

Research Article

The Role of African Forest Elephants (*Loxodonta africana cyclotis*) as Ecosystem Engineers and Human Encroachment Threats in Mount Cameroon National Park, SWR, Cameroon

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Abstract

African elephants (*Loxodonta Africana cyclotis*) serve a pivotal role in shaping forest ecosystems, particularly in regions like Mount Cameroon national park. Their size and behavior impact various ecological components, from canopy structure to understory dynamics. Also, elephants play a crucial role as ecosystem engineers, and their foraging and browsing behaviors induce significant disturbances that shape forest characteristics. This study explored the impact of African forest elephants' activity on the forest ecology of Mount Cameroon national park, focusing on six key areas, forest canopy structure, tree species composition, forest tree regeneration, vine growth, forest understory dynamics, and large trees formation. Research data collection was carried out five days each month, for a period of six months. Systematic vegetation plots within selected sites were established to examine tree abundance and species diversity. Quadrats and transects were equally used to capture data on the types and numbers of trees, especially focusing on both preferred and less preferred species by elephants. The results of this study showed that African forest elephant activity recorded a significant association on forest canopy structure $r=0.309$ $P=0.001$, tree species composition $X^2=83.267$ $df=6$ $P=0.000$, forest tree regeneration $X^2=45.891$ $df=6$ $P=0.000$, vine growth $X^2=54.030$ $df=6$ $P=0.000$, forest understory $X^2=69.696$ $df=6$ $P=0.000$, and large trees structure $X^2=73.283$ $df=6$ $P=0.000$ respectively. Furthermore, human-wildlife conflict revealed a significant link on elephant population threat $X^2=63.720$ $df=4$ $P=0.000$, biodiversity rating $X^2=63.154$ $df=4$ $P=0.000$, and elephants grouping behaviour $X^2=62.876$ $df=4$ $P=0.000$ respectively. Forest elephants play a crucial role in rainforest ecosystem. Their activities, including browsing, trampling, and creating trails, modify the forest structure, which in turn affects resource availability and habitat for other species. As human populations expand into rainforest areas, elephants face habitat loss and fragmentation. This encroachment reduces the space available for elephants to roam and feed, leading to population declines. The findings indicated that elephant interactions result in increased biodiversity, altered species distributions, and varying regeneration patterns, which collectively contribute to the resilience of forest ecosystems. This research equally underscores the importance of elephants in maintaining ecological balance in Mount Cameroon national park and provides insights for effective conservation strategies aimed at protecting both elephant populations and the valuable forest habitat they help sustain.

Keywords

African Elephant, Forest Ecosystem, Ecosystem Engineers, Understory Dynamics

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1. Introduction

African forest elephants (*Loxodonta cyclotis*) are critical ecological actors within the rainforests of Sub-Saharan Africa. Their activities are not just significant for their immediate environment; they play a pivotal role in shaping the dynamics of forest regeneration [22]. This literature review synthesizes existing research on how the behavior and ecological functions of forest elephants influence forest regeneration, highlighting their roles in seed dispersal, habitat modification, competition dynamics, and the overall biodiversity of forest ecosystems [25]. They play a pivotal role in shaping forest ecosystems, particularly in regions like Mount Cameroon National Park [36]. Their sheer size and behavior impact various ecological components, from canopy structure to understory dynamics. Elephants are known as ecosystem engineers due to their ability to modify habitats significantly. Elephants create gaps in the forest canopy by uprooting trees and breaking branches, facilitating greater light penetration [7, 19]. This alteration leads to varied microhabitats that promote the growth of multiple plant species. Research in similar ecosystems, like the Gorongosa National Park, supports the idea that canopy gaps created by elephant activities are essential for fostering biodiversity and varying growth forms in forests [29]. The foraging habits of elephants impact the ecological balance of forest ecosystems by selectively browsing certain species. Elephant browsing can lead to a decline in preferred tree species while favoring less palatable ones, altering overall tree species composition within a forest [26]. This dynamic results in shifts that can reduce diversity, as documented in several protected areas across Africa. Selective pressure exerted by elephants allows for the establishment of tree species that are more resilient to browsing, ultimately reshaping forest composition over time [27].

One of the primary ecological functions of African forest elephants is their role as seed dispersers. As herbivores, they consume various fruits and seeds, subsequently facilitating the propagation of numerous tree species. Elephant dung serves as a nutrient-rich medium for seed germination, significantly enhancing the survival rates of seeds that pass through their digestive systems [27, 16]. Research indicates that seeds ingested by elephants experience higher germination rates compared to those directly sown in the soil. This phenomenon is attributed to the beneficial microflora present in elephant dung, which helps in breaking down seed coats and optimizing nutrient availability [34]. Elephants preferentially consume certain fruits, leading to selective dispersal that promotes not only the regeneration of favored species but also increased plant diversity across the landscape [18].

Research indicates that elephants significantly contribute to seed dispersal through their dung, aiding in forest tree regeneration. Seeds of various tree species pass through the elephant's digestive system, enhancing germination rates [16]. Moreover, disturbance from elephant activities stimulates regeneration by

creating clearings where young plants can thrive, as demonstrated in studies [28]. However, elephant activities can also hinder regeneration if preferred species are heavily browsed, emphasizing the balancing act they perform in forest dynamics [38]. The disturbance caused by elephants influences not only tree populations but also vine dynamics within the forest. Increased sunlight from canopy gaps promotes vine growth, allowing these climbing plants to exploit vertical space in the forest [31]. While vines can enhance overall biodiversity and provide habitat, unchecked vine growth may outcompete saplings and smaller tree species, as documented in studies [32]. This interplay between vine growth and tree regeneration underscores the complexity of forest ecosystem responses to elephant activity [44].

Elephant activities lead to a heterogeneous understory, fostering a rich diversity of herbaceous plants and seedlings. Understory responses to elephant browsing, finding increases in plant diversity and density where elephants had previously foraged [10]. The nutrient cycling facilitated by elephants through dung deposition further enriches the soil, promoting understory growth and the establishment of new plant species. This dynamic emphasizes the critical role elephants play in enhancing forest understory biodiversity. The impact of elephants on large formation trees can be profound. Removal of large trees through elephant disturbance not only alters forest structure but also creates habitats for various wildlife [41]. Large trees, which often serve as keystone species, are essential for maintaining ecological stability [30]. The loss or alteration of these trees due to elephant activity can thus have far-reaching implications for the forest ecosystem and its associated fauna. Their activities reshape canopy structure, alter tree species composition, enhance tree regeneration, and affect vine and understory dynamics. While elephants contribute to biodiversity and ecological resilience, their impact is complex and can lead to challenges, such as species decline, if not managed properly [14]. Future research should focus on longitudinal studies to understand the long-term effects of elephant activities and the implications for conservation strategies aimed at balancing elephant populations with forest health in protected areas.

2. Materials and Method

2.1. Description of Study Area

The study area for this research is Mount Cameroon National Park, located in the Southwest Region of Cameroon, Central Africa. The park is situated between the geographical coordinates of 4°04'N to 4°23'N and 9°02'E to 9°22'E [43] (Figure 1). Mount Cameroon National Park is located in the southwestern part of Cameroon, covering an area of approxi-

mately 58,178 hectares [24]. The park is centered on the majestic Mount Cameroon, an active volcano that reaches an elevation of 4,040 meters above sea level [40]. Mount Cameroon National Park is home to a diverse array of floral and wildlife species. The park's tropical rainforest vegetation is dominated by species such as *Terminalia superba*, *Lophira alata*, and *Sacoglottis gabonensis* [43]. The park also supports a rich diversity of wildlife, including the African forest elephant (*Loxodonta*

africana cyclotis), the drill (*Mandrillus leucophaeus*), and the critically endangered Cross River gorilla (*Gorilla gorilla diehli*) [24]. The park is situated within the drainage basin of the Mungo River, which flows along the northern and eastern boundaries of the park [39]. Additionally, several smaller streams and rivers, such as the Dibonda River and the Mokoko River, originate from the slopes of Mount Cameroon and flow through the park, contributing to the overall hydrological system [43].

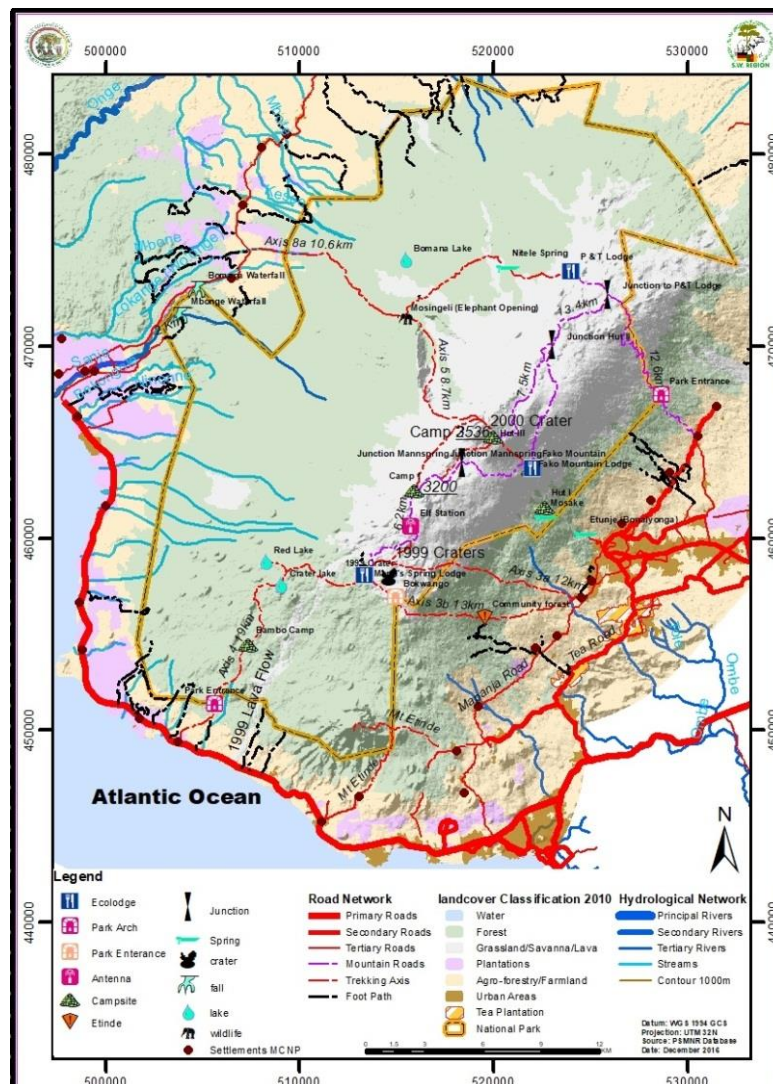


Figure 1. Map of Mount Cameroon National Park, Source [43].

2.2. Research Data Collection and Analysis

The research data collection was programmed five days each month, for a period of six months. During this periods observations were made to assess the effects of elephant activity on various ecological components in Mount Cameroon national park. Identification and categorization of forest areas was carried out based on known elephant activity levels and ecological characteristics. Selected sites represented diverse

habitats, including primary forests, secondary growth, and areas recently affected by elephant foraging. Observations and documentation on elephant behaviors were made related to foraging and movement through marked plots, utilizing a combination of direct observation and camera traps to gather data on their impact on the vegetation [6]. Systematic vegetation plots within selected sites were conducted to examine tree abundance and species diversity. Quadrats and transects were equally used to capture data on the types and numbers of trees,

especially focusing on both preferred and less preferred species by elephants. Establishment of smaller plots was done within larger inventory plots to assess tree seedlings and saplings. Also, counting and categorizing vine species was carried out within regeneration and larger tree plots. Furthermore, the surrounding areas were monitored for signs of elephant interaction, such as bark stripping or uprooting. Statistical models, such as chi-square and correlations were employed to evaluate the relationships between elephant activity levels and ecological variables, canopy structure, species composition, [33].

3. Results

The forest elephant activity recorded a significant association on forest canopy structure $r=0.309$ $P=0.001$ (Figure 2),

tree species composition $X^2=83.267$ $df=6$ $P=0.000$ (Figure 3), forest tree regeneration $X^2=45.891$ $df=6$ $P=0.000$ (Figure 4), vine growth $X^2=54.030$ $df=6$ $P=0.000$ (Figure 5), forest understory $X^2=69.696$ $df=6$ $P=0.000$ (Figure 6), and large trees structure $X^2=73.283$ $df=6$ $P=0.000$ (Figure 7) respectively. Forest elephants (*Loxodonta cyclotis*) play a critical role in shaping the structure and composition of tropical forests. Their activities significantly influence various ecological components, including forest canopy structure, tree species composition, forest tree regeneration, vine growth, understory dynamics, and large tree structure. The activities of forest elephants significantly influence various aspects of forest ecosystems. Their role as ecosystem engineers is vital for maintaining biodiversity and the structural complexity of tropical forests. Understanding these influences is crucial for conservation efforts and forest management strategies [22].

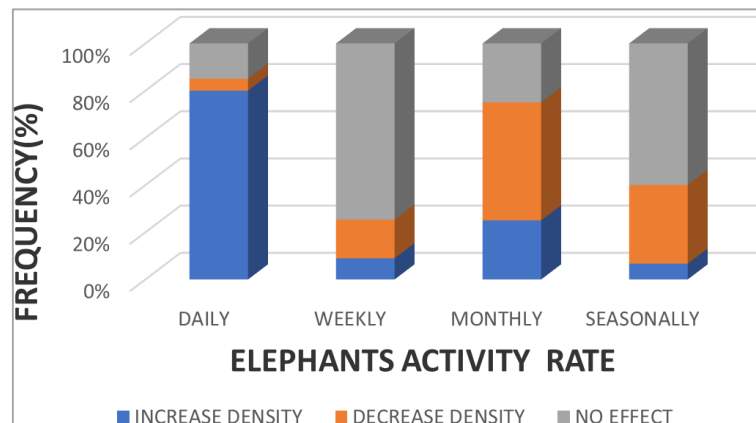


Figure 2. Effect of Elephants Activity and Forest Canopy Structure.

Forest elephants contribute to the dynamics of the forest canopy by creating gaps through their foraging behavior. These gaps allow for increased light penetration, which can promote the growth of understory plants and younger trees. As elephants feed on trees, they may uproot or break branches, leading to a more heterogeneous canopy structure [17].

Elephants exhibit selective feeding habits, often targeting specific tree species [29]. This selective foraging can alter species composition by favoring certain species over others, leading to shifts in community dynamics. For instance, their preference for softer, fruit-bearing trees can enhance the growth of these species while suppressing others [4]. This selective pressure can affect biodiversity and ecosystem resilience.

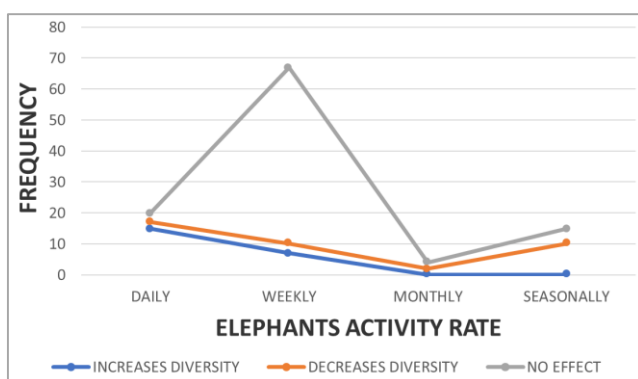


Figure 3. Elephants Activity and Tree Species Composition in the Forest.

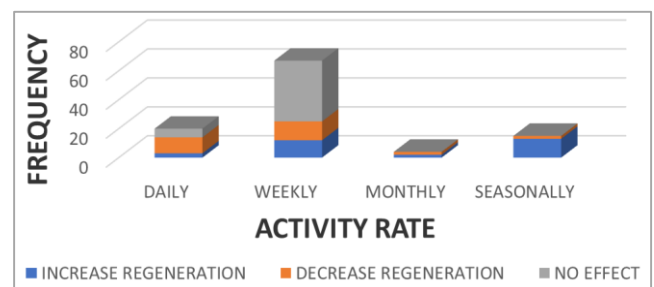


Figure 4. Elephants Activity and Forest Tree Regeneration.

The disturbance caused by elephants enhances tree regeneration by creating favorable conditions for seedlings [25]. The gaps and soil disturbances promote seed dispersal and germination. However, the impact on regeneration varies by species; some may thrive while others struggle in the changed environment [13].

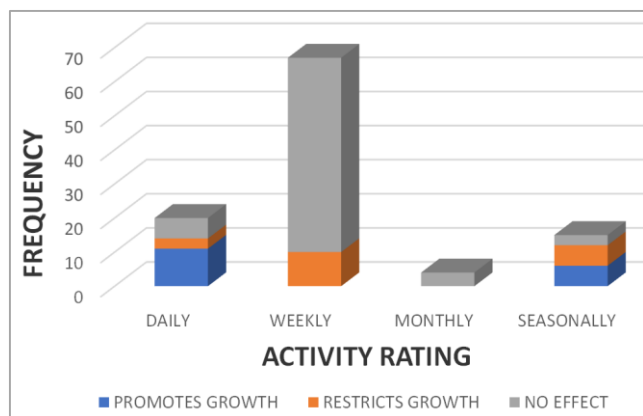


Figure 5. Elephants Activity and Vine Growth.

Elephant activity influence vine dynamics in the forest. By creating openings and disturbances, they facilitate vine growth, which often benefits from increased light availability. However, this can lead to competition with tree saplings and affect overall forest dynamics [12].

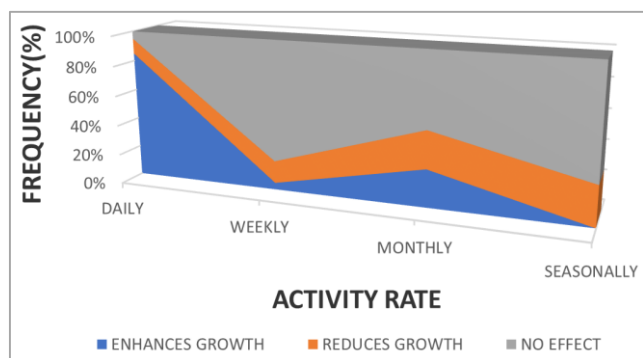


Figure 6. Elephants Activity and Forest Understory.

The understory is significantly affected by the activities of forest elephants. The creation of gaps and soil compaction from their movement encourages the growth of understory plants, including shrubs and herbaceous species. This increase in understory vegetation provides habitat for various fauna but may also alter the competitive landscape for tree seedlings [35]. Elephants often target large trees, impacting their structure and health. By breaking branches or uprooting trees, elephants alter the age structure of forests and influence the stability of large trees [30]. This activity can lead to a reduction

in the number of mature trees, which are critical for maintaining forest integrity and biodiversity [37].

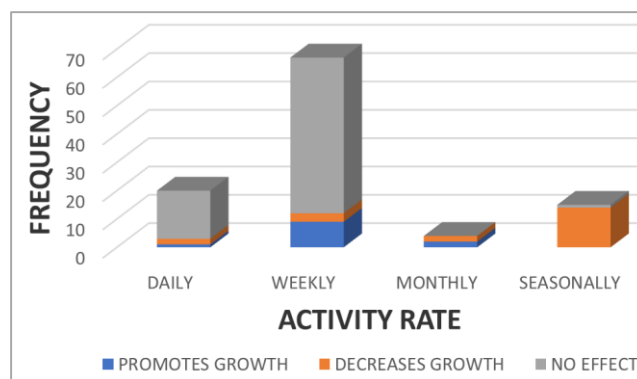


Figure 7. Elephants Activity and Large Trees.

Elephants aid in the dispersal of seeds from large trees through their consumption of fruits. Their dung serves as a nutrient-rich medium for seed germination, facilitating the spread of tree species across the landscape [6]. By browsing and uprooting smaller vegetation, elephants create gaps in the forest canopy [36]. These gaps allow more sunlight to reach the forest floor, promoting the growth of young trees and enabling larger trees to thrive by reducing competition for light [30]. The dung of elephants enriches the soil with nutrients, benefiting nearby large trees [14]. This nutrient cycling enhances soil fertility, which supports the growth and health of tree species in the ecosystem [38]. Elephants often strip the bark from trees, particularly when feeding on certain species. This behavior can lead to tree stress or even death if the bark is removed extensively [4].

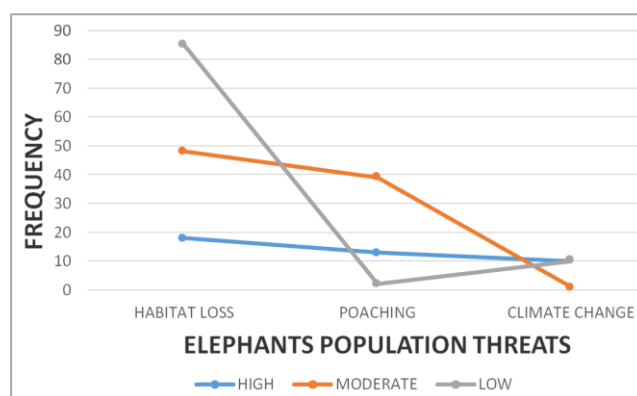


Figure 8. Human-wildlife Conflict and Elephant population Reduction Threat.

Human-wildlife conflict also revealed a significant link with elephant population threat $X^2=63.720$ $df=4$ $P=0.000$ (Figure 8), biodiversity rating $X^2=63.154$ $df=4$ $P=0.000$ (Figure 9), elephants grouping behaviour $X^2=62.876$ $df=4$ $P=0.000$

(Figure 10) respectively. Human-wildlife conflict poses substantial threats to elephant populations, reduces biodiversity, and alters their social behavior. Addressing these conflicts through effective management strategies is essential for the conservation of elephants and the ecosystems they inhabit. Human wildlife conflict (HWC) is one of the leading threats to elephant populations worldwide. As human activities expand into elephant habitats, conflicts arise, often resulting in

retaliatory killings or habitat destruction. Studies show that increased encounters between elephants and humans can lead to significant declines in local populations [45, 14]. The loss of elephants not only affects their populations but also disrupts ecosystem dynamics, as they play a critical role as ecosystem engineers.

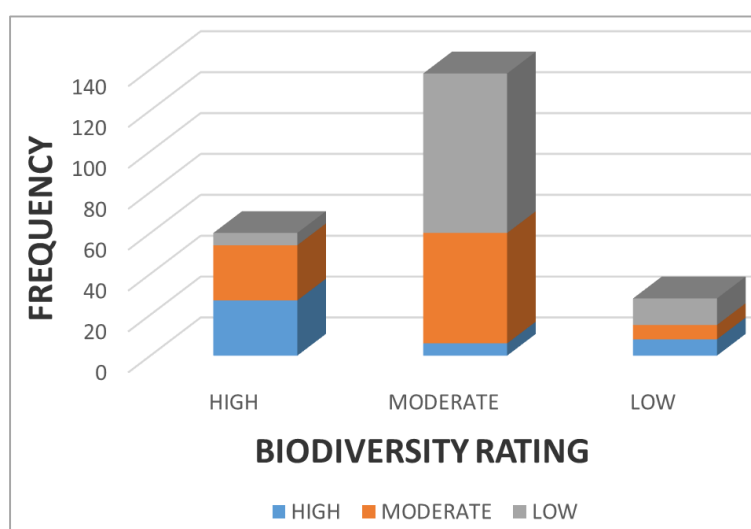


Figure 9. Human-wildlife conflict and Biodiversity Rating.

Human-wildlife conflict can adversely affect biodiversity ratings within ecosystems. As elephants are driven from their habitats due to conflict, the biodiversity that relies on their presence is also threatened. Elephants contribute to maintaining forest structure and promoting species diversity through

their feeding habits [9, 11]. The decline of elephant populations can lead to overgrowth of certain plant species, reducing habitat variety and threatening other wildlife.

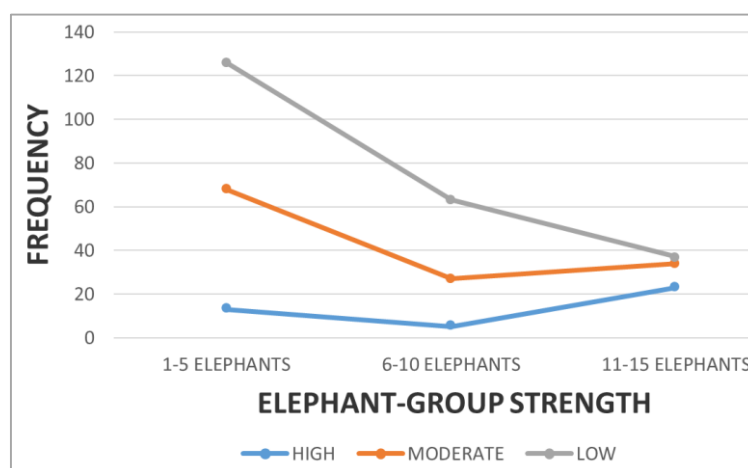


Figure 10. Human-wildlife Conflict and Elephants Grouping Behaviour.

Human-wildlife conflict significantly influences the social structure and grouping behavior of elephants. When faced

with threats from human activities, elephants may alter their traditional grouping patterns to enhance safety. For example,

elephants may form smaller, more dispersed groups to reduce detection risk or increase mobility in search of resources [21]. Additionally, matriarchs may change their leadership strategies to adapt to increased risks, impacting social cohesion and dynamics within herds [41].

4. Discussion

The structure of the forest canopy significantly influences the activity of African elephants in rainforest ecosystems. Forest elephants (*Loxodonta cyclotis*) are a distinct species from savanna elephants *Loxodonta africana*). Forest elephants play a crucial role as ecosystem engineers in these environments. Their activities, including browsing, trampling, and creating trails, modify the forest structure, which in turn affects resource availability and habitat for other species. Forest elephants are often found in higher densities in open canopy forests, including secondary forests, where understory browse is more abundant compared to closed canopy forests [30]. Dicotyledon browse is most abundant in open canopy terra firma forests, light gaps, and swamps, while monocotyledon food is concentrated in terra firma forests and swamp patches [3]. Elephants exhibit higher browsing rates in open canopy forests, particularly swamps [2]. Fruit availability is negligible in swamps but high in closed canopy terra firma forests, with its distribution being temporally and spatially irregular [23]. Quasi-nomadic ranging in search of fruit patches is a low-risk, high-payoff strategy for elephants [42]. Elephants clear the understory of the forest, promoting the growth of larger trees by reducing competition for light and soil [1].

Elephants act as ecosystem engineers, influencing canopy structure through browsing and movement [40]. Found that elephants create trail systems that facilitate efficient exploitation of resources like water, minerals, and fruit. These trails exhibit lower canopy height and cover, with a different vertical distribution of plant density compared to areas off the trails. Elephants consume leaves, bark, wood, stems, roots, and fruit from numerous plant species [45]. They preferentially consume low wood density vegetation and fruits from larger trees, potentially promoting forests with higher aboveground biomass [6]. Elephant activities, such as stomping saplings, peeling bark, and breaking limbs, shape the forest canopy. They reduce the density of plants, influencing forest canopy cover and creating new habitat types for other organisms [15]. Disturbance caused by elephants can lead to increased bird community diversity due to increased environmental heterogeneity [1].

African elephants exert a multifaceted influence on forest tree regeneration within rainforest ecosystems, acting as both facilitators and inhibitors of various processes. Their activities significantly shape forest structure, composition, and diversity, with cascading effects on carbon sequestration and overall ecosystem health. Forest elephants are crucial seed dispersers, consuming a wide variety of fruits and depositing seeds across considerable distances. Some tree species rely almost entirely

on elephants for seed dispersal, making forest elephants indispensable for maintaining rainforest biodiversity. Germination rates significantly increase after passing through their digestive tracts. This process helps maintain forest diversity and facilitates the colonization of new areas. Forest elephants disperse a daily mean of 346 large seeds per 1 km² of at least 73 tree species, transporting about a third of the large seeds for more than 5 km [23]. Elephants contribute to nutrient cycling by consuming diverse foods and depositing nutrients throughout the forest via their dung. This process helps maintain soil fertility and supports plant growth and survival. By browsing and trampling vegetation, elephants reduce the density of smaller trees and undergrowth, promoting the growth of larger, slower-growing trees with higher wood density and carbon storage capacity [45]. This thinning of the canopy allows smaller tree species and younger plants to access sunlight. Furthermore, the disturbance created by their movements can create open patches of land where dispersed seeds can take hold and grow. Elephants can cause damage to trees through browsing, trampling, debarking, and breaking branches. This can reduce the survival rates of smaller trees and saplings, particularly those of preferred species. In areas with high elephant densities, this can lead to a decrease in seedling and sapling densities.

Elephants contribute to the dispersal of vine seeds by consuming fruits and excreting seeds over large distances. This process aids in the colonization of new areas by vine species, enhancing genetic diversity and distribution. Some tree species rely completely on seed ingestion and subsequent dispersal by elephants [6, 5]. Through browsing and trampling, elephants create gaps in the forest canopy. These disturbances allow more sunlight to penetrate to the forest floor, promoting vine growth. Elephants clear the understory of the forest, allowing large trees to spread their roots and grow to their greatest heights [29]. The dung of elephants enriches the soil with nutrients, which can enhance the growth of various plant species, including vines. While elephants can promote vine growth by creating gaps, they also browse on young vines and other vegetation. This browsing can inhibit vine recruitment and growth, particularly for species that are preferred by elephants. The physical impact of elephant movement can damage vine root systems and reduce overall vine density. In some cases, the disturbance caused by elephants may favor certain vine species over others, potentially leading to a decline in overall vine diversity [36].

Elephants create gaps in the forest canopy through their browsing and trampling behaviors. These gaps allow sunlight to reach the understory, promoting the growth of understory plants, including grasses, shrubs, and small trees. Elephants clear the understory of the forest, allowing large trees to spread their roots and grow to their greatest heights [30]. Elephants are important seed dispersers. Their dung provides a nutrient-rich environment for seeds to germinate, promoting understory plant diversity [44]. The trampling of elephants can damage the root systems of large trees, particularly in areas

where elephants frequently move. This disturbance can compromise the stability and health of these trees [27]. Elephants may preferentially feed on certain large tree species, potentially leading to a decline in those populations. This selective pressure can alter the composition of the forest ecosystem over time [9].

The impact of human-wildlife conflict on elephant populations in rainforest ecosystems is significant and multifaceted. As human populations expand into rainforest areas, elephants face habitat loss and fragmentation [22]. This encroachment reduces the space available for elephants to roam and feed, leading to population declines [8]. Human activities such as agriculture and logging can deplete food resources for elephants. When elephants venture into agricultural areas in search of food, conflicts arise, often resulting in retaliatory killings [20]. Conflicts can escalate to poaching, where elephants are hunted for their ivory and other body parts. The increase in human-wildlife conflict often correlates with higher poaching rates, further threatening elephant populations [4]. Encounters with humans can lead to direct injuries or fatalities for elephants. Elephants may be shot or injured in attempts to deter them from crops, leading to increased mortality rates [8]. Human-wildlife conflict can disrupt elephant social structures, as matriarchs may be killed or separated from their herds during conflicts. This disruption can affect the survival and reproductive success of the remaining individuals [27]. Continuous human presence and conflict can lead elephants to alter their natural behaviors, including foraging and movement patterns. Elephants may become more nocturnal to avoid humans, which can impact their health and reproduction [9]. Human-wildlife conflict poses a significant threat to elephant populations in rainforest ecosystems. By understanding and addressing these conflicts, conservationists can work towards safeguarding elephant populations and their habitats.

The effect of human-wildlife conflict on the biodiversity crisis in elephant habitats is profound and multifaceted. Human encroachment for agriculture, urban development, and infrastructure leads to habitat loss for elephants and other species. This fragmentation disrupts ecosystems, reducing the overall biodiversity in these areas [8]. Elephants play a crucial role as ecosystem engineers, helping to maintain the structure of their habitats through foraging and movement patterns. Conflicts that reduce elephant populations can destabilize these dynamics, resulting in decreased plant diversity and altered animal communities [20]. Conflicts often escalate to poaching, not just of elephants for their ivory but also of other wildlife as humans turn to bushmeat or other resources. This indiscriminate hunting contributes to the decline of various species, exacerbating the biodiversity crisis [4]. The reduction of elephant populations can lead to changes in species interactions, such as increased competition among herbivores for limited resources. This shift can disadvantage less competitive species, leading to further declines in biodiversity [27]. With fewer elephants, the natural browsing and foraging behaviors that help maintain diverse plant communities are diminished.

This can result in overgrowth of certain species, reducing habitat heterogeneity and overall biodiversity [9]. As humans expand into elephant habitats, critical areas for wildlife are often lost. This not only affects elephants but also other species that rely on the same habitats, leading to broader biodiversity loss [8]. Human-wildlife conflict significantly impacts the biodiversity crisis in elephant habitats. By understanding and addressing these conflicts, conservationists can work towards protecting both elephants and the rich biodiversity of their ecosystems.

5. Conclusion

The findings highlighted that elephants are not merely inhabitants of these forests; they are critical ecosystem engineers whose activities profoundly influence forest structure, biodiversity, and regeneration processes. Elephant activities lead to the creation of canopy gaps that increase light availability, fostering diverse understory growth. These changes in canopy structure not only enhance the growth of various tree species but also improve the habitat for numerous other flora and fauna. The deliberate browsing behavior of elephants facilitates the establishment of a complex multilayered canopy, essential for maintaining ecological balance and promoting biodiversity. The selective foraging patterns of elephants have a significant impact on the composition of tree species within the forest. Through their feeding preferences, elephants can decrease the prevalence of certain species, allowing others to thrive. This selective pressure can lead to shifts in forest dynamics, promoting a diverse range of species adapted to varying levels of disturbance. The findings highlight the need for ongoing monitoring of species composition to understand the long-term ecological consequences of elephant interactions. Elephants also contribute positively to forest regeneration through seed dispersal, enhancing the germination rates of various tree species. Their dung serves as a nutrient-rich medium that supports seedling establishment across disturbed areas. The relationship between elephants and tree regeneration underscores their role in maintaining forest health and resilience. The impacts of elephants on large formation trees are profound, affecting not only the structural integrity of the forest but also the habitats that numerous species rely upon. The removal or damage to these critical trees can lead to cascading effects throughout the ecosystem, altering animal behavior and plant community dynamics. The presence of mature trees can influence the growth of younger trees and the health of the forest overall, emphasizing the need for conservation measures that protect these giants.

Conflicts of Interest

The authors declare that there are no conflicts of interest related to this manuscript. None of the authors received funding or support from any organization that could influence the

research. Additionally, authors have no personal relationships that could potentially bias the research or its outcomes. Also, authors have no competing interests or affiliations with organizations that might be perceived as influencing the manuscript. This statement is intended to ensure transparency and uphold the integrity of the research.

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