The costs of living with elephants in the areas adjacent to Marsabit National Park and Reserve

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Abstract

Crop raiding by elephants is a serious management problem around protected areas in Kenya. This is because of changes in the land use systems in these areas, with crop farming occurring in areas where it did not previously. Crop raiding by elephants was monitored in the area adjacent to Marsabit National Park and Reserve between August 2004 and July 2005 (excluding December 2004 and April 2005 due to rains). A total of 414 farms were raided, with the farmers loosing KES 15,034,610 (USD 208,814) during the period. Crop raiding was higher in August 2005 (KES 5,598,660 or USD 77,759) than in August 2004 (KES 503,960 or USD 6999). Tribal clashes in August 2005 contributed to unguarded farms and consequently elephants were presented with an opportunity to raid. The situation was peaceful in August 2004 and farmers had adequate time to guard their farms using scaring strategies to keep elephants away. There is an urgent need to revive the collapsed fence project in order to reduce the cost incurred by farmers due to elephants raiding their crops.

Résumé

L'envahissement des cultures par les éléphants est un problème sérieux de gestion des aires protégées au Kenya. Ceci est à cause des changements de systèmes de l'usage foncier dans ces régions, où les cultures existent dans les régions où elles n'existaient pas précédemment. L'envahissement des récoltes par les éléphants a été suivi dans la région adjacente au Parc/Réserve National de Marsabit entre le mois d'août 2004 et le mois de juillet 2005 (à l'exception des mois de décembre 2004 et d'avril 2005 à cause des pluies qui ont rendu les routes de la région d'étude impassables). Un total de 414 fermes a été envahi, les fermiers perdant KES 15.034.610 (USD 208.814) pendant cette période. L'envahissement des cultures était plus élevé au mois d'août 2005 (KES 5.598,660 ou USD 77.759) qu'au mois d'août 2004 (KES 503.960 ou USD 6.999,4). Les violences tribales en août 2005 ont dépouillé les fermes de leurs gardes et par conséquent ont donné aux éléphants une occasion de les envahir. C'était paisible en août 2004 et les fermiers avaient du temps adéquat pour garder leurs fermes. L'envahissement des cultures peut être minimisé si les fermiers augmentent leur vigilance sur les fermes en utilisant des stratégies effrayantes pour tenir à l'écart les éléphants. On doit urgemment raviver le projet de clôture qui s'est effondré pour réduire le coût encouru par les fermiers à cause des éléphants qui envahissent les cultures.

Introduction

Marsabit National Reserve and Forest Park is an important elephant habitat in northern Kenya. The elephant population declined from 900 individuals in 1973 to 219 individuals in 1992 due to poaching (Litoroh et al. 1994). The elephants use Marsabit Forest as a dry season refuge and disperse into the vast lowlands during the rains. A small resident herd of fewer than 30 elephants is believed to use the forest during the wet season (Litoroh et al. 1994).

A conflict between species arises if they share limited resources. Elephants and humans experience conflict over resources (water, space and forage). Human-wildlife conflicts occur when wildlife destroy crops, property and/or cause injuries and deaths (Akama et al.

1993; Kangwana 1993; Ngure 1993; Omondi 1994). Over the years, human-wildlife conflicts in Africa have been increasing due to increasing human population (Akama et al. 1993; Kangwana 1993; Ngure 1993), which has resulted in encroachment on areas which used to be occupied by wildlife, including elephants (Dublin et al. 1997; Hoare and Toit 1999). Kenya is no exception as the rapid increase of human population immediately after independence and associated changes in land use and land tenure systems have led to the loss of wildlife habitats. Crop farming in some areas has replaced nomadic pastoralism resulting in human-wildlife conflicts. In Marsabit, the elephant's range is declining due to habitat fragmentation resulting from an increase in human population and associated changes in land use and land tenure (Oroda et al. 2005). Settlements and farms are found around the Marsabit forest mountain. The human population around the forest mountain increased by 153% from 17,000 people in 1979 to 43,000 people in 2006 (Oroda et al. 2005). Accordingly, the land under crop farming increased by 700% from 3596 ha in 1973 to 30,000 ha in 2005 (Oroda et al., 2005). Additionally, land under settlement increased from 105 ha in 1973 to 409 ha in 2005, a 300% increase in 32 years (Oroda et al. 2005).

The origin of human-wildlife conflict in Kenya can be attributed to the establishment of parks and reserves as wildlife protected areas, with communities settling next to them. The establishment of protected areas was mostly realized by removing the local communities either by treaty or by force. In this way, the communities lost their land rights. In some areas like Amboseli, the government promised the pastoral communities alternative water sources and grazing fees as compensation. However, the promises were not honoured (Western 1989; Waithaka 1994). The same scenario is observed in Nairobi National Park (Akama et al. 1993), Tsavo area (Mutinda and Waithaka 1995) and Masai Mara National Reserve (Omondi 1994). During the 21st century, the explosive human population growth has heightened the need to provide food for humans. This has led to agricultural expansion into 'what is believed to be' wildlife areas, making human-wildlife conflict issues more complex, for example, in Nairobi National Park (Akama et al. 1993; Tsavo area (Mutinda and Waithaka 1995) and Masai Mara National Reserve (Omondi 1994). People forced out of their land have not been properly compensated and there are not clear revenue-sharing policies and laws, which create problems for protected areas in Kenya to deal with revenue-sharing related issues.

Elephants are known to cause severe damage to crops within the affected areas. They can destroy entire fields of crops (Barnes et al. 1995; Hillman-Smith et al.1995; Lahm 1996; Naughton-Treves 1998). As a result, many people have a more negative perception of them than of other wildlife species (Naughton-Treves 1998; Hoare 2000). It is thus important to gain a thorough understanding of the nature, extent and cost of human-elephant conflict in order to develop and direct mitigation measures.

Human-elephant conflict studies have been carried out in many areas (Hoare 1999a, 2000; Barnes et al. 1995; Bhima 1998; Parker and Osborne 2001; Sitati et al. 2003 and 2005; Nysus et al. 2000; Sukumar and Gadgil 1988; Sukumar 1989 and Smith and Kasiki 1999). All of these studies presented a detailed account of the nature of human-elephant conflicts. However, none of them quantified the monetary costs of living with elephants.

In this paper, we investigate the monetary values of crops lost due to raiding by elephants in the areas adjacent to Marsabit National Park/Reserve. We focus on the contribution of elephants to loss of revenue for communities living next to the park/reserve. The purpose is to stimulate managers and policy makers to design management options that will be geared towards either reducing crop raiding and associated revenue loss or compensating communities adequately once appropriate laws are enacted.

Materials and Methods

Study area

Marsabit National Reserve/Park is located in Marsabit District, Eastern Province, about 600 km from Nairobi and about 300 km from Isiolo town. It lies at longitude 37° 20' E and latitude 2° 20' N (Litoroh et al. 1994; Fig. 1).

The rainfall regime in Marsabit is characterized by two rainy seasons, with peaks in April and November. The annual rainfall is between 50 and 250 mm within the plains and 800 to 1000 mm in the highlands. The evaporation rate is high, at about 2400–2600 mm/year (Synott 1979). The eco-climatic zone of the forest is categorized as sub-humid and the surrounding plains fall within the very arid category (Eiden et al. 1991).

The common vegetation communities in the park/reserve are dwarf shrub-land, shrub-land, woodland, perennial grassland, evergreen to semi-deciduous bushland, and evergreen forest (Herlocker 1979). Some common tree species are *Croton megalocarpus*, *Strombosia*

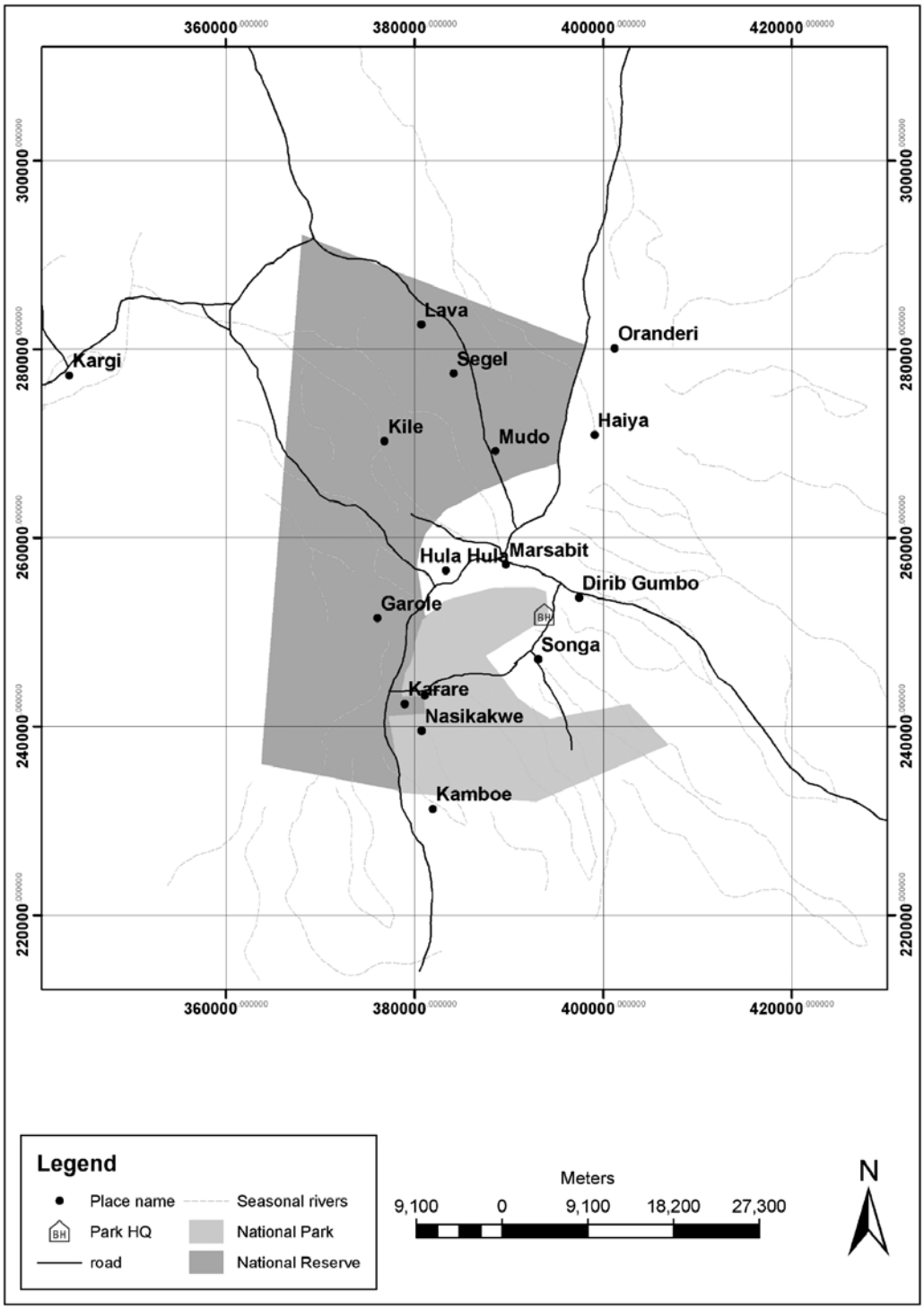

Figure 1. Location of Marsabit National Park and Reserve and its adjacent area.

scheffler, *Diospyros abyssinica*, *Olea africana* and *Olea capensis* (Schwartz 1991). The common shrubs include *Techlea nobilis*, *Pyrathus sepialis*, *Bauhinia tomentosa*, and *Rinorea* spp. (Mclaughlin et al. 1973)

Common fauna include elephants (*Loxodonta africana africana*), greater kudu (*Tragelaphus strepsiceros*), buffalo (*Syncerus caffer*), bushbuck (*Tragelaphus scriptus*), common duiker (*Sylvicapra grimmia*), warthog (*Phacochoerus aethiopicus*), olive baboon (*Papio anubis*), vervet and Syke's monkey (*Cercopithecus aethiops* and *Cercopithecus mitis*), lion (*Panthera leo*) and leopard (*Panthera pardus*) (Mclaughlin et al. 1973).

The local inhabitants are Rendile, Gabbra and Boran pastoralists and Burji crop farmers. The Burji settled in the area as refugees from Ethiopia in the early 1980s, but are now recognized as settlers by the Kenya government (Litoroh et al. 1994). They introduced crop farming and a sedentary lifestyle to the local nomadic pastoralists, and sedentary agriculture is now gaining popularity among the pastoral groups in the area. Increased formal education and cultural erosion among the pastoralists is also forcing them to adopt crop farming and sedentary lifestyles as a form of land use since they no longer have the time and do not see the need to lead a nomadic lifestyle. As a result, people have now settled in Badassa, Drib Gombo, Songa, Kituruni and Karare and are practising crop farming. These areas have soils suitable for agriculture and receive sufficient rainfall enabling the cultivation of maize, bananas and other fruits and vegetables.

Data collection and analysis

Data was collected from the occurrence book as described by Kangwana (1996) and Waithaka (1999). In this study, information on farms raided by elephants was obtained from the occurrence book of the Kenya Wildlife Service (KWS), Marsabit Station. Other procedures of collecting human-elephant conflict data were used as described in Kangwana (1996) and Hoare (1999b). Names of individuals who reported the cases were obtained and visited. They later identified other farms that had been raided within their area. In-depth monitoring of farmlands concentrated on collecting the data on crop-raiding incidences and property destruction by elephants including associated costs. During farm visits, the data collected included: data/time when elephants visited farms and destroyed crops/property, number of elephants involved, crops completely destroyed, crops partially destroyed, time when elephants left, how long they stayed on the farm and any other property they destroyed (Kangwana 1996).

To establish the cost of crops destroyed, different approaches were used for different crops. For maize, beans and wheat, the area was measured and, based on information from the Ministry of Agriculture, crop yields (in terms of sacks per acre) were estimated. For paw paws, guavas and bananas, individual fruits were counted, and based on information from the Ministry of Agriculture, costs were established based on market values in Marsabit town. If the fruit tree was wholly or partially destroyed, we used another intact fruit tree of the same size as a proxy and counted the number of fruits and estimated

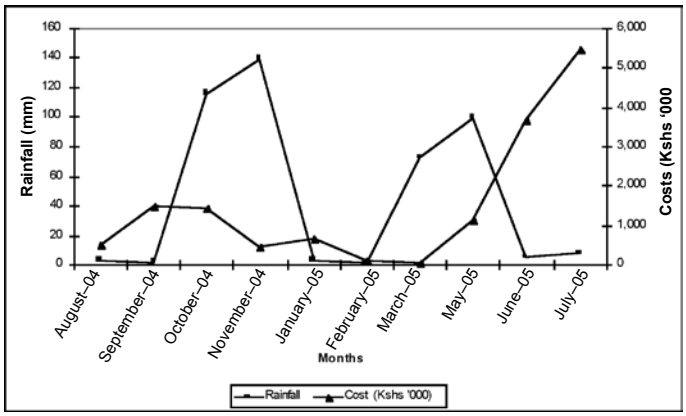

Figure 2. The relationship between rainfall and costs of losses incurred because of crop raiding by elephants in the area adjacent to Marsabit National Park and Reserve (source of rainfall data: KWS, Marsabit Station).

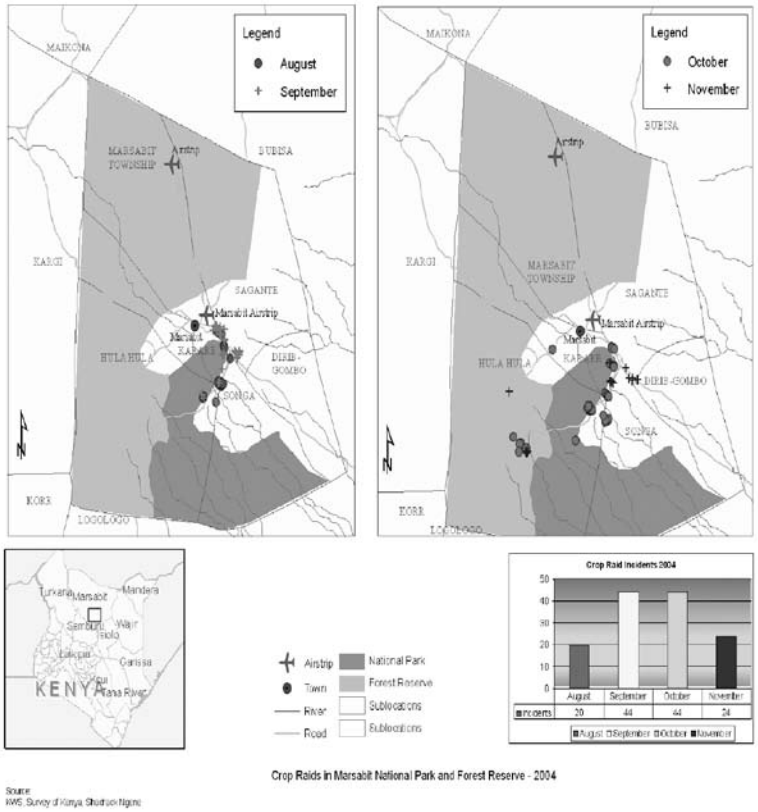

Figure 3a. Number of farms raided August–November 2004

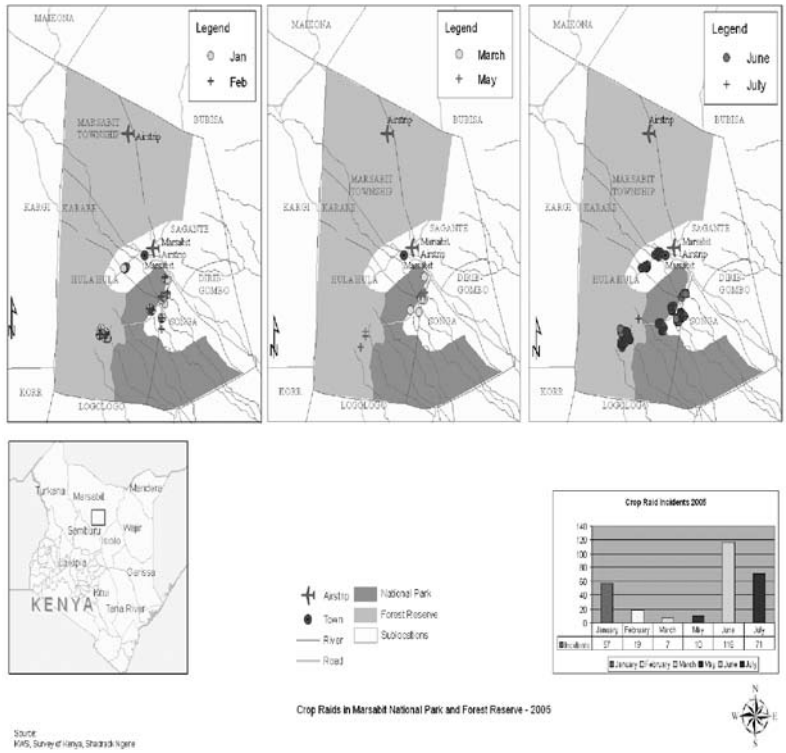

Figure 3b. Number of farms raided January–July 2005 (excluding April 2005).

Table 1. Cost of different crops destroyed by elephants (August 2004 to July 2005)

Type of crop	Aug '04	Sep '04	Oct '04	Nov '04	Jan '05	Feb '05	Mar '05	May '05	Jun '05	Jul '05	Total (KES)
Sugar cane (no.)	6000	7,350	0	0	0	0	0	0	0	0	13,350
Tomato (kgs)	200	500	525	0	16,000	0	0	0	0	0	17,225
Pigeon peas (kags)	23,400	130,500	45,000	0	4500	0	0	0		256,500	459,900
Mangoes (bags)	39,900	597,825	276,750	37,500	6000	0	0	43,500	156,000	162,000	1,319,475
Sukuma (bundles)	6000	0	2000	0	0	0	0	0	4000	3260	15,260
Banana (no.)	94,500	474,000	322,500	1500	28,500	42,000	12,000	18,000	103,500	126,000	1,222,500
Maize (bags)	160,500	0	0	50,400	322,125	22,050	0	166,500	1,295,250	2,188,500	4,205,325
Gruveria (no.)	2000	0	17,000	63,000	3000		0	0	0	0	85,000
Oranges (bags)	25,000	33,750	1500	25,000	0	0	0	3375	0	3000	91,625
Miraa (kgs)	104,600	73,000	99,600	1200	68,000	15,000	32,400	241,600	32,400	98,000	667,800
Shalkeda (bundles)	1070	11,160	34,860	630	800	50	0	0	6000	2000	56,570
Tuff (kgs)	250	0		5000	0	0	0	0	4500	300	10,050
Fodder plant (bundles)	18,000	98,800	527,800	65,500	112,000	2200	0	0	0	0	824,300
Avocado (no.)	40	9690	1000		0	2000	0	1000	1800	6000	21,530
Paw Paw (no.)	9600	54,750	112,200	0	4200	1500	0	93,000	11,490	81,540	368,280
W. supporter (bundles)	3600	10,000	0	0	0	0	0	0	0	0	13,600
Napier grass (bundles)	2000	0	1000	0	500	0	0	0	0	0	3500
Cassava	0	1500	500	0	0	0	0	0	0	7200	9200
Honey (L)	0	4000	0	0	0	0	0	0	0	0	4000
Fence destruction	4300	3500	2890	8600	0	0	600	0	0	0	19,890
Guava (bags)	3000	2500	700	0	0	12,000	0	0	500	1000	19,700
Beans (kgs)	0	0	0	230,400	96,750	0	0	549,000	1,652,625	2,164,500	4,693,275
Sweet potatoes (kgs)	0	0	0	0	4500	0	0	7500	91,500	242,505	346,005
Sorgum (bags)	0	0	0	0	0	0	0	0	1000	12,000	13,000
Potatoes (bags)	0	0	0	0	0	0	0	0	61,500	64,500	126,000
Wheat (bags)	0	0	0	0	0	0	0	22,500	105,750	81,000	209,250
Ground nuts (kgs)	0	0	0	0	0	0	0	0	125,000	74,000	199,000
Total	503,960	1,512,825	1,445,825	488,730	666,875	96,800	45,000	1,145,975	3,652,815	5,475,805	15,034,610

their cost, as advised by the Ministry of Agriculture. The farmers helped us to identify the proxy fruit trees. The cost of mangoes lost was based on estimates of yield for a tree, which we extrapolated to estimate the losses and costs based on the percentage of mango trees destroyed. The cost of miraa was obtained by estimating the number of kilograms lost by portion of plant destroyed. Also, discussions were held with individual farmers and other experienced old farmers to establish whether the values obtained were reasonable. To ensure that data on crops lost were the result of elephant raids, the presence of elephants on the farms was verified by locating elephant footprints and dung. Further verification was undertaken from the crops destroyed as described by Kangwana (1996) as elephants feed on crops in a unique and conspicuous manner. In farms that lacked evidence of elephant presence, further data collection was discontinued. A chi-square test was performed to establish whether the observed and expected costs due to crop raiding by elephants differed significantly.

Rainfall data was acquired from the KWS Marsabit Station's rainfall database. The rainfall data was categorized into three classes, which included less than 50 mm (dry months), 50–100 mm (intermediate months), and over 100 mm (wet months).

All the farms that had crop-raiding incidences were geo-referenced and the information mapped using ARC-GIS 9.1 GIS software to produce crop-raiding distribution maps. The raw data was organized into corresponding row x column contingency tables. SPSS computer software was used to analyze the data for chi-square analysis and Microsoft Excel for calculation of percentages. Calculations of the chi-square test were used as described and explained in Zar (1984). From the raw data, chi-square analysis was performed to test whether the observed crops lost due to elephant raiding differed significantly from the expected values and this was compared for different months. Descriptive statistics (percentages) were computed from the raw data to guide the interpretations of the chi-square values. A 99%; 0.01 confidence limit was used.

Table 2. A comparison of crops destroyed by elephants in the Marsabit Forest environs (August 2004 and August 2005)

Type of crop	August 2004		August 2005	
	Quantity	Costs (KES)	Quantity	Costs (KES)
Sugar cane (no.)	240	6,000	100	2,500
Tomato (kgs)	4	200	100	5000
Pigeon peas (bags)	5.2	23,400	5	22,500
Mangoes (bags)	26.6	39,900	231	187,500
Sukuma (bundles)	600	6000	100	1000
Banana (no.)	63	94,500	974	1,461,000
Maize (bags)	107	160,500	843	1,264,500
Gruveria (no.)	2	2000	0	0
Oranges (bags)	5	25,000	14	69,000
Miraa (kgs)	523	104,600	843	168,600
Shalkeda (bundles)	107	1070	1024	10,240
Tuff (kgs)	5	250	720	36,000
Fodder plant (bundles)	90	18,000	3146	629,200
Avocado (no.)	4	40	462	4620
Paw Paw (no.)	320	9600	3406	507,180
W. supporter (bundles)	72	3600	1201	60,050
Napier grass (bundles)	20	2000	0	0
Cassava	0	0	183	25,000
Wheat (bags)	0	0	10	45,000
Fence destruction	-	4300	0	0
Guava (bags.)	3	3000	0	0
Pumpkins (no.)	0	0	30	1500
Irish potatoes (bags)	0	0	1	1500
Ground nuts (bags)	0	0	14	53,100)
Lemon (bags)	0	0	10.5	5250
Beans (kgs)	0	0	238.56	1,073,520
Sweet potatoes (kgs)	0	0	12	18,000
Total		503,960		5,598,660

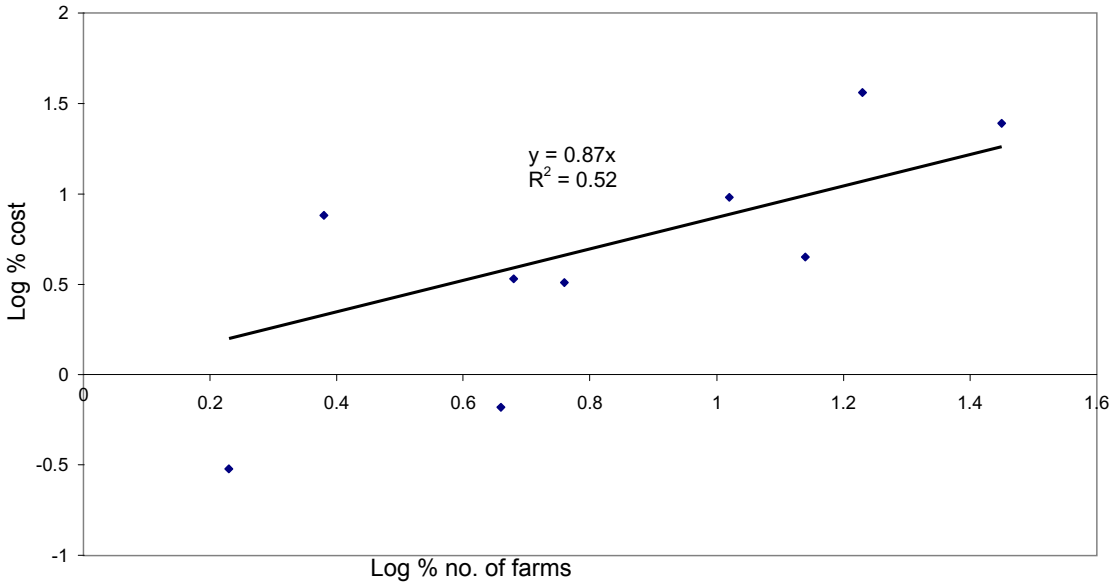

Figure 4. Log % number of farms raided verses log % costs of crop raids by elephants (August 2004–July 2005).

Results

Rainfall and cost of crop raiding

During the drier months (<50 mm rainfall) the cost of living with elephants was higher than during the wet months (>100 mm rainfall; X^2=95; P<0.01; fig 2). The dry months (<50 mm rainfall) were January, February, August, and September, whereas the intermediate (50–100 mm rainfall) and wet (>100 mm rainfall) months were March to May and October to November. A higher number of farms were raided during the dry months (<50 mm rainfall) than during the intermediate (50–100 mm rainfall) and wet (>100 mm rainfall) months (X^2=406; P< 0.01).

Number of farms raided

A total of 414 farms were raided between August 2004 and July 2005 (results exclude data for December 2004 and April 2005 due to rains, which made it impossible to drive around the study area). The percentage of farms raided during the period was 4.8% (n=20), 10.6% (n=44), 10.6% (n=44), 5.8% (n=24) respectively; and 13.8% (n=57), 4.6% (n=19), 1.7% (n=7), 2.4% (n=10), 28.5% (n=118), and 17.1% (n=71; Fig. 3a and 3b). The percentage of farms raided each month was significantly different (X^2=60.87; df=9; p< 0.01). The highest and lowest number of farms raided was in June 2005 and March 2005 respectively (Figures 3a and 3b).

Costs of losses due to crop raiding

Between August 2004 and July 2005, the community surrounding Marsabit National Park and Reserve lost KES 15,034,610 (USD 208,814) as a result of crop raiding by elephants (Table 1). The crops raided most and which had the highest contribution to the total loss were beans (31.22%), maize (28%), mangoes (8.78%), bananas (8.1%), fodder plants (5.48%), miraa (4.44%), pigeon peas (3.06%), paw paws (2.45%), and sweet potatoes (2.3%).

There was a significant difference in the percentage of monthly losses due to elephant crop raids (X^2=121; df=9; p< 0.01). The highest losses of 24.30% (n= KES 3,652,815 or USD 50,733.5) and 36.42% (n = KES 5,475,805 or USD 76,052.8) respectively were recorded between June and July 2005. The months which experienced low losses were August 2004 (3.35%), September 2004 (10.06%), and October 2004 (9.62%), November 2004 (3.25%), January 2005 (4.44%), and May 2005 (7.62%). The lowest losses were experienced during the months of February and March 2005 (0.64% and 0.3% respectively).

Monthly data on the number of farms raided and costs incurred due to the raids were compared (Fig. 4). There was a moderate correlation between the log percentage number of farms raided and log percentage costs of crops destroyed (R^2=0.51). Crop raiding by elephants in August 2004 and August 2005 were compared (Table 2). The raiding was higher in August 2005 (KES 5,598,660 or USD 77,759) than in August 2004 (KES 503,960 or USD 6999.4).

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Discussion

This study indicates that crop raiding in Marsabit takes place throughout the year with the greatest losses generally taking place during the January–March and May–July periods. These are the periods during which elephants disperse into the forest or are near the farmed settlement areas. These periods coincide with maize and beans' growth and maturation as these crops are planted twice a year. The variation of costs resulting from crop raiding by elephants and the number of farms raided shows that it does not automatically mean that if many farms are raided, the costs incurred will be high that month. Factors such as the type of crops raided, community vigilance, and extent

of destruction during a visit may influence the costs associated with crop raiding during specific months. Additionally, the total number of farms raided by elephants (79%) was high during the drier months (<50 mm rainfall), making these months show the highest total cost due to crop raiding by elephants. It implies that the observed number of farms raided was high when rainfall was low. Our results contradict those of Kioko et al. (2006), who reported that crop raiding incidents by elephants in Amboseli were insignificantly related to rainfall. In Marsabit, during the drier months, elephants diurnally move to and from the Marsabit mountain forest to the lowland shrub-lands passing farms and therefore crop raiding takes place.

Due to increased insecurity resulting from tribal clashes between May and August 2005, farms were left unattended and elephants were moving freely within farms destroying crops, which resulted in high costs due to elephants' crop raiding. This period coincided with the time the elephants were inside the forest and the ripening of the crops (especially maize, beans and pigeon peas). However, it was peaceful in August 2004 and farmers had adequate time to guard their farms and therefore the costs of losses resulting from crop raiding by elephants were low. These observations indicated that the guarding of farms by farmers reduces crop-raiding incidences as reported by Caitlin et al. (2000); Nysus et al. (2000), and Sitati (2003 and 2005). Comparison of data for August 2004 and August 2005, with the former being peaceful and latter period not peaceful (due to the tribal clashes between May and August 2005) shows the importance of community vigilance in reducing crop raiding by elephants.

Different crops are raided during different months. The Marsabit elephants use the forest as a dry season refuge and disperse into the vast lowlands during the rains but a small resident herd is believed to utilize the forest during the wet season (Litoroh et al. 1994). This resident population stays in the bush-land surrounding the forest and makes random visits to farms during the rainy season (pers. obs.). The extent of migration of the elephants during the rainy season depends on the amount of rainfall and its distribution. During periods of low and unevenly distributed rainfall, elephants have been observed to remain close to the forest and not to go beyond Logologo or Gudas, a distance of about 20–30 km from the east and south of the forest edge. The elephants move to and from the forest edge and in the process raid farms in Karare, Hula Hula, Songa, Kituruni, Badasa, Dirib-Gombo, and Gabbra Scheme.

Herds of elephants are normally expected back in the forest from January to February and from June to July each year. These are the periods when most of the water sources away from the forest dry up and also the quality of browse and grazing decreases. Additionally, this coincides with the ripening of maize and beans, during which period elephants invade farms, resulting in high losses of crops.

The observed pattern of crop raiding during the year shows that once the beans and maize harvesting is over, farmers living next to the forest stop being vigilant. This allows elephants to move freely within farms near the forest and further from the forest, where they raid other crops like miraa, bananas and paw paws. Miraa and bananas are raided the whole year, perhaps because they remain green throughout the year. For probably the same reason, a considerable amount of destruction is caused to mango and avocado trees, *shalkeda*, fodder plants and sweet potatoes. This destruction is greater during the period preceding the rains.

Conclusions

When crops are unguarded, elephants are partly responsible for revenue loss to the Marsabit community due to crop raiding. To address the losses incurred, there is a need to develop long- and short-term mitigation strategies on human-elephant conflicts in Marsabit. The community needs to be encouraged to be vigilant throughout the year to minimize losses. However, there are additional indirect costs incurred due to people spending sleepless nights guarding their crops from raids by elephants and other wildlife. In extreme cases, children are unable to attend school because their parents require assistance in chasing away or scaring off elephants and other wildlife from their farms or because the routes to school become too dangerous due to the presence of elephants. Our study did not include the indirect costs incurred by living with elephants. Therefore, if such indirect costs were included in the analysis, the cost of living with elephants would be even higher.

Recommendations

The following actions are recommended:

- A community-based elephant raids reporting strategy using community scouts should be established. This will create employment for a few locals and will provide additional data to give a wider picture of the problem. The scouts could be part of the KWS field research assistants.
- Construction of the Marsabit Fence, which had been designed to fence off villages rather than the forest itself, should be revived. Wind power could be a source of electricity to operate the fence since the area is windy and has hills that could house the equipment.
- There is need to build the capacity of the community members to make them responsible for maintaining the fence. A fence maintenance fund needs to be established and mechanisms for its administration agreed upon. It was noted that failure of the fence erected by the Food for the Hungry was partly due to lack of funds to maintain it.
- In the near future, compensation for crop raiding will start and there is a need to put in place measures to minimize human-wildlife conflicts.
- Further comparative research on the total cost (direct and indirect) of living with elephants and other wildlife in the area adjacent to Marsabit National Park and Reserve is required.

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References

Akama J.S., Lant CL, Burnett GW. 1995. Conflicting attitude towards state wildlife conservation programs in Kenya. *Society & Natural Resources* 8:133–144.

Barnes R.F.W., Azika S., Asamoah-Boateng B. 1995. Timber, cocoa, and crop-raiding elephants: A preliminary study from Southern Ghana. *Pachyderm* 19:33–38.

Caitlin E.O., Rodwell T., Rice M., Hart A.H. 2000. Living with the modern conservation paradigm: can agricultural communities co-exist with elephants? A five-year case study in East Caprivi, Namibia. *Biological Conservation* 93:381–391.

Dublin H.T., McShane T.O., Newby J. 1997. *Conserving Africa's Elephants: Current Issues and Priorities for Action*. WWF, Gland, Switzerland.

Eiden A., Keith G., and Jonnes M. 1991. large scale monitoring of rangelands vegetation using NOAA/11 AVHRR LAC data. *Range management handbook of Kenya* Vol. III, Part IV. Ministry of livestock, Nairobi, Kenya.

Hillman-Smith A.K.K., De Merode E., Nicholas A., Buls B., Ndey A. 1995. Factors affecting elephant distribution at Garamba National Park and surrounding reserves, Zaire, with a focus on human elephant conflict. *Pachyderm* 19:39–48.

Hoare R.E., du Toit J. 1999. Coexistence between people and elephants in African Savannas. Conservation Biology, 13: 633-639

Hoare R.E. 1999a. Assessing the evidence for the existence of habitual problem elephants. Pages 1–2. IUCN African Elephant Specialist Group Report, Nairobi, Kenya.

Hoare R.E. 1999b. A standardized data collection and analysis protocol for human-elephant conflict situation in Africa. IUCN African Elephant Specialist Group Report, Nairobi, Kenya.

Hoare R.E. 2000. African elephants and humans in conflict: the outlook for co-existence. *Oryx* 34:34–38.

Kangwana K., ed. 1996. *Assessing the impact of human-elephant interactions. Studying elephants*. African Wildlife Foundation, Nairobi, Kenya.

Kangwana K. 1993. Elephants and Maasai: Conflicts and conservation. Unpublished PhD. thesis, Cambridge University, Cambridge, United Kingdom.

Kioko J., Kiringe J., Omondi P. 2006. Human-wildlife conflict outlook in the Tsavo-Amboseli ecosystem, Kenya. *Pachyderm* 41:53–60.

Lahm S.A. 1996. A nation–wide survey of crop raiding by elephants and other species in Gabon. *Pachyderm* 21:69–77.

Litoroh M., Nicholas A., Masinde P. 1994. A survey of the Marsabit National Reserve elephants and large mammal population. A KWS report, Nairobi, Kenya.

McLaughlin J.S., Dougherty DG, McLaughlin EC. 1973. A conceptual master plan for Marsabit National Reserve. A National Parks of Kenya Report, Nairobi, Kenya.

Mutinda H., Waithaka J. 1995. The elephant-human conflicts in some areas around Tsavo ecosystem. Unpublished KWS report, Nairobi, Kenya.

Naughton-Treves L. 1998. Predicting patterns of crop damage by wildlife around Kibale National Park, Uganda. *Conservation Biology* 12:156–168.

Ngure N. 1993. History of present status of human–elephant conflicts in Mwatate-Bura area, Kenya. MSc thesis, University of Nairobi, Kenya.

Nyhus P.J., Tilson R., Sumianto M. 2000. Cropraiding elephants and conservation implications at Way Kambas National Park, Sumatra, Indonesia. *Oryx* 34:262–274.

Omondi P. 1994. Wildlife-human conflicts in Kenya: Integrating wildlife conservation with human needs in the Mara region. PhD thesis, Mcgill University, Montreal, Canada.

Oroda A.S.K., Olukoye, G.A., Koske, J., Lambrechts, C., 2005. The impact of land sub-division and sedentarization on the land cover dynamics in Mt. Marsabit area, Kenya. Marsabit Forest Project: UNEP/AGREF Technical Report, UNEP, Gigiri, Nairobi.

Parker G.E., Osborne F.V. 2001. Dual-season crop damage by elephants in Eastern Zambezi Valley, Zimbabwe. *Pachyderm* 30:49–56.

Schwartz H.J. 1991. Marsabit District. *Range management handbook of Kenya* Vol. II part I. Ministry of livestock development, Nairobi, Kenya.

Sitati N.W., Walpole M.J., Smith R.J., Leader-Williams, N. 2003. Predicting spatial aspects of human–elephant conflict. *Journal of Applied Ecology* 40:667–677

Sitati N.W., Walpole M.J., Leader-Williams, N. 2005. Factors affecting susceptibility of farms to crop raiding by elephants: Using a predictive model to mitigate conflict. *Journal of Applied Ecology* 42:1175–1182.

Smith R.J., Kasiki S. 1999. *A Spatial Analysis of Human–Elephant Conflict in the Tsavo Ecosystem, Kenya.* AfESG Report. IUCN/SSC, Gland, Switzerland.

Sukumar R. 1989. *The Asian Elephant: Ecology and Management*. Cambridge University Press, Cambridge, UK.

Sukumar R., Gadgil M. 1988. Male-female differences in foraging on crops by Asian elephants. *Animal Behaviour* 36:1232–1235.

Synott T.J. 1979. Impact of human activities and land practices on grazing lands. IPAL technical report D-2. UNEP-MAB integrated project for arid lands, UNESCO, Nairobi, Kenya.

Waithaka J.M. 1999. Monitoring human-elephant conflicts through remotely located stations. *Pachyderm* 27:66–69.

Waithaka J.M. 1994. The ecological role of elephants in restructuring plants and animal communities in different eco-climatic zones in Kenya and their impact on land-use practices. PhD thesis, Kenyatta University, Nairobi, Kenya.

Western D. 1989. Why manage nature? *Conservation for the 21st century* (Western D. and M.C. Pearl eds.) New York: Oxford University Press.

Zar H.J. 1984. Biostatistical analysis. Printice-Hall International Inc, USA.