary values (USD). Figure 7-B summarized the cost-effectiveness analysis of the 17 crop protection methods. Figure 7-D shows the distribution of the four key variables in the study. Rethinking conventional approaches to human-wildlife conflict management. These results require all stakeholders to integrate the adaptive capacities of socio-ecological systems that were previously underestimated. We advocate for a more nuanced and robust integrated management framework. This framework must go beyond simple crop protection; it must provide a sustainable framework for socio-economic and ecological resilience.

Comprehensive Multivariate Analysis of Human-Monkey Conflict Dynamics

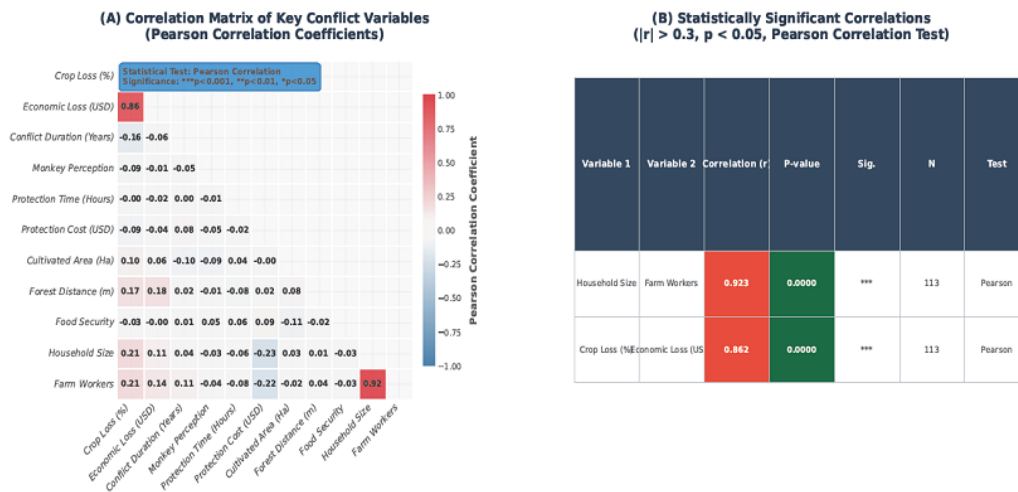


Figure 6: Multivariate analysis of human-monkey conflict dynamics. The correlation matrix (A) shows Pearson correlation coefficients between the eleven human-monkey conflict variables. The table (B) lists the two statistically significant correlations ($|\tau| > 0.3$; $p < 0.05$) identified, including the strongest relationship between household size and number of farm workers ($\tau = 0.923$; $p = 0.0000$). $N = 113$ for all tests

Comprehensive Analysis of Human-Monkey Conflict: Statistical Overview

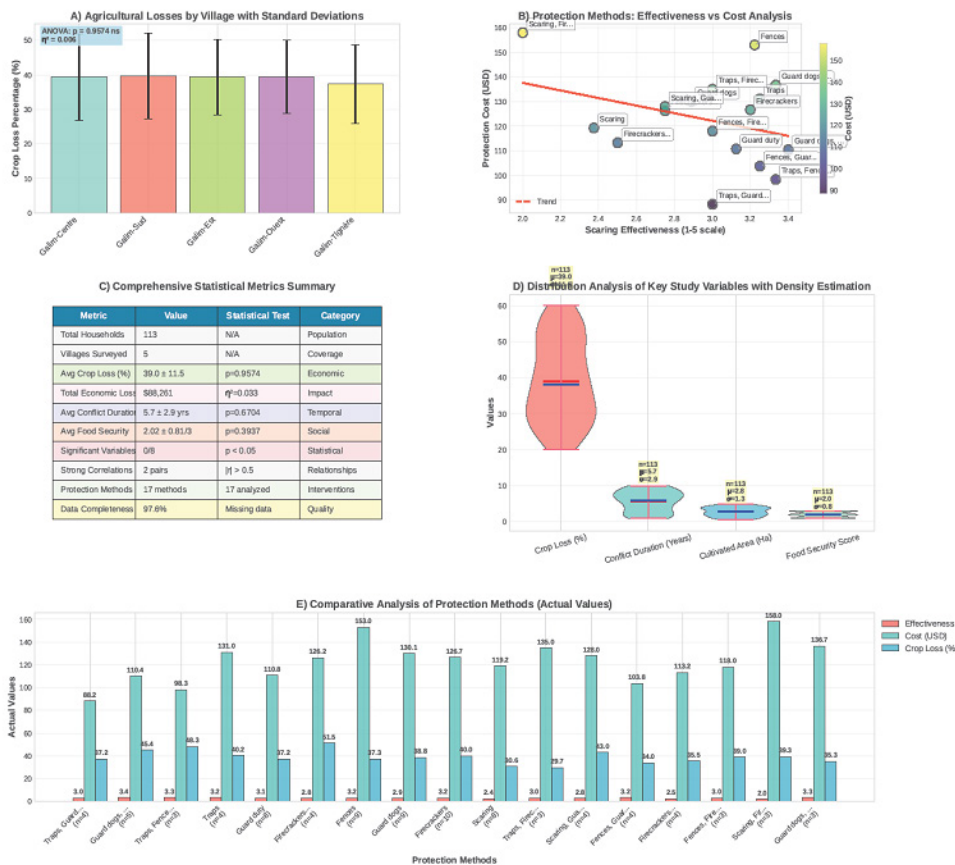


Figure 7: Multidimensional statistical analysis of the human-monkey conflict. (A) shows agricultural losses per village (mean ± standard deviation) with no significant difference (ANOVA, $p = 0.9574$). (B) analyzes the cost-effectiveness of the 17 protection methods. (C) summarizes the main statistical metrics, including an average crop loss of $39.0\% \pm 11.5\%$ and an average conflict duration of 5.7 ± 2.9 years. (D) presents the distribution of the four main study variables. (E) details the actual effectiveness, cost, and loss values for each combined protection method. $N = 113$ households for all analyses.

LIMITATIONS

A critique of the conceptual design of this study reveals limitations, which are mainly methodological. Potential biases are related to the statements made by respondents, as their answers may be false or incomplete due to memory impairment. The study on human-wildlife conflict conducted by Dickman (2010) identified the same methodological limitations. The sample of 113 households remains modest despite its required statistical representativeness, and this modest sampling may limit the generalization of these results to all mountain regions of Mount Galim-Tignère. A time series of at least 5-10 years should capture more than 80% of the variability in key conflict parameters, including the perceptions of local resident. Effort to reduce this limitation will be addressed in a forthcoming publication currently in progress on the temporal evolution of the conflict and socio-ecological resilience, among other topics.

CONCLUSION

The conflict between humans and gray vervet monkeys around Galim-Tignère in Cameroon was studied during six field missions carried out in this region. Despite the resilience of local socio-ecological systems, the study revealed significant losses inflicted by monkeys on local crops. These losses represent an average of 39.0%, equivalent to USD 88, 261 per year per household. Resilience was reflected in the statistical non-correlation between observed agricultural losses and food insecurity within households, which can be explained by the remarkable diversification of livelihoods among villagers. Current protection methods, mainly firecrackers, are received as costly (USD 122.9/year with 5.4 h/week). The use of these current protection methods is also perceived as ineffective, while farmers' perceptions of gray vervet monkeys are polarized and unaffected by the duration of the conflict. These results call for a new paradigm for managing human-wildlife conflict, an approach that must strengthen local socio-ecological resilience. There is urgent need to propose a practical integrated management framework that includes an early warning system, the promotion of alternative mitigation methods, and the strengthening of livelihood diversification. The approach formulated aims to promote sustainable coexistence by protecting both the livelihoods of local residents and the conservation of gray vervet monkeys in attractive landscape of Central Africa.

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