CROP RAIDING BY PRIMATES AROUND MONT SANGBÉ NATIONAL PARK, CÔTE D'IVOIRE: SEASONAL PATTERNS, SPECIES-SPECIFIC IMPACTS, AND FARMER RESPONSE STRATEGIES

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ABSTRACT

Conflicts between wildlife and farmers are common throughout sub-Saharan Africa, particularly in areas surrounding protected areas. These interactions result in significant crop losses and raise challenges for human–wildlife coexistence. This study investigates crop damage caused by primates in the buffer zone of Mont Sangbé National Park, Côte d'Ivoire. A field survey was conducted between February and April 2022, targeting 120 farming households across three villages surrounding the park. Data collection focused on damaged crop types, primate species involved, seasonal patterns of damage, affected plant parts, and control methods used. Statistical analyses, including chi-square tests and graphical visualizations, were conducted to investigate the relationships between crop types, damage characteristics, and protection strategies. A total of 202 damage incidents were recorded, with *Erythrocebus patas* responsible for 93.6% of cases. The most affected crops were cashew, maize, and rice. Damage was more frequent during the rainy season (68.8%) than the dry season (47.0%), indicating seasonal variation in risk profiles. Vegetative organs such as stems and tubers were the most vulnerable. Most farmers (66.8%) did not implement any protective measures, while human surveillance was the most commonly used method (20.3%). Significant associations were found between crop type, damage nature, and control method, revealing locally adapted agricultural responses to primate pressure. The findings highlight intense primate-induced pressure on crops, with species- and season-specific vulnerabilities. However, local adaptation of control strategies remains limited. An integrated management approach combining surveillance, non-lethal techniques, and community awareness is essential to reduce conflict and promote sustainable coexistence.

Keywords: Human–wildlife conflict, Crop damage, Problematic primates, Seasonal variation of damage, Control methods, Integrated management

INTRODUCTION

Interactions between wildlife and agricultural systems represent a growing concern in areas where protected ecosystems border rural communities, particularly within the fragmented landscapes of sub-Saharan Africa (Nyirenda *et al*., 2013; Storch *et al*., 2024). These interactions, commonly referred to as human–wildlife conflicts, are especially pronounced in the buffer zones of national parks, where agricultural activities coexist with rich but vulnerable biodiversity (Bariregа *et al*., 2010; Gayo, 2025).

Among the species involved, primates are frequently identified as major crop raiders, causing significant economic losses and fueling socio-ecological tensions (Anshebo *et al*., 2025; Deneke *et al*., 2024; Webber and Hill, 2014). Their ability to incorporate cultivated crops into their diet reflects a high degree of behavioral and ecological flexibility (McLennan and Hill, 2012), but also poses serious challenges for sustainable human–primate coexistence (Estrada *et al*., 2017; Torres-Romero *et al*., 2023).

The pressure exerted by primates on crops is exacerbated by deforestation, habitat fragmentation, and agricultural expansion, which reduce the availability of natural resources and drive wildlife closer to cultivated areas (Campbell-Smith *et al*., 2012; Chesney, 2024). In this context, semi-terrestrial primate species are particularly visible and active in agricultural zones, making them frequent targets of farmers' complaints (Strum, 2010).

In response to these pressures, rural communities have developed various deterrent strategies. However, the effectiveness of these methods remains uneven and often depends on the availability of resources, local knowledge, and risk perception (Anshebo *et al*., 2025; Barua *et al*., 2013; Deneke *et al*., 2024). Recent studies emphasize the importance of integrating local ecological knowledge and community perceptions into conservation and conflict mitigation strategies (Chesney, 2024; Storch *et al*., 2024).

Despite numerous reports of crop damage by primates, few studies have systematically quantified these phenomena in relation to crop types, agricultural seasons, and control methods. In particular, there is a lack of localized data to identify the most problematic species, the most vulnerable crops, and the most effective protection strategies. This gap limits the ability of park managers and rural communities in Côte d'Ivoire to develop appropriate and sustainable responses.

The primary objective of this study is to characterize crop damage caused by primates in the vicinity of Mont Sangbé National Park in Côte d'Ivoire, identify the responsible species, determine the most affected crops, investigate seasonal variations in damage, and examine the control methods employed by farmers.

Specifically, the study seeks to quantify the frequency of crop damage by primates and the types of crops affected, analyze the seasonal distribution of damage between the dry and rainy seasons, identify the most vulnerable plant parts, assess the control methods employed and their distribution across crop types, and explore statistical associations between crop type, nature of damage, and protection strategies, to better understand the local dynamics of human–primate conflict and inform management interventions.

MATERIALS AND METHODS

Study Site

This study was conducted in the buffer zone of Mont Sangbé National Park, located in the Man region of western Côte d'Ivoire. Established in 1976, the park spans an area of 95,000 hectares and serves as a vital sanctuary of biodiversity (Lauginie, 2007). Surrounding the park is a 200,000-hectare inhabited buffer zone, characterized by the presence of four ethnic groups—Yacouba, Toura, Mahou, and Worodougou—and a mosaic of agricultural activities, including both subsistence and commercial crops.

Fieldwork was carried out in rural areas adjacent to the park, where human–wildlife conflicts are particularly frequent (Koffi *et al*., 2024). This context makes the region especially relevant for studying interactions between local communities and protected ecosystems. The study sample consisted of 120 farming households, evenly distributed across three villages located in close proximity to Mont Sangbé National Park: Toulo (8.152492° N, 7.398339° W), Sorotonan (8.089529° N, 7.124255° W), and Kokialo (7.992472° N, 7.480007° W), with 40 households randomly selected in each village. These locations were chosen based on their strategic geographic position and the high frequency of interactions between local populations and wildlife, making them particularly suitable for analyzing human–wildlife dynamics (**Fig.1**).

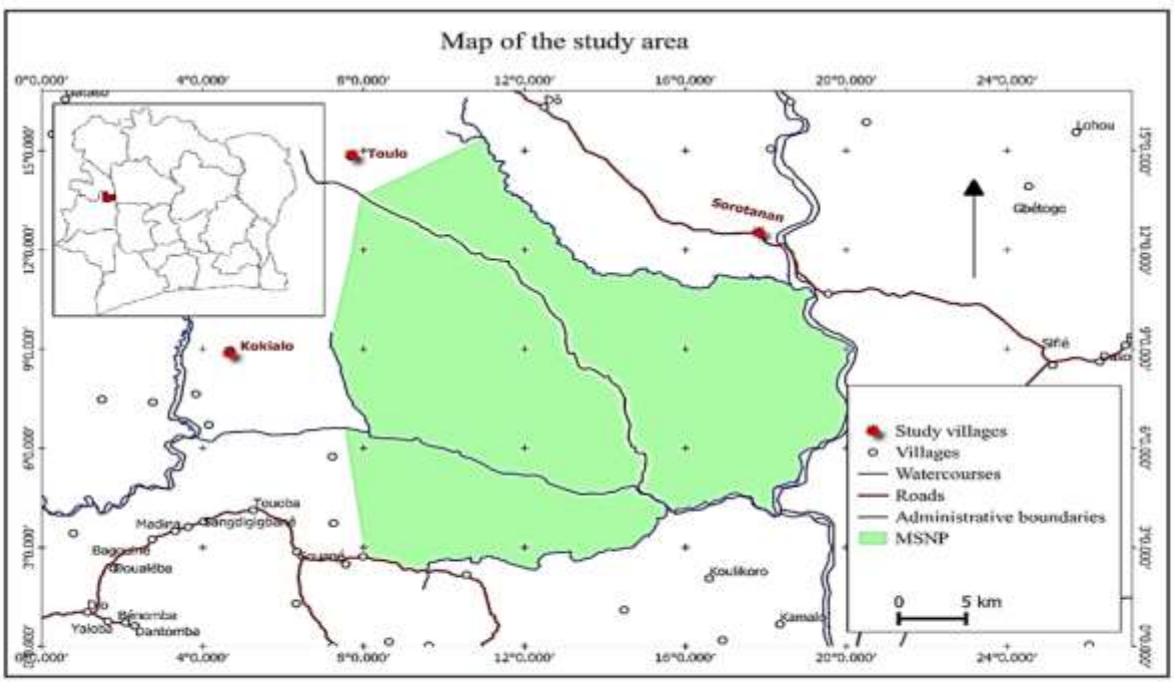

Fig. 1. The location of the study villages.

Data Collection

Between February and April 2022, a field survey was conducted in three villages located on the periphery of Mont Sangbé National Park to document crop damage caused by primates and analyze the control strategies adopted by farmers. The data collection team consisted of three experienced surveyors, supported by two ecologists from the Ivorian Office of Parks and Reserves (OIPR), who assisted in the preliminary identification of primate species responsible for the damage, as well as the affected crop species. Subsequently, primate species were scientifically confirmed using Kingdon's field guide (Kingdon, 2014), while cultivated plant species were validated using the identification manual published by the Centre National de Recherche Agronomique of Côte d'Ivoire (CNRA, 2024). The survey was based on a structured questionnaire covering several key topics: types of crops cultivated, primate species identified as crop raiders, damage observed during the dry and rainy seasons, affected plant parts (roots, stems, leaves, flowers, fruits, tubers, seedlings), and control methods employed by farmers.

Statistical Analyses

Statistical analysis focused on quantifying the frequency of crop attacks by calculating the percentage of damage incidents per crop type, which were then visualized graphically to highlight the most targeted crops. A seasonal comparison of damage was performed by calculating the proportion of affected plots during the dry and rainy seasons, and a chi-square test of independence was applied to assess the statistical significance of the seasonal differences. Control methods were categorized, quantified, and visualized using horizontal bar charts generated with the ggplot2 package in R (version 4.4.3). Two cross-tabulation analyses were conducted: one between crop types and damage types, and another between crop types and control methods. In both cases, contingency tables were constructed and analyzed using chi-square tests, with standardized residuals visualized as heatmaps to highlight the most significant associations. All statistical procedures were performed using R, version 4.4.3.

RESULTS

Crop Damage by Primates

A total of 202 crop damage incidents were reported by the 120 surveyed households around Mont Sangbé National Park, representing an average of 1.68 occurrences per household. These figures reflect a significant level of pressure exerted by primates on local agricultural systems.

Two primate species were identified as responsible for the damage. The patas monkey (*Erythrocebus patas*; Schreber 1774) accounted for the vast majority of attacks, with 189 cases (93.6%), compared to only 13 cases (6.4%) attributed to the green monkey (*Chlorocebus sabaeus*; Linnaeus 1766). This strong asymmetry indicates that the patas monkey is the primary crop-raiding species in the study area, both in terms of frequency and overall impact. Although green monkey consistently causes damage when present, their activity range appears to be much more limited.

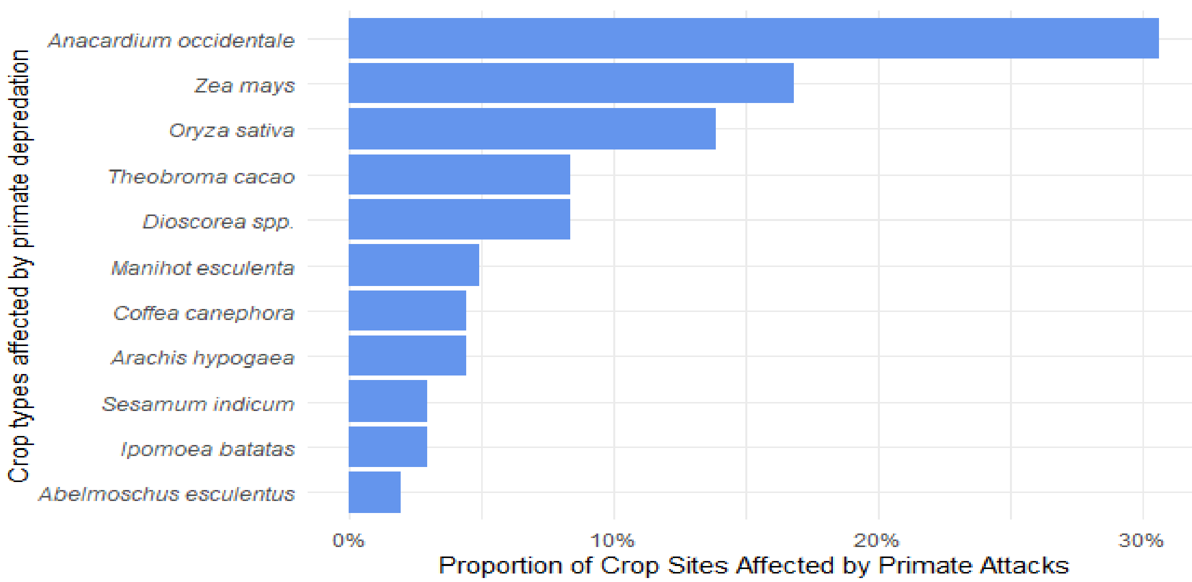

Fig.2. Primate Depredation on Crops: Types and Site-Level Impact.

Analysis of crop-specific damage distribution revealed that 11 crops were damaged by primates, with varying levels of vulnerability among cultivated species (**Fig.2**). Cashew orchards (*Anacardium occidentale* L.) accounted for 30.7% of damaged plots, followed by maize (*Zea mays* L., 16.8%) and rice (*Oryza sativa* L., 13.9%). Yams (Dioscorea spp.) and cocoa (*Theobroma cacao* L.) showed similar damage rates of approximately 8.4%, while cassava (*Manihot esculenta* Crantz) and groundnuts (*Arachis hypogaea* L.) each represented between 4% and 5% of cases. Marginally affected crops included coffee (4.5%), sweet potato (*Ipomoea batatas* (L.) Lam., 3%), sesame (*Sesamum indicum* L., 3%) and okra (*Abelmoschus esculentus* (L.) Moench, 2%).

This ranking of crops by exposure to damage suggests that cashew, maize, and rice should be prioritized for protection measures, likely due to their high attractiveness to primates. Furthermore, the results highlight the need to focus management efforts on the patas monkey, while maintaining targeted monitoring of the green monkey to detect potential spatiotemporal shifts in its crop-raiding behavior.

Seasonal Variation in Crop Damage

Out of the 202 plots affected by primate crop raiding, 95 (47.0%) experienced damage during the dry season, while 139 (68.8%) were impacted during the rainy season, indicating a significantly higher pressure from primates during the wet period. This inter-seasonal difference may be explained by the greater availability of mature crops during the rainy season. Additionally, increased vegetation density during this period may facilitate primate movement and concealment, making crops more vulnerable to attacks.

The data show that 107 plots were damaged exclusively during the rainy season, 63 exclusively during the dry season, and 32 plots were affected in both seasons. A Yates-corrected Pearson chi-square test ($\chi^2 = 100.05$; df = 1; $p < 2.2 \times 10^{-16}$) indicates that the distribution of primate attacks is not independent between seasons. Notably, the number of plots affected in both seasons is substantially lower than expected under the assumption of independence. This suggests a seasonal dissociation in risk profiles: a plot raided during the dry season is less likely to be targeted again during the rainy season, and vice versa.

Such dynamics may reflect seasonal variations in crop phenology, the availability of natural resources, or changes in primate movement patterns.

Crop-Specific Vulnerability Across Seasons

The distribution of primate attacks across crop types reveals contrasting vulnerability profiles (**Fig. 3**). Cashew orchards were heavily targeted during the dry season (27.7% of plots) but minimally affected during the rainy season (3.5%). This pattern may correspond to a post-harvest period when leftover fruits attract primates. In contrast, maize and rice were almost untouched during the dry season but heavily raided during the rainy season (16.8% and 13.9%, respectively), likely due to their maturity stage and accessibility during that period.

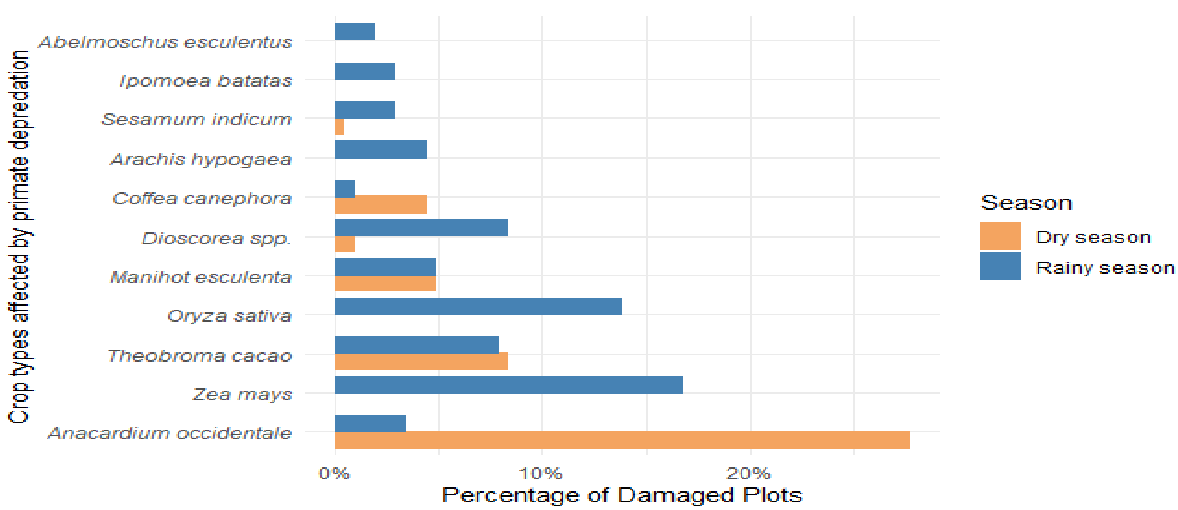

Fig. 3. Crop Damage by Primates Across Seasons.

Cocoa and cassava exhibited stable damage rates across both seasons (8.4% vs. 7.9% for cocoa; 4.9% for cassava in both cases), suggesting consistent attractiveness throughout the year. Other crops—including yams, coffee, groundnuts, sweet potato, sesame, and okra—were primarily affected during the rainy season, indicating the need for seasonally targeted protection strategies.

Management Practices and Farmer Responses

Analysis of management practices reveals that the majority of farmers (66.8%) do not implement any protective measures against primate incursions, leaving their plots highly vulnerable to damage (**Fig. 4**). This lack of response may be attributed to economic or logistical constraints that limit access to effective deterrents. Among households that adopted control strategies, direct human surveillance ("field guarding") was the most commonly used method, reported by 20.3% of respondents. This practice, based on active presence in the fields, is perceived as effective and relatively accessible, although it is time-consuming and difficult to sustain over long periods.

Capture and trapping techniques ranked second (8.9%), followed by the use of live deterrents such as scarecrows (3.5%). Traditional hunting with weapons was marginal (0.5%). This heterogeneity in method adoption reflects disparities in available resources, technical knowledge, and perceptions of the effectiveness of different approaches.

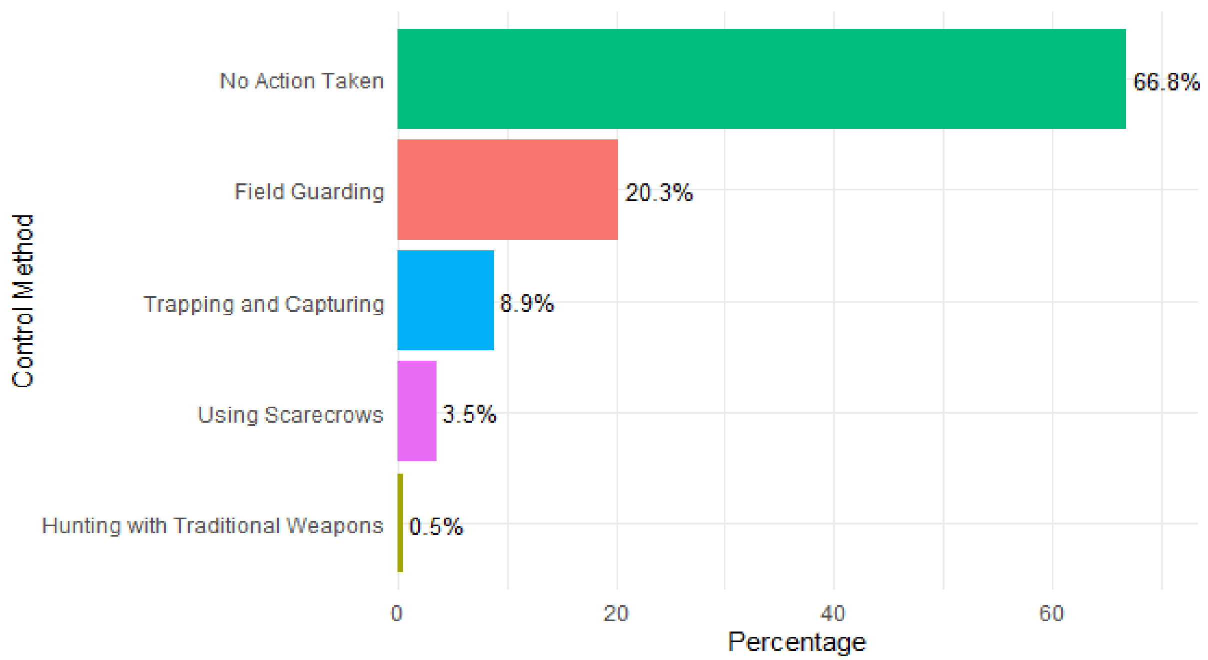

Fig. 4. Distribution of Control Methods.

Association Between Crop Type and Damage Characteristics

Statistical analysis revealed a significant association between crop type and the nature of observed damage. The high value of the chi-square statistic ($\chi^2 = 506.81$; df = 60; $p < 2.2 \times 10^{-16}$) led to a clear rejection of the independence hypothesis, indicating that damage profiles vary significantly across different cultivated species.

Analysis of standardized residuals highlighted notable deviations between observed and expected frequencies, revealing statistically overrepresented or underrepresented crop–damage combinations (**Fig.5**). For instance, rice stems were damaged far more frequently than expected (standardized residual = 10.88), as were the tubers of yam and cassava (residuals = 7.88 and 6.98, respectively). Yam seedlings also showed marked vulnerability (residual = 6.04). Conversely, maize flowers and yam fruits were less frequently attacked than expected (residuals = –2.03 and –3.63), suggesting lower attractiveness of these plant organs to primates.

These discrepancies confirm that the relationship between crop type and damage form is not uniform. Certain crop species exhibit particularly vulnerable organs, underscoring the need for targeted protection measures.

Association Between Crop Type and Control Method

Analysis of the relationship between crop type and control method revealed a statistically significant association ($\chi^2 = 78.27$; df = 40; $p = 2.8 \times 10^{-4}$), indicating that protection practices are not evenly distributed across crop types.

In other words, the choice of control strategy is strongly influenced by the specific crop, indicating that farmers tailor their responses to agronomic constraints and vulnerability profiles.

Examination of standardized residuals from the chi-square test identified specific associations between certain crops and control methods (**Fig. 6**). Direct human surveillance (field guarding) was significantly overrepresented for sweet potato (residual = 3.43), suggesting heightened attention to this crop, likely due to its vulnerability or economic value. Trapping and capturing were strongly associated with sesame (residual = 4.74), indicating a targeted strategy possibly linked to the nature of damage or field configuration. Attacks on rice were more frequently accompanied by traditional hunting (residual = 2.31) and the use of scarecrows (residual = 2.06), reflecting a diversity of responses to a highly exposed crop.

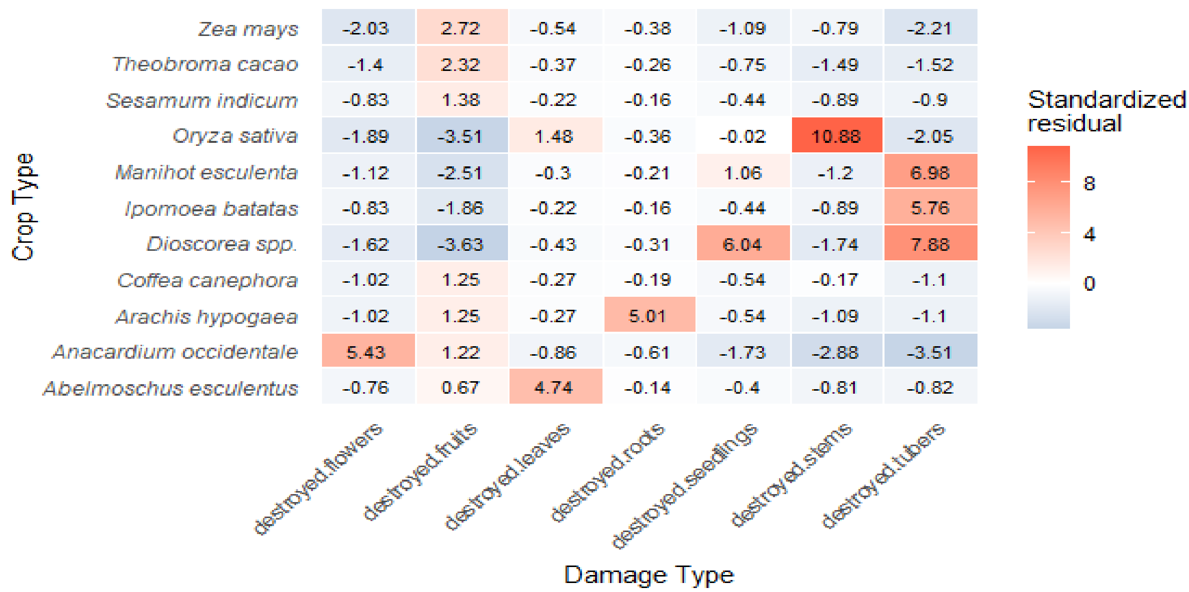

Fig. 5. Heatmap of Standardized Residuals Between Crop Type and Damage Type.

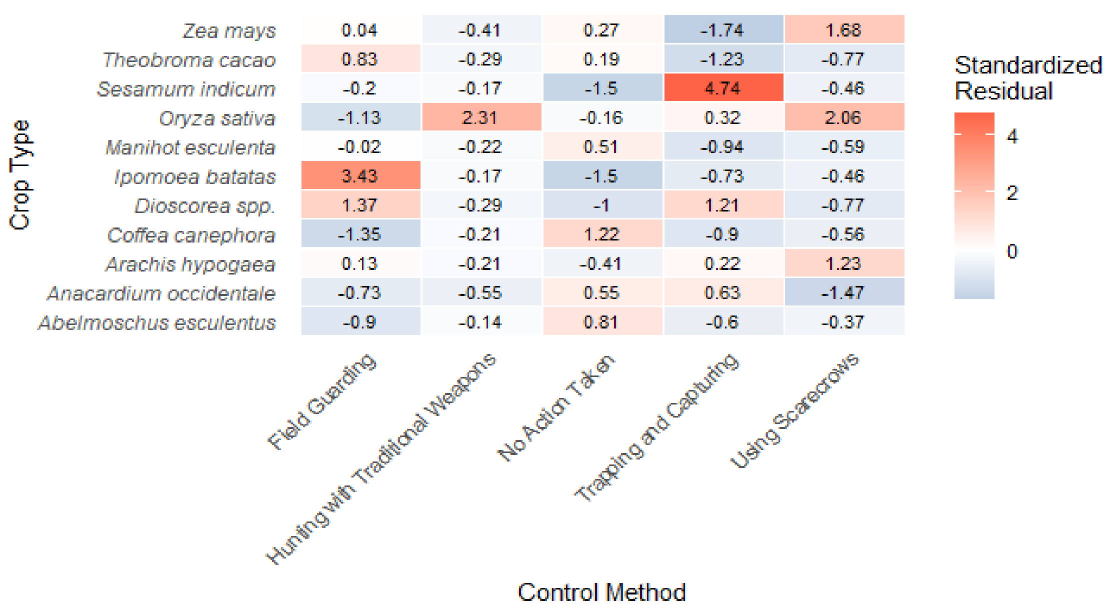

Fig. 6. Heatmap of Standardized Residuals Between Crop Type and Control Method.

No crop–method combination showed a residual below –2, indicating that no control method was systematically neglected for any given crop. These results suggest that farmers adjust their protection strategies based on crop characteristics, available resources, and local experience. Sweet potatoes benefit from close monitoring, sesame from intensive trapping, and rice from a combination of deterrent measures, including scaring and traditional hunting methods.

DISCUSSION

These findings from the buffer zone of Mont Sangbé National Park reveal significant primate pressure on subsistence crops, with an average of 1.68 damage incidents per household. This level of incursion is comparable to that reported in other human–wildlife interface zones across West Africa (Hill, 2000; Naughton-Treves *et al*., 1998). The predominance of patas monkey (93.6% of attacks) over green monkey (6.4%) suggests either behavioral specialization or a higher local density of the dominant species, as observed in other savanna contexts (Saj *et al*., 2001; Strum, 2010).

The ranking of affected crops indicates that certain plant species are particularly attractive to primates. Cashew, maize, and rice alone account for over 60% of damage cases. These results align with the findings of (Warren *et al*., 2007), who noted that primates tend to target crops with high energy value or rapid maturation. Crop phenology plays a key role in this dynamic, influencing the seasonal timing of attacks.

Damage intensity was significantly higher during the rainy season (68.8%) compared to the dry season (47.0%), reflecting increased availability of agricultural resources during the wet period. The chi-square test confirmed a seasonal dissociation in risk profiles, suggesting that ecological and behavioral factors vary across seasons (Hill, 2000). This observation is consistent with Hill (2005), who reported that primate movements toward agricultural zones are often driven by resource scarcity during the rainy season.

The absence of protective measures among 66.8% of households highlights a structural vulnerability in farming systems. The predominance of direct human surveillance (20.3%) as a control method reflects a strategy that is accessible but labor-intensive and difficult to sustain (Saj *et al*., 2001). Trapping (8.9%) and scarecrow use (3.5%) remain marginal, while traditional hunting is nearly absent (0.5%). These findings support (Hill, 2017), who emphasized that economic and logistical constraints limit the adoption of effective deterrent methods.

Standardized residual analysis from the chi-square test revealed significant associations between specific crops and specific types of damage. Rice stems, yams and cassava tubers, and yam seedlings were particularly vulnerable, whereas maize flowers and yam fruits were less frequently targeted. These results confirm that vegetative organs are often the most exposed, requiring targeted protection measures, as recommended by (Warren *et al*., 2007).

Finally, the statistically significant association between crop type and control method indicates local adaptation of management practices. For example, sweet potatoes benefit from close monitoring, sesame from intensive trapping, and rice from a combination of deterrent measures, including scaring and traditional hunting methods. These adjustments reflect farmers' empirical knowledge of crop-specific risk profiles (Hill, 2005; Webber and Hill, 2014).

CONCLUSION

This study, conducted in the buffer zone of Mont Sangbé National Park, highlights significant primate pressure on local agricultural systems, with an average of 1.68 crop-raiding incidents per household. The results show that the patas monkey is by far the most involved species, accounting for over 93% of attacks, while the green monkey, although consistently damaging when present, appears to have a more spatially restricted range. The analysis reveals differentiated crop vulnerability, with cashew, maize, and rice being the primary targets. The marked seasonality of attacks—more frequent during the rainy season—underscores the importance of considering crop phenology and ecological dynamics when planning protection measures. Farmers' control strategies were found to be heterogeneous and often limited, with the majority of plots left unprotected. Human surveillance remains the most commonly used method, despite its labor-intensive nature. Statistical associations between crop type, damage characteristics, and control methods confirm a degree of local adaptation in practices, shaped by experience and crop-specific constraints. These findings emphasize the need to develop integrated human–wildlife conflict management approaches that combine active monitoring, non-lethal deterrents, and community awareness. A better understanding of primate behavior and crop vulnerability factors will help optimize interventions, reduce agricultural losses, and promote sustainable coexistence between rural communities and the park's biodiversity.

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