

## INTERACTIONS BETWEEN CROPPING SYSTEMS DIVERSITY AND CROP RAIDER PRESSURE IN A TROPICAL AGROFORESTRY ZONE IN THE WESTERN CÔTE D'IVOIRE

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### ABSTRACT

This study investigates the relationship between cropping system diversity and crop raider pressure in the agroforestry zone surrounding Mont Sangbé National Park in Côte d'Ivoire. In the context of expanding agriculture and forest fragmentation, farmers must manage a mosaic of food and cash crops while contending with wildlife incursions. The research aims to understand how the structure of cropping systems influences the diversity and abundance of crop-raiding species, to inform more effective and sustainable control strategies. Between February and April 2022, surveys were conducted with 120 households across three villages. Data collected included crop types, cultivated areas, crop raider species, and farmers' perceptions of damage. The analysis focused on crop distribution, pest diversity, and the construction of a pest-crop interaction matrix. Fifteen cultivated species were identified, with cashew being the most widespread. Twenty-five crop raider species were recorded, with *Erythrocebus patas*, *Thryonomys swinderianus*, and *Quelea erythrops* accounting for nearly half of all incidents. Rice and cashew were the most affected crops. By grouping crops into functional guilds (cereals, tubers, arboreal, and secondary), the study proposes a framework for tailoring pest management strategies to local ecological and economic conditions, thereby enhancing the resilience of tropical farming systems.

**Keywords:** Human-wildlife conflict, Crop raiding, Agroforestry systems, Pest management strategies, Perception of damage, Functional crop guilds.

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### INTRODUCTION

In tropical agricultural systems, agricultural sustainability depends on a complex interaction between agronomic diversity, ecological processes, and biotic pressures (Altieri, 2009; Matson et al., 1997). In West Africa, and particularly in Côte d'Ivoire, farmers are increasingly confronted with human-wildlife conflicts, exacerbated by habitat fragmentation, the expansion of agricultural areas, and the decline of forest resources (Brou et al., 2024; Kouao et al., 2018; Lamarque et al., 2010). These changes lead to more frequent attacks by crop pests, jeopardizing food security, household incomes, and the overall stability of agricultural systems. In this context, agroforestry practices in western Côte d'Ivoire illustrate a growing trend: the coexistence of a wide range of food and cash crops, alongside a variety of multi-species crop pests (Koffi et al., 2024; Kouao et al., 2018). The variability of cultivated areas, the richness of pest species, and the proximity to forested areas generate varied vulnerability profiles for households (Webber and Hill, 2014). Faced with these challenges, farmers resort to defense strategies ranging from traditional monitoring methods to selective trapping, often relying on indigenous knowledge (Hill, 2017). Despite the wealth of research, the scientific literature remains fragmented. Agronomic studies primarily focus on crop diversity (Altieri, 1999; Kremen and Miles, 2012; Letourneau et al., 2009; Matson et al., 1997; Tschamtker et al., 2005), while ecological studies focus on pest species identification (Bellotti et al., 1994; Perfecto and Vandermeer, 2008; Stenseth et al., 2003).

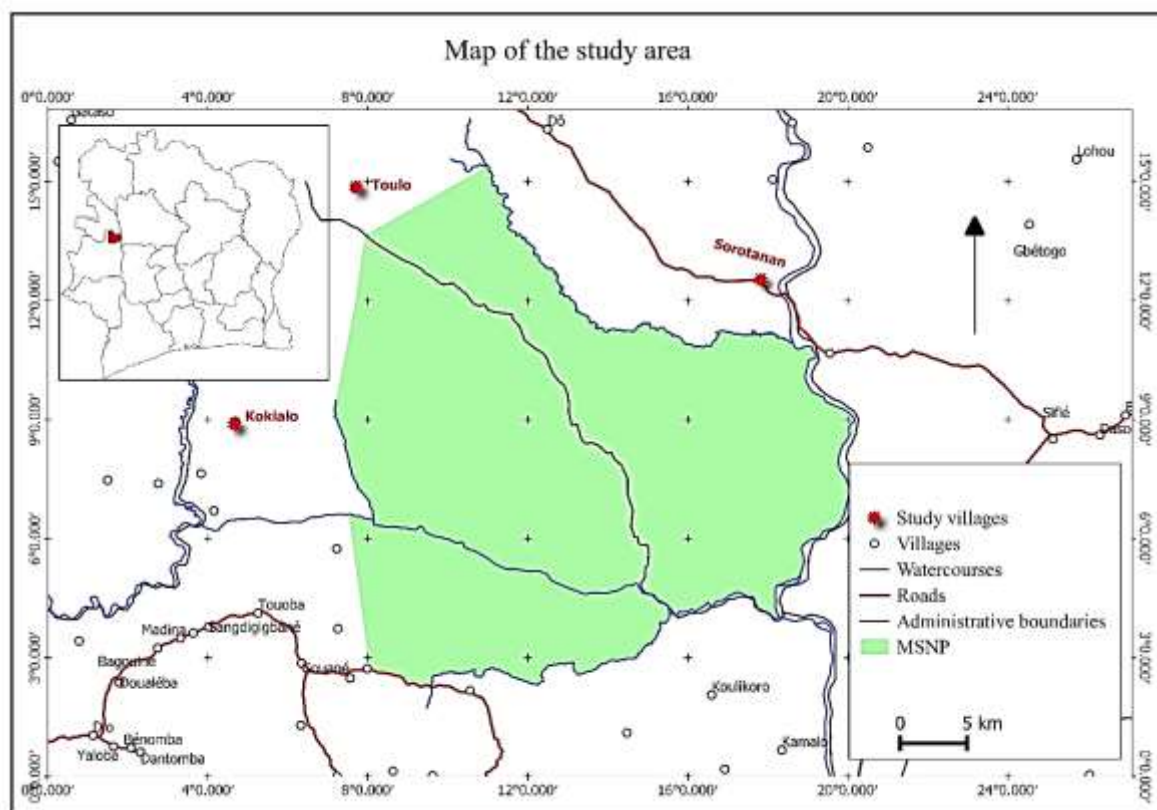
The main objective of this article is to explore the link between cropping system diversity and the occurrence of crop pests. To answer this question, the study conducts a comprehensive cross-analysis integrating agronomic and ecological diagnostics within an agroforestry zone in western Côte d'Ivoire. It begins with a detailed examination of the structure of cropping systems and land distribution among different plant species, in order to quantify spatial heterogeneity and assess the relative importance of each crop. The study then identifies the predominant crop pests, analyzing their frequency of occurrence, ecological specialization, and distribution among different crop types. This analysis is further developed by assessing the relationships between crop categories and pest species. By articulating these dimensions, this work aims to provide useful diagnostic elements for the design of differentiated technical

support systems, adapted to local realities and farmers' vulnerability profiles. This improves understanding of the relationships between agricultural biodiversity and biotic pressures.

## MATERIALS AND METHODS

### Study site

The study was conducted in three villages adjacent to the Mont Sangbé National Park (MSNP) located in western Côte d'Ivoire: Toulô, Sorotonan, and Kokialo (**Fig.1**). The MSNP encompasses an area of 95,000 hectares and lies between latitudes 7°51' - 8°10' North and longitudes 7°03' - 7°23' West. At an elevation of 1,052 meters, the park is distinguished by a variety of vegetation types, including dense, open, and gallery forests. This extensive botanical diversity has established the MSNP as a refuge for numerous endangered animal species, highlighting its importance as a crucial biodiversity reserve (Lauginie, 2007). The Mahouka and Toura are the principal ethnic groups residing and engaging in agricultural activities within the Mount Sangbé region. These groups are involved in the cultivation of a variety of crops, including rice (*Oryza sativa* L.), maize (*Zea mays* L.), cassava (*Manihot esculenta* Crantz), peanuts (*Arachis hypogaea* L.), cashew (*Anacardium occidentale* L.), coffee (*Coffea canephora* Pierre ex A.Froehner), and cocoa (*Theobroma cacao* L.). These communities are recognized for their commitment and agricultural proficiency.



**Fig.1.** Location of the study area.

### Data collection

The data collection process was conducted between February and April 2022. Within each village, a random selection of 40 households was undertaken, culminating in a total of 120 households surveyed. To facilitate the data gathering, three interviewers were allocated to each village and were accompanied by three local translators proficient in the local languages as well as French. During the interviews, respondents were afforded the choice to communicate in either French or their native language. In cases where both the household head and their spouse were present, the interview was conducted with both individuals; however, if only one was available, the interview proceeded with that single participant. Throughout the surveys, the residents meticulously documented the variety of plants they cultivated, the extent of land under cultivation, and the wild animals that were detrimental to their crops. The communities referred to these wild plants and animals either in their local languages or in French. Ecologists

from OIPR played an instrumental role in the surveys by assisting in the identification of the flora and fauna involved. The classification of crop raider species was corroborated using morphological description guides authored by Hilary Fry and Keith (2020), Kingdon et al. (2024, 2013), Kingdon and Happold (2024), and Urban et al. (2020).

### Data analysis

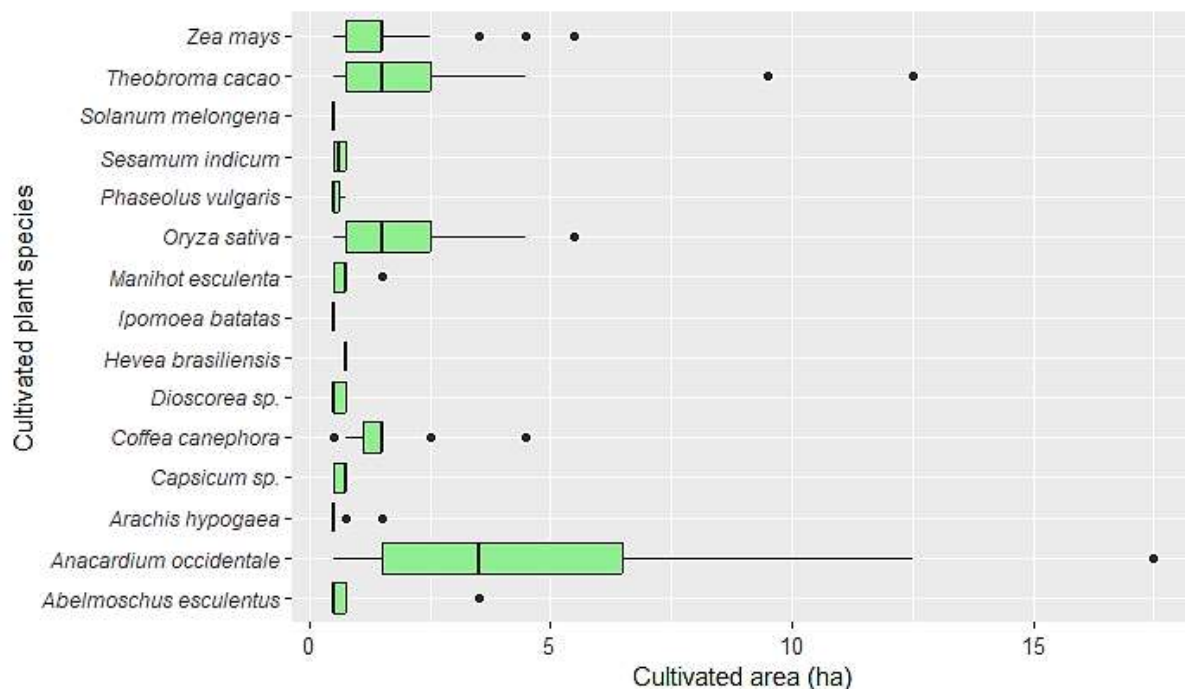
In order to assess agronomic diversity and variability across cultivated landscapes, we conducted a comprehensive analysis of the documented plant species and their respective botanical families. We employed boxplots to visualize the distribution of cultivated areas by species, which facilitated the identification of dominant crop types and illuminated variances in area coverage. The taxonomic diversity of the crop raider population was evaluated by identifying the families and species responsible for inflicting damage. Household exposure to these crop raiders was quantified using measures of central tendency and dispersion, including minimum, quartiles, median, mean, and maximum values, and further illustrated by a horizontal bar graph organized in descending order of frequency. To investigate the interactions between crop raiders and crops, we constructed an occurrence matrix by cross-referencing plant and animal species. Each cell within this matrix denotes the number of observations for a specific crop-raider crop pair. This matrix was depicted as a heatmap utilizing the `heatmap` package in R Version 4.4.2, which aided in discerning patterns of vulnerability and preferential associations.

## RESULTS

### Plot Area Distributions and Crop Species Diversity in a Multi-Family Farming System

A total of 1,085 plots were allocated among 120 households, resulting in an average of approximately 8.9 plots per household. The survey identified 15 cultivated species across 10 distinct botanical families, yielding an average of 1.5 species per family. This moderate level of diversity reflects a farming system that is both specialized, characterized predominantly by a few significant families, and diverse, due to the inclusion of more marginal families, thereby providing a comprehensive representation of local agricultural practices.

Box plot analysis (**Fig. 2**) revealed significant heterogeneity among cropping systems. Cashew ( $n = 265$ ) emerged as particularly predominant, with a median area of 3.5 hectares and a wide interquartile range of 1.5 to 6.5 hectares. The average area was 4.69 hectares, influenced by extreme plot sizes (maximum = 17.5 hectares), which resulted in a strongly right-skewed distribution, indicating the presence of notably large cashew fields.



**Fig.2.** Distribution of cultivated areas by cultivated plant species.

Among the annual crops, Rice (n = 352) and Maize (n = 113) both exhibited a median size of 1.5 hectares; however, their distributions differed slightly. Rice displayed an interquartile range of 0.75 to 2.5 hectares, while maize had a narrower range of 0.75 to 1.5 hectares, reflecting greater fragmentation of rice fields. Cocoa (n = 95) mirrored this trend with a median size of 1.5 hectares and an interquartile range of 0.75 to 2.5 hectares, but also included larger orchards, with a maximum size of 12.5 hectares. Smaller food crops, such as Cassava (n = 102), Peanut (n = 42), and Sesame (*Sesamum indicum* L.) (n = 8), were primarily concentrated in more confined areas, with median sizes ranging from 0.5 to 0.75 hectares and narrow interquartile ranges (generally 0.5 to 0.75 hectares), indicating complementary plots within diversified farms. Finally, species for which observations were limited, including the rubber tree (*Hevea brasiliensis*, Müll.Arg. 1865), the eggplant (*Solanum melongena* L.), and the bean (*Phaseolus vulgaris* L.), demonstrated complete homogeneity, with the minimum values being equal to the maximum values.

### **Taxonomic Diversity, Species Richness, and Incidence Patterns of Crop Raider Assemblages**

A taxonomic analysis identified a total of 16 crop raider families, encompassing 25 distinct species, resulting in an average of 1.56 species per family. This diversity illustrates a combination of plurispecific and monospecific families, reflecting significant variability in species occurrence. The distribution of crop raider species across households demonstrated considerable heterogeneity in exposure: some households reported as few as two species, while others identified up to 11 species. Notably, half of the households recorded between five and seven species (IQR = [5; 7]), with a median of six, indicating that at least 50% of farms encountered six or more crop raider species. The mean species count was 6.08, slightly above the median, suggesting a moderate positive skew attributable to a few particularly diverse farms elevating the average. The first quartile (Q1 = 5) and third quartile (Q3 = 7) reveal that one-quarter of households were exposed to five or fewer crop raider species, while another quarter encountered seven or more. The relatively consistent average of six species suggests a uniform level of crop raider pressure across the majority of agricultural enterprises. Nonetheless, the presence of households with exceptionally high species richness, exhibiting up to 11 species, underscores particular agronomic or ecological conditions, which may be linked to crop diversity or proximity to wooded environments.

The occurrence analysis (**Fig.3**) indicates that crop raiding is predominantly concentrated among a select group of primary species: the patas monkey (*Erythrocebus patas*; Schreber 1774) (206 occurrences, 19.0%), the grass cutter (*Thryonomys swinderianus*; Temminck 1827) (183 occurrences, 16.9%), and the red-headed quelea (*Quelea erythrops*; Hartlaub 1848) (141 occurrences, 13.0%). Collectively, these species account for nearly half (48.8%) of the 1,085 recorded incidents. Subsequent to these dominant species are medium-sized rodents such as the striped ground squirrel (*Xerus erythropus*; E. Geoffroy 1817) (86 occurrences, 9%) and the green-bush squirrel (*Paraxerus poensis*; A. Smith 1830) (74 occurrences, 8%), along with various other taxa, including the African savanna hare (*Lepus victoriae*; Thomas 1893), the double-spurred francolin (*Francolinus bicalcaratus*; Linnaeus 1766), and the northern giant pouched rat (*Cricetomys gambianus*; Waterhouse 1840), each representing an intermediate proportion (6 to 9%). At the lower end of the distribution, ten species constitute less than 1% of occurrences, highlighting an extensive tail of rare crop raiders.

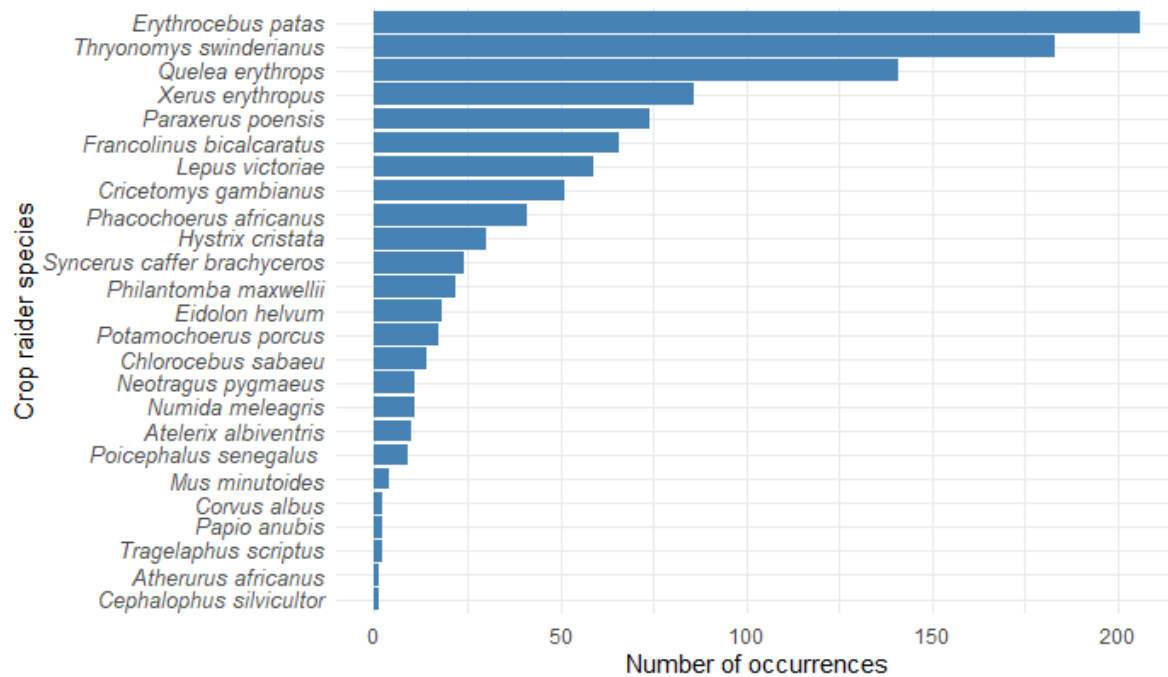


Fig.3. Crop raider species occurrences.

#### Damage Occurrence Matrix of Crop Raiders on Crops: Host Vulnerability Patterns and Functional Guild Classification

The damage occurrence matrix comprises twenty-five crop-raiding animal species organized in rows and fifteen crop species aligned in columns, culminating in 375 potential combinations (Fig.4). Of these, 174 combinations have been documented in at least one occurrence of damage, constituting nearly 46% of all possible interactions. The occurrence values span from 1 to 139, with a median of 3 for all non-zero observations. This substantial variability underscores the heterogeneous nature of damage pressures: certain crops endure severe attacks from a limited number of crop-raiding animal species, whereas others experience moderate pressure from multiple species.

Rice is identified as the most vulnerable crop, experiencing interactions with twelve crop-raiding species, collectively responsible for 353 instances of damage. The granivorous bird species, the red-headed quelea, accounts for 139 of these instances, followed by the large rodent, the grass cutter (119 occurrences), and the primate, the patas monkey (31 occurrences). This combination of avian, rodent, and primate presence in rice fields highlights the complex nature of the threat. Cashew is ranked second, encountering twenty crop raider species across 265 instances. The patas monkey remains the primary raider of cashew (63 occurrences), followed by the green-bush squirrel (33 occurrences) and the northern giant pouched rat (25 occurrences). Cassava and maize are classified as intermediate. Cassava is exposed to twelve raiders, resulting in 102 recorded instances, including the grass cutter (28 occurrences), the warthog (*Phacochoerus africanus*; Gmelin 1788) (22 occurrences), and the crested porcupine (*Hystrix cristata*; Linnaeus 1758) (23 occurrences), illustrating the impact of fossorial rodents and suids. Maize engages in 113 interactions with twelve crop raiders, led by the patas monkey (37 occurrences), the double-spurred francolin (16 occurrences), and the striped ground squirrel (13 occurrences), indicating shared vulnerabilities among primates, galliform birds, and sciurids. Cacao is subject to raids from thirteen species in 95 instances. The primary offenders are the green-bush squirrel (37 occurrences), the northern giant pouched rat (16 occurrences), and the patas monkey (20 occurrences). The patas monkey is the most widespread generalist crop raider, engaging with fourteen crops and a total of 240 reports. Its broad diet includes cereals, tubers, and fruit trees, establishing it as a major concern. The grass cutter primarily targets root crops and rice, documented in 184 reports, while the red-headed quelea specializes in rice (139 reports). The sciurid species, the green-bush squirrel and the striped ground squirrel, occupy a canopy niche, primarily raiding cocoa and cashew, with 74 and 86 reports, respectively. The northern giant pouched rat, a highly adaptable burrower, chiefly affects cashew and cocoa orchards (51 reports). The swine species, the warthog and the red river hog (*Potamochoerus porcus*; Linnaeus 1758), which forage on root surfaces, are reported in 41 and 12 cassava and yam instances, respectively. Galliform birds, such as the double-

spurred francolin and the helmeted guineafowl (*Numida meleagris*; Linnaeus 1758), primarily target cereals and legumes.

The methodological approach initiates with categorizing cereals, specifically rice and corn, as being under the collective influence of primates, granivorous passerines, and rodents. Subsequently, root crops, including cassava, yam (*Dioscorea sp.*), and sweet potato (*Ipomoea batatas* L.), are identified as susceptible to threats from large rodents and suids. Tree crops such as cashew, cocoa, and coffee are observed to be vulnerable to predation by primates and squirrels. Ultimately, low-density secondary crops — encompassing sesame, chili pepper (*Capsicum sp.*), okra (*Abelmoschus esculentus* L.), and peanuts — exhibit more diffuse interaction profiles. This categorization provides a systematic framework for the integrated management of crop raiders, effectively corresponding to the diverse interactions identified.

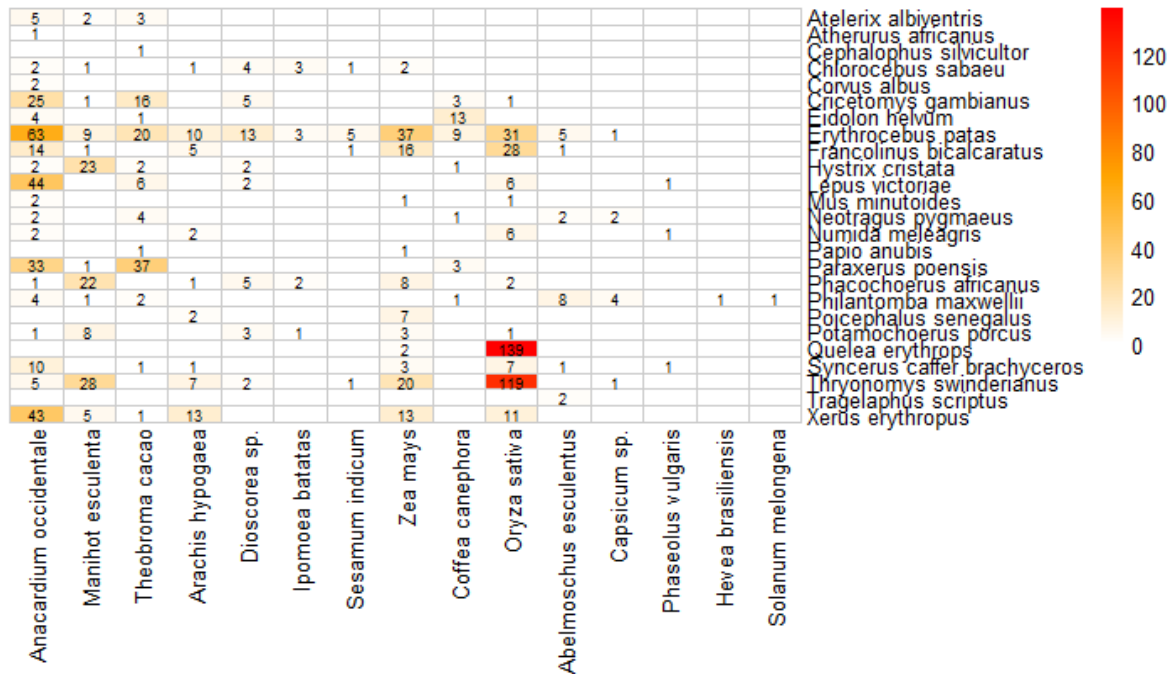


Fig.4. Interactions between crop raiders and cultivated crops.

## DISCUSSION

The results of this study emphasize the complexity and diversity inherent in tropical agricultural systems, specifically regarding crop variety and crop raider pressures. A collection of fifteen species from ten botanical families was identified, with a pronounced predominance of Cashew, Rice, and Maize. This configuration reflects a dual approach: a focus on a few commercially valuable crops alongside a secondary level of diversification. This observation is consistent with the findings of He et al. (2019), which suggest that the incorporation of complementary crops can mitigate crop raider impacts while enhancing the resilience of the agricultural system. The analysis of cultivated areas reveals highly asymmetrical distributions: cashew orchards encompass significantly larger plots, reaching up to 17.5 hectares, whereas fields devoted to annual crops such as rice and maize, in addition to smaller cash crops like cassava and peanuts, remain fragmented and typically restricted to less than 2.5 hectares. These findings are in alignment with the observations of Tschardt et al. (2005), who demonstrated that variability in patch size affects habitat alternation and influences the movement of both crop raiders and their natural predators. Our occurrence matrix identified 25 animal species impacting 15 crops, with approximately 46% of possible combinations observed in nature. The dominance of the patas monkey, the grass cutter, and the red-headed quelea—accounting for 48.8% of all observations—supports the findings of Naughton-Treves et al. (1998) and Benítez-López et al. (2019), underscoring the significant role of large primates, giant rodents, and granivores in human-wildlife conflicts within West Africa. This imbalance manifests a phenomenon of a 'reservoir' of crop raiders, indicating that effective management strategies should primarily target these three species to enhance the overall efficacy of integrated approaches. The spatial distribution of risk indicates that farms are impacted by two to eleven

species of crop raiders (median = 6), revealing a relatively uniform pressure across the majority of farms. However, there are notable hotspots where species richness is particularly pronounced. This pattern reflects the concept of crop raider hotspots as described by Bianchi et al., (2006), highlighting how the proximity of wooded areas or hedgerows around plots facilitates the persistence of crop raider populations, subsequently leading to increased levels of infestation. The proposed functional classification, delineating four guilds—cereals, root crops, tree crops, and secondary crops—provides an operational framework for adapting control measures. For instance, the convergence of primates, passerines, and rodents on rice supports the integrated implementation of anti-bird nets, anti-primate fencing, and ground trapping, as recommended by Letourneau et al. (2011). Similarly, the protection of cashew and cocoa orchards could be enhanced through agroforestry solutions, such as thorny barriers or understory repellent crops, to curtail access for squirrels and larger rodents (Perfecto and Vandermeer, 2008). Ultimately, the variation in plot sizes and the balance between specialization and cultural diversification underscore the necessity for management strategies at the landscape scale. By enhancing habitat connectivity for beneficial organisms while physically isolating the most vulnerable areas, it is possible to reduce overall crop raider pressure without resorting to chemical pesticides, as advocated by (Veres et al., 2013).

### Conclusion

This investigation elucidates an agricultural landscape marked by a rich cultural mosaic and diverse crop-raider pressures. A total of fifteen cultivated species, predominantly comprising cashew, rice, and maize, are administered across extensive, fragmented plots. Furthermore, twenty-five animal species from sixteen families affect an average of six crops per household, with occurrences reaching a peak at eleven. The analyses highlight the heterogeneity of the cultivated areas, encompassing extensive cashew orchards as well as auxiliary plots of cassava and peanuts. Significantly, three crop raiders—the patas monkey, the grass cutter, and the red-headed quelea—constitute nearly half of the reported damages. The study's occurrence matrix and its graphical depiction delineate distinct functional guilds, including cereals, tubers, fruit trees, and secondary crops, thus providing a comprehensive framework to guide appropriate control measures. This integrated approach, which harnesses both the diversity of local farming practices and the specific specialization of crop raiders, establishes a methodological and operational foundation for the development of sustainable management strategies in tropical agricultural systems.

### REFERENCES

- Altieri, M.A. (2009). Agroecology, small farms, and food sovereignty. *Mon. Rev.*, 61: 102–113.
- Altieri, M.A. (1999). The ecological role of biodiversity in agroecosystems, *in: Invertebrate Biodiversity as Bioindicators of Sustainable Landscapes*. Elsevier, pp. 19–31.
- Bellotti, A.C., A.R. Braun, B. Arias, J.A. Castillo and J.M. Guerrero (1994). Origin and management of neotropical cassava arthropod pests. *Afr. Crop Sci. J.*, 2: 407–417.
- Benítez-López, A., L. Santini, A.M. Schipper, M. Busana, and M.A. Huijbregts (2019). Intact but empty forests? Patterns of hunting-induced mammal defaunation in the tropics. *PLoS Biol.*, 17: e3000247.
- Bianchi, F.J.J.A. C.J.H. Booij and T. Tschardtke (2006). Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proc. R. Soc. B Biol. Sci.*, 273: 1715–1727. <https://doi.org/10.1098/rspb.2006.3530>
- Brou, P.M., K. Ouattara, P.D. Vale, A.E.H. Monket and N.A. Houa (2024). Conflicts Hommes-Hippopotames Communs (*Hippopotamus amphibius* Linné, 1758) dans les Départements de Bettié et de Toumodi en Côte d'Ivoire. *Afr. Sci.*, 25: 13–22.
- He, H., L. Liu, S. Munir, N.H. Bashir, Y. Wang, J. Yang and C. Li (2019). Crop diversity and pest management in sustainable agriculture. *J. Integr. Agric.*, 18: 1945–1952. [https://doi.org/10.1016/S2095-3119\(19\)62689-4](https://doi.org/10.1016/S2095-3119(19)62689-4)
- Hilary F.C. and S. Keith (2020). *The Birds of Africa: Volume VII*. Bloomsbury Publishing, London.
- Hill, C. (2017). Crop Raiding, *In: The International Encyclopedia of Primatology*. pp. 1–5. <https://doi.org/10.1002/9781119179313.wbprim0109>
- Kingdon, J., T. Butynski and J. Kalina (2024). *Mammals of Africa: Volume II*. Bloomsbury Publishing, London.
- Kingdon, J. and D. Happold (2024). *Mammals of Africa: Volume III*. Bloomsbury Publishing, London.
- Kingdon, J., D. Happold, T. Butynski, M. Hoffmann, M. Happold and J. Kalina (2013). *Mammals of Africa: Volume VI*. Bloomsbury Publishing, London.
- Koffi, K.C., K.H. Bohoussou, K.N. Kouadio, K.A. Brou and A. Beda (2024). Phenological Stage of the Destruction of Crops by Wild Animals Around Mont Sangbé National Park, Western Côte d'Ivoire. *Int. J. Agric. Biol.*, 33: 6.

- Kouao, M.L., J.-C.K. Bene, A.D. Koffi, B.A. Kouame and I. Kone (2018). Caractérisation des dégâts provoqués par la faune sauvage à la périphérie de la Forêt des Marais Tanoe-Ehy au sud-est de la Côte d'Ivoire. *Int. J. Biol. Chem. Sci.*, 12: 1717–1730.
- Kremen, C. and A. Miles (2012). Ecosystem services in biologically diversified versus conventional farming systems: benefits, externalities, and trade-offs. *Ecol. Soc.*, 17.
- Lamarque, F., J. Anderson, R. Fergusson, M. Lagrange, Y. Osei-Owusu and L. Bakker (2010). Les conflits humains-faune en Afrique: causes, conséquences et stratégies de gestion.
- Lauginie, F. (2007). Conservation de la nature et aires protégées en Côte d'Ivoire. NEI/Hachette et Afrique Nature, France.
- Letourneau, D.K., I. Armbrecht, B.S. Rivera, J.M. Lerma, E.J. Carmona, M.C. Daza, S. Escobar, V. Galindo, C. Gutiérrez, S.D. López, J.L. Mejía, A.M.A. Rangel, J.H. Rangel, L. Rivera, C.A. Saavedra, A.M. Torres and A.R. Trujillo (2011). Does plant diversity benefit agroecosystems? A synthetic review. *Ecol. Appl.*, 21: 9–21. <https://doi.org/10.1890/09-2026.1>
- Letourneau, D.K., J.A. Jedlicka, S.G. Bothwell and C.R. Moreno (2009). Effects of Natural Enemy Biodiversity on the Suppression of Arthropod Herbivores in Terrestrial Ecosystems. *Annu. Rev. Ecol. Evol. Syst.*, 40: 573–592. <https://doi.org/10.1146/annurev.ecolsys.110308.120320>
- Matson, P.A., W.J. Parton, A.G. Power and M.J. Swift (1997). Agricultural Intensification and Ecosystem Properties. *Science*, 277: 504–509. <https://doi.org/10.1126/science.277.5325.504>
- Naughton-Treves, L., A. Treves, C. Chapman and R. Wrangham (1998). Temporal patterns of crop-raiding by primates: linking food availability in croplands and adjacent forest. *J. Appl. Ecol.*, 35: 596–606. <https://doi.org/10.1046/j.1365-2664.1998.3540596.x>
- Perfecto, I. and J. Vandermeer (2008). Biodiversity Conservation in Tropical Agroecosystems: A New Conservation Paradigm. *Ann. N. Y. Acad. Sci.*, 1134: 173–200. <https://doi.org/10.1196/annals.1439.011>
- Stenseth, N.C., H. Leirs, A. Skonhøft, S.A. Davis, R.P. Pech, H.P. Andreassen, G.R. Singleton, M. Lima, R.S. Machang'u, R.H. Makundi, Z. Zhang, P.R. Brown, D. Shi and X. Wan (2003). Mice, rats, and people: the bioeconomics of agricultural rodent pests. *Front. Ecol. Environ.* 1: 367–375. [https://doi.org/10.1890/1540-9295\(2003\)001\[0367:mraptb\]2.0.co;2](https://doi.org/10.1890/1540-9295(2003)001[0367:mraptb]2.0.co;2)
- Tscharntke, T., A.M. Klein, A. Kruess, I. Steffan-Dewenter and C. Thies (2005). Landscape perspectives on agricultural intensification and biodiversity – ecosystem service management. *Ecol. Lett.*, 8: 857–874. <https://doi.org/10.1111/j.1461-0248.2005.00782.x>
- Urban, E.K., F.C. Hilary and S. Keith (2020). *The Birds of Africa: Volume II*. Bloomsbury Publishing, London.
- Veres, A., S. Petit, C. Conord and C. Lavigne (2013). Does landscape composition affect pest abundance and their control by natural enemies? A review. *Agric. Ecosyst. Environ.* 166: 110–117.
- Webber, A.D. and C.M. Hill (2014). Using participatory risk mapping (PRM) to identify and understand people's perceptions of crop loss to animals in Uganda. *PLoS One* 9: e102912.

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