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EFFICACY OF ELECTRIC FENCES IN MITIGATING HUMAN-ELEPHANT CONFLICTS ALONG THE NORTHERN BOUNDARY OF MURCHISON FALLS NATIONAL PARK, UGANDA

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1.0 INTRODUCTION

1.1 Background

The negative interactions between humans and elephants arising from shared space and overlapping food resources are commonly represented as human - elephant conflicts (HEC) (Fernando *et al*., 2008). These take the form of crop raiding, property and water facility damage, and human injury (Malley & Gorenflo, 2023), human fatalities (Sampson *et al*., 2021) and retaliatory killings from local communities in response to high crop losses (Kamdar *et al*., 2022). Therefore, HEC have been considered as one of the greatest challenges to the conservation of elephants as well as to the people that share landscapes with them (Kamdar *et al*., 2022). The conflicts have greatly affected the global population of the Asian (*Elephas maximus*) and the African elephants (*Loxodonta africana*) (Köpke *et al*., 2024; Shaffer *et al*., 2019).

Several methods have been used across the world to mitigate HEC, such as acoustic deterrents, culling, translocation, physical barriers, and psychological barriers (Gunaryadi *et al*., 2017). A growing number of efforts has involved the use of non-lethal solar-powered electric fences (Van Eden *et al*., 2016), as a tool for African elephant conservation in coupled human and natural systems (CHANS) (Kioko *et al*., 2008), which deter elephants from entering farms and villages and are seen to be more cost effective than sturdier barriers (Sapkota *et al*., 2014). Non-lethal electric fences act as a deterrent for elephants by giving a high voltage (>5,500 volts), pulsed, non-lethal shock when touched (Kamdar *et al*., 2022). As a determined elephant can often charge through the fence without lasting pain, these fences are more a psychological barrier for elephants than a physical one (Kamdar *et al*., 2022). However, there are few empirical studies demonstrating the effectiveness of these electrified barriers in deterring elephants from causing conflicts among communities residing near protected areas (Kioko *et al*., 2008). In addition, the factors determining the effectiveness of electric fences are not fully understood (Kioko *et al*., 2008). A study by Mumby & Plotnik (2018) reported that electric fence effectiveness relies on fence regular maintenance so that the fence regularly delivers an effective shock.

In Uganda, electric fences have been installed around Queen Elizabeth Protected Area (QEPA) and Murchison Falls Protected Area (MFPA) (Rusoke, 2024; Space for Giants, 2023). Basing on available information about the effectiveness of electric fences in mitigating HEC, there has relatively been little success in Uganda, because even where the fences have been installed elephants were adapting to bringing them down (R.Katebaka *personal communication*, 2024). With respect to these challenges, this study focused on assessing the efficacy of electric fences, document the affected local communities' perceptions on these barriers and their adaptive management of HEC, as well as build their capacity in exploring the practices to improve the fences especially in sections that the study found less effective and weak.

1.2 The electric fence

Electric fences serve as barriers that deter animals from crossing boundaries by delivering controlled electric shocks. The design and configuration of such fences are tailored to the behaviour and strength of the target species in this case, elephants (Figure 1).

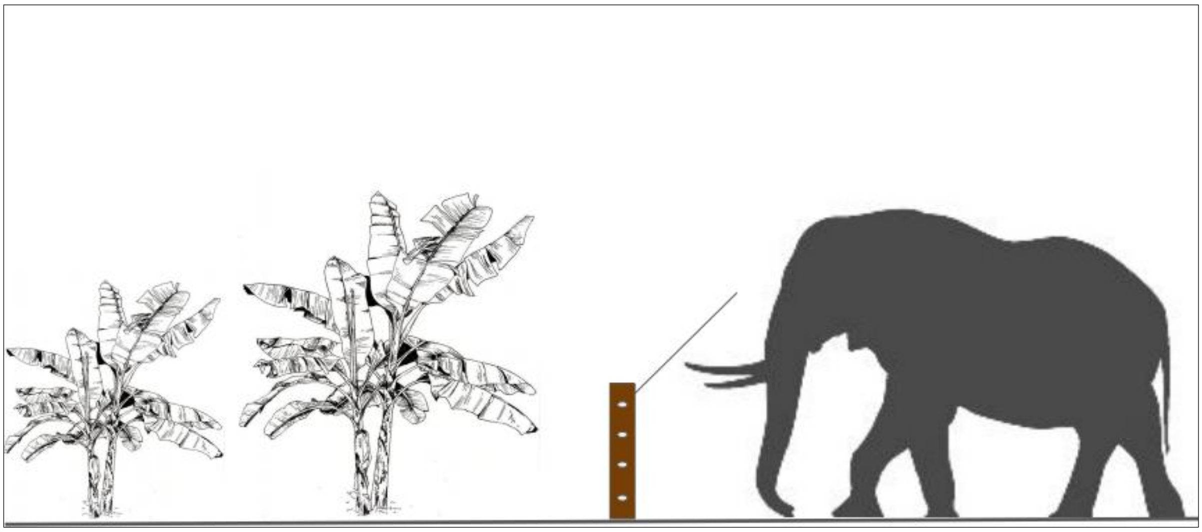

Figure 1. Diagram illustrating the configuration of the electric fence. Source: Space for Giants, 2023.

The fence system in the study area spans approximately 53 kilometres and is powered by eight control units. Each unit operates on three solar panels, each capable of generating 100 watts of power, and is supported by two batteries with a total capacity of 200 ampere-hours, producing a maximum of 9.9 kilo volts of direct current. To safeguard the system from adverse weather conditions such as lightning and thunderstorms, each control unit is equipped with a lightning arrestor or diverter (Plate 1 and Figure 2). Additionally, the fence is integrated with a monitoring system that sends mobile phone alerts in the event of breakages or when an animal becomes entangled, enabling rapid response and maintenance (S. Abura *personal communication*, 2024).

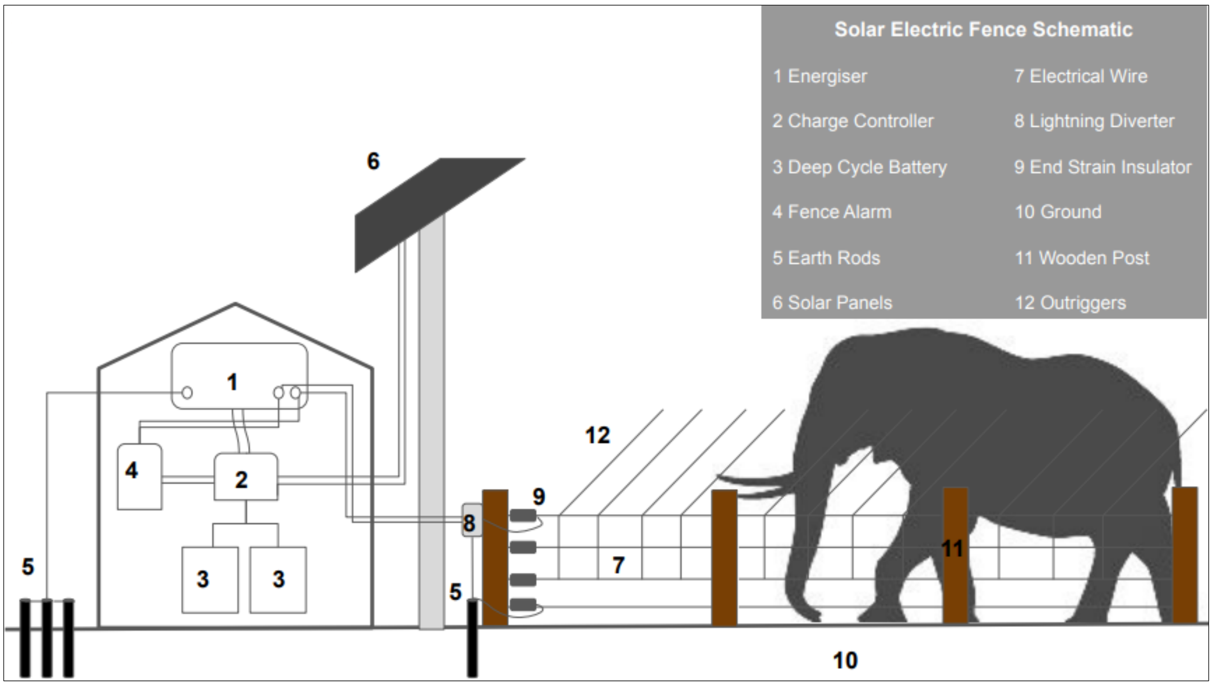

Figure 2. Diagram showing the operational components of the electric fence system. Source: Space for Giants, 2023.

The electric fence functions as both a physical and psychological barrier. When an elephant comes into contact with the live wires, it receives a brief but powerful and memorable electric shock (Figure 3). The shock intensity depends on the energy output and the total resistance in the circuit. Over time, elephants learn to associate the fence with discomfort and are conditioned to avoid it. Effective operation of such fences requires initial animal training to instil respect for the barrier and ensure long-term deterrence.

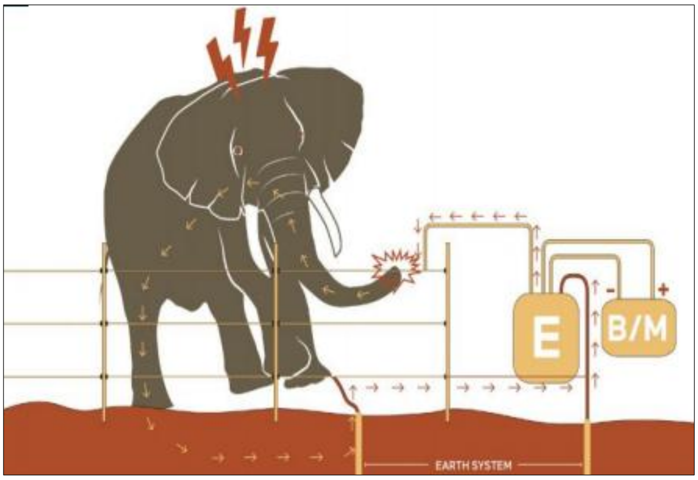

Figure 3. Schematic diagram illustrating how the electric fence operates. Source: Space for Giants, 2023.

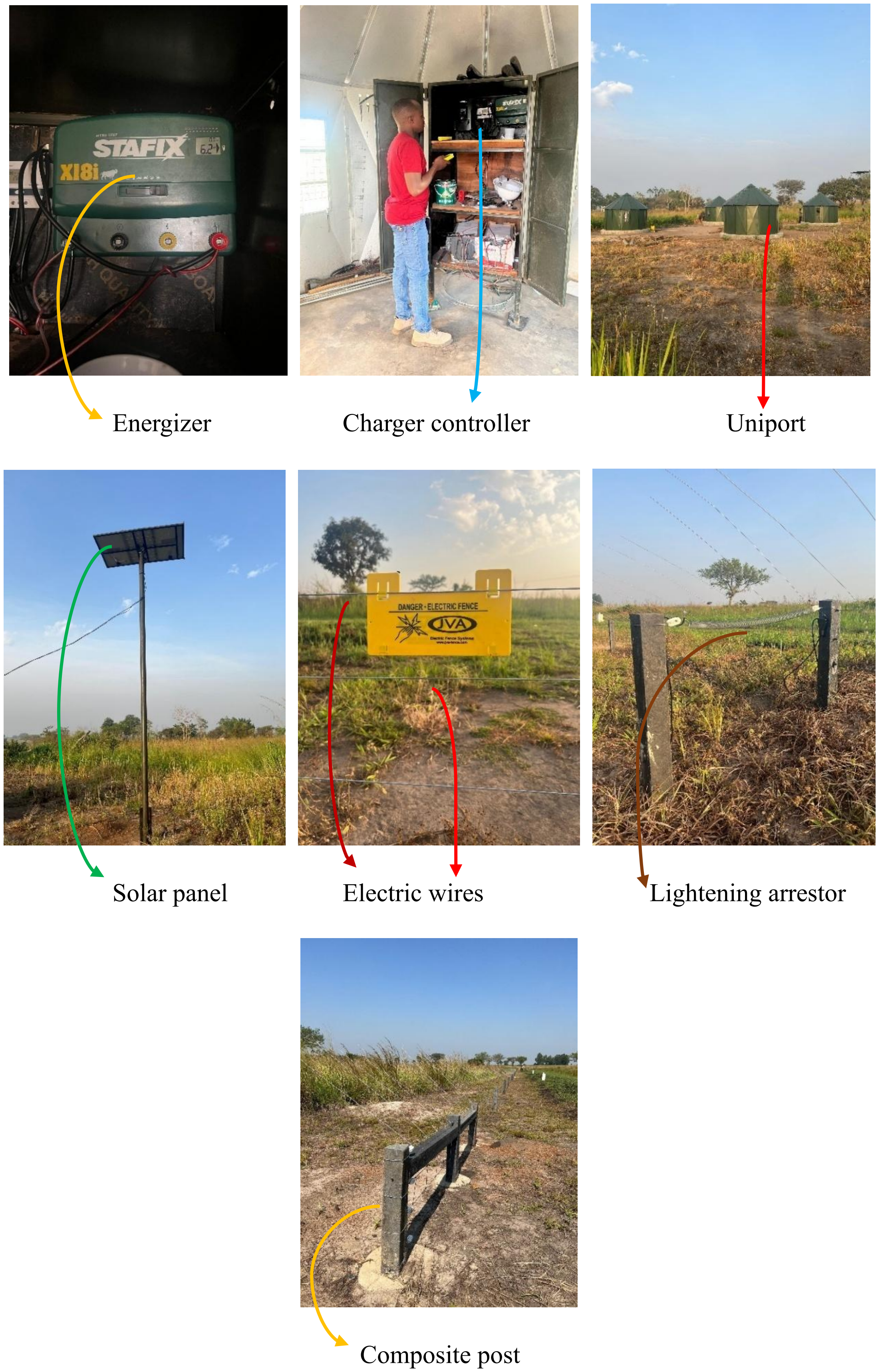

Plate 1. Schematic diagram illustrating the operational components of the electric fence system. © Isma Kasule.

2.0 METHODS

2.1 Study area

The research took place in six villages (Wii Anaka, Pajengo-Lolim, Yagopinno, Apaara B, Akulidia and Bombay) all situated within one-to-two-kilometre distance from the electric fence installed along the northern boundary of Murchison Falls National Park (MFNP). Table 1 provides the details about the study villages. The park which encompasses the project area is located between 2° 15′ 0″ N and 31° 48′ 0″ E in the northwestern Uganda (Figure 4). It is the largest national park in Uganda covering 3,893 km^2 of land including core, buffer, and transition zones. The park is under management of Uganda Wildlife Authority (UWA). Generally, the study area receives a hot and humid climate with relative humidity averages 60% and the temperature ranges from a mean maximum of 29ºC to a mean minimum of 22ºC. Two rainy seasons are received, from March to May, and from August to November. The months from December to February are the driest (Uganda Wildlife Authority, 2013).

Table 1. Study villages, their administrative locations, and electric fence coverage in Nwoya and Oyam Districts, Northern Uganda.

Village	Parish	Sub-county	District	Distance covered by electric fence (km)
Wii Anaka	Latoro	Purongo	Nwoya	6
Pajengo-Lolim	Latoro	Purongo	Nwoya	4
Yagopino	Pawatomero	Purongo	Nwoya	4
Apara B	Juma	Kamdini	Oyam	2
Akulidia	Juma	Kamdini	Oyam	3
Bombay	Juma	Kamdini	Oyam	3

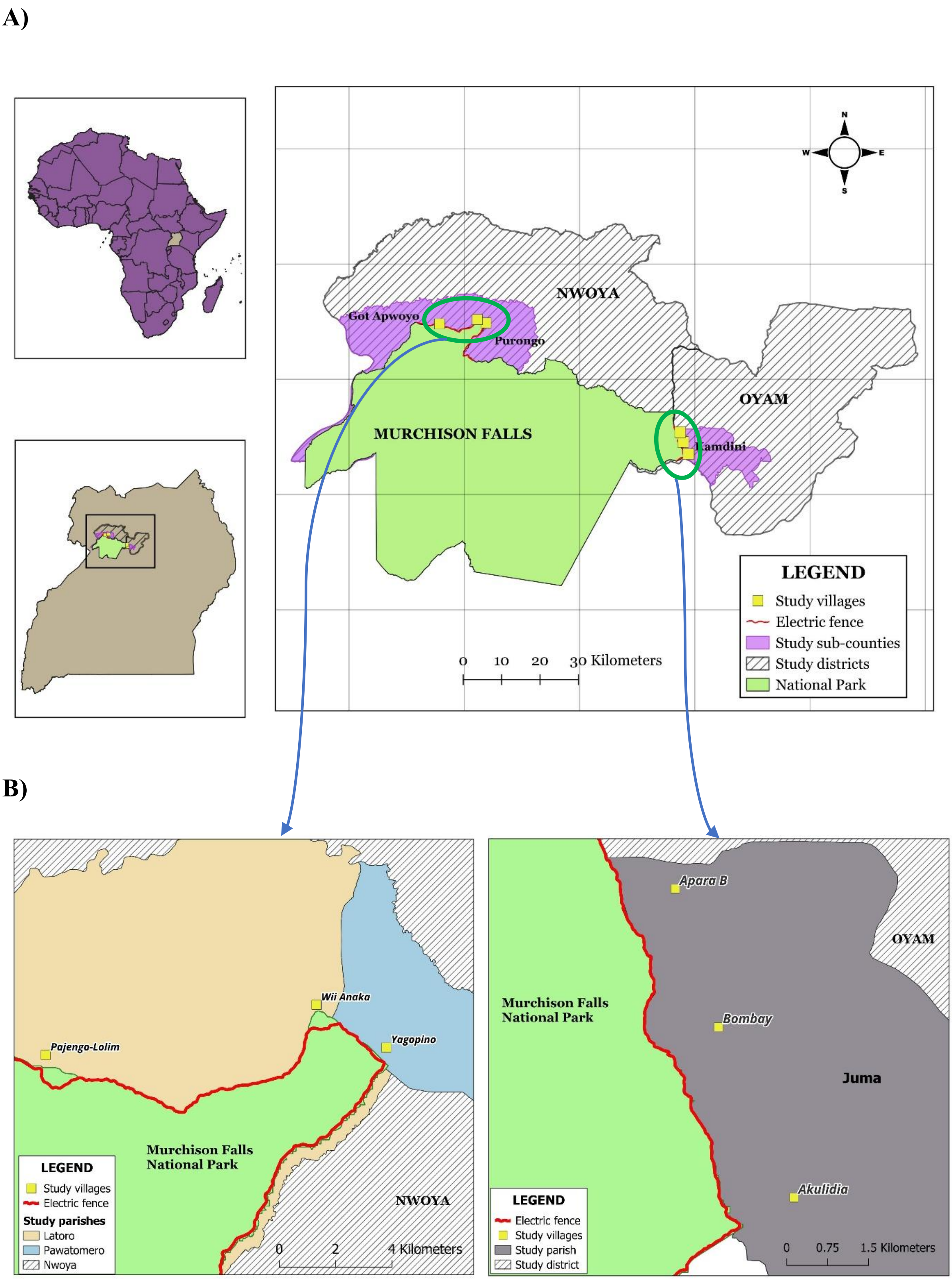

Figure 4. (A) Location of Uganda in Africa, highlighting the two districts, Nwoya and Oyam where the six study villages are situated in relation to MFNP. (B) Detailed map showing the proximity of study villages to the electric fence along the park boundary.

2.2 Sample design

The sample size of 270 households was determined with a 95 % confidence level and a bias of less than 5.0 %. The distribution of surveyed households in each village was achieved through systematic random sampling, ensuring proportionality to the total number of households in each respective village. Informed consent was obtained from the respondents before administering the survey.

2.3 Questionnaire design

The questionnaire was developed in English, translated to the local Acholi and Luo languages, and back-translated to English to ensure accuracy of item wording. The questionnaire consisted of six main sections. The first section fetches demographic profile of the respondents (Table 2). The second section collected information about the HEC experience, third section; awareness and attitudes towards the electric fence, forth section; effectiveness of the fence, fifth section; community involvement in the decision-making process of fence installation, and the sixth section collected the final thoughts. The questionnaire items were developed using a combination of methods, including a literature review, input from experts through in-depth interviews, and the creation of new measurements (Nguyen *et al*., 2023). Questions were answered in both open (e.g., What role do you think your community can play in maintaining and monitoring the fence?) and closed (e.g., Have the fences improved your safety and that of your family?) formats.

2.4 Data collection

The research questionnaires were administered over a period of approximately two months, with the first survey conducted in December 2024 and the second in March 2025. To ensure data quality and adherence to ethical standards (Kreuter *et al*., 2008), four research assistants were trained prior to fieldwork. The training sessions aimed to minimize interviewer effects by standardizing interview scripts used to describe the study, obtain informed consent, and present questionnaire items consistently.

Interviews were conducted face-to-face, with each session involving an individual respondent and two interviewers, one responsible for administering the structured questionnaire and the other for recording responses (Plate 2). Data were initially recorded on printed questionnaires. Each interview lasted approximately 20 minutes, and participants were informed of their right to decline to answer any or all questions without consequence.

To support spatial analysis of HEC, the Global Positioning System (GPS) coordinates of each respondent's location were recorded using a handheld GPS device. These coordinates were later used to map the distribution of reported HEC incidents across the study area.

Plate 2. Research team conducting community interviews. © Isma Kasule

2.5 Data analysis

Descriptive statistical analysis was conducted using R version 4.5.0 (R core team 2025) to summarize and visualize the data. Key variables across the six thematic sections of the study were aggregated, and response frequencies were calculated and converted into percentages. Bar charts, pie-charts and tables were generated to illustrate trends in responses.

No inferential or comparative analysis was performed between the two identified HEC hotspots, as the study objectives did not require comparison between sampled locations.

Geospatial analysis was also conducted using the sf package in R version 4.5.0 (R core team 2025). GPS coordinates of survey respondents were extracted from the dataset and converted into simple features for mapping. These spatial data points were visualized alongside shapefiles of MFNP and the constructed electric fence to illustrate the distribution of surveyed households and the spatial extent of the HEC hotspots.

Statistical analyses were conducted to assess the impact of the campaign on participants' knowledge of elephant conservation, based on their pre- and post-campaign quiz scores. This were used to determine whether there was a significant difference in the participants' knowledge before and after the sensitization campaign, with the assumption that quiz responses were paired for each participant.

3.0 RESULTS

3.1 Participants' demographic profile

The demographic profile of the participants is summarized in Table 2, providing detailed information. More men participated in the survey, compared to women, 51.9% (n = 140) and 48.1% (n = 130) respectively. Participants represented a range of age categories, with the majority (34.4%) aged between 30–39 years. This suggests that the study included predominantly experienced individuals with knowledge of HEC. A significant proportion of the participants (90%, n = 243) were farmers, which was 9 times the number of non-farmers (10%, n = 27). Notably, 70% (n = 191) of the participants had lived in their villages for more than 10 years, which enhanced the reliability and depth of the information provided regarding historical patterns of HEC in the area.

Table 2. Participants' demographic profile.

Variable	Frequency (participant)	Percentage (%)
Gender		
Male	140	51.9
Female	130	48.1
Age (years old)		
≤ 20	7	2.6
20 - 29	54	20
30 - 39	93	34.4
40 - 49	49	18.2
50 - 59	36	13.3
≥ 60	31	11.5
Occupation		
Farmers	243	90
Non-farmers	27	10
Time lived in village (years)		
≤ 1	4	1.5
1 - 5	34	12.6
6 - 10	44	16.4
≥ 10	191	70.0
Total	270	100

3.2 Frequency of HEC

Prior to the installation of the electric fence, the majority of participants (97.4%, *n* = 263) reported experiencing HEC, while only 2.6% (*n* = 7) had not encountered such incidents. In terms of conflict frequency, a year before the electric fence was installed, 75.9% (*n* = 205) participants had experienced the conflicts more than five times, 19.3% (*n* = 52) 2-5 times while the 2.2% (*n* = 6) had experienced the conflicts once. In the year preceding fence installation, a total of 399 conflict incidents were recorded. Figure 5 shows that crop damage accounted for the largest share of these incidents (65.7%, *n* = 262), followed by human injuries (14.0%, *n* = 56), human fatalities (11.5%, *n* = 46), and property damage (8.8%, *n* = 35).

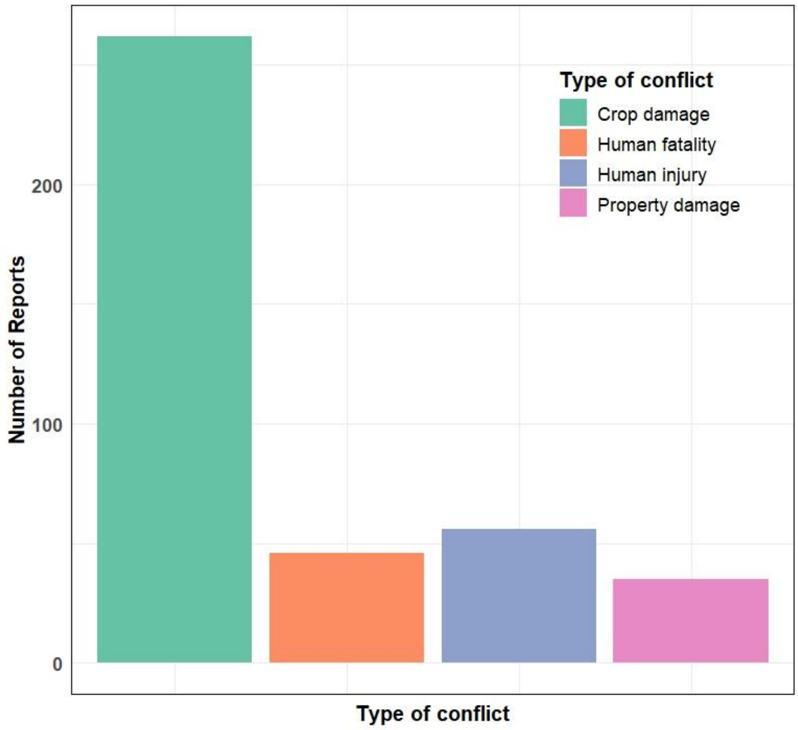

Figure 5. Reported frequency of different types of human-elephant conflict experienced by community members in the study area.

3.3 Spatial distribution of HEC

Community interviews conducted during the study revealed that HEC were particularly concentrated in two clusters. The first cluster of conflict hotspots was identified along the far eastern boundary of the park, specifically in the villages of Apaara B, Akulidia, and Bombay. A second hotspot was observed in the northwestern boundary of the park, encompassing the villages of Wii Anaka, Yagopinno, and Pajengo-Lolim. These two geographically distinct clusters represent the primary zones of heightened HEC within the study area (Figure 6).

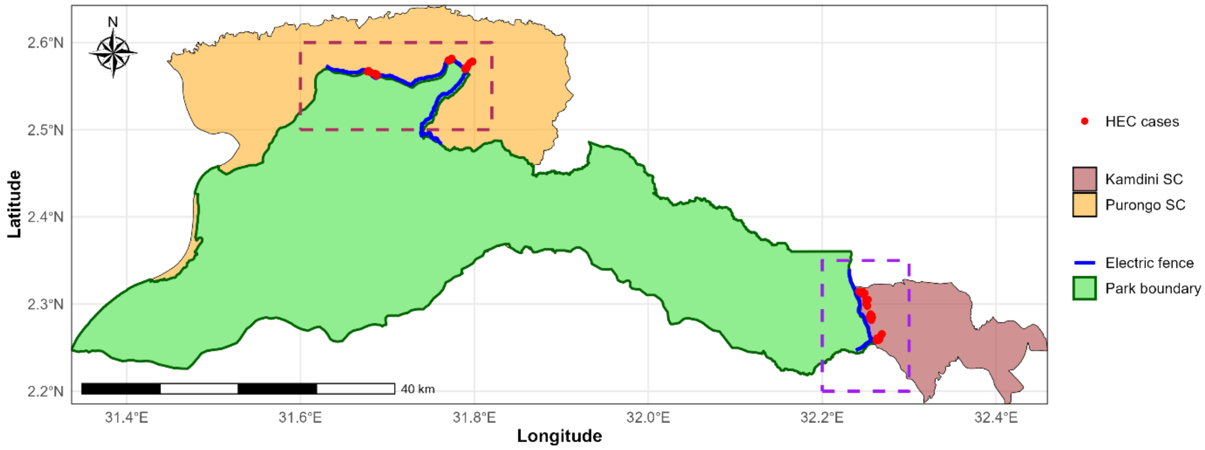

Figure 6. Map illustrating the spatial distribution of HEC hotspots around the northern boundary of MFNP.

3.4 Electric fence effectiveness

The effectiveness of the electric fence was evaluated using a number of six measurable factors; (1) community awareness about the fence, (2) consideration of community views during the installation process, (3) community attitudes towards the fence, (4) fence ability to stop crop damage by elephants, (5) fence ability to improve people's safety and (6) fence durability to serve as a long-term solution to the conflicts.

3.4.1 Community awareness about the fence

To assess community awareness, participants were asked whether they had been informed or involved in the decision-making process regarding fence installation in their villages. Findings revealed that the government of Uganda utilized multiple communication channels to reach communities affected by HEC around MFNP (Figure 7). A majority of participants (70.6%, n = 190) reported receiving information through community meetings, followed by government officials (17.8%, n = 48), friends or neighbours (9.3%, n = 25), and local radio broadcasts (3.7%, n = 10).

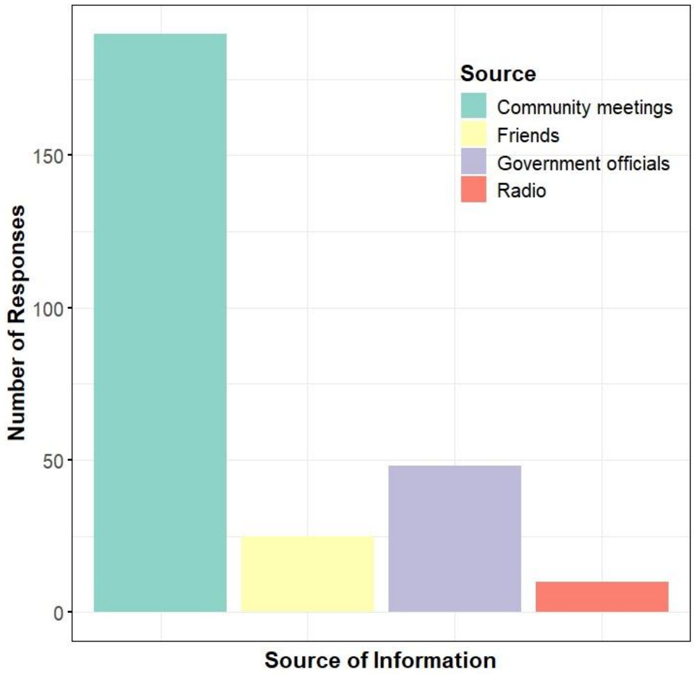

Figure 7. Frequency of cited media sources used to sensitize communities about the electric fence.

3.4.2 Consideration of community views

The majority of participants (89%, $n = 242$) indicated that their views were considered during the installation of the electric fence. Only a small proportion (7.04%, $n = 19$) reported that their views were not taken into account. These findings highlight the inclusiveness and fairness of the installation process, which likely contributed to increased community acceptance and support for the electric fence initiative.

3.4.3 Community perception of the fence purpose

Understanding community perceptions of electric fences in mitigating HEC was a core objective of the study. Participants shared a range of perspectives on the fence's intended purpose (Table 3)

Table 3. Perceived purposes of the electric fence by the interviewed participants.

Fence purpose	Frequency (responses)	Percentage
Protecting crops from elephant raids	232	47.2%

Protecting people from elephant attacks	151	30.7%
Stopping elephants from entering villages	102	20.7%
Others (prevention of poaching, limiting illegal access to park resources, and safeguarding domestic animals)	7	1.4%
	492	**100**

3.4.5 Fence ability to reduce of crop damage

Majority of participants (97.4%) reported that the electric fence has effectively reduced crop damage caused by elephants. Despite this, isolated incidents of elephant intrusion were noted, particularly in areas where fence gaps remain. Nevertheless, the results strongly suggest that electric fencing is a more effective solution compared to previously used mitigation strategies such as elephant trenches and chili fences. This was further evidenced by the presence of large cultivated fields along sections of the fence (Plate 3 and 4).

Plate 3. Maize (left) and cassava (right) plantations ready for harvest in Apaara B. © Mastula Nakitende

Plate 4. Mixed crop fields adjacent the fence at Pajengo-Lolim (left) and millet sowing at Akulidia (right). © William Luwaga

3.4.6 Fence ability to improve safety

An overwhelming majority of participants (97%, *n* = 262) reported that the electric fence has significantly enhanced their safety by effectively preventing elephants from exiting the park and entering nearby villages, reportedly with a 99.9% success rate. Communities highlighted the increased sense of peace and security since the fence's installation. Notably, children can now attend school without the fear of encountering elephants along the way, a common occurrence before to the fence.

3.4.7 Fence durability

When asked about the long-term potential of the electric fence, 54.8% (*n* = 148) of the participants believed it to be a sustainable solution for mitigating HEC. However, 30% (*n* = 81) expressed doubts about its long-term effectiveness, primarily citing concerns about the current fence design. Specifically, the use of wooden poles was criticized, as these are vulnerable to termite damage, rotting in waterlogged areas, and cracking under extreme heat. Furthermore, wooden poles can be easily pushed over by elephants, which would require frequent and costly replacements posing challenges for long-term maintenance and sustainability.

3.5 Explored practices to strengthen the fence effectiveness

Through field-based consultations with local communities, several practical measures were identified to improve the effectiveness of the electric fence. These include:

1. Replacing wooden poles with composite (plastic) or metallic alternatives to prevent damage from termites, decay, and cracking thereby enhancing durability and reducing long-term maintenance costs (Plate 5).

2. Creating fire lines along the fence by slashing or using herbicides to reduce the risk of wildfires and short circuits caused by overgrown vegetation (Plate 4).

3. Filling fence gaps by installing electric fence in previously uncovered sections of the park boundary to ensure continuous protection.

4. Regular fence patrols to monitor the condition of the fence, deter vandalism or damage by poachers, and facilitate prompt reporting of issues.

5. Introducing beehive fences alongside the electric fence as an additional deterrent to elephants and to support community-based conservation initiatives.

Plate 5. Tested practices: slashing along the fence line (left), use of composite posts (center), and spraying undergrowth with herbicides (right). © Isma Kasule

In addition, the project assessed the willingness of community members to contribute to the long-term maintenance of the electric fence beyond the project's duration. Among the 270 participants interviewed, 63.7% (*n* = 172) expressed willingness to continue reporting damages along the fence, 17% (*n* = 46) were willing to assist with fence repairs, and 10% (*n* = 27) indicated they would participate in patrols as fence scouts. The remaining 9.3% (*n* = 25) did not express interest in any specific maintenance role (Figure 8).

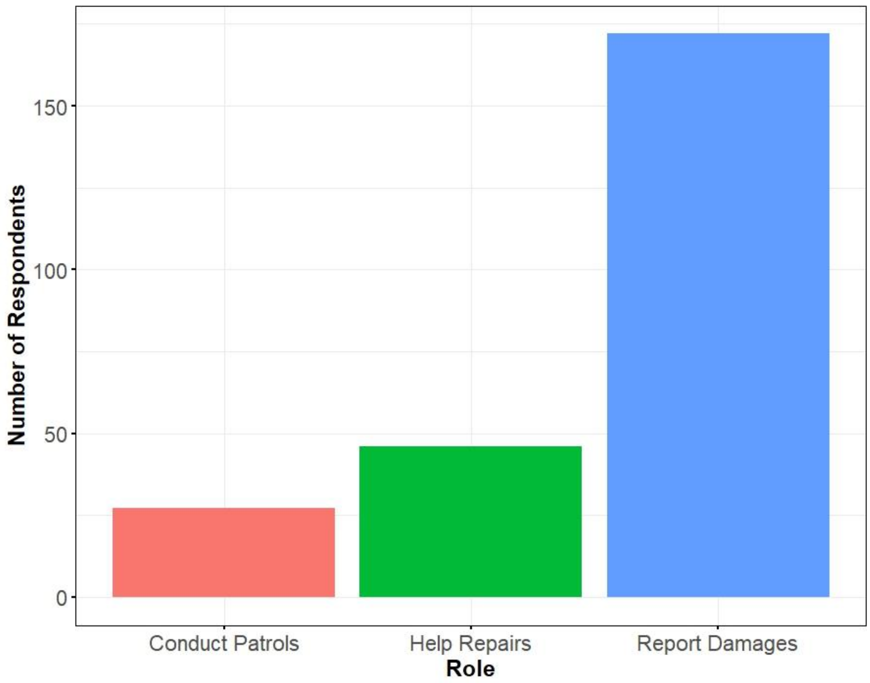

Figure 8. Community willingness to participate in various electric fence maintenance roles.

3.6 Elephant conservation awareness campaign

3.6.1 Sample selection

The elephant conservation awareness campaign was conducted from 24th to 25th March 2025 at Wii Anaka Primary School, situated approximately 75 meters from the electric fence installed to mitigate HEC. Prior to implementation, written informed consent was obtained from the school administration to ensure formal approval for engaging with learners. The campaign specifically targeted upper primary classes; Primary 4 through Primary 7 comprising a total of 180 learners (approximately 45 per class). A random sample of 40% (n = 72) of the total learners was selected to participate in both pre- and post-campaign quizzes designed to assess changes in knowledge and attitudes toward elephant conservation and human-elephant coexistence.

3.6.2 Campaign design

The selected learners participated in both pre- and post-campaign quizzes, each comprising three main sections: Elephant Basics, Elephant Behaviour, and Elephant Facts. The quiz content was adapted from WWF educational classroom materials to ensure relevance to the local context and the learners' educational levels.

The Elephant Basics section focused on identifying the differences between male and female African elephants, as well as understanding the functions of key body parts such as the trunk, ears, and tusks. The Behavioural section assessed learners' knowledge of the different behavioural zones of elephants, including the comfort, alert/suspicious, warning, and critical zones, which reflect the animal's stress or aggression levels (Plate 6). Finally, the Elephant Facts section tested general knowledge about African elephants, covering aspects such as their habitat, ecological role, lifespan, diet, and conservation status (Plate 7 and 8).

Plate 6. Selected participants learning about the different behavioural zones of the African savanna elephant © William Luwaga

Plate 7. Articulating facts about the African savanna elephant to selected participants. © Mastulah Nakitende

Plate 8. Participants of the campaign sitting for one of the elephant quizzes. © William Luwaga

3.6.3 Impact of the campaign

3.6.3.1 Participants' demographic profile

Of the 72 sampled participants, 48.6% (n = 35) were male and 51.4% (n = 37) were female. In terms of age distribution, the majority (84.7%, n = 61) were between 10 and 15 years old, followed by 9.7% (n = 7) aged 5–10 years, and 5.6% (n = 4) aged 15–20 years (Figure 9).

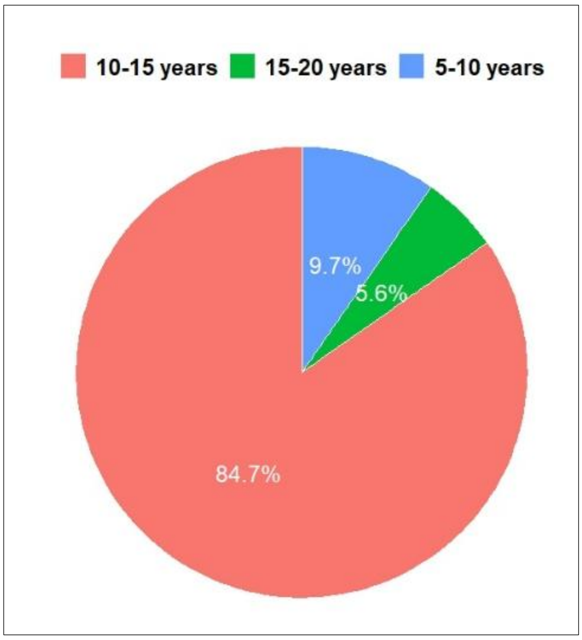

Figure 9. Age distribution across sampled participants of the elephant conservation awareness campaign.

The elephant conservation campaign revealed a statistically significant increase in learner knowledge following the elephant conservation awareness campaign ($t = 2.70$, $df = 71$, $p = 0.009$). Learners improved their total quiz scores by an average of 7.47 points, with a 95% confidence interval ranging from 1.96 to 12.97 (Figure 10).

The elephant conservation campaign also indicated a statistically significant increase in quiz scores following the elephant awareness campaign ($V = 1321.5$, $p = 0.0067$), suggesting improved understanding of elephant conservation and human-elephant coexistence among the learners.

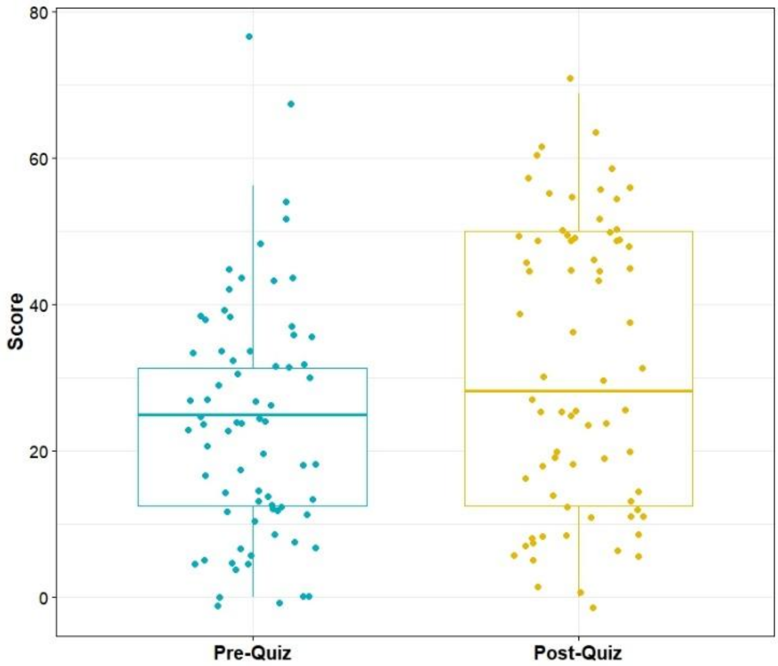

Figure 10. Change in percentage score of the African elephant pre and post quizzes.

The average pre-quiz score among learners was 23.87%, while the post-quiz score increased to 31.34%, showing a mean improvement of 7.47% (Figure 11). This notable gain in knowledge highlights the effectiveness of the awareness campaign in enhancing students' understanding of elephant basics, behaviour, and conservation. The distribution of score improvements across all 72 learners is shown in figure 12. Most learners experienced a positive improvement in their scores, with the majority clustered between 5 and 10 points of gain. This indicates that the awareness campaign had a widespread positive effect, as very few learners had no improvement or a decrease in score.

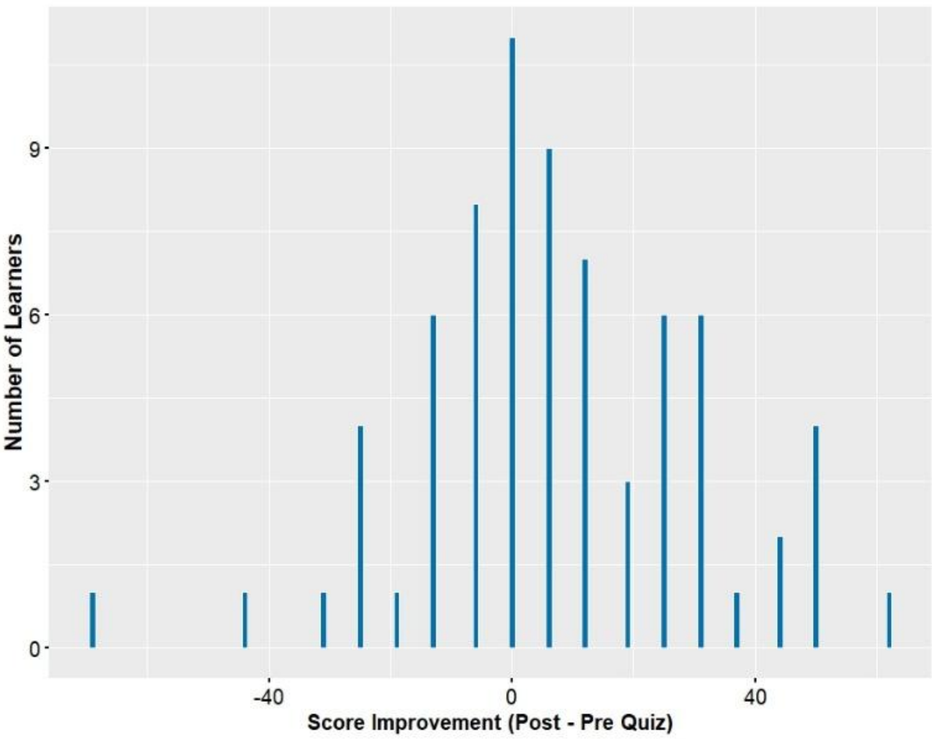

Figure 11. A presentation of individual learner's score improvement after the awareness campaign.

With guidance from the teaching staff, participants' pre- and post-campaign quizzes were scored, and their performance ranked based on average percentage scores. The top 30 performers out of the 72 learners who participated in the elephant conservation campaign were identified and awarded scholastic materials in recognition of their outstanding performance (Plate 9).

Plate 9. 1 and 2: Moment after rewarding the best performers from the elephant conservation awareness campaign. © Richard Anywar

4.0 CONCLUSIONS

The installation of the electric fence has proven to be an effective intervention in mitigating the long-standing human-elephant conflict HEC in the region. It has significantly enhanced the safety of community members, safeguarded farmlands, and successfully contained elephants within the boundaries of MFNP, reducing incursions into surrounding villages.

However, despite its effectiveness, the fence has also brought unintended challenges, notably increasing the distance and cost for communities to access essential resources such as firewood, water, and traditional medicine. These findings highlight the complex trade-offs involved in human-wildlife conflict mitigation and underscore the need for integrated approaches that consider both conservation goals and community livelihoods.

Community sensitization and awareness campaigns emerged as crucial tools in reshaping local perceptions of wildlife conservation. These efforts foster positive attitudes, promote coexistence, and strengthen community support for wildlife protection in increasingly human-dominated landscapes.

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