INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
24–0361/2025/33:330309
http://www.fspublishers.org

Full Length Article

Phenological Stage of the Destruction of Crops by Wild Animals Around Mont Sangbé National Park, Western Côte d'Ivoire

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Received 20 August 2024; Accepted 23 September 2024; Published online 25 December 2024

Editor: Abdul Wahid

Abstract

Côte d'Ivoire is a West African country with a wealth of important forest resources. Protected areas have been created in the country to protect some flora and fauna. People living near protected areas tend to grow in them, resulting in conflicts between humans and animals. The animals destroy crop fields at different phenological stages of development. However, there is little scientific information on this phenomenon in protected areas. To address this problem, a study was carried out to find out the phenological stage of the destruction of crops by wild animals around Mont Sangbé National Park in Côte d'Ivoire. The study surveyed 120 farmers in three villages near the park to determine the frequency of damage to the crops by animals. The Generalized Linear Model (GLM) was used to fine the relationship between plant destruction and destructive animals. The study identified 26 crop pests, 17 of which caused damage. These pests threatened 16 crops, and eight were likely to be destroyed. Crop damage occurred in all stages of development, from seedling emergence to fruit production, but mainly during fruit production. These findings are important to policymakers and practitioners to guide the design of crop protection measures in protected areas. Furthermore, these results may have broader implications for the development of predictive models for interactions between humans and wildlife.

Keywords: Crop raiders; Crop phenology; Human-wildlife conflict; Côte d'Ivoire

Introduction

Protected areas are established to conserve diverse flora and fauna, often at risk of extinction. These areas are renowned for their rich biodiversity. In Côte d'Ivoire, for example, Mont Sangbe National Park is home to 69 species of mammals (OIPR 2011) and 370 species of birds, some of which are classified as threatened on the IUCN Red List (Lauginie 2007). Communities residing near these protected areas interact with local wildlife, which can lead to human-wildlife conflict.

There is a growing awareness of the significance of wildlife-human interactions, leading to many conservation organizations to prioritize this aspect (Osborn and Parker 2003; Madden 2004; Peterson *et al.* 2010; Hoare 2012). Human-wildlife conflict refers to situations in which wildlife negatively impacts humans and vice versa (Draheim *et al.* 2015). These interactions have adverse effects on the economy, society, culture, wildlife conservation, and the environment at large (Distefano 2005; Dickman 2010; Mekonen 2020). Such conflicts commonly arise in the vicinity of protected areas (Parker *et al.* 2007), especially affecting communities near these areas (Mekonen 2020). Animals can damage human habitats and pose risks to individuals (Huaping *et al.* 2019). However, the majority of conflicts stem from the destruction of crops by wildlife (Hill 2017; Moumbock *et al.* 2020; Tamrat *et al.* 2020). Wildlife feeding habits are influenced by proximity to agricultural land (Moumbock *et al.* 2020). For instance, elephants may ravage village farms when their habitat is encroached on by agriculture (O'Connell-Rodwell *et al.* 2000; Osborn and Parker 2003; Naughton-Treves and Treves 2005).

Agricultural practices in close proximity to protected areas lead to conflicts between humans and wildlife (Bulte and Rondeau, 2007). With a growing population

To cite this paper: Christophe KK, BK Hilaire, KK Norbert, BK Anselme, B Alex (2025). Phenological stage of the destruction of crops by wild animals around mont sangbé national park, western Côte d'Ivoire. *Intl J Agric Biol* 33:330309. https://doi.org/10.17957/IJAB/15.2285

increasingly dependent on agriculture for sustenance and economic stability (Cervantes-Godoy *et al.* 2014), the demand for natural and biological resources is increasing (Mehring *et al.* 2020). Overexploitation and scarcity of arable land lead to soil fertility depletion, prompting farmers to encroach on protected areas where the land remains fertile. This encroachment diminishes the living space of wildlife and fragments their habitats, forcing them to damage crops (King and Powell 2007), thereby endangering the survival of numerous species, particularly those facing the risk of extinction (Cromsigt *et al.* 2013). Consequently, in response to crop damage, humans often resort to killing wildlife.

There are several factors that influence the consumption of crops by wildlife. The stage of crop development plays a crucial role in the probability that herbivores cause damage (Gross *et al.* 2018). African farmers often lack modern protection methods, such as complete fencing and greenhouses, leaving crops vulnerable to wildlife attacks at any time. The stage of development of crops also affects their susceptibility. Farmers often attribute damage to a specific animal based on the tracks left behind, although scientific evidence is limited. It is essential to understand the impact of different stages of growth on the vulnerability of crops to herbivores to develop effective protection strategies, especially in the management of human-wildlife conflict near national parks where humans and animals co-exist (Gross *et al.* 2018).

The objective of this research was to provide crucial information on the impact of wildlife near Mont Sangbé National Park (MSNP) in Côte d'Ivoire on crop fields and identify the specific animals responsible for crop damage and the stage of crop development in which attacks occur.

Materials and Methods

Study area

The research was carried out in three villages surrounding the Mont Sangbé National Park (MSNP) in western Côte d'Ivoire: Toulô, Sorotonan, and Kokialo (Fig. 1). MSNP, which spans 95,000 ha, is located between latitudes 7°51' – 8°10' north and longitudes 7°03' – 7°23' west. It derives its name from Mount Sangbé, which stands at an altitude of 1052 m. The diverse vegetation of the park includes dense forests, open forests, and gallery forests. This botanical wealth has placed the MSNP as a haven for numerous endangered animal species, thus serving as a significant biodiversity reserve (Lauginie 2007). The Mahouka and Toura are the main ethnic groups doing agriculture in the region. They cultivate rice (*Oryza sativa* L.), maize (*Zea mays* L.), cassava (*Manihot esculenta* Crantz), peanut (*Arachis hypogaea* L.), cashew nuts (*Anacardium occidentale* L.), coffee (*Coffea canephora* Pierre ex A. Froehner), and cocoa (*Theobroma cacao* L.) are recognized for their dedication and agricultural expertise.

Data collection

Data were collected between February and April 2022. In each village, 40 households were randomly selected, totaling 120 households. Three interviewers and three local translators, fluent in local and French languages, were assigned to each village. During the interviews, participants had the option to speak in French or their local language. If the head of the household and the spouse were present, the interview was conducted with both; otherwise, it was conducted with one of them. The following three key questions were made in order to accurately identify the phenological stages of crop damage by wild herbivores:

1. What crops are susceptible to damage from wild herbivores?
2. Which wild herbivore species commonly cause crop damage?
3. In what stages of development are crops most susceptible to damage by wild herbivores?

Throughout the surveys, local populations identified several plants that are prone to damage. These plants are commonly grown in Côte d'Ivoire, and the communities refer to them using their local names or in French. The OIPR ecologists who participated in the surveys assisted in identifying the plants referred to by their local names.

The respondents provided the names of the animal species that cause damage to their crops in French or their local languages. OIPR ecologists helped us identify the animals mentioned in the local languages. Collaborating with the participants, we confirmed the identity of the animal species based on the morphological description guides of Kingdon *et al.* (2013); Hilary Fry and Keith (2020), Urban *et al.* (2020); Kingdon *et al.* (2024); Kingdon and Happold (2024). Thanks to these guides, we were able to scientifically identify the species involved in the damage.

Our study classified the phenological stages into three distinct phases: seedling stage, which includes germination; the leaf development stage, which includes flowering; and the fruiting stage, which corresponds to fruit growth and maturation.

Statistical analysis

Descriptive statistics were used to evaluate the frequency of herbivore raids in fields, identify the most affected stage of plant growth, and determine the responsible animal species. The frequency of the attack was quantified by the number of reports of crop attacks by wild herbivores. We specifically focused on crops reported by at least 10 households as being affected. The frequency of attacks per crop represented the number of herbivores identified as attackers for the damaged crops. We only considered animals mentioned at least 10 times for damaged crops. The stage of growth in which the crop was consumed was classified according to the number of reports indicating whether destruction occurred during germination, leaf growth, or fruiting.

To analyze the impact of crop growth phases on crop consumption by animals, we employed a generalized linear model (GLM) with a Poisson distribution and a log link function. The growth phase served as an explanatory variable, while the frequency of crop consumption by animals during this phase was the response variable. Before conducting the GLM, we performed normality tests, which indicated a normal distribution of the data. Our assumption was that the animals did not uniformly damage crops, some targeting seeds during germination, others affecting stems and leaves during development, and some impacting fruits after fruiting. GLM analysis was conducted using R version 4.2.0 (R Core Team 2022).

Results

Most frequent crop raided

Results indicated that all 120 participants had experienced crop damage from wild herbivores. Wild herbivores damaged 16 different types of crops from 11 different families of vascular plants. Among these, eight crops were repeatedly mentioned as the most attacked (Christophe *et al.* 2024).

According to Fig. 2, the crops most frequently attacked included three cash crops and five food crops. It should be noted that some cash crops suffered significant damage from wildlife. Cashew, cocoa, and coffee were the most affected, with cashew being the most affected in the Anacardiaceae family. Cocoa, from the Malvaceae family, and coffee, from the Rubiaceae family, ranked second and third, respectively, among the most affected crops.

The most commonly targeted food crops were rice, maize, cassava, peanut and yam (*Dioscorea* sp.), which belong to the Poaceae, Euphorbiaceae, Fabaceae, and Dioscoreaceae families, respectively (Christophe *et al.* 2024).

Most frequent crop raiders

The villagers identified 26 species of wild animals responsible for damaging agricultural crops, which were classified into two groups: 21 mammals and 5 birds, belonging to ten orders. Among the 120 observations recorded, 17 wild herbivores representing seven different orders were reported more than ten times, designating them as the most common pests (Fig. 3). These data further revealed that certain animals, such as rodents, primates, passerines, and gallinaceous birds, are more likely to cause damage and farmers frequently mention them as the main crop pests.

Rodents such as the grass cutter (*Thryonomys swinderianus*; Temminck 1827) and the green-bush squirrel (*Paraxerus poensis*; A. Smith 1830) were frequently cited as major crop pests by farmers. Similarly, primates, particularly the patas monkey (*Erythrocebus patas*; Schreber 1774), were known to cause considerable damage and were often cited by farmers as among the most destructive. Regarding birds, galliformes, such as the double-spurred francolin (*Francolinus bicalcaratus*; Linnaeus 1766) were commonly cited for the significant damage they cause in rice, maize, and cashew nut fields. Passeriformes were responsible for significant damage in rice fields, with the red-headed quelea (*Quelea erythrops*; Hartlaub 1848) being the most incriminated by farmers. These birds pose a major problem in rice fields and farmers are struggling to find effective methods to control them (Christophe *et al.* 2024).

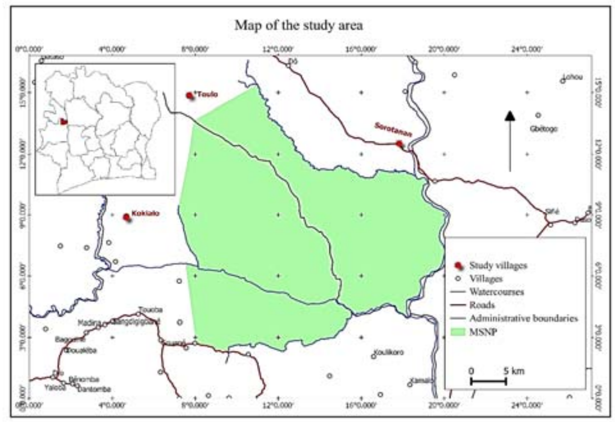

Fig. 1: The location of the study villages

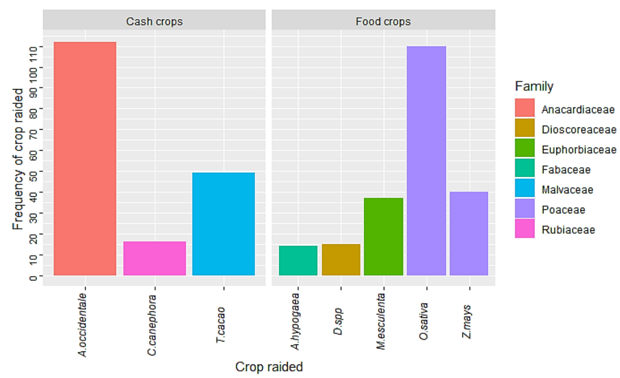

Fig. 2: The frequency of crop raided

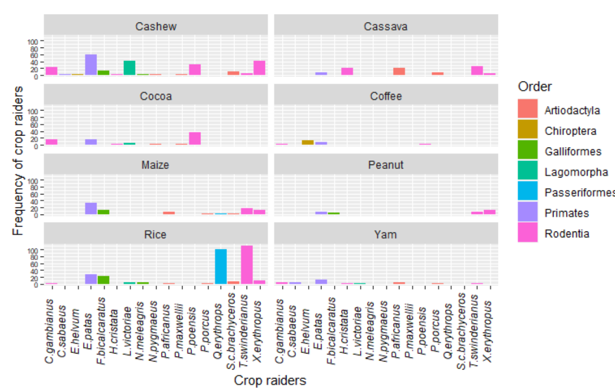

Fig. 3: The frequency of crop raiders

Growth stages of the crops raided

Fig. 4 illustrates that crops surrounding the MSNP are particularly susceptible to damage during various growth phases, especially during leaf development and fruiting. During the fruiting stage, the primary culprits that cause damage, in order of importance, were grass cutter, patas monkey, red-headed quelea, and green-bush squirrel. Grass cutter mainly cause havoc in rice, cassava tubers and maize. Patas monkey primarily inflicted damage on cashew and maize plantations. Red-headed quelea mainly targeted rice fields, while green-bush squirrel mainly attacked cocoa and cashew nut plantations.

During the leaf growth stage of cultivated plants, the main pests, in order were grass cutter, red-headed quelea, and patas monkey. Grass cutter mainly attacked rice and then maize. Red-headed quelea concentrated on the leaves of rice. Patas monkey targets first rice and then cashew. During the sowing phase, crops are also attacked by wild animals, although less frequently than during fruiting or leaf development. Seedlings were predominantly threatened by birds, particularly red-headed quelea and double-spurred francolin, which attacked the young shoots of rice.

Influence of crop raiders on seedlings

Three bird species i.e., the red-headed quelea, the double-spurred francolin, and the helmeted guineafowl (*Numida meleagris*; Linnaeus 1758) significantly ($P < 0.05$) impacted the sowing of peasant crops (Table 1). These birds tended to consume seeds after sowing, affecting their germination, and also fed on emerging young shoots. A larger population of these birds increased the risk of destroying seedlings. Furthermore, a mammal species, the northern giant pouched rat (*Cricetomys gambianus*; Waterhouse 1840), was found to cause significant ($P < 0.05$) damage to seedlings. The incidence rate ratios (IRR) of these species were greater than 1, indicating a higher probability of causing significant damage to crop at the sowing stage compared to other animals (Christophe *et al.* 2024).

Influence of crop raiders on leaf development

There were four animal species with IRR greater than 1 during the leaf development phase of crops (Table 2). This suggests a higher likelihood of significant damage from these species compared to others. The species were the patas monkey and the grass cutter, both mammals, the African buffalo (*Syncerus caffer brachyceros*; Gray 1837), a bovid, and the red-headed quelea, a bird. Their presence was strongly related to observed crop damage during the vegetative phase ($p < 0.05$), with a greater presence leading to more attacks on crops during leaf development. These species were recognized to cause substantial damage to leaves and stems during this phase (Christophe *et al.* 2024).

Table 1: GLM regression results of the influence of animals on seedlings

Characteristic	IRR[1]	95% CI[1]	p-value	
C. gambianus	1.53	1.19, 1.93	<0.001	***
C. sabaeus	1.63	0.44, 4.88	0.4	
E. helvum	1.63	0.26, 5.44	0.5	
E. patas	1.34	0.71, 2.35	0.3	
F. bicalcaratus	1.41	1.20, 1.64	<0.001	***
H. cristata	1.77	0.29, 5.81	0.4	
L. victoriae	1.34	0.79, 2.01	0.2	
N. meleagris	1.67	0.97, 2.71	0.049	*
N. pygmaeus	1.62	0.26, 5.32	0.5	
P. africanus	1.69	0.28, 5.38	0.5	
P. maxwellii	1.69	0.28, 5.38	0.5	
P. poensis	1.69	0.28, 5.38	0.5	
P. porcus	1.88	0.42, 6.10	0.3	
Q. erythrops	1.48	1.09, 2.02	0.013	*
S. c. brachyceros	1.69	0.28, 5.38	0.5	
T. swinderianus	1.62	0.26, 5.32	0.5	
X. erythropus	1.54	1.28, 1.83	<0.001	***

[1]IRR = Incidence Rate Ratio, CI = Confidence Interval
Signif. codes: 0 '***' 0.001 '**' 0.01'*' 0.05 '.' 0.1' ' 1

Table 2: GLM regression results of the influence of animals on leaf development

Characteristic	IRR[1]	95% CI[1]	p-value	
C.gambianus	1.37	0.22, 4.51	0.7	
C.sabaeus	1.37	0.22, 4.51	0.7	
E.helvum	2.74	0.81, 6.90	0.058	
E.patas	1.42	1.20, 1.69	<0.001	***
F.bicalcaratus	1.37	0.22, 4.51	0.7	
H.cristata	1.37	0.22, 4.51	0.7	
L.victoriae	1.44	0.79, 2.43	0.2	
N.meleagris	1.37	0.22, 4.51	0.7	
N.pygmaeus	1.37	0.22, 4.51	0.7	
P.africanus	1.14	0.62, 2.00	0.7	
P.maxwellii	1.40	0.71, 2.54	0.3	
P.poensis	1.20	0.42, 2.70	0.7	
P.porcus	1.54	0.64, 3.24	0.3	
Q.erythrops	1.41	1.03, 1.96	0.036	*
S.c.brachyceros	1.38	1.00, 1.85	0.039	*
T.swinderianus	1.34	1.06, 1.69	0.014	*
X.erythropus	1.39	0.84, 2.18	0.2	

[1]IRR = Incidence Rate Ratio, CI = Confidence Interval
Signif. codes: 0 '***' 0.001 '**' 0.01'*' 0.05 '.' 0.1' ' 1

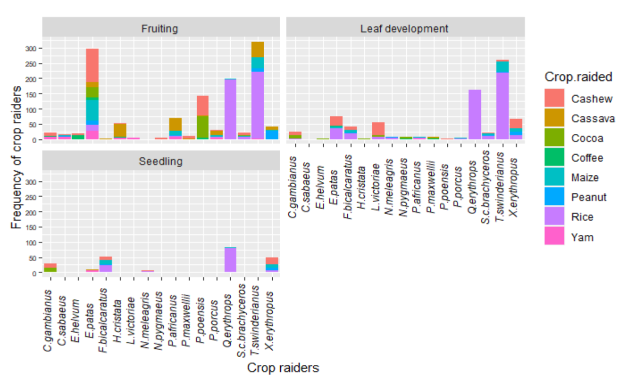

Fig. 4: Crop damage according to the growth stage of plants

Influence of crop raiders on fruiting

The results of the regression analysis indicate that the fruiting phase was the most affected by pests, and most animals contributed significantly to crop damage during this period. Specifically, seven animals, including six mammals and one bird, had IRR > 1 during this phase, highlighting their significant involvement in crop damage ($p < 0.05$). The mammals implicated were the straw-colored fruit bat (*Eidolon helvum* Kerr 1792), the African buffalo, the grass cutter, the green-bush squirrel, the warthog (*Phacochoerus africanus* Gmelin 1788), and the patas monkey. Furthermore, the red-headed quelea, a bird, caused the most destruction during the fruiting period (Table 3).

Discussion

Wildlife-induced crop damage is a major concern in the MSNP area. Every farmer we consulted confirmed that their crops were damaged by wildlife. In this context Angela *et al.* (2014) noted that wildlife damages the majority of farms in forest reserves. Furthermore, a study conducted near the Lake Piso Reserve in Liberia showed an increase in crop attacks, which weakened community support for biodiversity conservation (Gbeaduh et al. 2018).

In this research, we have identified a total of 26 species of wildlife that threaten agriculture around MSNP, 14 of which are a serious threat. It should be noted that various wild animals are known to damage crops on farms adjacent to the MSNP. Previous studies in other natural reserves, such as Mount Cameroon National Park and Mole National Park in Ghana, have reported similar findings (Attia *et al.* 2018; Wiafe 2019). Here we have observed that wildlife selectively targeted specific crops based on their stage of development. For example, species such as grass cutter and red-headed quelea are drawn to rice fields, while patas monkey and green-bush squirrel often target cashew nut plantations. These observations support Hill (2017) findings, which suggest that crop attacks depend on the type of plant and its degree of maturity. Furthermore, Mamo *et al.* (2021) demonstrated that wildlife can significantly impact various crop growth stages. In their research in the southern forests of Ethiopia, they noted that wildlife attacks occur throughout the stages of crop development (Mamo *et al.* 2021).

Our research indicated that wild animals attack crops predominantly during the fruiting stage, which is consistent with the findings of various studies. For example, Assogba *et al.* (2019) observed that wildlife damage to crops was more prevalent during this stage near the W National Park in Benin. Similarly, Marchal and Hill (2009) observed an increase in crop attacks during fruiting in North Sumatra, Indonesia, and Thapa (2010) reported similar observations in Bardia National Park in Nepal.

Conclusion

Wild animals were found to cause considerable damage to crop in the farmlands surrounding the MSNP. More than 20 mammal and bird species were responsible for causing extensive damage to local farmers' fields.

Table 3: GLM regression results of the influence of animals on plant fruiting

Characteristic	IRR[1]	95% CI[1]	p-value	
C.gambianus	1.15	0.91, 1.43	0.2	
C.sabaeus	1.10	0.79, 1.50	0.6	
E.helvum	1.23	1.00, 1.51	0.047	*
E.patas	1.22	1.12, 1.33	<0.001	***
F.bicalcaratus	1.26	0.52, 2.73	0.6	
H.cristata	1.17	0.97, 1.41	0.10	
L.victoriae	1.25	0.71, 2.07	0.4	
N.meleagris	0.79	0.13, 2.53	0.7	
N.pygmaeus	1.14	0.28, 3.03	0.8	
P.africanus	1.23	1.04, 1.46	0.016	*
P.maxwellii	1.16	0.80, 1.63	0.4	
P.poensis	1.19	1.06, 1.34	0.004	**
P.porcus	1.20	0.98, 1.45	0.067	
Q.erythrops	1.28	1.03, 1.60	0.029	*
S.c.brachyceros	1.25	1.02, 1.50	0.025	*
T.swinderianus	1.18	1.04, 1.35	0.010	**
X.erythropus	1.23	0.99, 1.52	0.056	

[1]IRR = Incidence Rate Ratio, CI = Confidence Interval
Signif. codes: 0 '***' 0.001 '**' 0.01'*' 0.05 '.' 0.1' ' 1

Moreover, these animals mainly targeted crops during the fruiting phase. Notably, not all crops were equally affected on the edge of the forest reserve. Understanding the relationship between crop life cycles and crop raiders can aid in planning agricultural development around forest reserves. These findings are useful to policymakers and practitioners in designing crop protection measures around protected areas.

Acknowledgments

Not applicable.

Authors' Contributions

KKC, BKH, and KKN designed the study; KKC, BKH, KKN, BKA, and BA performed field work and collected data; KKC, BKH, KKN, BKA, and BA analyzed data and drafted the manuscript. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare that they have no conflict of interest.

Data Availability

Data presented in this study will be available on a fair request to the corresponding author.

Ethics Approval

Not applicable to this paper.

Funding Source

This research was funded by the support fund of the

Ministry of Higher Education and Scientific Research in Côte d'Ivoire.

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