# The performance of electric fences as elephant barriers in Amboseli, Kenya

**Article** *in* African Journal of Wildlife Research · April 2008
DOI: 10.3957/0379-4369-38.1.52

# The performance of electric fences as elephant barriers in Amboseli, Kenya

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Received 13 June 2006. Accepted 17 July 2007

**Electric fencing is increasingly used as a tool for elephant (*Loxodonta africana*) conservation in human-dominated landscapes and there are few empirical studies to demonstrate that electrified barriers are effective in deterring elephants from raiding crops. The factors determining the effectiveness of electric fences are not fully understood. We assessed the performance of Namelok and Kimana fences in reducing human–elephant conflict by comparing the frequency of crop-raiding by elephants and the perceptions of farmers on the effect of the fences in reducing elephant crop-raiding within fenced and adjacent unfenced farmlands. We also examined the effect of intact fence wires, presence of current and amount of voltage on fence breakage by elephants. Electric fencing reduced elephant crop-raiding and other forms of human–elephant conflicts. Namelok fence was not broken by elephants whereas Kimana fence was broken several times probably because it borders Kimana Sanctuary which provided cover where elephants could retreat after crop-raiding. The mere presence of current did not minimize fence breakage by elephants. Elephants entered fenced areas more frequently when the fence wires were broken than when wires were intact. Our results suggest that, location of fences in relation to landscape factors, maintenance of effective non-electrified fences and proximity of fences to areas of high elephant concentration are significant determinants of fence performance in mitigating elephant crop-raiding.**

**Key words**: crop-raiding, elephants, fencing, human elephant conflicts.

## INTRODUCTION

Human–elephant (*Loxodonta africana*) conflict refers to the negative interactions between humans and elephants. Some of the negative effects of elephants to humans include crop-raiding and deaths and injuries to humans and livestock (Tchamba 1995). On the other hand, elephants are killed and their range severely altered by human activities (Haigh *et al.* 1979; Kangwana 1995). Human–elephant conflict is widespread in most elephant range areas (Blanc *et al.* 2003) and has intensified where elephants and humans are in close contact (Naughton *et al.* 1999). It is particularly a major concern where former elephant range has been encroached by farmlands (Osborn & Parker 2002).

Human–elephant conflict is increasingly jeopardizing elephant conservation as many elephants get killed by wildlife authorities in attempts to reduce conflict. Elephants are also killed illegally by local people in response to destruction of their crops, and deaths and injuries to their livestock (Omondi *et al.* 2004). In Kenya, for example, 130 elephants were killed in human–elephant conflict situations between 1990 and 1993 whereas elephants killed 108 people during the same period (Kiiru 1995). In the Tsavo-Amboseli area in Kenya, 15 people were killed and 24 injured by elephants between 1993 and 2004. In the same area during the same period, 44 elephants were killed (Kioko *et al.* 2006b).

Electric fences are increasingly being used to reduce crop damage by elephants (Andau & Payne 1992; Thouless & Sakwa 1995). The fences act as physical as well as psychological barriers to separate elephants from settled areas (Sukumar 1986). In Kenya, more than 1200 km of electric fencing has been installed to protect farmlands from elephants and an additional 1300 km of fencing is planned (Omondi *et al.* 2004). Electric fences are expensive to install and maintain and most community fence projects in Africa are funded externally or by corporations. While electric fences are considered effective in reducing

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crop-raiding (Hoare 2003), literature on the use of electric fencing to manage crop-raiding by elephants suggest that a number of factors including fence design, voltage, maintenance, elephant pressure and behaviour may influence their success (Seidensticker 1984; Thouless & Sakwa 1995; Garai & Carr 2001; Hoare 2003). Considering the high installation and maintenance cost of electric fencing, there is a need for more research to establish the factors that determine the effectiveness of electric fences in deterring elephant crop-raiding.

In this study, we examined the performance of Kimana and Namelok electric fences near Amboseli National Park (ANP) and Kimana Sanctuary (KS) in the Amboseli region of Kenya. We compared the extent of elephant crop-raiding in the fenced and adjacent unfenced areas. We also assessed the perceptions of farmers in fenced areas on whether the electric fences had reduced elephant depredation on their crops and other property. In addition, we assessed performance of the fences by comparing the proportion of those cultivating inside the fences and reported human–elephant conflicts with a proportion of those cultivating outside the fenced areas and reported human–elephant conflicts. We finally examined the effect of intact and broken fence wires, presence of current and amount of voltage on elephant entry into the fenced areas. We took advantage of the irregular fence maintenance regime and varying voltage to assess the effect of intact and broken fence wires, the presence of current and the amount of voltage on level of elephant fence breakage.

## MATERIALS AND METHODS

### *Namelok and Kimana electric fences*

Kimana and Namelok fences, 38 km and 24 km long, respectively, enclose two intensively irrigated, cultivated areas near ANP and KS (Fig. 1). The Kimana fence directly borders KS and Namelok fence is 3 km from ANP and 5 km from KS.

Elephants concentrate in ANP and KS in the dry season (Western & Lindsay 1984; Kioko *et al.* 2006a). ANP has a density of 2.85 ± 1.80 elephants/km$^2$ (Okello 2005) while KS has a density of 1.9 ± 0.96 elephants/km$^2$ (Kioko *et al.* 2006a). Rainfall in the Amboseli area ranges from 900 mm on the eastern slopes of Mt Kilimanjaro to 300 mm in the lowlands (Berger 1993). Springs and rivers associated with Mt Kilimanjaro provide water for irrigated farming within the fenced areas. The main crops grown are maize (*Zea mays*), onions (*Allium cepa*), tomatoes (*Lycopersicon esculentum*) and beans (*Vigna faba*). The increase in elephant crop-raiding, notably in the dry season and at night, led to fencing of Kimana and Namelok areas to separate humans and elephants (Kioko *et al.* 2006b).

The Kimana and Namelok fences were completed in 2000 at a cost of US$9000/km with financial support from European Union. The fences are a Gallagher model that consists of six wires; four live and two earth wires and are 2 m high supported by wooden posts that are 8 m apart. The fences are solar-powered and each consists of six and four power units, respectively. A power unit has a solar panel, a 12 volt power battery, and an energizer providing power to a 6 km length of the fence. The fences were managed by a fence committee elected by the farmers within the fenced areas. Farmers inside Kimana and Namelok fenced areas were expected to contribute US$4507 and US$2400 per year, respectively, towards salaries for the fence attendants and other fence maintenance costs. The money provided by local farmers was, however, insufficient for proper maintenance of the fences.

### *Monitoring the status of Kimana and Namelok fences and elephant entry into farmlands*

We monitored elephant entry into the farms enclosed by Kimana and Namelok fences and in the farms outside the fences in Kimana swamp, and Isinet (Fig. 1). Elephant entry into the fenced areas was monitored from April 2003 to March 2004 by walking the perimeter of electric fences. The farms raided were detected by following fresh elephant tracks. We estimated the number of elephants breaking the fences or entering into the areas from elephant tracks; a method that has been used elsewhere (Chiyo & Cochrane 2005) and from occasional sightings of elephants. To estimate the area in km$^2$ under cultivation at sites monitored for elephant crop-raiding, we took Global Positioning System (GPS) coordinate readings of boundaries of these sites and determined the areas using Arcview GIS. We maintained daily records on the status of fences and particularly noted if the fence wire strands were broken, intact, or had current or no current. These records were used to establish the status of the fences prior to elephant entry into the fenced areas. We

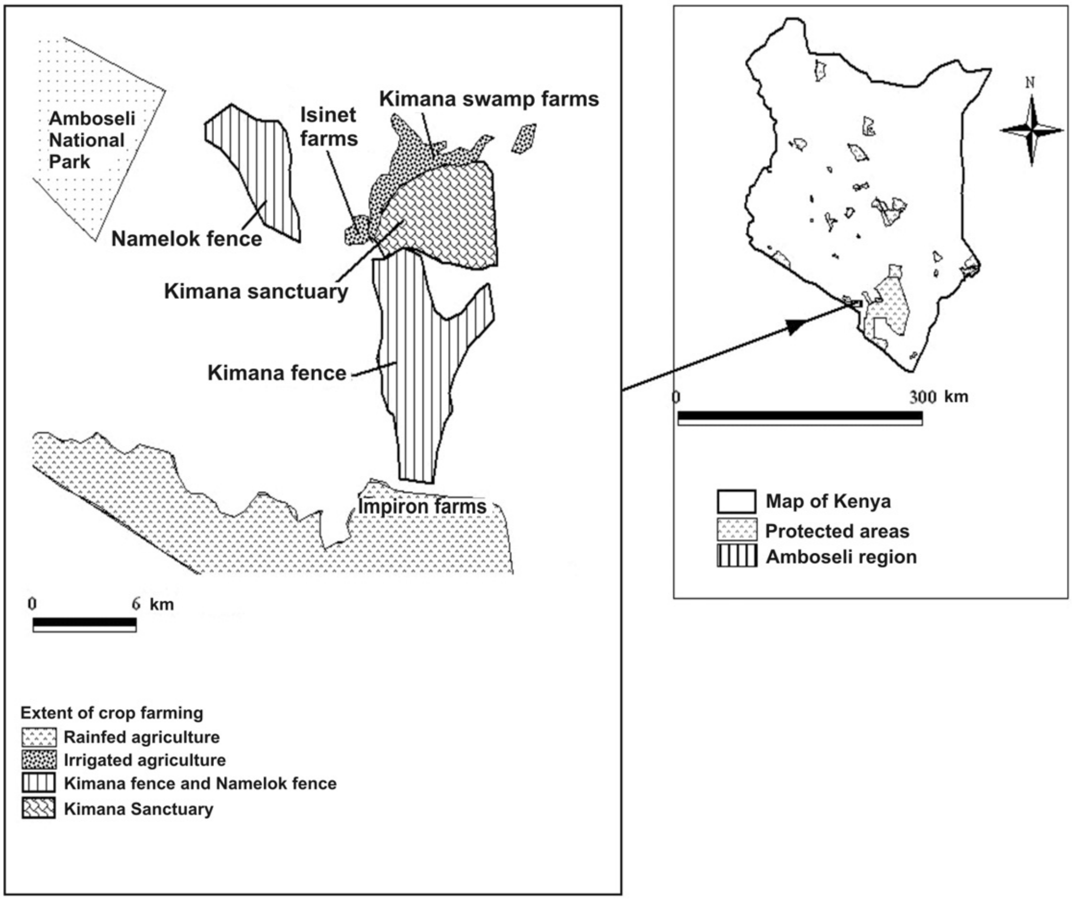


**Fig. 1**. Location of the Kimana and Namelok fence in relation to Amboseli National Park (ANP) and Kimana Sanctuary (KS). Inset, Map of Kenya showing the Amboseli region.

measured the voltage (kV) of each power unit on a weekly basis using a digital fence voltmeter (Gallagher Group Ltd, Nairobi, Kenya) to check for battery output and the flow of electric current in each of the 6 km fence sections. We also noted the number of days it took for the fence to be repaired after it had been broken by elephants.

*Interviews*

We conducted interviews using a standardized questionnaire to gather information on farmer's perceptions regarding the performance of the electric fences in mitigating human–elephant conflicts. Farmers were asked if they had experienced depredations on their crops, injuries and deaths to livestock, or other property damage by elephants and if they stayed out at night to guard their crops from elephants. In addition, farmers in the fenced areas were asked if they perceived elephant crop-raiding to have declined since the fences were established. For maize, a crop which is considered by the farmers as the most valuable (Kioko, *et al.,* 2006b), we asked the farmers their perceived yield per acre and the quantity of yield per acre lost to elephants in a crop season. Based on those figures, we estimated the perceived monetary value of maize production and perceived losses per farmer to elephants using local market prices of maize.

From a total population of 939 and 500 farmers inside Kimana and Namelok fences, 16% ($n$ = 154) and 13% ($n$ = 66) were randomly interviewed, respectively. In the unfenced farms in Isinet, Kimana swamp and Impiron, 29% ($n$ = 349) of the farmers ($n$ = 1200) were interviewed.

*Data analysis*

An elephant crop-raiding incident in this study was defined as the occurrence of a single elephant foray per day on one or multiple farms. In order to compare crop-raiding incidences between sites, we determined the frequency of elephant crop-raiding incidences per $km^2$ per month. We used Mann-Whitney $Z$ statistic to test if there was a significant difference in the number of raiding incidents per $km^2$/month in areas enclosed by Kimana fence and the adjacent unfenced (Kimana swamp and Isinet) areas. The effect of fencing on the extent of elephant crop-raiding, guarding effort, and damage to storage and containment structures was assessed by comparing farmers' responses in fenced and unfenced areas on whether they guarded and experienced elephant depredation using Chi-square goodness of fit statistic. We compared the mean perceived economic losses attributed to elephants within the fenced and unfenced areas for maize using a student t test on log-transformed data as the original data was not normally distributed.

To evaluate the effect of fence voltage on the frequency of fence breakage by elephants, we examined the relationship between the weekly frequency of elephant entry through each six-kilometre section of fence powered by a power unit and the voltage of the respective power unit prior to elephant entry into the fenced area using a Spearman rank correlation test.

The effect of broken or intact wires on the frequency of fence breaking by elephants was evaluated by comparing the frequency of elephant entry through the fence when it was either intact or broken with the number of days the fence was either broken or intact using a chi-square test of independence. Similarly, to test for the effect of current on elephant entry through the fence, we used a chi-square test of independence between the duration in days the fence was with or without current and frequencies of fence breaking during the time the fence was with or without current, respectively. These analyses were carried out using the data collected from Kimana fence, but since fence breaking was limited to a 6 km section of the fence, it was not necessary to convert the frequency of fence breakage per length of fence.

## RESULTS

Elephants broke through the Kimana fence 368 times and did not break through the Namelok fence during a one-year period. In 83% ($n$ = 305) cases when elephants entered through the Kimana fence, observations of their tracks showed that they used a 10 km strip that borders an *Acacia tortilis* woodland inside KS. The group sizes of elephants penetrating the Kimana fence ranged from 1–2 individuals, with a mean (±S.D.) of 1.07 ± 0.06.

Unfenced farmed areas (Isinet and Kimana swamp) adjacent Kimana fence received a higher frequency of elephant crop raids than farms inside Kimana fence (mean ± S.D. = 4.3 ± 0.71 and 0.5 ± 0.18 raids/$km^2$/month, respectively; $Z$ = 2.892, $P$ = 0.0038). Forty per cent ($n$ = 61) of farmers inside Kimana fence reported that they had experienced elephant crop raids while all the farmers interviewed in the adjacent unfenced farms (Isinet, Kimana swamp and Impiron) reported that they experienced elephant crop raids ($n$ = 349) ($\chi^2$=161.64, $P$ < 0.001). The majority of the farmers 93% ($n$ = 98) cultivating inside Kimana and Namelok fences felt that the level of elephant crop damage on their farms had reduced within a four-year period since the electric fences were established ($\chi^2$ = 163.53, $P$ < 0.001). The perceived monetary value of elephant crop damage differed significantly between fenced and unfenced areas ($t$ = –13.506, $P$ < 0.0001). The farmers interviewed inside Kimana and Namelok fences perceived that they lost on average (±S.D.) US$10.0 ± 1.96 per acre/season worth of maize crop due to elephant damage compared to a mean (±S.D.) of US$42.79 ± 9.48 by farmers cultivating maize in Isinet, Kimana swamp and Impiron areas. Mean maize crop yield per acre pooled for the fenced and unfenced areas using local market prices was US$105 ± 44 (range US$43–232, $n$ = 32). This is equivalent to a perceived average loss in maize crop yields per acre per season of US$10.0 (7.0%) and US$43.0 (41.0%) in the fenced and the unfenced areas, respectively, because of elephant damage.

The number of farmers who reported that they guarded their crops against elephants was significantly lower inside Kimana fence (44.1%, $n$ = 75) compared with farmers who reported guarding in the unfenced farmlands of Isinet, Kimana swamp and Impiron (59.2%, $n$ = 207) ($\chi^2$ = 11.99, $P$ = 0.001). Twenty-seven per cent of farmers ($n$ = 112) inside Kimana and Namelok fence had their storage and containment structures such as granaries, water tanks and cattle enclosures destroyed by elephants compared to 40.8% ($n$ = 142) by those in Isinet, Kimana swamp and Impiron areas ($\chi^2$ = 11.30, $P$ = 0.001).

The presence of intact fence wires with electric current had a significant effect in reducing elephant breakage through the Kimana fence ($\chi^2 = 6.45$, $P = 0.011$). Elephants entered inside Kimana fence 148 times in 93 days when the fence wires had been broken. We observed that elephants at times walked up to the fence line in Namelok and other sections of Kimana fence and did not break the fence to enter the farms in the fenced areas even though the intact fence had no current. The presence of an electric current did not seem to significantly reduce elephant entry into the fenced areas ($\chi^2 = 0$, $P = 1$). In fact, elephants broke through the Kimana fence 124 times in 124 days when the fence had current and 96 times in 96 days when the fence had no current but had intact wires. Similarly, the voltage of the fence sections was not significantly correlated to the frequency of fence breaking by elephants ($r_s = 0.039$, $n = 124$, $P = 0.933$). The mean (±S.D.) voltage for Kimana and Namelok fences was 3.5 ± 3.7 kV and 2.1 ± 3.3 kV, respectively. Namelok fence had intact fence wires for the entire fence perimeter but electric current was only limited to a 100 m distance from one of the power units due to a technical fault that allegedly occurred during fence construction. Two of the four power supply units in Namelok fence had been stolen and had not been replaced for a year. In the case of Kimana fence, the entire fence perimeter had intermittent current and the fence wires were frequently broken. Whenever elephants broke Kimana fence, it took on average (±S.D.) 7 ± 1.5 days for the fence to be repaired. While Namelok fence had not been broken through by elephants, the general fence maintenance was poor as evidenced by overgrown bushes along the fence. There were only a few farmers (6; 3.9%) who felt that they were responsible for maintaining the fences as expected after the fence construction phase.

## DISCUSSION

This study shows that the presence of an electric current made no difference to the level of fence breaking by elephants. Similarly, this study did not find an inverse relationship between fence breaking and fence voltage as expected. In India, electric fences with a voltage of 5 kV were noted to produce sufficient electric shock to deter elephants from breaking fences (Sukumar 1994). An electric fence with a voltage maintained at 5.5 kV in Mwea, Kenya, has been reported to successfully deter elephants (Omondi *et al.* 2004). Similarly, Hoare (2003) noted that fences with voltage maintained at 5 kV would deter most elephants. Kimana and Namelok fences had intermittent current and a very variable voltage with a mean (±S.D.) of 3.5 ± 3.7 kV and 2.1 ± 3.3 kV, respectively. Consistently low or variable voltage has been speculated to increase the level of fence breaking by elephants exposed to fences (Thouless & Sakwa 1995). In this situation, elephants habituated to fence breaking learn to avoid electric shock by employing tusks to break electrified wires or by pushing down electric fence posts using their feet to bring down fences. It is likely that the reason we did not observe the relationship between voltage and fence breaking was because most raiding was caused by habitual raiders with the skill to break down fences while avoiding electric shock.

Elephant pressure on farming enclaves measured in terms of proximity of farms to areas with high elephant density, elephant corridors or vegetation cover has been suggested to influence the success of elephant barriers (Seidensticker 1984; Sukumar 1986; Hoare 2001). During this study, the frequency of fence breaking by elephants was higher in Kimana fence and absent in Namelok fence probably because of the proximity of Kimana fence to KS. By contrast, Namelok fence, located 3 km from ANP and 5 km from KS had no immediate area where elephants could retreat to after a farm raid. Kimana Sanctuary has an elephant density of 1.9 ± 0.96 elephants per km$^2$ compared to 0.18 ± 0.08 elephants per km$^2$ in the area that lies between KS, Kimana fence, Namelok fence and ANP (Kioko *et al.* 2006a). Kimana fence lies in the proximity of *Acacia tortilis* woodland, whereas Namelok fence has no nearby woodland. In fact the majority of fence breaking incidents in Kimana fence occurred in a section of the fence bordering *A. tortilis* woodland in KS. This woodland harboured elephants that frequently broke through the fence. This observation is supported by previous findings that the proximity of forest cover to agricultural areas is a strong predictor of heavy crop raiding by elephants (Nyhus *et al.* 2000). Woodlands provide suitable foraging areas for elephants as well as cover that may minimize detection by humans or provide shelter from the high temperatures during the day in hot areas (Kinaha *et al.* 2007). The Kimana woodland may have provided a suitable area for staging crop raids since they could retreat into the safety of the protected area (KS) where angry farmers could not harass them.

In this study, sections with intact fence wires reduced elephant entry into fenced areas compared to the fence sections that had the fence wires broken. We observed that elephants walked up to the fence line in Namelok and other sections of Kimana fence and to our surprise they did not break into the fenced farms even though the intact fence had no current. This result might explain why the level of elephant crop raiding and other forms of human–elephant conflicts was significantly lower in the fenced areas as demonstrated by the lower level of assessed crop damage in fenced compared to unfenced farms and likewise the farmers' perceptions towards the performance electric fences. This result further underlies the importance of effective non-electrified barriers as potential elephant barriers where elephant pressure is minimal.

### Implications for management

This study underscores the importance of electric fencing in mitigating human–elephant conflicts. The findings suggest that landscape factors, such as the presence of woodlands are important in determining the effectiveness of electric fences. It is therefore imperative that fences located near woodlands that provide potential cover to crop-raiding elephants or in areas of high elephant densities should be intensely managed or reinforced. Alternatively these areas should have problem animal control mechanisms in place. The fence management in terms of repairs and problem animal control efforts should focus on those stretches adjacent favourable elephant cover (Hoare, 1995).

Our results imply that effective non-electrified barriers may equally deter crop-raiding elephants in areas where elephant pressure is minimal. In Amboseli region, experimental chilli-tobacco rope cost about US$114 per km and was observed to deter elephants from crop-raiding (Kioko *et al.* 2007). However, even simple, non-electric fences need maintenance and strategic positioning with regard to elephant movement if they are to be effective at least in the short-term (Hoare 2001). Kimana and Namelok fences clearly lacked adequate maintenance as shown by the time it took for the fence to be repaired once broken by elephants. The funds potentially available from the farmers for the maintenance of Kimana and Namelok (about US$ 111 per km per annum) were lower than the expected annual estimate of US$540 based on 6% fence maintenance cost per km per annum of the fence construction cost in Laikipia district, Kenya (Thouless & Sakwa 1995). Hoare (1995) also quotes maintenance costs of community enclosure type fences in Zimbabwe to be 5% per km/annum of fence construction costs. It therefore becomes imperative to formulate a sound fence maintenance system, especially where the fences are to be managed by the local people in the long term. Hoare (2001) suggests that private sector participation is critical for the success and sustainability of fencing projects. This should be coupled with education of the local people on the importance of fence maintenance as surprisingly even though they perceived the level of elephant crop damage to have reduced, few farmers felt that they were responsible for maintenance of the fences.

## ACKNOWLEDGEMENTS

We thank Kenya Wildlife Service Elephant Program for financially supporting our work. We highly appreciate the logistical and technical support provided by the School for Field Studies and Amboseli Trust for Elephants. This manuscript was greatly improved by input from two anonymous reviewers.

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Corresponding Editor: G. Cumming