Human-Wildlife conflicts at the interface between Mt. Kenya National Park/National Forest and small holder farming communities in Embu County

Swedish University of Agricultural Sciences, SLU
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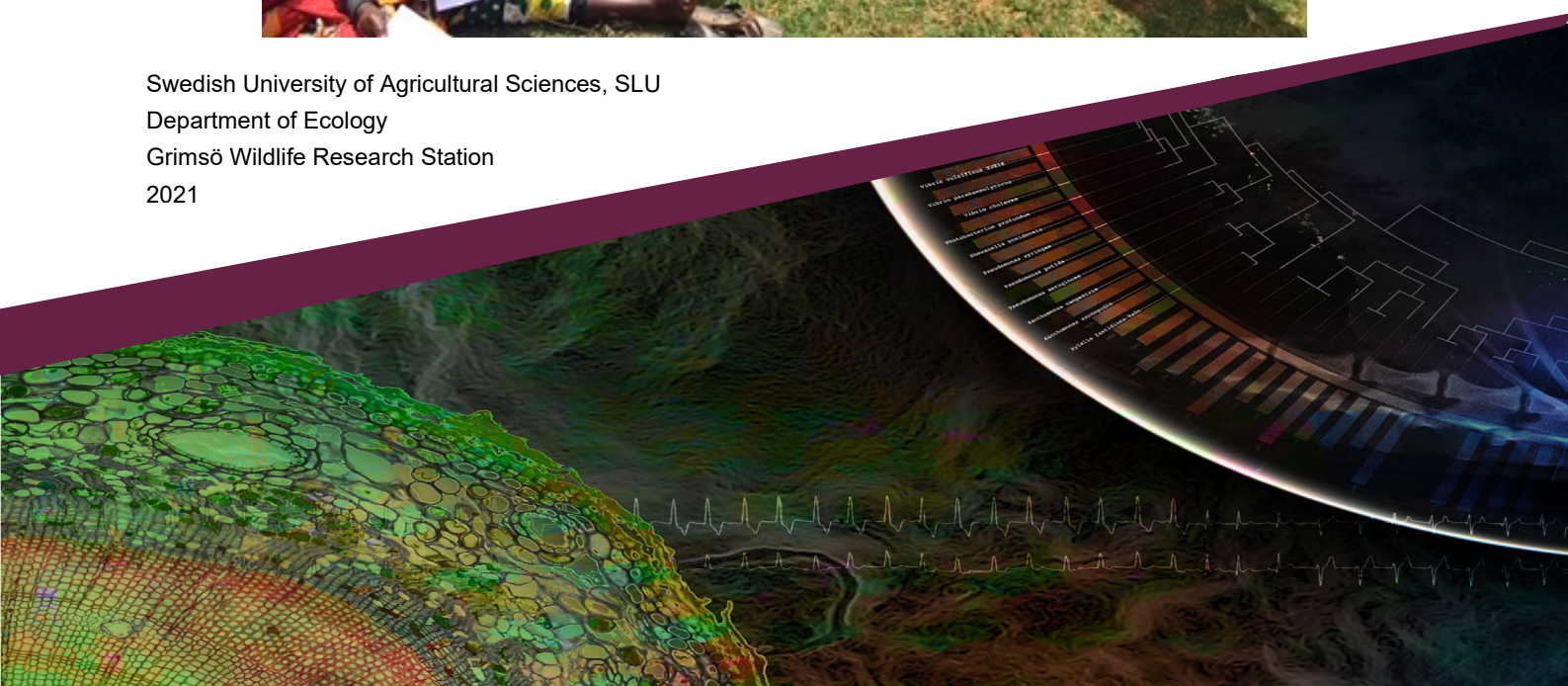

Human-Wildlife conflicts at the interface between Mt. Kenya National Park/National Forest and small holder farming communities in Embu County

Human-Wildlife-konflikter i området mellan Mt. Kenya National Park/National Forest och småbrukarsamhällen i Embu County, Kenya

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Abstract

Human-wildlife conflict (HWC) is a common problem for many farming communities around protected areas like parks, reserves and forests all around the world. In Kenya where most farming occurs at smallholder levels, HWC:s could be highly significant as it may lead to a complete loss of crops and livestock. Such cases have previously been experienced by smallholder farming communities around Mt. Kenya national park/natural forest, but many have gone unreported. To minimise these conflicts, the government of Kenya, in collaboration with the Rhino Ark Foundation have constructed an electric fence around the forest.

The main aim of this study was to collate and document experiences of crop raiding by wildlife on small holder farms in Embu County, Kenya that are adjacent to the forest. It also aimed at evaluating the effectiveness of the electric wildlife fence along the forest line through Embu County. To achieve this, questionnaires were administered to 181 small holder farmers living and farming within 5 km of the electric fence on the approximately 60 km long forest line. The questionnaires sought to gather information on the wildlife species causing damages, the magnitude of damage suffered by the farmers on the crops and livestock before and after the construction of the fence, the interventions they have in place to prevent such damage and other suggestions to prevent wildlife raids. Wildlife cameras were also used to track wildlife activity at night time. A total of 169 questionnaires were retrieved and 455 pictures downloaded from the cameras.

Results show that the percentage of crops destroyed by wildlife was significantly higher in the year before the wildlife fence was constructed in 2016 compared to the period after the fence (2016-19). Currently the naked mole rat (*Heterocephalus glaber*) and the Kenyan African (*Tachyoryctes ibeanus*) were reported as the most frequent pests on crops after the fence construction. Elephants were the most severe crop raiders before the fence construction, but their raiding ceased completely after the fence installation. The white tailed mongoose (*Ichneumia albicauda*) and eagles (*Accipitridae* family) were the most frequently reported raiders on livestock. Maize, macadamia and bananas were the most commonly targeted crops while chickens were the most targeted livestock. Over 90% of the farmers indicated that the fence significantly contributed to a reduction of HWC:s. However, they also suggested additional fencing for both crops and livestock, as well as trapping and poisoning of raiders like moles and mongooses that were responsible for most of the crop damage and livestock attacks. This study recommends that farmers devise innovative ways of dealing with the threat of small animals. These may include aggressive fencing and growing crops and keeping livestock that are not targeted by small animals. It is also recommends that the Kenya Wildlife Service (KWS) develop innovative ways of compensating affected farmers and prevent further loss. The KWS may also train farmers on procedures to follow in reporting cases of wildlife invasion and on food choices of various wildlife species inhabiting the forest so that they avoid growing crops or keeping livestock that are prime targets for wildlife.

Preface

This report is a result of a study conducted through cooperation by the University of Embu (UoEm), the Swedish University of Agricultural Sciences (SLU) and Mt. Kenya Community Forest Association (CFA) Farmer Groups, from April to June 2019. The study was supported by SLU and the Linnaeus Palme student exchange programme.The main aim of this study was to collate and document experiences of crop raiding by wildlife on small holder farms in Embu County, Kenya that are adjacent to the Mount Kenya National Park/National forest. This information will be useful not only to the farmers themselves in determining effective interventions to minimize future crop raiding, but also to wildlife managers and policy makers in determining effective ways of managing human-wildlife interactions and planning. The study also aimed at evaluating the effectiveness of an electric wildlife fence that was constructed around the forest by the government in collaboration with the Rhino Ark Foundation in 2016 to prevent raiding of farms by wildlife. The information and other results presented in this report will be useful to wildlife managers, government officers, community leaders and other policy makers in evaluating the success of the intervention and thus determining its effectiveness and value.

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Abbreviations

CFA	Community Forest Association
KFS	Kenya Forest Service
KWS	Kenya Wildlife Service
SLU	Swedish University of Agricultural Sciences
UoEm	University of Embu

1. Introduction

Human-wildlife conflict has been a major challenge for many small holder farmers at the edge of Mount Kenya Forest in the counties of Embu, Kirinyaga, Meru and Nyeri through which the forest transects. This challenge has been in the form of invasion and destruction of crops by wildlife and frequent attacks of their livestock by wild carnivores (Musyoki, 2014). Most studies that have examined crop invasion by wildlife in Mount Kenya Forest have concentrated in Meru, Kirinyaga and Nyeri counties that have longer forest lines, but no study has been done in Embu County which has a shorter forest line of approximately 60 km (KFS, 2010). Besides, such studies have only concentrated on crop destruction by elephants (*Loxodonta Africana*), which can cause destruction of over 75% of crops, besides destroying homes and injuring livestock and even humans (Kamweya et al., 2012). Cases of wildlife attacks on livestock and crop destruction by wildlife have also occurred in Embu County but have largely gone unreported. While elephants are associated with severe crop damage in many areas that border the Mount Kenya Forest, wildlife species like primates, wild pigs and other wild small mammals and birdsalso cause significant damage (Kamweya et al., 2012; Weinmann, 2018). Monkeys and baboons are clearly attracted to ripe maize and can cause a significant loss to farmers especially because most farmers are small holder and grow crops mainly for their own consumption on small fractions of their farms (Hill, 2000). Despite Embu County having a relatively short forest line with Mount Kenya Forest compared to other bordering counties, there are significant numbers of small holder farms along this line. Embu's farmers have frequently suffered loss of crop and livestock wherever wildlife invades their farms. Most farmers on the forest edge are small holder and without any intervention, losses may occur of up to 100% of their crops and significant loss of livestock.

This study aimed at collating and documenting the experiences of these farmers on raiding of their farms by wildlife. In 2016, the government, through the Kenya Wildlife Service and with the support of the Rhino Ark Foundation constructed an electric fence along the forest edges as a key intervention in mitigating rampant human-wildlife conflict. This study also aimed at evaluating the effectiveness of the wildlife fence so as to determine its value to the farmers. To achieve these objectives, questionnaires were administered to farmers living and practicing farming activities within approximately 5 km of the wildlife fence to establish the levels of crop damages and livestock attacks on their farms in the year before and after the building of the wildlife fence. The questionnaires also sought to establish what other interventions farmers have put in place, or would suggest putting in place to curb the problem of wildlife raids.

2. Methods

2.1. Site description

The study was conducted on the upper reaches of Embu County where farmlands intersect with Mount Kenya NationalPark and the adjacent Forest. The site is an approximately 60 km long transect of forest line from the border of Embu County with Kirinyaga County on the West to the border with Tharaka-Nithi County on the East. A "buffer zone" of tea fields owned by the Kenyan government exists between the forest and small holder farmlands, and was meant to prevent forest encroachment by smallholder farmers living around the forest. An electric fence was constructed on the forest edge by the Kenyan government together with the Rhino Ark foundation to reduce incidences of human-wildlife conflict. Construction of this fence started in Kirinyaga County in 2012 and by November 1, 2019, it had progressed through about half of the forest line in Meru County (Figure 1). The Embu County study area was covered by the fence in 2016. The area is on an approximate altitude of 1525 m above sea level, receives an average precipitation of 1495 mm per annum and has an annual average temperature of 21°C (KFS, 2010). The area is densely populated with an approximate density of 650 persons per km^2. Each household (of approximately 7 people) occupies an average land area of about 0.5 acres (approx. 2,000m^2). The main economic activity of people in the area is smallholder farming, growing tea (*Camellia sinensis*) as the main cash crop but also coffee (*Coffea arabica*) and macadamia (*Macadamia spp*), as well as a number of food crops which include avocado (*Persea americana*), mango (*Mangifera spp*), bananas (*Musa spp*), sugar cane (*Saccharum spp*), potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), arrowroots (*Colocasia esculenta*), yams (*Dioscorea spp*), cabbage (*Brassica oleracea* var. capitata), maize (*Zea mays*), beans (*Phaseolus vulgaris*), cassava (*Manihot esculenta*), tomatoes (*Solanum lycopersicum*), tree tomatoes (*Solanum betaceum*), passion fruit (*Passiflora edulis*) and water melons (*Citrullus lanatus*).A number of farmers also grow napiergrass (*Pennisetum purpureum*) as feed for their small numbers of livestock. The common livestock kept by the community members include cattle (*Bos taurus*), goats (*Capra aegagrus hircus*), sheep (*Ovis aries*), chickens (*Gallus gallus domesticus*), rabbits (*Oryctolagus cuniculus*) and pigs (*Sus scrofa domesticus*). The community is organized in Community Forest Associations (CFAs) for the purposes of co-managing the forest with the government (KFS, 2010).

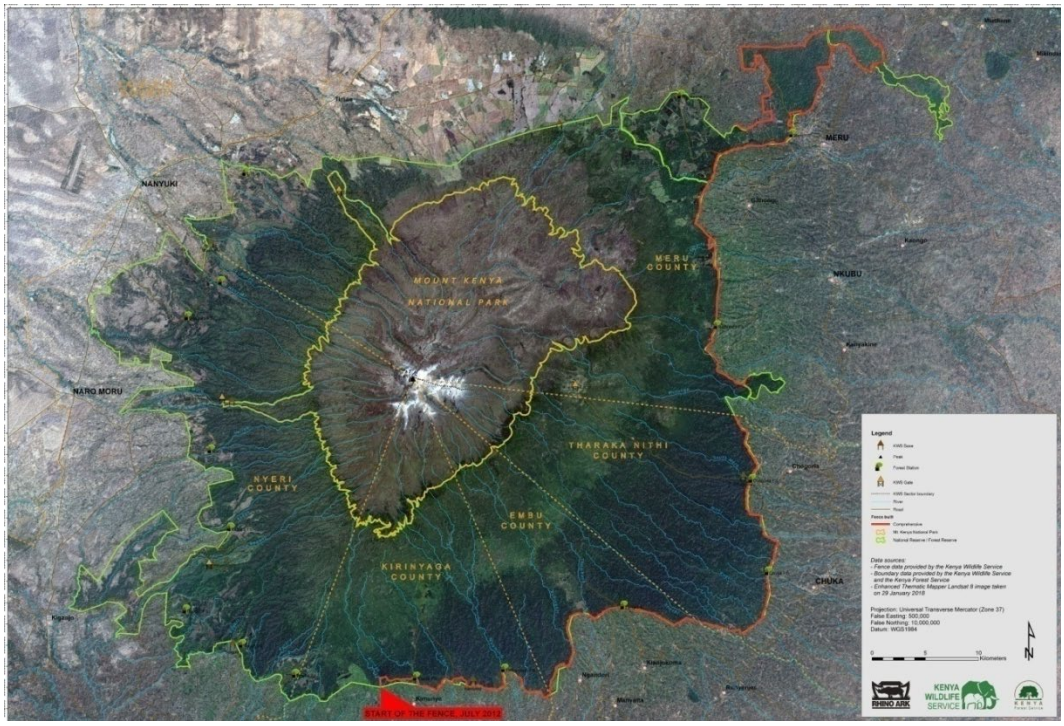

Figure 1: Progress of the construction of electric fence around the Mount Kenya forest by November 1, 2019. Construction of the fence started in Kirinyaga County in 2012 and much of the study site (Embu County) was covered in 2016 (Rhino Ark, 2019).

2.2. Data Collection

For the purposes of data collection, CFAs and their leadership were the main sources of data and information. Across the Embu County project site, there are 9 CFAs commonly referred to as 'bits'. These are, from the East to West, Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kiii. Data collection was conducted during the months of March, April, May and June in 2019 using a questionnaire that was administered to members of each CFA.A focused group discussion was organized with the CFA leaders (3 from every group) to discuss the modalities of administering questionnaires and installing the cameras.A draft questionnaire was discussed, tested and details agreed upon with the leaders. The leaders were also shown how to install the cameras at different locations. Wildlife cameras (ScoutGuard SG-550M 14SHD) were also used to capture images of wild animals around the farms at night and the information used to complement data collected using questionnaires. Wild animals mostly visit the farms at night and there is less human traffic during nighttime hours. The cameras were motion triggered with infra-red lights that could illuminate at night without producing light that could scare away the animals.

Following the agreement with the CFA leaders, meetings were held on separate days with CFA members of each group and questionnaires administered to each

CFA member present. Members unable to read or write were assisted in filling the questionnaires with the help of local interpreters. Specific CFA leaders participated in the process of installing cameras on various crop-raiding sites in selected homesteads. The selected homesteads were those where wildlife visits were reported to be more common, but also where the security of the cameras could be guaranteed. Cameras were left to stand in a single location for 5-7 days in one homestead. The cameras were set to take three photos at 5 second intervals once triggered by motion within the field of view. These photos were saved to a secure-digital memory card (SD-card) that would then be retrieved to download the pictures onto a computer. Cameras were only activated at nighttime between 7.00 pm in the evening and 7.00 am in the morning when there was minimal human activity which could 'falsely' trigger them to take pictures. Besides, many farmers said that most raiding by wildlife occurs during the night. In each of the 9 bits, an average of 20 questionnaires was administered and a total of 181completed questionnaires retrieved. Wildlife cameras were installed in a total of 14 locations within the 9 bits and a total of 455 pictures were downloaded at different times over the course of the project period.

3. Results

Results show that farmers in the area grow tea as the main cash crop. They also grow coffee and macadamia as cash crops albeit in smaller quantities. The main food crops for the households are maize, beans, bananas, cabbages, carrots, kales, cassava, potatoes, sweet potatoes, cucumber, papayas, passion fruits, spinach and yams. Othercommon crops grown include avocado, sugarcane, napier grass, arrowroots. The common livestock and domesticated animals reared by the farmers include: cattle, goats, sheep, pigs, chicken, rabbits, dogs and cats.

3.1. Crop raiding

The percentage of crops farmers reported to be destroyed by wildlife was significantly higherin the year before the wildlife fence was constructed in 2016 (2015) compared to the post-wildlife fence period (2019) for all cropsexcept arrowroots, carrots, cassava, passion fruits, tomatoes and yams according to the questionnaire data analysis(Figure 2). Naked mole rat (*Heterocephalus glaber*) (149 cases), Kenyan african mole rat (*Tachyoryctes ibeanus*) (143), white tailed mongoose (*Ichneumia albicauda*) (132) and eagles (*Accipitridae* family) (121) were the most frequently reported wildlife raiders on croplandsafter installation of the wildlife fence, while elephants (18), wild pigs (*sus scrofa*) (13) and other animals (8) were least frequent(Figure 3). Mole rats and monkeys (*Cercopithecus albogularis*) (105)were the main causes of destruction of crops whilemongoose and eagleswere the main predators reported responsible for livestock damage, predating mainly on chicken. African mole rat reportedly fed largely on macadamia (31), followed by maize (21) and potatoes (7) (Figure 4A). Naked mole rat fed mainly on maize (19), bananas (14), napier grass (13), potatoes (12) and sugarcane (11) (Figure 4B), while monkeys and baboons (*Papio cynocephalus*) fed largely on maize (56 and 14 incidences respectively) (Figures 4C and D). Other wildlife that caused substantial damage to crops were elephants (destroying mainly maize and bananas pre-fence); Honey badger (*Mellivora capensis*) and black rat (*Rattus rattus*) (maize); Porcupine (*Coendou rothschildi*) (cassava) and rabbits (kales and beans) (Figure 3).

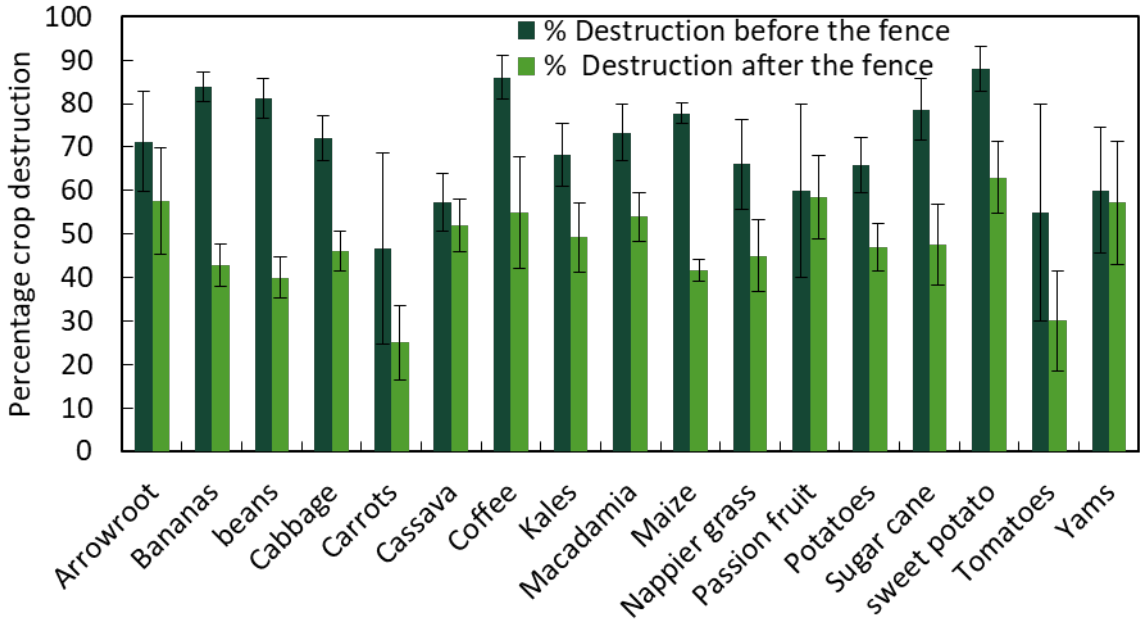

Figure 2: Reported mean percentage (±SE) of crops destroyed by wildlife in the study area before and after installation of the wildlife fence in 2016. Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya 2019.

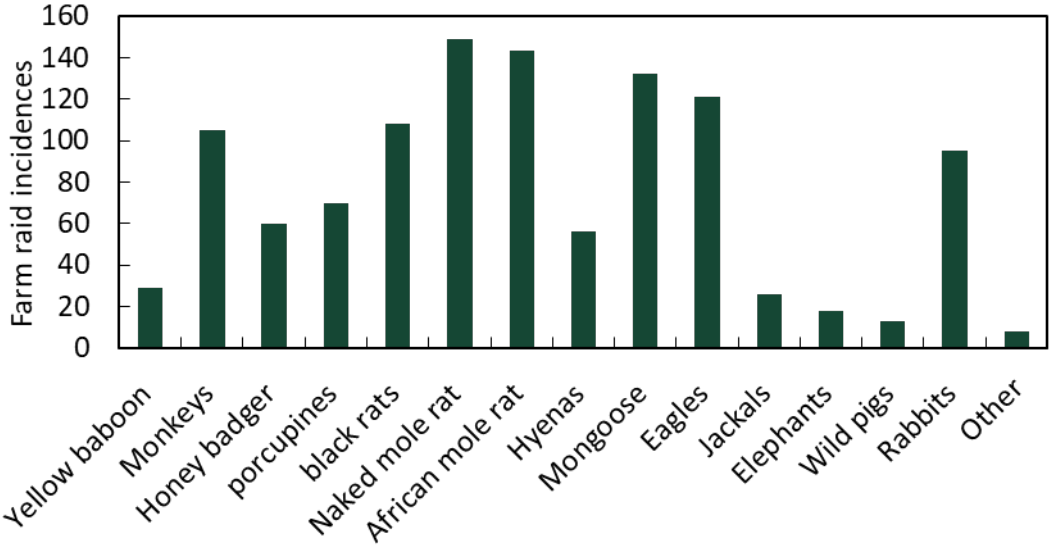

Figure 3: Number of incidences during which various wild animals were reported to have raided farmlands in the study area after the installation of the wildlife fence in 2016. Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya 2019.

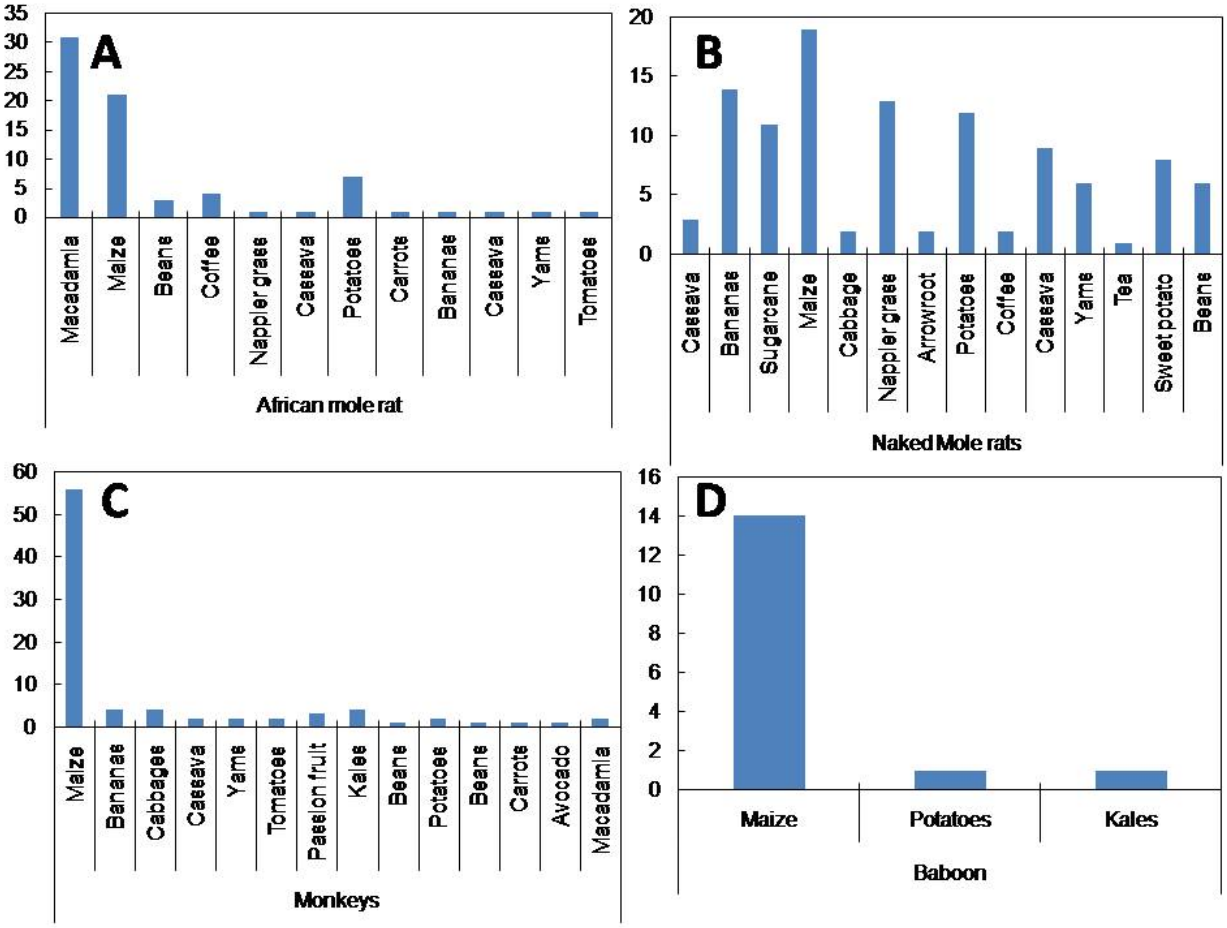

Figure 4: Number of incidences during which the African mole rat (A), Naked mole rat (B), Monkeys (C) and Baboons (D) were reported to have raided various crops in the study area after installation of the wildlife fence in 2016. Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya 2019.

3.2. Livestock attacks

Reported incidences of livestock attacks by wildlife weregenerally higher during the year before the fence was constructed (2015) (137 cases) compared to post fence construction year of 2019 (129 cases) (Figure 5). Chicken were the highest predated livestock with 641 incidences before the fence and 482 after the fence (Figure 6). They were followed by 122 reported attacks on goats before and 46 attacks after, and sheep with 88 and 43 incidences before and after the fence respectively. The least attacks reported were on cattle at 12 and 8 incidences before and after the fence respectively (Figure 6). However, there were increased reported incidences of attacks on chicken by mongoose and eagles in the period after the fence compared to pre-fence period (Table 1, Figure 7). The most commonly reported

predator of chicken was mongoose while the greatest predation on sheep and goats was reported to be by hyenas and feral dogs respectively (Figure 7).

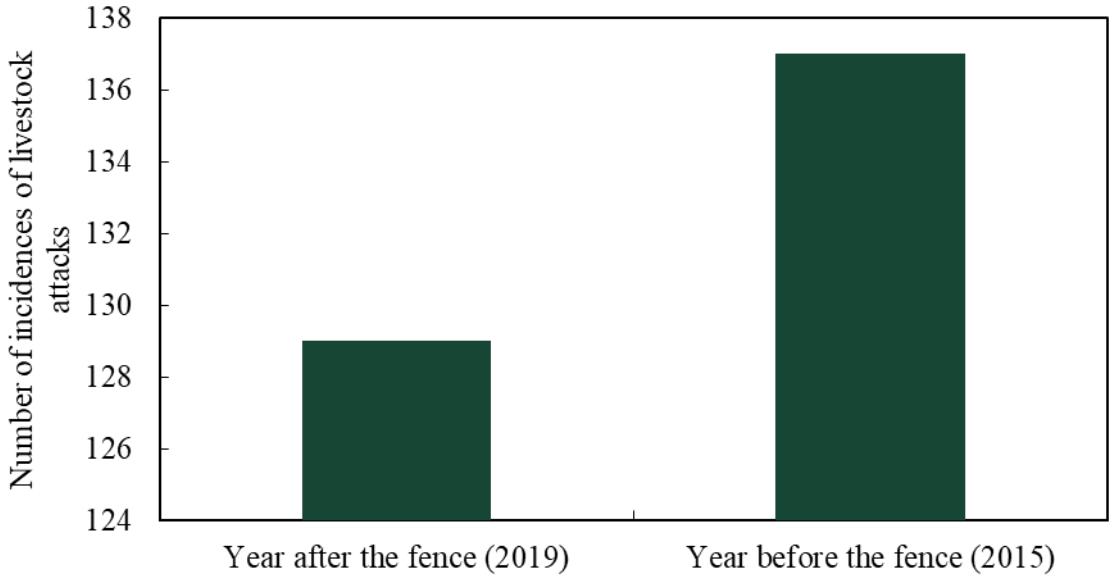

Figure 5: Total numbers of incidences during which various wild animals were reported to have attacked livestock in the year after the wildlife fence was constructed (2019) and one year before the fence was constructed (2015). Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya 2019.

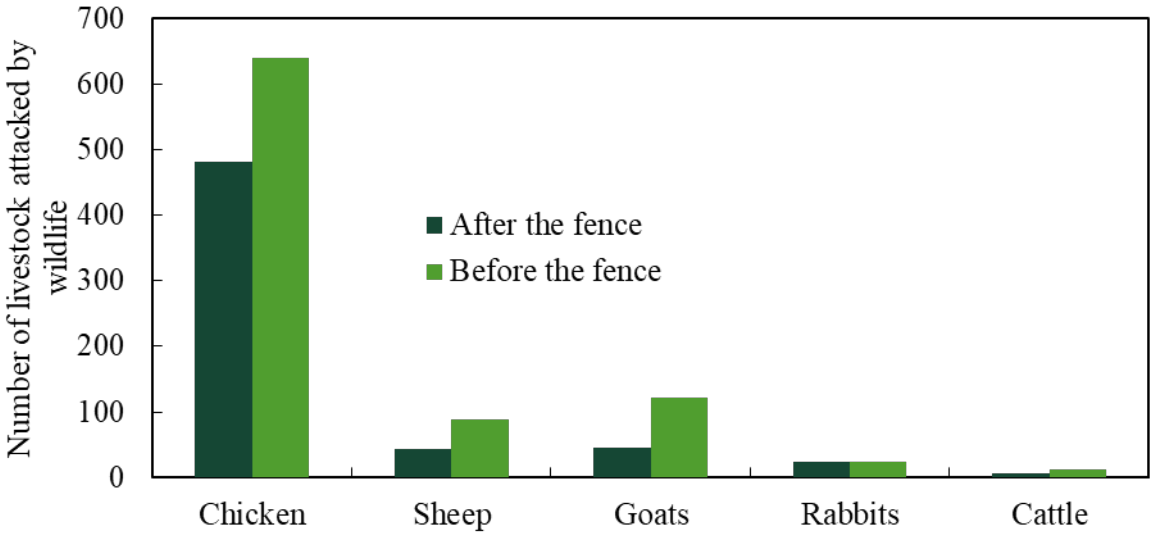

Figure 6: Number of incidences during which various livestock were reported to have been attacked by wildlife before and after the installation of the wildlife fence. Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya 2019.

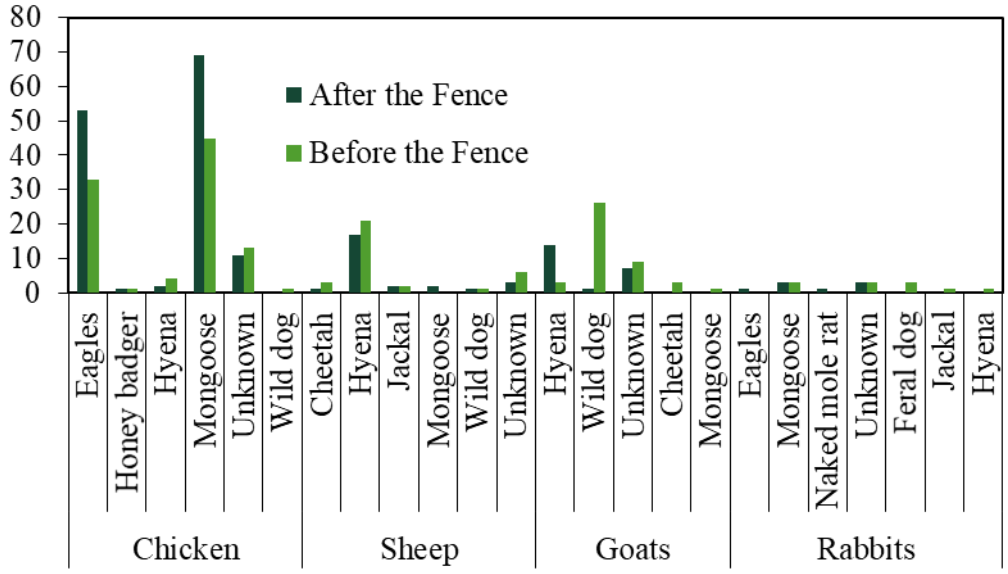

Figure 7: Number of incidences during which various livestock were reported to have been attacked by various wild animals before and after the installation of the wildlife fence. Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya 2019.

3.1. Preventive actions for crops

A majority of farmers who adopted measures to keep wild animals away from their farms used fences (30.6%) while the smallest number used scarecrows (5%) (Figure 8A). A significant number of respondents (25%) reported that they killed depredating wildlife by either trapping or poisoning them whenever the animals ventured into their farms. Others used various ways of scaring them away,which included use of sticks and stones (14%); dogs (6%); and shouting at them (19%) (Figure 8A). Besides, farmers also suggested various ways through which, in their opinion, would be most effective in preventing animals from destroying their crops, irrespective of whether they had already adopted them or not. The most preferred suggestion was fencing (41.7%) followed by trapping (22.3%) and poisoning (12.6%) (Figure 8B). The least suggested methods were increasing the electric current in the wires of the wildlife fence and scaring animals with stones and shouting at them, each at 0.97% (Figure 8B).

Table 1: Mean number of reported livestock attack incidences by wild animals on livestock in the year after the wildlife fence was constructed (2019) and one year before the fence was constructed (2015). Letter 'n' represents the total number of livestock attack incidences reported. Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya during the project period in 2019.

		After the fence		Before the fence	
Livestock	**Predated by**	**n**	**Mean**	**n**	**Mean**
Chicken	Eagles	53	6.0	33	6.3
	Honey badger	1	-	1	4.0
	Hyena	2	1.0	4	4.3
	Mongoose	69	5.7	45	11.8
	Wild dog	-	-	1	2.0
	Unknown	11	4.8	13	7.3
Sheep	Cheetah	1	-	3	3.0
	Hyena	17	2.3	21	3.4
	Jackal	2	5.0	2	5.0
	Mongoose	2	3.0	-	-
	Wild dog	1	-	1	-
	Unknown	3	2.0	6	2.2
Goats	Cheetah	-	-	3	2.5
	Hyena	14	2.8	26	4.1
	Mongoose	-	-	1	1.0
	Wild dog	1	6.0	1	6.0
	Unknown	7	2.3	9	2.4
Rabbits	Eagles	1	10.0	-	-
	Mongoose	3	4.0	3	15.0
	Naked mole rat	1	10.0	-	-
	Hyena	-	-	1	4.0
	Jackal	-	-	1	2.0
	Feral dog	-	-	3	-
	Unknown	3	-	3	-

3.2. Preventive actions for livestock

Several measures were suggested in preventing livestock attacks by wild predators. These included Fencing (58%) followed by cages/sheds (9%), Trapping wildlife (8%) and increased current on the wildlife fence (7%) (Figure 8C). The least preferred methods included reporting to authorities and using scarecrows at 1% each (Figure 8C). A majority of the farmers had a positive evaluation of the electric fence erected by the government to keep away the wildlife. On a scale of 0 to 10(0=doesn't work, and 10=works perfectly), 51% of the farmers gave it a score

of 7 and another 40.6% gave it a score of 8. However, on the very extremes, 1.5% of the respondents gave it a zero score while 3% said the fence works perfectly (Figure 8D).

3.3. Wildlife cameras

Out of the 455 pictures taken by the wildlife cameras, a majority of them (380) were either unclear or captured images that were not of interest to the study including human beings, vegetation and domestic animals like chicken and cats. The remaining 75 pictures were of domesticated dogs (30), African mole rats (20), White tailed mongoose (12), Naked mole rats (10) and the common genet (*Genetta genetta*) (3) (Table 2). The pictures were captured on different dates and in different locations of the Embu County study site. The dogs were more widespread and were captured by cameras in at least 7 of the 14 locations in the 9 bits (Figure 9). The African mole rat was equally widespread and was captured by cameras in 6 out of the 9 locations (Figure 10).The white tailed mongoose had a much lesser presence being captured by cameras in 4 of the 9 locations within the study area (Figure 11). Both the naked mole rat and the common genet had the least number of occurrences. The naked mole rat was captured ten times but only in Rwikithia bit (Figure 12) while the genet was captured three times in Thambana bit (Figure 13).

Table 2: Number of pictures of different wild animals captured by wildlife cameras in 14 households within the 9 bits in Embu County, Kenya between 7.00 am and 7.00pm during the project period in 2019.

Wild animal	**Number captured by camera**
Common genet (*Genetta genetta*)	3
Naked mole rat (*Heterocephalus glaber*)	10
White tailed mongoose (*Ichneumia albicauda)*	12
African mole rat (*Tachyoryctes ibeanus*)	20
Feral dogs (*Canis lupus familiaris*)	30

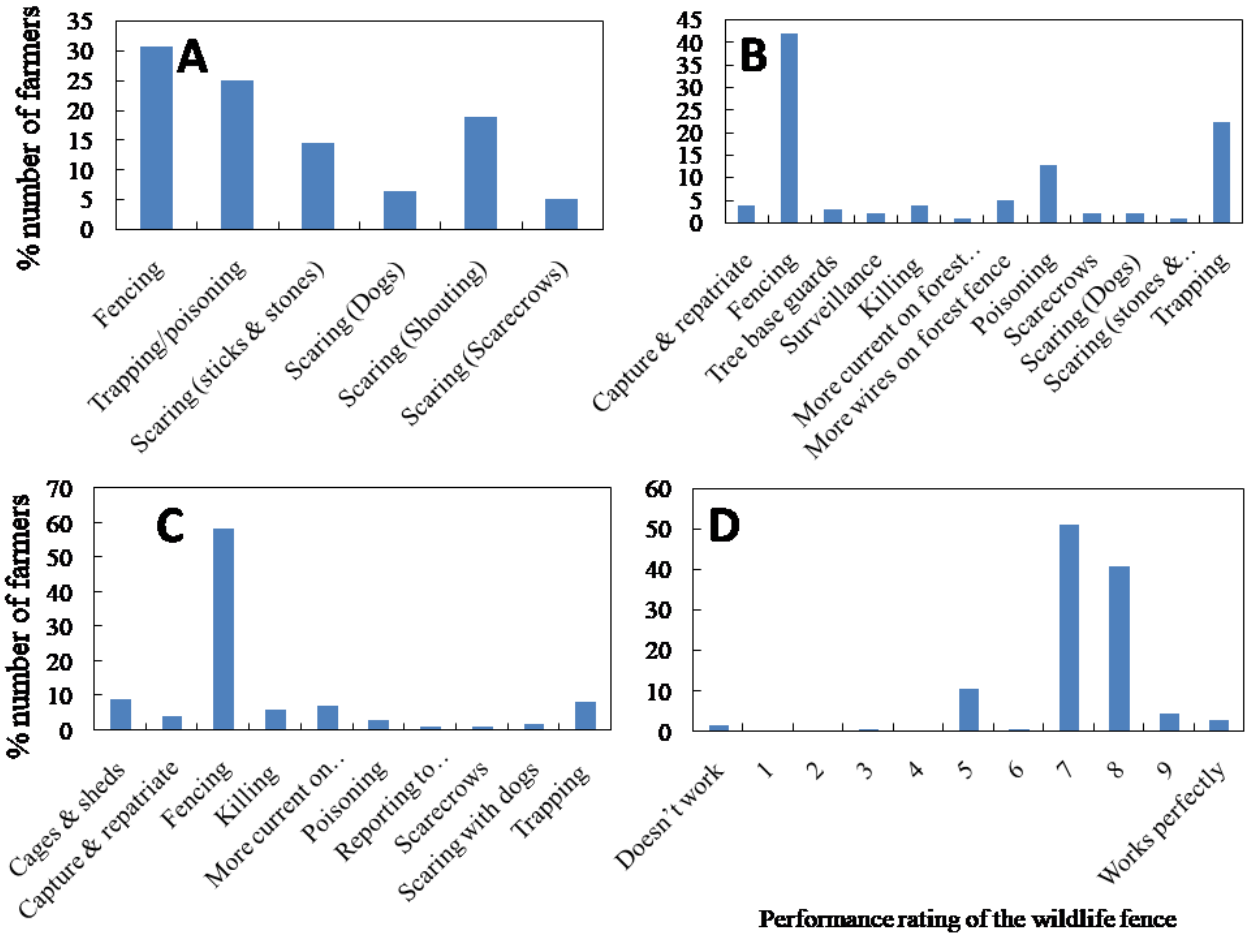

Figure 8: Percentage of farmers using various deterrent techniques to keep wildlife animals away from their farms (A); Percentage of farmers who suggested various deterrent techniques as most preferred ways of preventing wild animals from destroying their crops (B); Percentage of farmers who suggested various deterrent techniques as most preferred ways of preventing predation of their livestock by wild animals (C); and Percentage of farmers who variously rated the performance of the wildlife fence. The ratings range from 0-10 where 0=doesn't work and 10=works perfectly (D). Data is based on 169 respondents in Kanduviu, Rwikithya, Irangi, Karimari, Gaciigi, Thambana, Rutune, Muthigi and Kii farming bits in Embu County, Kenya, during the project period in 2019.

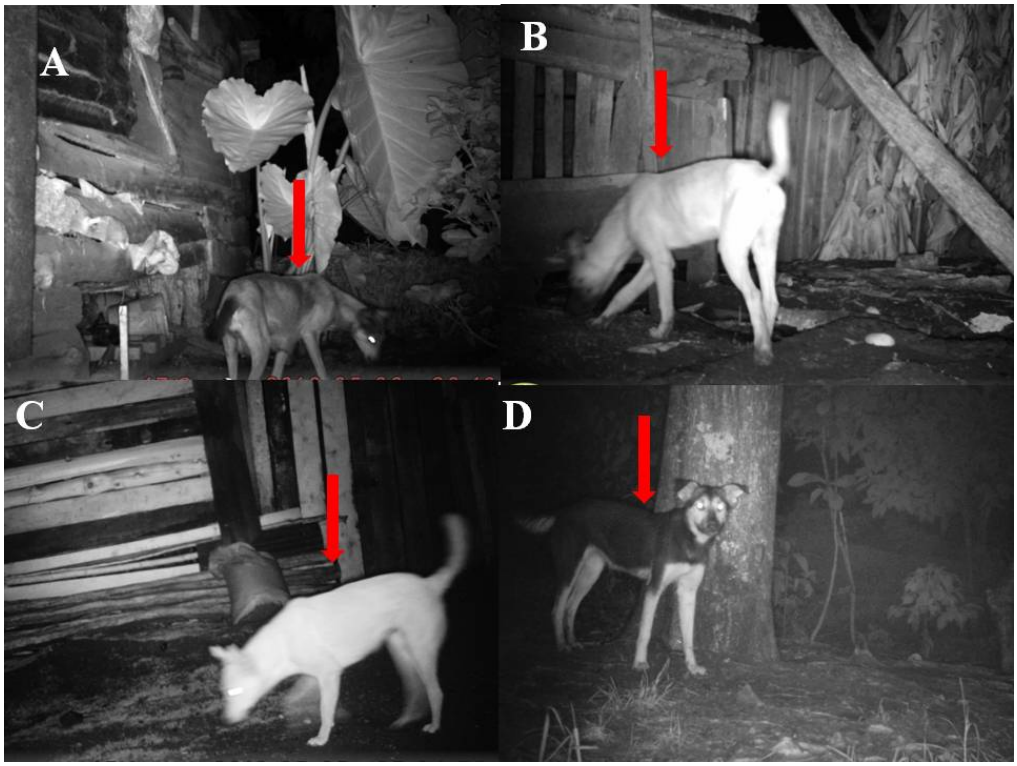

Figure 9: A sample of pictures of dogs captured by wildlife cameras placed in different locations (plates A-D) within the study site on different dates over the project period. Dogs were captured by cameras in at least 7 of the 14 locations in the 9 bits.

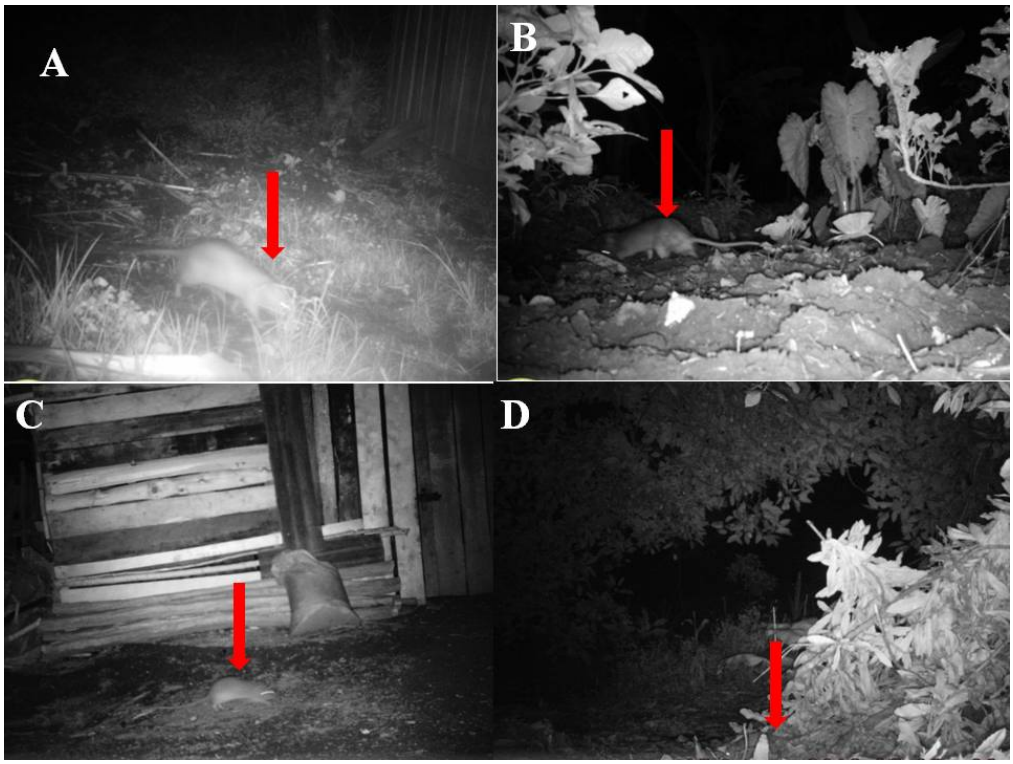

Figure 10: A selection of pictures of the African mole rats captured by cameras placed in different locations of the study area (Plates A-D). The African mole rats were captured by cameras in 6 of the 14 locations in the 9 bits.

Figure 11: A selection of pictures of the white tailed mongoose captured by cameras placed in four different locations of the study area (Plates A-D). The white-tailed mongoose was captured by cameras in 4 of the 14 locations in the 9 bits.

Figure 12: A selection of pictures of the naked mole rat captured by cameras placed in Rwikithia bit within the study area (Plates A-D). The naked mole rat was only captured by cameras in this bit.

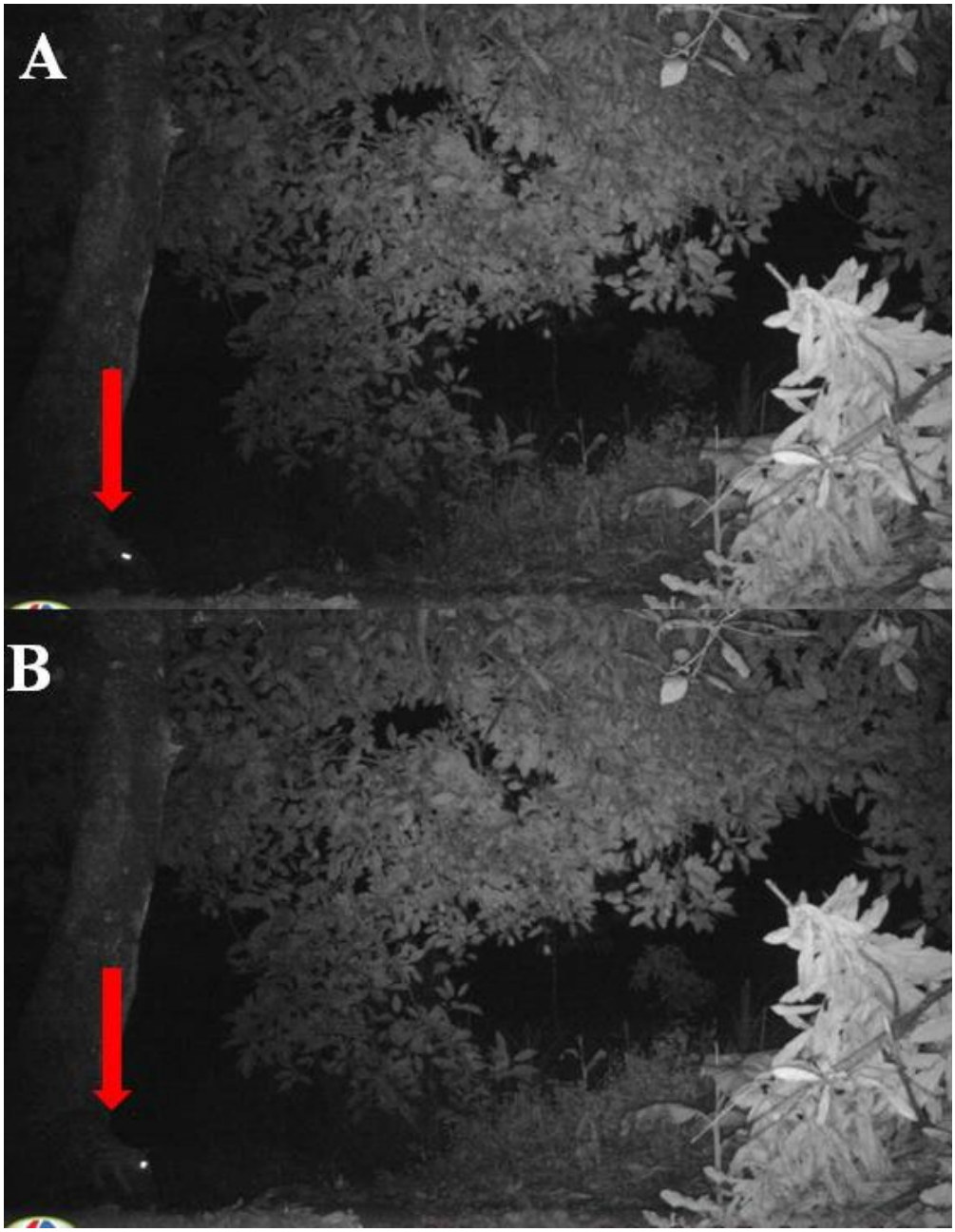

Figure 13: A selection of pictures suggesting a Genet captured by cameras placed in Thambana bit within the study area (Plates A and B). The Genet was captured only by cameras in this bit.

4. Discussion

Results from this study confirm that people living in Embu County, Kenya and practicing small holder farming activities within 5 km of Mount Kenya Forest have frequently suffered crop and livestock losses from wildlife raids over the years (Kamweya et al., 2012; Weinmann, 2018). These losses were higher before the installation of the electric fence along the forest edge by Kenya Wildlife Service and the Rhino Ark Foundation in 2016. The fence seems to have completely stopped or significantly reduced the raids by elephants and other large mammals, although in the absence of data on the roaming patterns for these animals in the forest, it is difficult to make a definite conclusion on the effect of the fence on farm raids by these animals. Elephants, which according to the farmers caused the greatest damage before the fence in 2016 were reported to have a population of 2579 in the whole of Mount Kenya National Park/National Forest (a population density of 1.28 elephants/km^2) in that year compared to a population of 2911 in 2001(KWS, 2016). Their population and density were however not known in 2019. In this study, the cropdestruction has declined by between 50% (for maize, beans, bananas and carrots) between 2016 and 2019.This reduction may to a large extent be attributed to successful containment of the large animals within the forest by the fence. During the same time period (2016 – 2019), attacks on livestock also decreased by 5.8%. It is however, unclear exactly what role the fence plays in this reduction.

As expected, the fence did not help in containing the small animals like moles, mongoose, monkeys and eagles that could penetrate through the gaps in the fence wires, burrow below the fence, fly over the fence or live within crop-growing fileds. These animals were reported by farmers to be responsible for most of the crop damage and livestock attacks reported after the fence was installed. However, during this period there were still a small number of cases where large carnivores like hyenas, jackals and feral dogs were reported to have attacked livestock (Figure 7). While jackals may be small enough to squeeze through the fence, attacks by hyenas were explained by possible incidences when the forest officers forgot to

close the forest gates through the night and hyenas sneaked out and attacked livestock in the farms (Personal communication).

Since most of the small animals could not be contained by the wildlife fence, and therefore could access the farms, the wildlife fence had a minimal effect on these crop-raiding species. Destruction of food crops like arrowroots, carrots, cassava, passion fruits, tomatoes and yams was still high over the period after the fence was built, and this is potentially due to these small animals. The naked mole rats, the African mole rats and the black rats which had a total of 213 reported crop-raiding incidences out of a total of 474 (44.9%) were the highest cause of crop destruction. This is most likely the case for many other species, like porcupines, mongooses and wild rabbits. However, a number of farmers indicated that there is barely any current in the fence wires so that it is likely that several animals crawl under or through the fence. Monkeys and baboons are known to be major crop raiders (Hill, 2000) and were together responsible for a combined total of 134 of the 474 incidences (28%). These animals are able to jump over the fence.

Naked mole rats, baboons and monkeys were the main crop raiders reported by farmers, destroying maize, bananas and potatoes which are a major food source for the community in the Embu area. Harvested maize in granaries was also subject to destruction by black rats. The naked mole rats were the major causes of destruction for macadamia, sugarcane and napier grass that form part of the main cash crops for the community. A number of wildlife cameras placed on the sampled farms were able to capture photos of wild animals including white-tailed mongoose (*Ichneumia albicauda*), the common genet (*Genetta genetta*), the naked mole rat (*Heterocephalus glaber*) and the African mole rat (*Tachyoryctes ibeanus*) and dogs (*Canis lupus familiaris*). Dogs seen on camera may have been guard dogs. Monkeys and baboons were frequently cited crossing between the farms and the forest. Farmers reported a few cases of crop destruction by elephants which ideally were locked out from the farms by the fence. The wildlife cameras placed in various strategic points of farms where this claim was made however did not capture any large mammals. The reports on raids by elephants could therefore not be

corroborated. It is possible that these reports were based on farmers' pre-fence experiences rather that real incidences of crop invasion by the elephants in the current circumstances. Besides the possible role of the fence in deterring attacks by large mammals, it is also possible that their recent roaming patterns inside the forest have excluded areas around the forest edges. Other factors may include possible changes in their populations and timing of the camera traps.

During the time period after the fence was constructed the number of livestock attacks by wildlife significantly reduced. Whether this is a coincidence or a result of a well-functioning electric fence is not clear. Still, after the fence was constructed it seems as if it almost completely prevented wild carnivores from leaving the forest to attack livestock. Again, like many of the species feeding on crops, most attacks on livestock reported during the period after the fence construction was by animals that potentially either burrow under the fence, fly over it or live within the crop areas. These animals included the mongoose and the eagles which were reported responsible for the highest number of attacks on chicken. Although reported attacks were still high before the fence was constructed, there was a marked increase in the attacks after the fence, and this may be attributed to increasing numbers of the wild depredating species or simply by an increased tendency to rear chicken amongst many of the farmers as an income generating venture. Some species of crop raiding animals may also live in the "buffer zone" of tea or other places outside of Mt. Kenya forest. In recent years, there has been a drive by various governmental and non-governmental organizations to encourage young farmers to engage in agribusiness activities as a way of boosting income (FAO, 2014). The mongoose reportedly attacked chicken at night, and their presence was captured by the wildlife cameras placed at various homes. However, no attacks were captured on film. Eagle attacks were reported to take place mainly during the day and no photos of eagles were collected. Such incidences are frequently experienced by farmers when chicken are free ranging out of their cages. Attacks on goats, sheep and cows can be attributed to larger carnivores like hyenas and feral dogs. While hyenas are rarely seen in the area, and were not captured by the wildlife cameras, they have been known to escape from the forest through wildlife gates when left open by the forest

wardens (personal communication). Misidentification by farmers in also possible. Dogs are common in the area and roam around freely in these communities (Menghistu et al., 2018). It is not possible to distinguish between feral and local dogs with photos. However, feral dogs and local dogs were captured repeatedly by the wildlife cameras placed in various homesteads.

Fencing by small holder farmers is a common method of controllingcrop damage by wildlife in many agricultural lands adjacent to forested areas (Thapa, 2010). There are however an array of other methods that have been used to achieve a similar end, ranging from simple techniques to scare away animals to extreme remedies of exterminating them (Fall and Jackson, 2002). In this study, fencing was the most commonly adopted method of keeping wildlife at bay. Multiple respondents reported lacking fencing materials but being interested in fencing methods. Other methods used to keep animals away from the farms in order of preference are shouting and screaming, throwing stones and sticks, protective dogs and use of scarecrows. This order is possibly a reflection of availability of particular scaring methods. It may also be a reflection of questionnaire design as the answer "Scarecrow" was filled in by farmers in the section marked "other." Many farmers would instinctively react to an animal raid by screaming and shouting at animals before deciding to pick up stones and sticks. Dogs are expensive to acquire while putting up scarecrows is relatively inexpensive. About a quarter of farmers who used deterrent measures to keep wildlife from their crop lands indicated that they had killed wildlife by either trapping or poisoning them. These occurrences were probably out of desperation by farmers whose crops and livestock were constantly being invaded by wildlife but lacked effective ways of mitigating such invasion. Killing of wildlife could pose a threat to their existence and potentially threatens loss of important wildlife species of unknown economic and cultural values especially those whose current populations haven't been determined. Poisoned animals can potentially pass along the food chain resulting in the poisoning of larger predator species of wildlife but also of cats and dogs. Although there was no evidence of the number of wildlife that were killed by either trapping or poisoning, results on the number of incidences of wildlife crop damages suggests that African

mole rats and naked mole rates were the greatest culprits. Besides the actual use of the various wildlife deterrent measures, opinions on the perceived effectiveness of such measures mirrored the actual use, irrespective of whether any measure was used or not. Fencing, for example was perceived as the most effective method followed by trapping and poisoning. While perception on effectiveness of fencing may have been influenced by the high approval ratings of the wildlife fence (a majority of farmers said it works near perfectly), the success of the household fences amongst farmers who use it likely enhanced the perception. The relatively high preference for use of traps and poison is possibly a reflection of either disinformation on appropriate wildlife handling procedures or dissatisfaction with wildlife management by the authorities. The Kenya Wildlife Service is responsible for all forms of wildlife in the country and has guidelines and procedures of handling wildlife in cases of human-wildlife conflict (KFS, 2010). In places where traps have been used to protect croplands from wildlife, the traps are made in such a way that they would either kill the animals immediately or the animals would be killed by the farmers if found in the traps (Hill, 2000). In the current study however, it was not clear what kind of traps farmers would prefer to use, but nevertheless, there was no incidence during the study where animals were caught in any form of a trap. Many farmers indicated that they would return the animals to the forest if they were caught by their traps. Others offered to catch and kill wildlife to present them to the wildlife authorities as evidence of crop/livestock raid if the animals were not “caught” on film.

5. Conclusions and recommendations

Our results show that there are clear differences in farmer reported crop-raiding by wildlife before the wildlife fence was constructed in 2016 and the period after its construction (2019). While farmers in Embu County still suffer wildlife damages, much of it is reported to be caused by small animals that are likely not affected by the fence since they live their lives in the farming areas outside the fence or are able to either burrow under the fence (mainly the various types of moles) or jump/fly over the fence (mainly monkeys, eagles and baboons). Other animals that are of concern are the mongoose and possibly dogs which are also able to easily cross the fence.

Results from this study suggest that farmers in Embu County perceive the Mt. Kenya forest wildlife fence to be successful in confining large wildlife like elephants and hyenas within the forest. These animals were a serious threat to crop and livestock before the fence was constructed (Kamweya et al., 2012). However, the fence alone will not protect small holder crops from all wildlife species. Since the farmers live and grow crops near the forest, and the threat from small animals is likely to persist, it is important that farmers devise innovative ways of dealing with this threat. Such may include aggressive fencing of their farmlands to keep away wildlife, growing crops that are less targeted by the small animals and shifting from growing crops to keeping livestock which are not a target of the small wildlife. The Kenya Wildlife Service which is the custodian of wildlife also need to work closely with the farmers to identify cases of crop and livestock loss due to wildlife and find innovative ways of compensating them and preventing further loss. Access to basic fencing materials and maintained fences appears to be lacking and may protect farmers' crops and livestock like chickens. Several farmers voiced an interest in funding for specific on-farm fencing. Kenya Wildlife Service also needs to train farmers living and farming adjacent to the forest on procedures to correctly identify local wildlife species and to follow in reporting cases of wildlife invasion. Such training could also include food choices of various wildlife species inhabiting the forest so that farmers avoid growing crops or keeping livestock that may be a prime target of wildlife.

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