Research Article

Stakeholders' Perception of Socioecological Factors Influencing Forest Elephant Crop Depredation in Gabon, Central Africa

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Forest elephant crop depredation incidents (CDIs) around Gabon's national parks threaten both villagers' livelihoods and conservation efforts for critically endangered forest elephants. Most CDI-mitigation efforts have focused on improving crop protection. We argue that conflicts will continue to escalate unless broader villager and elephant needs are addressed simultaneously. For that reason, we investigated the factors contributing to CDIs as a first step toward mitigating conflict by fostering coexistence. We compiled perceptions of 24 villagers and 22 conservation professionals at Lopé National Park in Gabon using semi-structured interviews, allowing participants to create individual narratives. We analyzed the narratives through content analysis, categorizing CDI perceptions into four connected *themes* to build a synthetic framework based on three landscape *contexts* across which six socioecological *drivers* fostered five landscape *dynamics* that led to five proximal *problem types* leading directly to CDIs. Two problem types were centered on ineffective crop protection methods and socioeconomic changes that have intensified rural exodus. The other two were centered on unmet elephant needs pushing them to seek crops. The fifth type, regular human-elephant negative interactions, resulted from increasing land use overlap by both villagers and elephants. Villagers framed the CDI problem primarily through their experiences of conflict in village areas. Professionals likewise saw the importance of direct conflict in village areas but also identified a broader suite of factors, including conservation policies, logging, and declining native fruit production pushing elephants toward villages in search of food and a safe environment. Common to both stakeholders' narratives was the perception that increased spatial and temporal

overlap was the greatest contributor to increasing CDIs. Points of agreement, such as those around regular human-elephant negative interactions and ineffective crop protection, may provide opportunities to build trust and prioritize initial interventions. Differences in perspectives should be investigated further to seek possible resolutions.

Introduction

Forest elephant (*Loxodonda cyclotis)* Crop Depredation Incidents (CDIs) have persisted in Africa's Congo Basin, leading to increased rural poverty (Lahm, 1996; Parker & Osborn, 2006; Madden & McQuinn, 2014). Most crop protection methods provide only short-term benefits, as elephants always find means to overcome almost every protection method or simply move to areas without any protection (Osipova et al., 2018). Faced with the loss of their livelihoods and in retaliation, people may kill protected forest elephants, *a critically endangered species (Epanda et al., 2019; Gobush, 2021; Rakotonarivo et al., 2021; Terada et al., 2021). T*he dual threats to people and elephants make it imperative to better understand the factors influencing forest elephant CDIs.

Forest elephant CDI persistence seems to be also related to a host of interactive factors, including habitat disturbances from extractive industries such as logging and mining pushing elephants to leave their forest habitats (Beirne et al., 2021), the high nutritional value of crops (Chiyo et al., 2005; Rode et al., 2006), gentle terrain used to grow crops (Ngama et al., 2019), the proximity of crops to native elephant food sources (Budd et al., 2020), and the integration of villages and crops with protected areas such as national parks (Mills et al., 2018).

Gabon, in central Africa, is home to approximately 95,000 forest elephants, representing more than 70% of the remaining individuals of endangered elephants globally (Maisels et al., 2013; Laguardia et al., 2021). Recently, CDIs have intensified throughout the country, threatening both the livelihood of local people and biodiversity. Overcoming such threatening factors, most efforts to mitigate forest elephant CDIs have focused on improving crop protection methods through the use of beehives (Ngama et al., 2016) and the installation of permanent electric fences (Mbina, 2023), as well as mobile electric fences recently. There is an understanding of the site-scale factors that directly influence CDIs, but there is a knowledge gap on how landscape-scale socioecological changes may interact with site-scale factors to perpetuate CDIs, making them so difficult to control. Gathering such knowledge is particularly important in Gabon, as the government established a network of 13 national parks, which

could have contributed to CDIs in nearby villages, across the country in 2002 for biodiversity protection. More recently, the government has elaborated a national land use planning system (PNAT) for optimum land allocation to different economic sectors, including national parks protection through ecotourism development.

With chronic conflict disrupting the lives of both villagers and elephants, we sought to gather knowledge and insights from local people who experience CDIs, and from experts who try to understand and manage CDIs in the context of elephant conservation efforts. Our goal was to identify the needs of both villagers and forest elephants as a foundation for developing land management strategies enabling human-elephant coexistence (Frank, 2016; Morehouse & Boyce, 2017; Tiller & Williams, 2021). Our specific objectives were to: 1) assess villagers' and conservation professionals' perceptions of the social and ecological factors driving forest elephant CDIs, and 2) derive a synthetic framework explaining the forces behind their persistence and severity in Gabon based on the precedent result.

Materials and Methods

Study Area

In Gabon, the abundance of forest elephants is due in large part to national and international conservation efforts, with nearly 10% of the country set aside as national parks. Among the 13 national parks established, Lopé National Park in central Gabon (Figure 1) represents the focus of this study. Around the park, villagers grow various crops, and crop fields are about 1 ha in size. Such crop fields, also known as plantations, are subsistence agriculture sources for villagers. Lopé National Park has one of the highest known CDIs (Walker, 2012) and represents a repository of relevant local ecological and environmental data.

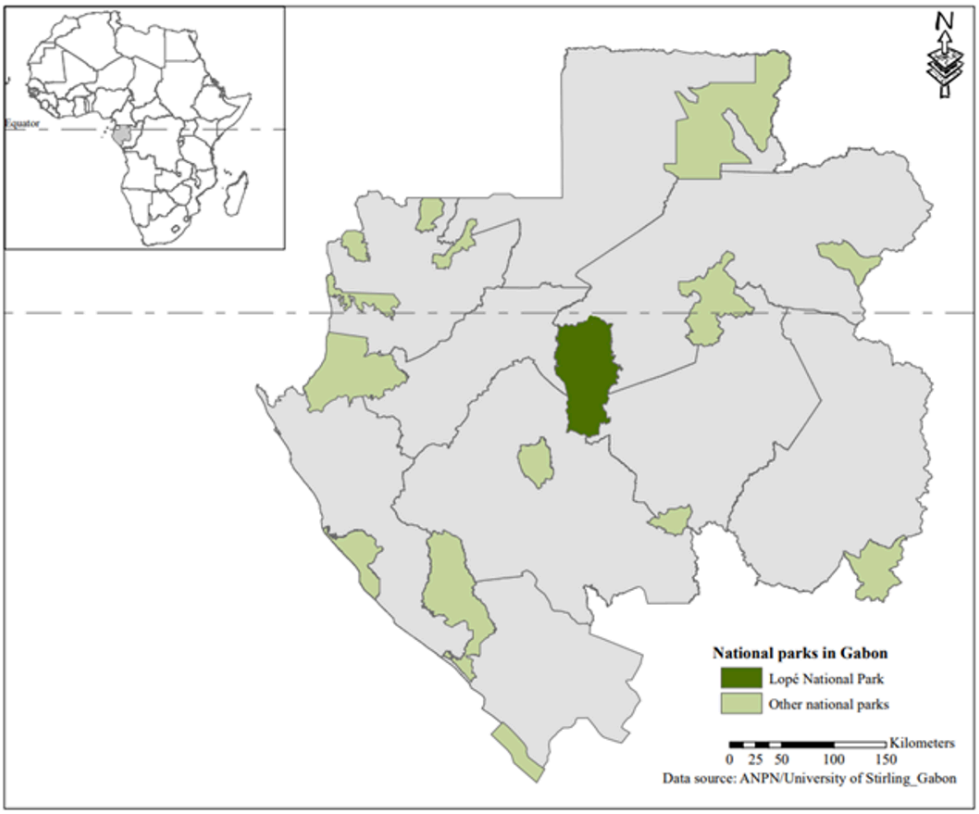

Figure 1. Gabon's 13 National Parks. The dashed line shows the equator in both panels.

Interview Procedure

Villagers were selected from two villages, Kazamabika and Ramba, when only permanent residents were present, near the park. Participants were grouped into two age groups: adults over 65 years old and adults of 18-64 years old, to allow the distinction of key stakeholders who have lived during the period prior to the ban on elephant hunting in 1981 and the national parks establishment in 2002. Conservation professionals were identified through three methods: the conservation network, the snowball method (Biernacki & Waldorf, 1981; Naderifar et al., 2017), and a literature review. Professionals comprised national park rangers and forestry agents stationed in that park, and researchers with expertise in the socioeconomics and ecology of human-elephant interactions, elephant behavior, and forest ecology in Gabon. Stakeholders included both villagers and conservation professionals.

We collected stakeholder CDI narratives through semi-structured interviews after ethical approval was granted, with the human subject research number 12182010.043, by the Institutional Review

Board at the University of Oregon. This interview method, based on three central questions with a set of questions (Appendix S1), was used to provide additional information when participants led the conversation in the direction of in-depth personal narratives (Wengraf, 2001; Galletta, 2013; Lune & Berg, 2016).

Each interview was unique to the stakeholder group. For villagers, interviews took place in January-February 2020 in person; villager interviews occurred over four weeks (two weeks in each village). The lead authors interviewed professionals from January to June 2020 in Libreville or at LNP, and remotely.

Interviews were conducted in person and remotely. The in-person interviews were a better fit with Gabonese culture, as traditional knowledge is transmitted orally (Bonhomme, 2007; Diogo & Cerena, 2015). Remote interviews were used because professionals were in different locations in Gabon and outside the country, and due to restrictions during the COVID-19 pandemic.

Interviews lasted from 15 minutes to an hour, depending on the length of participants' storytelling. With their permission, all interviews were recorded to capture their entire narrative. Interviews were conducted in French, the official language spoken in Gabon. A translator was often needed, as few elderly villagers communicated only in their native languages. Thus, a family member translated the questions from French into their native language and back to French. The family members were interviewed prior to their elders to avoid influencing the family members' narratives. On the contrary, professionals from the United Kingdom and the United States were interviewed in English.

Data analysis

Interview recordings in French were transcribed directly into English after multiple reviews to ensure that the content and context of the interviewees' responses were accurately captured. When the context could not be translated directly, words, expressions, and sentences were written in French and later translated into English. The final English transcripts were analyzed through qualitative content analysis composed of thematic and quantitative analyses, with CDIs as the unit of study by stakeholder group (Gore & Kahler, 2012; Bernard, 2017).

Thematic analysis of the transcripts

Thematic analysis was conducted in three phases. In phase one, transcripts were read to identify passages (typically one or more sentences) that responded to one of the two primary interview topics:

the context of crop depredation incidents (CDIs) across space and time and drivers of changes in resources used by elephants across space and time. Each topic included a main question with 7-9 subquestions that could be used to follow up on an interviewee's responses to a given question (Appendix S1). This full suite of questions guided the identification of transcript passages related to each main question, and these passages were interpreted to code their main ideas. In phase two, all passages and codes were categorized by main question and linked to an identifier number randomly assigned to each interviewee. Data were further analyzed to verify the link between passages and codes and to condense the number of codes. After multiple verifications of the passage expressions and codes, and their groupings, the codes were categorized into CDI subthemes and then further consolidated into higher-level themes. In phase three, each identified interview passage was characterized into a schema, or fundamental unit of explanation for the CDI problem, comprising a set of themes and associated subthemes that were derived from an interviewee's narrative.

Analysis of themes by stakeholder groups

We conducted a quantitative analysis to determine the percentage of interviewees who characterized each theme and associated subthemes by stakeholder group, and across all interviewees. Interviewees who referred to multiple coded items in a category (theme or subtheme) were counted only once. We then reorganized each individual passage according to its two or more constituent themes and compiled all such passages into synthetic diagrams showing the connections between themes of each stakeholder group, and both were weighted by the number of respondents who identified each thematic connection. We illustrated how individual interview passages were assigned to the figure and, when appropriate, (Appendix S2). When multiple passages from a single interviewee were connected to two themes, that connection was counted only once in the computation of arrow width. The code for each passage was then organized in the order of the themes to provide a common framework among passages.

Results

Results are reported in four different parts: (1) interview participant demographic profiles, (2) identification of CDI themes and subthemes, (3) breaking down of themes by stakeholder group, and 4) a synthetic framework exploring the differentiation of results for villagers and conservation professionals and integrating both stakeholder groups' perceptions.

Participant demographic profile

Twenty-four villagers (52%) and twenty-two conservation professionals (48%) were interviewed, making a total of 46 participants out of the 40-60 target participants. Twelve villagers came from each of the two selected villages, including seven adults over 65 years old and five adults of 18-64 years old from Kazamabika village, and four adults over 65 years old and eight adults of 18-64 years old from Ramba village. Professionals included nine park agents, three forestry agents, and 10 researchers.

Identified themes and subthemes

Four central themes were derived to capture participants' characterization of CDIs and their causes: landscape context, drivers, dynamics, and problem types. The derivation of the four themes was broadly inspired by the conceptual framework of Emerson et al. (2012), which was developed to guide collective plans of action through collaborative governance. In our conceptualization, drivers turn the wheels of landscape change in specific locations to set the dynamics in motion, leading to the immediate problem types contributing directly to CDIs. Because most passages contained a representation of each theme within its storyline, passages portrayed causal chains linking one theme to another.

Three contexts characterized the landscape setting for the interviewee's passage. Six drivers characterized socioeconomic and ecological influences (e.g., policies, elephant behavior) that operated in that landscape context to foster CDIs by changing landscape dynamics. Five dynamics characterized the CDI-relevant landscape change processes resulting from the drivers, which could propagate to other landscape contexts. Five problem types characterized how the outcomes of the dynamics resulted in the proximate and direct causes of CDIs.

Breakdown of each theme by stakeholder group

We report the percentage of interviewees from each stakeholder group who described each theme's categories and the dominant associated subthemes for each category. Besides the summaries below, examples of transcribed narratives for the three themes of driver, dynamic, and problem types are provided in separate appendixes for each theme (Appendix S4, S6, and S8).

Landscape Context

Interviewees' descriptions of the causes and consequences of CDIs were associated with three landscape contexts: multiple-use forest, protected area, or village area. Multiple-use forests are managed to extract natural resources, including harvesting timber and Non-Timber Forest Products (NTFPs), as well as for wildlife hunting (e.g., for bushmeat). They were referred to by 25% of villagers and 86% of professionals. Protected areas are sites where most natural resources extraction is prohibited, except under traditional customary rights granted to local communities by the state, while biodiversity conservation is the priority of the state and park management authorities. They were referred to by 21% of villagers and 45% of professionals. Village areas include both inhabited spaces and forested areas that villagers use for plantations and gathering NTFPs such as native fruits and vegetables. They were referred to by 92% of villagers and 91% of professionals.

Drivers

Six categories of drivers emerged from the descriptions of villagers and professionals: 1) elephant foraging behaviors, 2) economic activities, 3) conservation policies, 4) village-elephant habitat spatial overlap, 5) rural exodus, and 6) disruption of native fruits production (Figure 2), each derived from 1-8 subdrivers (Appendix S3). *Elephant foraging behavior* was the most frequently identified driver of CDIs. It was brought up by 70% of interviewees, and nearly equally by villagers (68%) and professionals (72%). This driver was derived from eight subdrivers related to forest elephants' needs to access food and be in a safe environment. The most frequently described drivers were elephant hunting/poaching (26%) and elephant crop preferences (24%), especially by professionals, and fences pushing elephants to other sites (17%) by villagers. The *economic activities* driver was identified by 52% of interviewees, mostly by professionals (82%). It was derived from four subdrivers, with logging by far the most frequently described driver, and the only one named by villagers. The *conservation policies* driver was identified by 41% of professionals. It was derived from two subdrivers related to elephant habitat protection: elephant hunting prohibition (35%) and park establishment (20%). The *village-elephant spatial overlap* driver was identified by 37% of professionals. It was derived from two subdrivers related to the transformation of the forest for villager behaviors: village location (by 28% of villagers) and plantation expansion (by 13% of professionals). The *rural exodus* driver was identified by 26% of both professionals and villagers, and it was derived from three subdrivers, with village depopulation as one of the most often mentioned drivers by both stakeholder groups. The final driver,

disruption of native fruits production, was identified by 15% of professionals, based on one subdriver related to the decrease in fruit availability due to a changing climate.

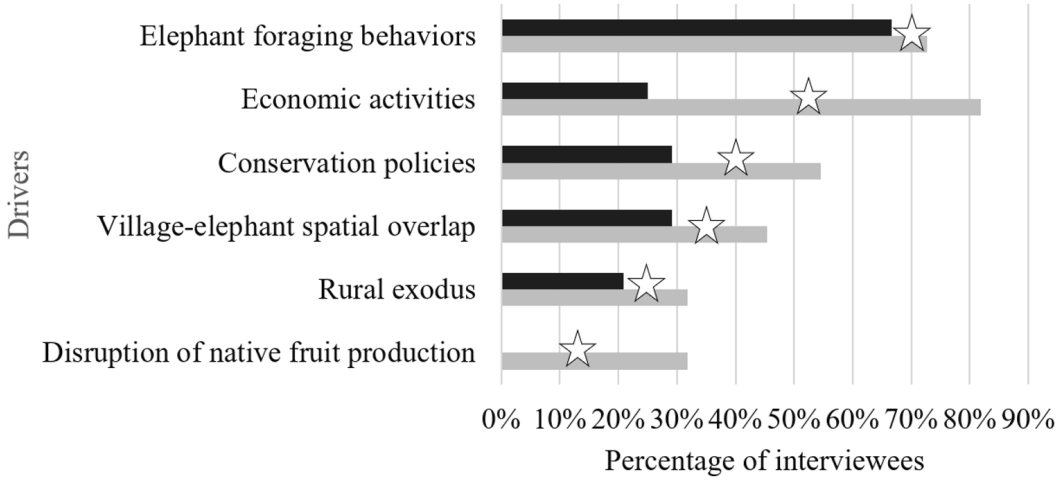

Figure 2. Interviewees' perceptions of drivers influencing CDs by villagers (black) and conservation professionals (gray). Stars show the average across all interviewees. Because the interviewees comprised almost equal numbers of villagers (n=24) and professionals (n=22), the percentages also reasonably represent the relative number of stakeholders by type.

Dynamics

Five categories of dynamics emerged from the descriptions of villagers and professionals: 1) Increased human-elephant interactions, 2) Reduced capacity to protect crops, 3) Forest structural changes, 4) Reduced native fruit availability, and 5) Decreased elephant safety (Figure 3), each derived from 1-10 subdynamics. Similar percentages of professionals and stakeholders described the first two dynamics, while the last three were identified mostly by professionals (Appendix S5).

Increased human-elephant interactions were the most frequently identified dynamics of both villagers (70%) and professionals (86%). They were derived from ten subdynamics focused on themes that emphasized how village areas had become safe environments for elephants to forage. The most common subdynamics were safe sites for elephants (30%), the inclusion of crops in elephants' diet (26%), protected forest elephants (15%), and decreased native fruits production (13%), with substantially different emphases by the two stakeholder groups. *Reduced capacity to protect crops* was identified by 50% of stakeholders, with somewhat greater emphasis from villagers. It was derived

from four subdynamics related to villager and elephant behavior changes. Professionals emphasized altered social dynamics, while villagers focused on ineffective crop protection methods. *Forest structural changes* was identified by 37% of professionals, and it was derived from three subthemes indicating forest degradation and habitat transformation. Both stakeholder groups focused on how village areas have become elephant habitats. *Reduced native fruits availability* was identified by 33%, primarily professionals, and it was derived from two subthemes indicating reduced numbers of native fruit trees and decreasing fruit production. *Decreased elephant safety* was identified by 26% of professionals, and it was derived from two subthemes related to hunting and poaching, and noise and machinery from logging operations.

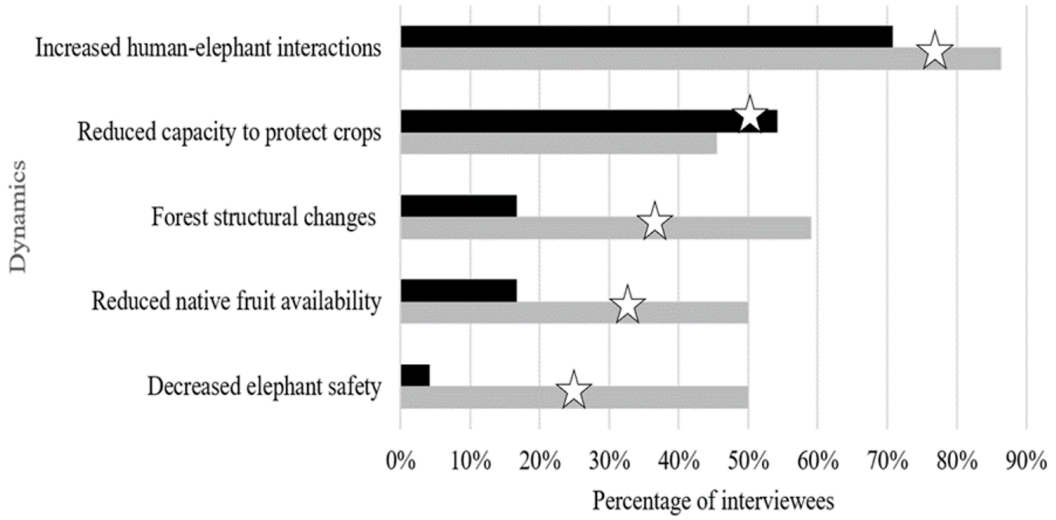

Figure 3. Interviewees' perception of dynamics influencing CDIs by villagers (black) and conservation professionals (gray). Stars show the average across all interviewees. Because interviewees comprised almost equal numbers of villagers (n=24) and professionals (n=22), the percentages also reasonably represent the relative number of stakeholders by type.

Problem types

Five problem types emerged from villagers' and professionals' perceptions of CDIs: 1) regular human-elephant negative interactions, 2) ineffective crop protection, 3) native fruit scarcity, 4) elephant insecurity, and 5) lack of a labor force (Figure 4), each derived from 1-7 subproblems (Appendix S7).

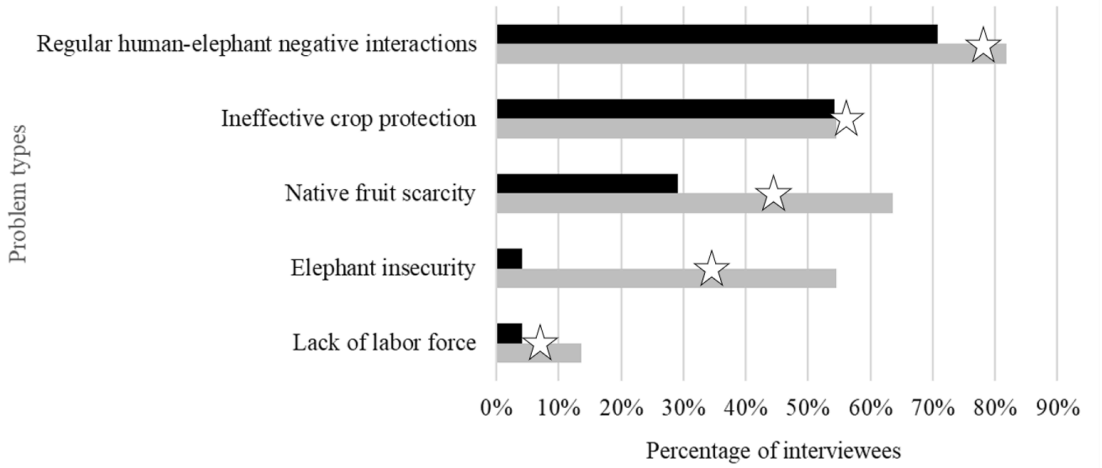

Figure 4. Interviewees' perceptions of problem types influencing CDIs by villagers (black) and conservation professionals (gray). Stars show the average across all interviewees. Because interviewees comprised almost equal numbers of villagers (n=24) and professionals (n=22), the percentages also reasonably represent the relative number of stakeholders by type.

The first two problem types were identified almost equally by villagers and professionals, while the last three were identified primarily by professionals (Appendix S6). *Regular human-elephant negative interactions* were the most frequently identified dynamics, brought up by 70% of villagers and 82% of professionals. They were derived from seven subproblems focusing on elephant disturbances, food disruption, interest in crops, villager issues, and the proximity of villagers and elephants. Among the subproblems, interviewees identified three: more elephants in village areas (48%), disturbance of the elephant habitat (35%), and village food resources attracting elephants (28%). The first and third subproblems were primarily identified by professionals, and the second by villagers. *Ineffective crop protection* was identified equally by the two stakeholder groups (54%). It was derived from four subproblems. The increased presence of elephants in the village and the absence of people in the village were the most mentioned subproblems by professionals and villagers, respectively. *Native fruits scarcity* was identified by 46% of professionals, and it was derived from two subproblems that were most often brought up by professionals, including native fruit scarcity (46%) and disturbance of the elephant habitat (24%). *Elephant insecurity* was identified by 28% of professionals, and it was also derived from two subproblems related to unsafe forests, as indicated by professionals. *Lack of a labor force* was the least frequently identified problem type and was mentioned only by 9% of professionals; it was derived from only one problem type, the absence of people in the village.

Synthetic framework of stakeholder perceptions of factors influencing CDIs

The sequencing of the four themes characterizes how socioeconomic drivers act in three landscape contexts to set in motion the dynamics. Such dynamics can propagate through the landscape, leading to the CDI problem types that people and elephants directly experience. In the two synthetic diagrams, one is for villagers (Figure 5A), and the other one is for professionals (Figure 5B). The relative width of each connecting arrow represents the percentage of interviewees whose passages connected to two themes (Appendix S9). For example, each driver influences one or more dynamics (Appendix S10), leading to the identified problem types (Appendix S11), which in return influence CDIs (Appendix S12). The perceptions of the two stakeholder groups were then combined to integrate their perspectives into a single synthetic diagram (Figure 6).

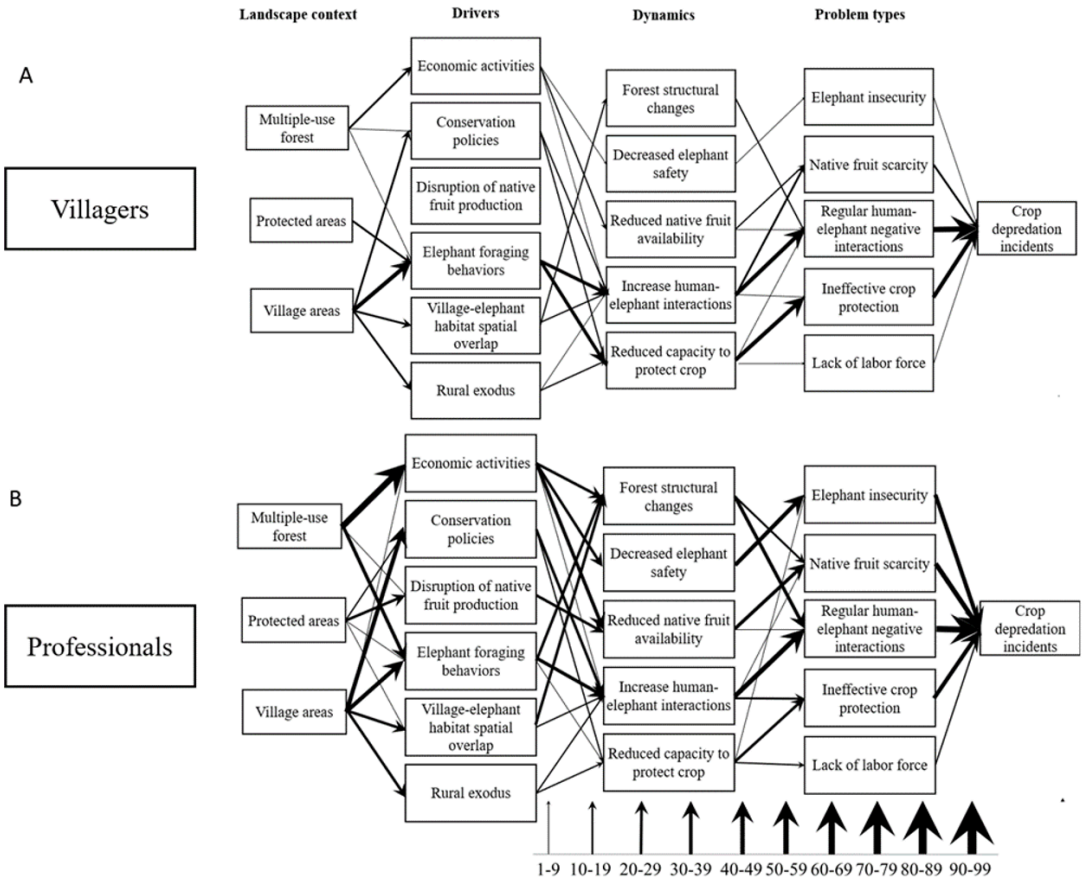

Figure 5. Conceptual framework showing how respondents from villagers (A) and conservation professionals (B) linked landscape context to drivers, dynamics, and problem types influencing CDIs. Arrow width is the percentage of respondents reporting a linkage between themes.

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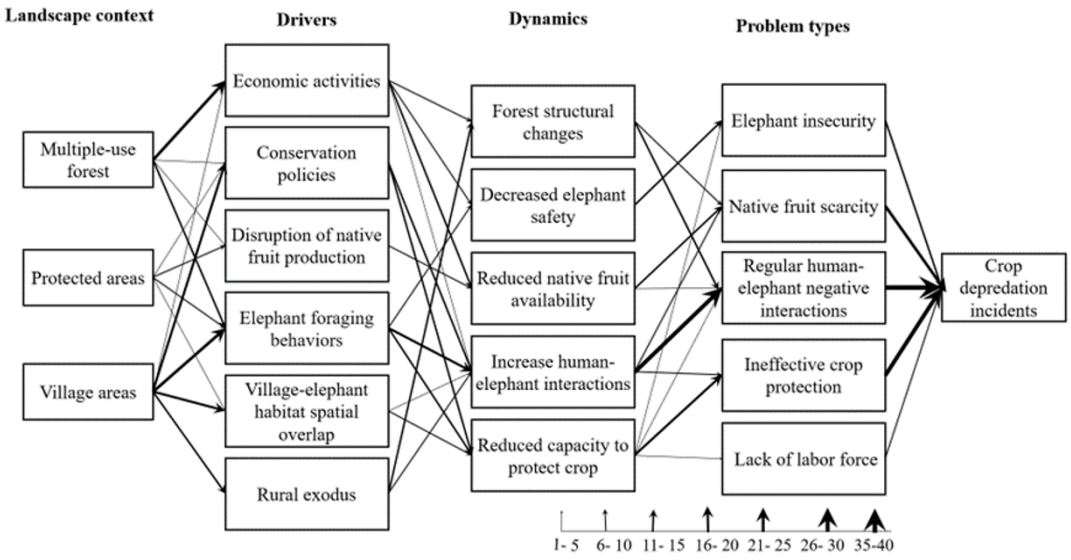

Figure 6. Conceptual framework showing how all respondents linked the landscape context to drivers, dynamics, and problem types influencing CDIs. Arrow width is proportional to the number of respondents reporting a linkage between themes.

Discussion

This section will explore the relationships identified through stakeholders' stories of the interactive relationships linked to the three landscape contexts: multiple-use forest, protected areas, and village areas, to drivers causing five dynamics of changes that led to five problem types influencing CDIs.

Multiple-use forest

Stakeholders connected multiple-use forests to four of the six drivers, primarily *economic activities* and *elephant foraging behaviors* (Figure 6). The economic activities have induced drivers of forest structural changes, decreased elephant habitat safety, and reduced native fruit production and availability (Blake, 2002; Poulsen et al., 2011). Forest structural changes from activities such as logging were described as key pushing factors of forest structure and composition changes, particularly by reducing the numbers of big trees and increasing the distance between them through selective harvest. Many of the most important timber trees that have been selectively logged (1-2 trees/ha) are important sources of fruits for both forest elephants and local people. Interviewees

reported, "*The fruiting tree species of which animals consumed fruits were also the trees logged in the past"* (Professional, ID 21*).* "*Logging activities reduce big trees in the forest*" (Villager, ID 7).

Large fruit trees are often the anchors of elephant trail systems (Short, 1981; Blake & Inkamba-Nkulu, 2004; Memiaghe, 2023), and trail systems are the spatial foundation for *elephant foraging behavior*s, meaning that established trails serve as an elephant herd's cognitive map of the results of their past foraging behaviors while increasing the efficiency of their movements as they seek fruits and other food sources (Fishlock et al., 2016; Presotto et al., 2019). Since older elephants' cognitive maps seem to be transmitted from generation to generation (Fishlock et al., 2016) and by disrupting elephant foraging behavior at the landscape scale, logging operations changing the landscape pattern and structure may push elephants to roam widely, searching for reliable food sources. Over time, they create an updated trail system that serves their dietary needs. Because of the reduced availability of fruit trees in logged areas, the disturbances caused by logging activities on elephant trail systems may push them to relocate into both protected areas and around villages, establishing new trail systems and patterns of behavior that will be passed on from one generation to the next. However, as time passes, elephants tend always to return to their previous trail systems.

In multiple-use forests, interviewees most often linked the driver of *elephant foraging behavior* with the dynamic of decreased elephant habitat safety. In addition to adjusting their foraging behaviors to changes in fruit distribution and production, they must adjust to increased noise and danger. "*Logging noise pushed elephants away* (Professional, ID 16). *Indeed, I was involved in logging before I worked in conservation. You cannot imagine the noise made by chainsaws, engines, and bulldozers* (Professional, ID 31)". "*Elephant fruiting trees were logged in the past. Elephants were then lost in the forest and came to the villages*" (Villager, ID 19). Furthermore, both noise and danger are brought into the forest with the use of guns during hunting and poaching.

Hunting and poaching are strongly associated with logging and other industrial extraction processes (Fay & Agnagna, 1991; Blake, 2002; Rakotonarivo et al., 2021), and both tend to affect elephant presence and behavior in forests and savannas (Kolowski et al., 2010; Yackulic et al., 2011; Vanthomme et al., 2013; Breuer et al., 2016). "*There is a displacement of elephants as they move away from poaching areas* (Professional, ID 36)," causing elephants to leave their usual areas based on their food sources and associated trail systems. "*...They leave their corridors when they are disturbed*" (Professional, ID 14). This process can be self-perpetuating as the proliferation of new roads provides ongoing access, and people involved in extractive industries may themselves take advantage of the opportunities (Wilkie et

al., 1992). Stakeholders mentioned it as "*More, people who worked take advantage to hunt animals, I saw that personally. I think that this is the cause of elephant movement at 100%"* (Professional, ID 31). In these ways, we argue that both the processes and outcomes of logging can contribute to stimulating new elephant foraging behaviors and reinforce them over time. Thus, these direct and indirect effects contribute to increasing CDIs, as elephants displaced by logging may seek food sources and safety provided by protected areas and village areas.

The complex interaction of drivers and dynamics, which stakeholders described as originating from multiple-use forests (Figure 6), primarily enhanced three problem types: elephant insecurity, native fruit scarcity, and, most importantly, regular human-elephant negative interactions. In this landscape context, then, we argue that multiple-use forests can be successfully managed as part of a landscape-scale strategy to mitigate CDIs. Although logging tends to create intense disturbances in tropical forests (Hosonuma et al., 2012; Tyukavina et al., 2018), including loud, disruptive activities and the loss of fruiting trees. Such short-term impacts on elephant behavior have been mitigated elsewhere by protecting forest elephant fruiting tree species and trail systems. It can be argued that the creation of different-aged patches of secondary forest in the gaps where trees have been logged out has the potential to provide important foraging areas for elephants so long as increased access for hunting and poaching is ensured and the effects of logging are controlled during and after this activity.

Protected areas

Stakeholders connected protected areas almost equally to four drivers: *conservation policies*, *disruption of native fruit production*, *elephant foraging behaviors,* and *village-elephant spatial overlap*. Hunting and poaching in protected areas were not noted in this landscape as strictly prohibited by the national park law of 2007. However, in other national parks, it is reported as a major factor (Maisels et al., 2013; Poulsen et al., 2017).

Conservation policies in Gabon were intended to create a safe environment for wildlife protection, including elephants, through the establishment of national parks, limiting logging operations within their boundaries (Laurance et al., 2006; Eba'a Atyi et al., 2022). Outside the parks, hunting of conserved species like elephants was highly restricted, and conservation efforts are in place to stop elephant poaching for ivory.

The effects of national park establishment, however, have propagated through the socio-ecological system in unintended ways. The expectation was that forest elephants would stay in these protected

areas in the absence of human activities, but some interviewees reported that they spend most of their time in surrounding human land use areas, particularly village areas. "*In 1981-2, the ECOFAC [conservation project] began; from there, people could not go into the forest as they wanted, not even hunting. At that time, animals* [elephants] *began to come close to people; these elephants have multiplied (*Villager, ID 22)". One of the reasons elephants are leaving their reserves may be the *disruption of native fruit production* by the rapidly changing global climate. The decline of fruit production is creating severe fruit scarcity (Bush et al., 2020), representing a central component of forest elephants' diet (White et al., 1993; Tchamba & Seme, 2008; Beirne et al., 2020; Fai et al., 2022). Since 1982, the wildlife reserve research station, which became Lopé National Park, has maintained a long-term forest fruit phenology dataset, and the data tend to show that fruit production has been in rapid decline since at least 1986 (Bush et al., 2020). As a result, elephants have to search longer and roam further to find fruits.

Like the loss of fruit trees from logging, the reduction of fruit production, including both fewer fruits on a tree and an increased number of years during which an individual tree cannot produce any fruits, may explain changes observed in *elephant foraging behaviors*. This observation has been emphasized for several important elephant fruit tree species such as *Sacoglottis gabonensis.* Elephants' tracks are linked to the variation of native fruit availability (Momont, 2007; Mills et al., 2018; Beirne et al., 2020; Bush et al., 2020), using trail systems that take them close to individual fruiting trees (Short, 1981; Blake, 2002; Blake & Inkamba-Nkulu, 2004; Memiaghe, 2023). They also use their acute sense of smell to determine when fruits are ripe across long distances (White et al., 1993; Plotnik et al., 2014) and have the capacity to smell from a distance away some crops and domestic fruits that direct them to the village areas (Villager, ID 34). For these reasons and others described above, the establishment of national parks has increased *village-elephant habitat spatial overlap*.

Although protected areas were created to provide elephants with safe refuges and abundant resources, they have not fully met the needs of elephants. For protected areas to serve their full potential and their central role in long-term wildlife conservation, addressing unintended consequences is crucial for elephants' safety. In addition, the disruption of the availability of native fruits in Lopé National Park, identified in interviews by several professionals and supported by recent studies, needs deeper attention around this park and other Gabon national parks.

Village Areas

As described above, displaced elephants from multiple-use forests and protected areas are under pressure to find reliable food sources to fulfill their year-round dietary needs and to escape from unsafe logged forests, hunting, and poaching pressure. Village areas, where CDIs occurred, appear to provide such a safe environment (Breuer et al., 2016) and a source of food (Mbamy et al., 2023). In that context, stakeholders connected village areas to five of the six drivers of landscape change, particularly to *conservation policies*, *elephant foraging behaviors,* and *village-elephant spatial overlap*.

Conservation policies were intended to protect habitats and wildlife inside national parks, but we can deduce that they had significant effects on villages inside or adjacent to the parks. Those inside the parks can no longer hunt at all, while those outside the parks can no longer hunt protected species, including elephants. Villagers may request that the forestry service kill a problem elephant, but the process is time-consuming and difficult to implement.

Interviewees reported a new, permanent forest elephant presence around village areas since the demarcation of the national park and since elephant hunting was prohibited (Professional, ID 14). Such a prohibition has certainly contributed to the increase in the number of elephants inside the park, where fruit scarcity is encountered, and has pushed them to look for fruit tree sources around villages (Lahm, 1993; Mills et al., 2018; Djoko et al., 2022). Interviewees echoed this idea, for example, by saying, "*I think they came here* [to the village] *when the forest did not produce fruits for them…*" (Villager, ID 11). Thus, the prohibition of lethal force and the impacts of rural exodus may explain the presence of elephants around villages.

With greater access to crops, *elephant foraging behaviors* have changed, and intrusions into villages are encountered more often now than before, especially in and adjacent to protected areas (Nsonsi et al., 2017; Mills et al., 2018; Beirne et al., 2019; Ngama et al., 2019).*"In the past, elephants were hard to see, and now, without hunting, they are around villagers. The elephants are more and more. In the past, one elephant was coming, and it used to eat and go back. Today, there are groups of more than six elephants* (Villager, ID 13). This observation is supported by (Laguardia et al., 2021) and (Meier et al., 2023), who reported that forest elephant group size is larger around areas with human activity and also in times of fruit unavailability in Gabon.

Increased pressure by elephants seeking crops in conjunction with rural exodus has made labor-intensive traditional crop protection methods less effective, as elephants become used to them or find

other means to overcome them. Traditional methods were managed by working-age youths and adults who have now left the village in search of a better livelihood in big cities. For all these reasons, villages in and adjacent to protected areas appear to be safe locations and reliable food sources for elephants (Mills et al., 2018). To help villagers protect their crops, electric fences have been introduced in some villages in and adjacent to LNP, and such protection methods have shown promising results but may push elephants toward other villages lacking such protection. The issue can also be exacerbated because of ineffective fencing materials allowing elephants to adapt quickly while breaking fences (Shaffer et al., 2019).

The inclusion of crops in elephants' diet is also fostered by their ongoing availability. The recurrent conversion of forests into plantations through slash-and-burn clearing each year (Angoué, 1999) may also stimulate elephant foraging behavior. After one to two years, plantations return to secondary forest with herbaceous plants, a key component of elephant forage. Forest elephants may also seek out crops because they provide important nutritional value, particularly minerals in their diets (Chiyo et al., 2005; Rode et al., 2006; Chiyo & Cochrane, 2008). Elephants grow bolder when they are pushed from the forest by a lack of food and roam to village areas where crops are reliably available on a year-round basis.

The combined effects of *conservation policies* and changes to *elephant foraging behavior*, described above, have certainly contributed to the increase in *village-elephant habitat spatial overlap*. Villagers stated that it used to be rare to see elephants in village areas. "*Elephants used to stop to eat some crops when they passed by village areas, mostly in plantations that were some distance away from housing sites* (Villager ID 13)." As a consequence, villagers used to have few interactions with forest elephants. "*Even hunters would have to walk around 50 km before seeing an elephant's footprint* (paraphrase of Villager, ID 33)." Their interactions with elephants were meaningful enough that they had ritual significance (Lewis, 2021). Villagers described how elephant hunters conducted traditional rituals to prepare a product that *they would spread on the footprints of the elephant they had targeted before they pursued it.* These interactions suggest that people and elephants once had their own places, with limited overlap in their use of the forest, potentially due to hunting pressure (Barnes, 1996).

Now, village areas offer elephants access to both food and shelter in Gabon *(Vanthomme et al., 2013; Wall et al., 2021)*, especially villages in and adjacent to protected areas (Nsonsi et al., 2017; Mills et al., 2018). Faced with a multifaceted problem, villagers lack the ability to deter elephants using lethal

force, as they once could: "*And the local population was weak against elephants. They could not do something to deter elephants from entering their plantations or gardens…*" (Professional, ID 3).

Conclusion

Forest elephant crop depredation poses dual threats to villagers' livelihoods and forest elephant conservation. Despite intensive efforts to prevent CDIs, solutions have proved elusive, with mostly temporary fixes rather than a long-term solution. Our purpose in this study, however, was primarily to explore stakeholders' perceptions of the socioecological factors influencing forest elephant CDIs around Lope National Park and to suggest a synthetic framework to better capture the persistence and severity of such a multifaceted problem affecting both villagers' livelihoods and elephant conservation efforts at a local landscape scale. In this study, we identified three primary landscape contexts based on the experiences of villagers and conservation professionals, in which six broadscale drivers have led to five dynamics that contributed to five key problem types directly influencing CDIs. Two of these problem types specifically relate to unmet elephant needs, leading them to seek out village areas and their crops to increase food resources. Two of the problem types are related to the lack of effective crop protection methods and broader issues of socioeconomic changes that have led to rural exodus. The fifth problem type, regular human-elephant negative interactions, has increased through the impacts of all five dynamics, mostly around the village areas. Despite their antagonism, villagers and elephants have common needs for a safe environment and reliable food sources. Villagers are faced with an urgent dilemma: the need to protect their crops and also to physically protect family members from elephants entering their villages. Disturbed forest elephants are faced with urgent needs for food sources and a safe environment. Thus, it is imperative to identify management strategies that bridge the combined landscape contexts of protected areas, multiple-use forests, and village areas to simultaneously satisfy the unmet needs of both villagers and forest elephants, rather than simply trying to mitigate CDIs through improved crop protection alone. An integrated suite of strategies focusing on human-elephant coexistence is highly needed and should aim at supporting the shared use of the larger landscape by both villagers and forest elephants. Achieving the latter will more likely contribute to improving both villagers' socioeconomic conditions and enhancing forest elephant conservation.

Statements and Declarations

Acknowledgments

The authors thank the Research Ecology Institution (IRET) for granting me a research authorization that allows me to conduct this research in Gabon, and the National Park National Agency (ANPN) for granting me permission to work at Lopé National Park. We thank professionals at Lopé National Park, including park agents, SEGC (Station d'Etudes des Gorilles et Chimpanzes) employees, Ministry of Forest and Water of Gabon agents, and the villagers. Throughout Gabon, I also thank all professionals who took the time to discuss this topic with me. Moreover, we thank the Former Gabon Oregon center team, who supported this study in Gabon and at the University of Oregon, as well as Lisa Korte and Mary Leighton for their voluntary support in terms of editing, and Mary Sharon for final editing. Finally, we thank the Institutional Review Board at the University of Oregon for the ethical approval of this study.

Conflict of Interest

The authors report no conflicts of interest in this research.

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Supplementary data: available at https://doi.org/10.32388/XSM9RG

Declarations

Funding: Former Gabon Oregon Center provided the funding for this study before stopping activities.

Potential competing interests: No potential competing interests to declare.