

Wildlife Exclusion and Resource Deprivation: The Socio-Ecological Paradox of Electric Fencing around Murchison Falls National Park, Uganda

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Abstract

Human-wildlife conflict (HWC) interventions often rely on hard boundaries, yet the systemic trade-offs of these physical barriers remain poorly understood. In this study, we examined the efficacy and trade-offs of a 44-km electric fence along Murchison Falls National Park's northern boundary installed by the Uganda Wildlife Authority. A cross-sectional mixed-methods design was used to collect data in six villages in Nwoya and Oyam districts. Data were from 414 adult respondents randomly sampled from 394 households, 45 key-informant interviews, and six focus-group discussions were used in addition to collect the information. Quantitative analysis revealed electric fencing as the significantly preferred intervention over traditional trenches (Friedman $\chi^2(5) = 902.0$, $p < 0.001$). Institutional records (2019–2023) validated this perception, confirming a significant drop in monthly HWC incidents ($t = -3.0$, $df = 46$, $p = 0.003$), including decreases in crop-raiding (550 to 415) and casualties. However, the data revealed an ecological mismatch: the fence successfully repels megafauna (elephants, buffaloes) but fails against primates, which still require localized, low-tech deterrents (such as, beehives, chilli). The central tension lies in the fence's socioeconomic toll. While community willingness to maintain the barrier through voluntary labor and monitoring is exceptionally high, the infrastructure has severed local access to essential park-derived resources—firewood, thatch grass, water, and medicinal plants—while lengthening transit routes. We argue that hard conservation barriers create a precarious equilibrium. If resource deprivation eclipses the benefits of conflict reduction, local stewardship will collapse. Long-term fence sustainability therefore hinges not on stricter exclusion, but on integrating high-tech barriers with community-led resource-access frameworks.

1. Introduction

Human-wildlife conflict (HWC) occurs when interactions between people and wild animals produce adverse consequences for human wellbeing, livelihoods, property or wildlife conservation. The problem is widespread, but its burden is especially acute in rural landscapes where protected areas adjoin smallholder farms and households depend directly on land and natural resources (Nyhus 2016; König et al. 2020). Crop raiding, livestock predation, property damage and human injury can erode household income and food security, while retaliatory killing, poisoning, snaring and habitat destruction can undermine wildlife populations and conservation goals (Anthony et al. 2010; Heinen 2012; Brackzkowski et al. 2020, 2023; Digun-Aweto and Van der Merwe 2020).

Large-bodied and wide-ranging species create particularly difficult management challenges. Elephants can destroy substantial areas of crops within short periods and can cause fatal encounters at long distances from protected areas, while buffaloes, antelopes, primates and smaller mammals may repeatedly raid farms close to protected-area boundaries. In Kenya's Amboseli landscape, electric fences have been evaluated as barriers to elephant movements, but their performance has depended on fence design, maintenance and animal behavior (Kioko et al. 2008). Similar studies show that barriers may reduce conflict locally while diverting animals towards unfenced sections, watercourses or neighboring communities (Osipova et al. 2018; Naidoo et al. 2022). This study anchors its inquiry within Political

Ecology to interrogate the power dynamics and structural trade-offs of physical conservation boundaries. While the fence solves an ecological problem (megafauna incursions), it introduces a political-economic crisis by cutting off a vulnerable population's safety net resources such as firewood, medicinal plants and water.

A range of non-lethal interventions has been developed to reduce HWC. These include electric or conventional fencing, trenches, beehive fences, chili-based repellents, scare shooting, guarding and community wildlife scouts. Their effectiveness varies by species, landscape and implementation quality. Beehives can deter elephants through their response to disturbed bees, although coverage, colony occupancy and maintenance all affect outcomes (King et al. 2007; King and Lawrence 2009). Chili fences and chili smoke have reduced some elephant incursions but may lose effectiveness in rain or when animals habituate or change routes (Parker and Osborn 2006; Hedges and Gunaryadi 2009; Chang'a et al. 2016). Reviews of crop-protection interventions therefore caution against expecting a single method to control all species and recommend adaptive combinations of barriers, deterrents and rapid-response measures (Montgomery et al. 2021).

Electric fencing is attractive because it can cover long boundary sections and reduce the labor required for nightly crop guarding. When properly installed and energized, it may reduce crop losses, injuries and opportunities for illegal entry (Thouless and Sakwa 1995; Kioko et al. 2008; Nima and Gurung 2018). However, fencing can fail when vegetation touches live wires, posts rot or burn, power is interrupted, wires are cut, animals identify weak points, or local users create openings. It may also impose costs on neighboring residents by blocking customary routes and access to water, fuelwood, grazing materials and other resources (Nyongesa Kassilly et al. 2008; van Eden et al. 2016). Community perceptions are therefore central to fence sustainability: people who experience clear benefits may support maintenance, whereas people who bear uncompensated costs may resist, damage or bypass the infrastructure (Mbanze et al. 2021; Shahi et al. 2023). The importance of social science research has long been recognized in all facets of protected areas management in general, and in cases of actual or potential conflicts in particular (Heinen 2010).

Murchison Falls National Park (MFNP) is a designated World Heritage Natural Site (e.g. Heinen 1995), Uganda's largest national park and it supports high mammal, bird, reptile, amphibian and plant diversity (Plumptre 2015). Its northern boundary adjoins farming communities in Nwoya and Oyam districts. The area has undergone substantial demographic and land-use changes following post-conflict resettlement and the expansion of economic activity in the Albertine region (Byakagaba et al. 2019). Communities cultivate maize, cassava, beans and other crops and have experienced repeated incursions by elephants, buffaloes, antelopes, baboons, monkeys, warthogs and smaller mammals. Following severe complaints of crop destruction and threats to human safety, the Uganda Wildlife Authority (UWA) began installing electric fencing in 2020 along approximately 44 km of the boundary.

Although electric fencing has been studied in other African and Asian settings, little evidence was available on its social acceptance and perceived effects around MFNP. This study therefore aimed to: (1)

assess community perceptions and attitudes towards HWC mitigation practices used around MFNP; (2) assess the effectiveness of electric fencing in reducing conflict; and (3) identify social, technical and management constraints affecting fence implementation. By combining household responses with focus groups, key-informant evidence and UWA incident records, the study provides locally grounded guidance for improving coexistence between wildlife and frontline communities.

2. Materials and methods

2.1 Study area

The study was conducted in communities bordering the northern section of MFNP in Nwoya and Oyam districts, northern Uganda (Fig. 1). MFNP covers approximately 3,983 km² and lies at the northern end of the Albertine Rift. The park contains savannah grasslands, woodlands, deciduous and evergreen forest patches, wetlands and riverine habitats. The local climate is generally hot and humid, with a mean temperature range of approximately 22–29°C and a long wet season from March to November, interrupted by relatively drier periods in June and July. The study villages were located within approximately 1 km of fenced boundary sections and were selected because of their direct exposure to wildlife incursions and the electric-fence intervention.

2.2 Study design and sampling

A cross-sectional mixed-methods design (e.g. Baral et al. 2025) combined a structured household survey with key-informant interviews, focus-group discussions and review of UWA HWC records. Three sub-counties were purposively selected: Purongo and Got-Apwoyo in Nwoya District and Kamdini in Oyam District. Six villages were then selected from UWA's list of frontline communities: Wii Anaka, Akulidiya, Lolim, Lawora, Dwocen-Pacho and Bombe.

Village household lists supplied by Local Council leaders formed the sampling frame. The study sampled 394 households and interviewed 414 adults aged 18 years or older. Village-level respondent totals were Wii Anaka (61), Akulidiya (60), Lolim (74), Lawora (80), Dwocen-Pacho (77) and Bombe (62). Households were distributed across village sectors to improve spatial coverage, and an available adult household head or spouse was invited to participate. The sample size was estimated using the Raosoft sample-size calculator and allocated proportionally among villages.

2.3 Data collection

Fieldwork was conducted from 21 October to 12 December 2023. The questionnaire collected data on age, sex, marital status, education, occupation, monthly income, household size, landholding, livestock ownership, distance from the park and use of park resources. Respondents ranked or evaluated six UWA-supported HWC interventions: trenches, beehives, chili deterrents, wildlife scouts, electric fencing and scare shooting. They also identified species deterred or not deterred by each intervention, changes

observed after fence installation, willingness to contribute to maintenance, perceived access costs and operational problems.

Most interviews were conducted in Acholi, with English used when preferred by respondents. Two local undergraduate research assistants supported translation and field administration. Local leaders reviewed the questionnaire for clarity and cultural appropriateness, introduced the research team and assisted with navigation through the villages, but did not answer on behalf of respondents. Each household interview lasted approximately 30 minutes.

Qualitative evidence was collected through 45 key-informant interviews: 15 community leaders and 30 local-government or other professionals with direct knowledge of HWC. One focus-group discussion was conducted in each village, giving six groups in total. Each group included approximately 12 participants selected to reflect variation in sex, age and community responsibilities. Researchers also made direct observations of fence condition and visible wildlife damage. UWA administrative records were used to compare reported HWC incidents before fence construction in 2019 with records available for 2023.

2.4 Data analysis

Questionnaire responses were edited, coded and entered into SPSS version 25. Frequencies, percentages, means and standard errors were used to describe respondents, household characteristics and intervention perceptions. A Friedman test compared ranked preferences for the six HWC management strategies. Where the overall test was significant, Wilcoxon signed-rank tests with Bonferroni adjustment were used for pairwise comparisons. Chi-square tests examined associations between categorical variables when expected cell counts were adequate. Exploratory logistic regression models assessed whether selected demographic and economic characteristics were associated with intervention preferences, resource access and willingness to support fence maintenance. Statistical significance was assessed at $p < 0.05$.

Open-ended responses, interview notes and focus-group evidence were grouped into themes relating to safety, livelihood benefits, species-specific performance, access restrictions, fence maintenance, wildlife adaptation and community-UWA relations. Qualitative findings were used to explain and contextualize the survey results rather than to estimate population prevalence.

2.5 Ethical considerations

Village authorities granted permission for field activities, the purpose of the research was explained to each participant and informed consent was obtained before interviews or focus-group participation. Participation was voluntary, and findings are reported in aggregate except for anonymized quotations.

3. Results

3.1 Respondent characteristics and dependence on local resources

Men comprised 51% of respondents and women 49%; the mean age was 37 years (SD 11.58). Most respondents were married (87%), had primary (53%) or secondary education (35%), and depended primarily on farming (78%). Seventy-one per cent reported monthly income below UGX 200,000. The mean household size was 6.2 people, mean landholding was 13.9 acres and the mean distance from the park boundary was 323.7 m (Table 1).

Table 1
Socio-demographic and household characteristics of respondents (n = 414)

Variable	Category/statistic	n or mean	%
Sex	Male	213	51%
	Female	201	49%
Age	Mean (SD)	37.0 (11.58) years	
Marital status	Married	362	87%
Education	No formal education	34	8%
	Primary	219	53%
	Secondary	144	35%
	Tertiary	17	4%
Primary occupation	Farming	404	78%*
Monthly income	< UGX 200,000	293	71%
	UGX 201,000-500,000	106	26%
Household size	Mean (SE)	6.2 (0.14) people	
Landholding	Mean (SE)	13.9 (0.95) acres	
Distance from park	Mean (SE)	323.7 (9.60) m	
Livestock ownership	Mean cattle	2.3 (0.21)	
	Mean goats	4.4 (0.21)	
Note. *Occupation responses in the thesis included multiple livelihood activities; the reported farming percentage is retained from the source.			

Households grew mainly maize, cassava and beans and owned an average of 2.3 cattle and 4.4 goats. Most land had been inherited (63%), indicating long-term residence and strong attachment to place. Before fence construction, nearly all respondents (99%) reported obtaining some benefit or resource from the park or its immediate boundary environment ($\chi^2 = 17.0$, $df = 2$, $p < 0.001$). Firewood, thatch grass, bushmeat, poles, water, wild foods and medicinal plants were frequently mentioned. Access occurred through permission from park managers, informal entry or unauthorized extraction. Education

was associated with the reported method of resource access ($p = 0.042$), with more educated respondents more likely to report requesting permission. Satisfaction with access was associated with inherited land tenure ($p = 0.007$), suggesting that long-established residents may have adapted differently to park rules.

3.2 Preferences for HWC management interventions

Electric fencing was overwhelmingly the most preferred intervention: 99% of respondents named it among their preferred measures. Chilli deterrents (30%), wildlife scouts (28%) and beehives (22%) received moderate support, while scare shooting (16%) and trenches (6%) were least preferred. Ranked preferences differed significantly among the six strategies (Friedman $\chi^2(5) = 902.0$, $p < 0.001$). Bonferroni-adjusted post-hoc tests found significant differences for most pairs; the exceptions were scare shooting versus beehives and wildlife scouts versus chili deterrents.

Respondents preferred the electric fence because it reduced incursions by dangerous large animals, lowered the time spent guarding crops and made night-time movement feel safer. An elderly woman aged 80 from Nwoya village explained that members of the households could sleep in their houses comfortably without constantly expecting elephants near stored maize. Another resident aged 76 from Akulidiya village, said that children no longer needed to be escorted early in the morning because the fear of elephants and buffaloes had declined. Respondents also viewed the fence as a large-area intervention that worked continuously when energized.

Table 2
Community preference and perceived strengths and limitations of HWC interventions

Intervention	Preferred	Main perceived strengths	Main perceived limitations
Electric fencing	99%	Continuous large-area barrier; reduced elephant and buffalo incursions; improved safety	Access restrictions; shocks; depends on voltage, intact wires and maintenance
Chilli deterrents	30%	Non-lethal; useful against some elephants and primates	Rain, wind and repeated application; smoke exposure; limited supply and market
Wildlife scouts	28%	Rapid local response; communication and collaboration with UWA	Labor-intensive; delayed reinforcement; limited equipment for dangerous animals
Beehives	22%	Potential deterrent for elephants and primates; possible honey benefits	Limited coverage and inactive hives; sting risk to people and livestock
Scare shooting	16%	Immediate noise response for large mammals	Requires rangers and ammunition; habituation; noise and safety concerns
Boundary trenches	6%	May slow elephants and trap some reptiles	Backfilling, bridging and erosion; costly maintenance; stagnant water and vegetation
<i>Note. Preferences were multiple responses and therefore do not sum to 100%.</i>			

Each alternative method had perceived strengths and limitations (Table 2). Scare shooting could produce an immediate response but depended on the timely arrival of rangers, the costs of ammunition and animals not becoming habituated. Wildlife scouts were valued because they were locally present and strengthened communication with UWA, but respondents considered them vulnerable when confronting buffaloes without adequate equipment or group support. Trenches occasionally slowed elephants and trapped reptiles, but respondents reported that elephants backfilled or bridged them and those unmaintained trenches accumulated vegetation and water. Chili was non-lethal and useful against some crop raiders, yet rain, wind, smoke exposure, limited availability and repeated application reduced its practicality. Beehives were considered useful where active colonies were present, but their spatial coverage was limited and respondents worried about stings to humans and livestock.

Exploratory regression models suggested that preferences were shaped by lived experience and household capacity. Longer residence was positively associated with preference for electric fencing ($p = 0.050$). Preference for scare shooting varied with distance from the park, family size and land size, while preference for chili deterrents varied with distance, income and cattle ownership. These associations should be treated as exploratory because effect estimates were not accompanied by confidence intervals in the source analysis.

3.3 Species-specific performance

No intervention was perceived to deter all problem species. Electric fencing was most strongly associated with elephants (84.8% of responses) and buffaloes (68.4%), with a lower perceived effect on antelopes (23.9%). Respondents nevertheless reported that small mammals, monkeys, snakes, baboons and warthogs continued to enter through or around fenced sections. In contrast, beehives and chili were more often associated with deterring baboons and other primates, while scouts and scare shooting were used principally against elephants, buffaloes and antelopes (Table 3).

Table 3
Species most frequently perceived as deterred and still entering under each intervention

Intervention	Most frequently reported as deterred	Most frequently reported as still entering
Electric fence	Elephants 84.8%; buffaloes 68.4%; antelopes 23.9%	Small mammals 42.3%; monkeys 31.1%; snakes 15.5%; baboons 13.1%
Wildlife scouts	Elephants 50.2%; antelopes 49.9%; monkeys 22.0%; buffaloes 17.4%	Elephants 40.0%; monkeys 16.3%; antelopes 12.6%
Scare shooting	Elephants 44.4%; antelopes 35.8%; buffaloes 32.9%	Elephants 36.9%; small mammals 29.3%; antelopes 16.0%
Trenches	Elephants 42.3%; buffaloes 33.3%; small mammals 30.9%; warthogs 28.5%	Elephants 59.6%; baboons 37.8%; monkeys 15.0%
Chilli	Elephants 39.6%; monkeys 23.9%; baboons 22.9%	Elephants 31.7%; warthogs 22.7%; small mammals 21.7%
Beehives	Baboons 34.1%; monkeys 31.2%; elephants 22.0%	Elephants 60.0%; antelopes 16.8%; small mammals 16.1%
<i>Note. Percentages are respondent perceptions from multiple-response questions and should not be interpreted as direct biological measurements.</i>		

These results reflected differences in body size, behavior and ability to exploit gaps. Focus groups reported that elephants sometimes followed the fence line to its endpoint, tested weak sections, used watercourses, or shifted to unfenced routes. Small mammals and primates could pass through wire spacing, and climb, dig or use vegetation to cross. Wildlife incursions also intensified around crop-maturation and harvest periods, particularly from June to December, when animals were perceived to detect ripe maize, cassava, sweet potatoes and other crops.

In addition to UWA-supported interventions, households guarded fields, made noise and mobilized adults or children to chase animals. Adults undertook 56% of reported guarding and children 44%. Choice of these local strategies was associated with perceived effectiveness, cost and availability ($\chi^2 = 17.0$, $df = 2$, $p < 0.001$). The continued use of household guarding despite electric fencing indicated that residual conflict remained important.

3.4 Effectiveness and livelihood effects of the electric fence

All respondents were aware of the fence, and 77% recalled a positive initial reaction because they expected relief from problem animals. Almost all respondents (99%) considered the fence effective, and 97% described it as the principal measure reducing attacks on crops and people. Perceived effectiveness did not differ significantly across measured demographic groups.

UWA records showed lower totals in 2023 than in 2019 for crop raiding, human injury and animals killed (Table 4). Crop-raiding incidents declined from 550 to 415, while recorded human injuries and animals killed each declined from 12 to 7. The data also show a significant decline in monthly crop-raiding and injury records after fence construction ($t = -3.0$, $df = 46$, $p = 0.003$). Because the comparison was observational and lacked an unfenced control area, it demonstrates a temporal association rather than definitive causation.

Table 4
UWA-recorded HWC incidents before and after fence installation

Incident type	2019 (before)	2023 (after)	Absolute and percentage change
Crop-raiding incidents	550	415	-135 (-24.5%)
Human injuries	12	7	-5 (-41.7%)
Animals killed	12	7	-5 (-41.7%)
<i>Note. Administrative counts supplied by UWA. The before-after comparison was observational and did not include an unfenced control.</i>			

Respondents described several livelihood and wellbeing benefits. Ninety-five percent reported increased household harvests, and 69% reported being able to grow a wider range of crops. Other frequently reported changes included fewer livestock attacks, less time spent guarding fields, improved night-time mobility and greater confidence that children could travel to school safely. These benefits explain the very high level of support for maintaining the fence.

The fence also produced costs. More than half of respondents reported reduced access to resources previously obtained in or near the park. Firewood, thatch grass, bushmeat, water, medicinal plants and construction poles were repeatedly mentioned. Some households had to travel farther, buy substitutes or rely on crop residues and materials from their own farms. Blocked shortcuts increased the time and cost of reaching water points, markets and social services. Respondents therefore held a broadly positive view of the fence while simultaneously expressing concern about livelihood restrictions and unequal access leading to economic burdens.

3.5 Willingness to maintain the fence and operational constraints

Ninety-nine per cent of respondents were willing to support fence maintenance. The most acceptable contributions were monitoring and reporting damage (84%) and providing labor such as slashing vegetation along the fence (74%). Only 7% were willing to contribute money, consistent with the low

reported household incomes. Almost all respondents also stated that the fence required complementary interventions rather than operating as a stand-alone solution.

The main technical challenges were termite damage to wooden posts, bushfires, rotting after heavy rain, vegetation touching wires, low or interrupted voltage, damage by elephants and buffaloes, and the limited height or coverage of some sections. Human-related problems included cutting or widening wires, illegal entry, theft or vandalism and delays in repairing damaged sections. Respondents reported that animals quickly exploited weak points and that incursions had shifted towards routes such as Laforo, Lagagi, water channels and unfenced endpoints.

Community members proposed using more durable metal or concrete posts at vulnerable locations, maintaining power reliably, clearing vegetation, replacing damaged wires promptly, extending coverage to identified gaps and water crossings, deploying more monitoring staff, strengthening penalties for deliberate vandalism and increasing public education. They also called for practical arrangements to meet legitimate needs for water, fuelwood, thatching materials and medicinal plants so that the fence would not create incentives for unauthorized crossings. The principal findings and management implications are summarized in Table 5.

Table 5
Key findings and priority management responses

Finding	Implication	Priority response
Strong protection against elephants and buffaloes	Large reductions in perceived risk, guarding time and crop losses	Maintain reliable voltage; rapid repairs; monitor breach points and high-risk seasons
Residual primate and small-mammal incursions	Wire spacing, climbing, digging and vegetation allow entry	Use targeted chilli, beehive, guarding and scout responses where locally appropriate
Resource and mobility restrictions	Longer routes and reduced access to firewood, water, thatch and medicine	Provide safe access arrangements and livelihood alternatives; develop community woodlots
Termites, fire, rain and vegetation	Posts weaken, wires sag and voltage drains	Use durable posts at vulnerable sites; firebreaks; scheduled slashing and inspections
Vandalism and illegal entry	Openings create wildlife breach points and increase repair costs	Combine enforcement with community monitoring, reporting and legitimate access alternatives
Conflict displacement	Animals move to fence endpoints, watercourses and unfenced villages	Map wildlife routes and incidents; coordinate across villages before extending the fence
<i>Note. Responses combine community recommendations with management implications derived from the study findings.</i>		

4. Discussion

4.1 Effectiveness against high-impact wildlife

The findings indicate that electric fencing has become the most accepted HWC intervention in the surveyed communities because it addresses the species perceived to create the greatest immediate threats: elephants and buffaloes. The reduction in recorded crop-raiding and injury incidents, together with strong respondent reports of improved harvests and safety, is consistent with studies showing that well-maintained electric fences can reduce elephant entry into farms (Thouless and Sakwa 1995; Kioko et al. 2008; Nima and Gurung 2018). The magnitude of community preference is important because social support is itself a component of infrastructure performance. Residents who view the fence as useful are more likely to report damage, clear vegetation and discourage vandalism.

Nevertheless, the evidence should not be interpreted as proof that the fence alone caused every observed reduction. Incident totals were compared across two time periods without a matched unfenced control, and reporting effort may have changed. Wildlife abundance, rainfall, crop availability, patrol intensity and other interventions may also influence annual HWC patterns. The study therefore provides convergent evidence of effectiveness - community perceptions, qualitative accounts and administrative trends - but not a controlled impact estimate. Future monitoring should compare fenced and unfenced boundary sections over multiple years and record fence voltage, breakages, repair time, crop stage and species responsible for each incident.

4.2 Why a combination of interventions is necessary

The study strongly supports species-specific and layered HWC management. Electric fencing was perceived to deter large mammals but was less effective against primates, small mammals and animals able to climb, burrow or pass between wires. Beehives and chili-based measures were viewed as relatively more useful against primates, while scouts and scare shooting provided flexible responses to animals already outside the park. This pattern agrees with broader reviews showing that no single crop-protection method performs consistently across species and contexts (Montgomery et al. 2021).

A combined system should use the electric fence as the principal barrier while deploying targeted measures at recurring breach points and during high-risk crop seasons. Beehive fences may be useful in selected locations where colonies can be maintained and communities benefit from honey, but they require adequate hive occupancy, training and safety planning (King et al. 2007; King and Lawrence 2009). Chili deterrents can supplement barriers but are sensitive to rainfall, wind, supply and repeated labour requirements (Parker and Osborn 2006; Hedges and Gunaryadi 2009; Chang'a et al. 2016). Wildlife scouts remain essential for rapid response, communication and verification of damage, especially where the fence ends or crosses rivers and roads. The most effective package is therefore likely to vary by village, species and season rather than being uniformly applied across the entire boundary, a conclusion also reached by others regarding communities near large protected areas (e.g. Shrivastava and Heinen 2007).

4.3 Social benefits, access costs and fairness

The social value of the fence extended beyond avoided crop loss. Respondents described sleeping more securely, travelling at night with less fear, spending less time guarding fields and allowing children to attend school more consistently. Such benefits are often undercounted in HWC assessments that focus only on the monetary value of crops or livestock. Reduced fear and labor demands can be particularly important for women, children and older residents, who may face disproportionate safety and time burdens.

At the same time, the fence altered access to resources and movement routes. Firewood, thatching grass, water, medicinal plants and other products contribute directly to household welfare in protected-area landscapes. When access is blocked without affordable alternatives, residents may face higher costs or become more dependent on illegal extraction. Similar tensions have been reported where conservation boundaries redistribute benefits and restrictions unevenly (Shrivastava and Heinen 2007; MacKenzie 2012; Mbanze et al. 2021). The MFNP results show that positive attitudes towards the fence can coexist with dissatisfaction about resource access; support should not be assumed to be unconditional.

UWA and local governments should therefore incorporate access planning into fence management. Options may include clearly marked gates or safe crossing points where ecologically appropriate, protected access to public water sources, community woodlots, distribution of tree seedlings, promotion of efficient cooking technologies, support for alternative thatching materials and transparent procedures for authorized collection of selected non-timber resources. Decisions should be made with affected villages and should recognize that households closest to the boundary bear both the greatest HWC risk and the greatest access costs.

4.4 Maintenance, displacement and co-management

Termites, fire, rainfall, vegetation and vandalism were not peripheral problems; they directly determined whether the fence remained an effective barrier. Wooden posts in termite-prone or waterlogged sites require frequent replacement, while vegetation contact drains power and may increase shock risk. Durable posts at high-risk sections, routine voltage checks, firebreaks, vegetation clearance and rapid-response repair teams are therefore essential. Community willingness to provide labor and report faults offers a practical foundation for co-management, but responsibilities, safety procedures and response times should be formally agreed. Community volunteers should not be expected to repair live electrical components without training and protective equipment.

The reported movement of animals towards unfenced routes is consistent with evidence that fences can displace rather than eliminate conflict (Osipova et al. 2018). Fences can also disrupt ecological connectivity if they are expanded without landscape planning (Naidoo et al. 2022). Extension should therefore be guided by incident mapping, wildlife-movement data and assessment of watercourses, corridors and neighboring settlements. Closing one breach without understanding animal routes may

transfer costs to other villages. Regular participatory mapping with scouts and residents can identify new hotspots and support targeted responses before severe incidents occur.

Human damage to the fence also requires a governance response. Wire cutting and unauthorized crossings may reflect poaching, theft, resource scarcity, distrust or poorly designed access arrangements. Enforcement is necessary for deliberate vandalism, but enforcement alone will not resolve the underlying incentives. Studies of wildlife crime and protected-area resource use show that effective interventions must distinguish among livelihood needs, opportunistic extraction and organized illegal activity (Travers et al. 2019). Strengthened communication, legitimate access alternatives, local monitoring and credible, proportionate sanctions should be implemented together.

4.5 Community participation and institutional trust

Only about half of respondents reported participation in meetings concerning the fence, despite near-universal willingness to help maintain it. This gap represents an opportunity. Meaningful participation should extend beyond informing residents after technical decisions have been made. Communities can contribute knowledge about historical wildlife routes, seasonal crop patterns, water access, fire risk, common breakage points and socially acceptable crossing arrangements. Evidence from conservation settings indicates that perceived fairness, responsiveness and benefits influence attitudes towards protected areas and compliance with management rules (van Eden et al. 2016; Afriyie et al. 2022; Shahi et al. 2023).

A locally accountable reporting system could improve both performance and trust. Each village could designate trained fence monitors linked to UWA response teams through a documented reporting channel. Basic information - date, location, species, type of breach, voltage status, crop stage, response time and repair date - should be recorded consistently. Public feedback on completed repairs and trends in incidents would demonstrate that community reports lead to action. Where scouts are expected to confront dangerous animals, they require appropriate training, communication equipment and clear protocols rather than reliance on improvised collective chasing.

4.6 Study limitations

Several limitations should guide interpretation. First, the household survey was cross-sectional and depended heavily on self-reported perceptions and recall. Respondents who experienced recent benefits or losses may have evaluated interventions differently. Second, villages were purposively selected near fenced sections; results therefore represent frontline communities and should not be generalized to all MFNP neighbors. Third, the before-after UWA comparison lacked an unfenced control and may be affected by changes in reporting, wildlife distribution or management efforts. Fourth, some percentages were derived from multiple-response questions and therefore do not sum to 100%. Fifth, the exploratory regression results lacked odds ratios and confidence intervals, limiting substantive interpretation. Finally, the study did not directly measure fence voltage, wildlife movement or crop loss values. These limitations do not negate the strong convergence of community and administrative evidence, but they

identify priorities for a more rigorous long-term evaluations and future directions of longer-term research efforts.

5. Conclusions and management implications

Electric fencing was the most preferred HWC intervention among surveyed communities around the northern boundary of Murchison Falls National Park and was associated with fewer recorded crop-raiding incidents, injuries and retaliatory animal deaths. Residents linked the fence to improved harvests, safer movement and reduced guarding burdens, and nearly all respondents were willing to support maintenance. Its strongest perceived effect was against elephants and buffaloes; primates, small mammals and other species continued to exploit gaps, vegetation, watercourses and unfenced routes.

The fence should therefore be managed as the core of an integrated, adaptive system rather than as a complete solution. Priority actions are to maintain continuous safe voltage, replace vulnerable posts with durable materials at high-risk sites, clear vegetation, create firebreaks, repair damage rapidly, monitor displacement to unfenced routes and deploy complementary beehive, chili and scout-based measures where species and local conditions justify them. Community participation should be formalized through trained village monitors, clear reporting channels and transparent response standards. Equally important, UWA and local authorities should address access costs through safe routes, water access and practical alternatives for fuelwood, thatching and other essential resources.

Future research should combine multi-year incident monitoring with direct measures of crop loss, fence condition, voltage, wildlife movement and household wellbeing in fenced and comparable unfenced areas. Such evidence would allow UWA to refine fence design and target investment while protecting both conservation objectives and the livelihoods of frontline communities.

Declarations

The authors have no relevant financial or non-financial interests to disclose.

Author Contribution

Henry Batenda: Developed and conceptualized the idea, collected and analyzed the data, and wrote the manuscript. Vicent Muwanika and Mnason Tweheyo : Supervised the research, write up- contribution, and reviewed the manuscript. Enock Sekubwa : Manuscript review and write-up. Onan Mulumba: Scientific writing of the paper and review of the paper. Joel Thomas Heinen : Review, writing of the paper, and funding of the study.

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Figures

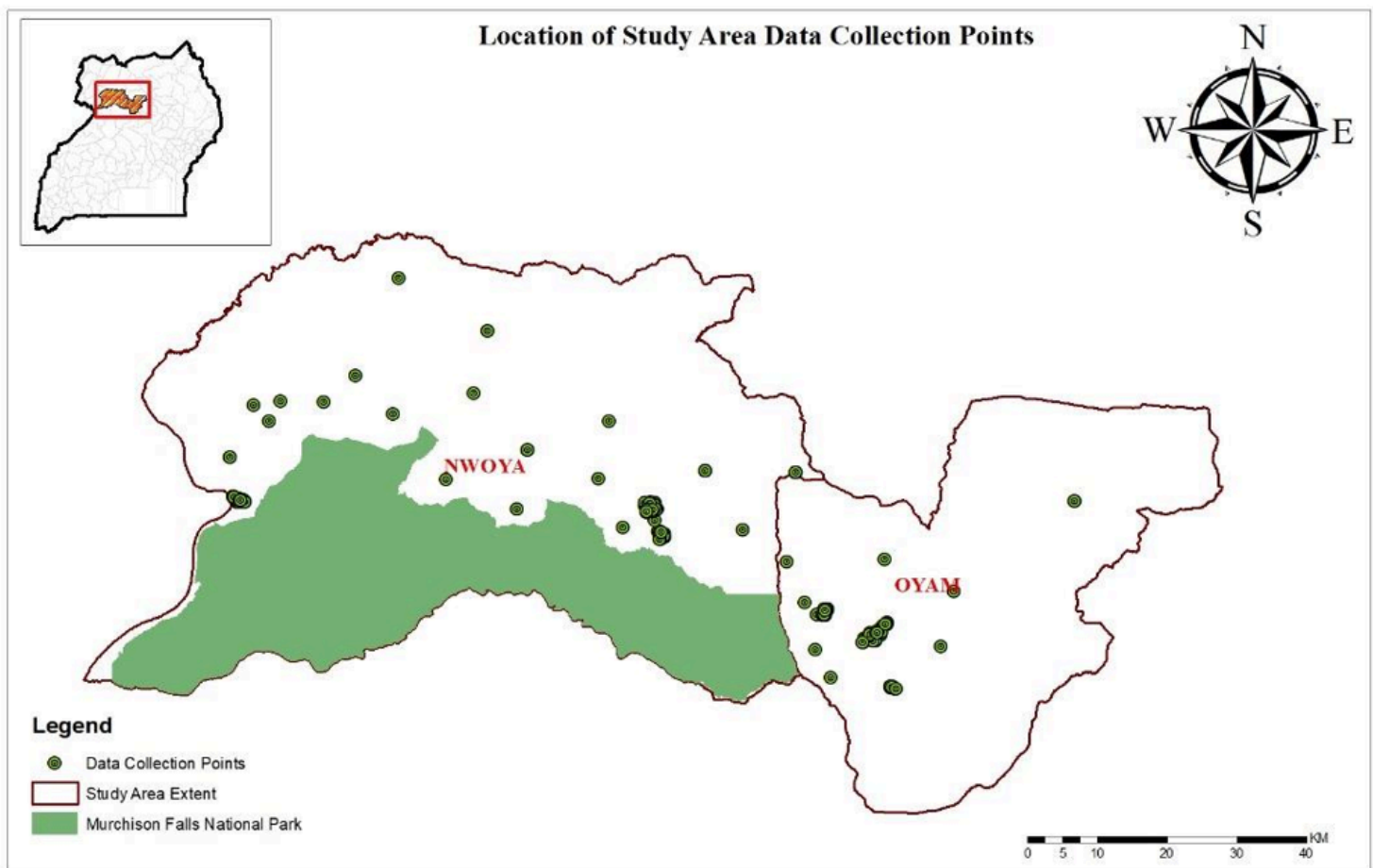


Figure 1

Murchison Falls National Park (solid green area) and the study districts of Nwoya and Oyam, with data-collection points (green circles). Adapted from the source (Batenda, 2025).