ASSESSMENT OF HUMAN-ELEPHANT CONFLICTS IN AREAS ADJACENT TO GRUMETI-IKORONGO GAME RESERVES, NORTHERN TANZANIA

BY

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ABSTRACT

Twelve villages adjacent to the Grumeti-Ikorongo Game Reserves (GIGRs) and part of the Serengeti National Park (SENAPA) in Bunda and Serengeti districts were selected to assess human elephant conflicts (HEC) from 2006 - 2009. The study aimed to identify the type of conflicts, determine the magnitude, spatial and temporal patterns of HEC incidences, and the effectiveness of the mitigation methods applied. Arc GIS (9.3v) was used to analyze spatial data. Statistical Package for Social Science (SPSS) was used to analyze the magnitude, temporal patterns, type of conflicts and the effectiveness of the mitigation methods. Regression analysis was carried out to illustrate crop raiding based on distance of villages from the protected area boundaries. Results showed that elephant crop damage constituted about 89% of all conflicts while human, elephant and livestock kill including damage of water structures and human interference accounted for 11%. Temporal trends indicated two peaks of elephant crop damage incidences, the highest peak started from April to June and the lowest from September to October. The spatial distribution of crop raiding incidences showed a series of clumped conflict zones confined in a narrow band of villages adjacent to the GIGRs and SENAPA boundaries. The magnitudes of crop damages were not similar across the villages as they were influenced by distance between the centre of the villages and the protected areas boundaries ($r = - 0.84$, $p < 0.001$). The overall level of crop damages was of medium category (44%). About 45% of the farmers used ineffective traditional methods to deter elephants while 48% of them did not deploy any method and 7% used a chilli method that showed effective deterrent results. The study recommended for upscalling the chilli method in order to reduce HEC to tolerable level.

DECLARATION

I, **LUCAS THOMAS MALUGU**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work and has neither been submitted nor being concurrently submitted for degree award in any other Institution.

…….. ……

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The above declaration is confirmed

…….. …….

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(Supervisor)

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Prof. D. G. Mpanduji Date

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DEDICATION

This work is dedicated to my parents and family. My father the late Thomas Mabula Lugi and mother Martha Kulwa who laid the foundation of my education. My wife

Elizabeth Sylivester Malugu, daughters Yustina and Anna, sons Thomas and Efraim who missed me while I was undertaking this study. Thank you for your patience, encouragement and prayers.

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LIST OF ABBREVIATIONS AND ACRONYMS

AfESG	African Elephant Specialist Group
CITES	Convention on International Trade in Endangered Species of Flora and Fauna
FFI	Flora and Fauna International
GGR	Grumeti Game Reserve
GIGR	Grumeti and Ikorongo Game Reserves
GIS	Global Information System
GPS	Geographical Positioning System
H	Hour
ha	Hectare
HEC	Human Elephant Conflict
IGR	Ikorongo Game Reserve
IUCN	International Union for Conservation of Nature
km	Kilometer
LGCA	Loliondo Game Controlled Area
MGR	Maswa Game Reserve
MNRT	Ministry of Natural Resources and Tourism
SENAPA	Serengeti National Park
SNAL	Sokoine National Agricultural Library
SPSS	Statistical Package for Social Science
SWRC	Serengeti Wildlife Research Centre
TANAPA	Tanzania National Parks
TAWIRI	Tanzania Wildlife Research Institute

URT	United Republic of Tanzania
UTM	Universal Transverse Mercator

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Human elephant conflicts (HEC) in particular the problem of crop raiding is arguably one of the crucial challenges in Africa for the conservation of the African elephants (*Loxodonta africana),* as well as threatening local communities livelihood settled on the adjacent land of many protected areas (Hoare, 2000; Sitati *et al.*, 2007; Tim *et al*., 2008). Typically, HEC occurs outside the protected areas, where the ranges of peoples and elephants overlap. For example, in the African continent, 70% of the African elephant range occurs outside protected areas (Blanc *et al.,* 2005), thus making HEC inevitable. Presently, elephant numbers appear to increase in some areas and so do their ranges (Blanc *et al.,* 2005) as well as the HEC and consequently the people's livelihood affected (Hoare and du Toit, 1999; Sitati *et al.*, 2003).

In Tanzania, HEC is also severe in many places bordering protected areas. In the northwestern part of Serengeti ecosystem, HEC has intensified in the past 4 - 5 years, particularly affecting communities settled on the adjacent land of the Grumeti Game Reserve (GGR), Ikorongo Game Reserve (IGR) and a small portion of Serengeti National Park (SENAPA), probably attributed by the recent increase in elephant population across the Serengeti ecosystem (Walpole *et al.*, 2004).

Like in many other parts of Africa, communities do report conflicts attributed to elephants over crops, property damages and the threats posed to human life as significant costs of living adjacent to protected areas, where crop damage is often the

major cause of conflicts (Newmark *et al.,* 1994). In Bunda and Serengeti districts, elephant crop raiding is a relatively recent phenomenon which appeared to reach epidemic proportions in 2004 (Walpole *et al.,* 2004). Since 2004 data on crop raiding by elephants have been collected at both village and district levels. For example, in Serengeti district, local communities apparently reported, a total of 323 ha (732tonnes) of damaged crops by elephants in the 2003/04 season (Bitala, 2004). Most reports of elephant crop losses are based on surveys of local peoples' perception of the problem and its impacts. It is recognized that the perceived and actual costs of such conflicts do not always match (Masunzu *et al.,* 1998; Gillingham and Lee, 2003). This presents a failure to point out the actual magnitude of the problem and the appropriate intervention to wildlife management authorities faced by the demand of local communities for problem animal control (Baldus, 1991; Gillingham and Lee, 1999).

HEC is more frequently reported and less easily tolerated than conflict with other wildlife species (Sitati *et al.*, 2003). This is due to the danger that elephants pose to people and the catastrophic damage that they can inflict particularly on crops. However, studies on HEC around protected areas elsewhere in Sub-Saharan Africa, have also shown the tendency of local people to over report the incidences and impacts (Naughton-Treves, 1997; Gillingham and Lee, 2003). Bitala (2004) reported that, people's estimates of the areas of crop farms damaged by elephants were inaccurate in the Serengeti district. To many local farmers, an area of 0.40 ha is an area of land that takes two days to plough by oxen, thus measured more broadly in time rather than space. This becomes more difficult to accurately estimate the size of

cultivated damaged farms, which may not always reflect the loss of yield (Walpole *et al*., 2004). The limitations in the methods and uniformity of HEC data collected across the districts are therefore evident. Data which rely on farmers' report of crop raids quite often overestimate the losses. Equally, the nature of the records taken by each village differs and contains no spatial or temporal information.

Effective mitigation of HEC is therefore essential element of several efforts to conserve elephants and improve local communities' livelihood (Hedges and Gunaryadi, 2009). However, effective mitigation requires well-tested and cost effective strategies, which in turn rely on accurate baseline information regarding the magnitude, spatial and temporal patterns of elephant incidences and an understanding of causal factors (Sitati *et al.,* 2007).

1.2 Problem Statement and Justification

Human-elephant conflicts, particularly crop raiding is a perennial conservation problem that appears to be increasing wherever elephant range overlaps with human settlement and cultivated areas (Newmark *et al.*,1994; Hoare, 2000; Walpole *et al*., 2004). Changes in the sizes of human and elephant populations, and lack of land use patterns, have increased the competition between humans and elephants for spaces and resources (Newmark *et al.,* 1994; Hoare and du Toit, 1999).

In areas adjacent to the Grumeti-Ikorongo Game Reserves (GIGRs), rapid human population growth (Tomas *et al.,* 2004) coupled with increased human activities in the adjacent land to the protected areas (Kaltenborn *et al.,* 2003), the increase in

number of elephants in the GIGRs (Goodman, 2003; TAWIRI, 2002) and the change of conservation practise of GIGRs from hunting to conservation concession has resulted into increased HEC in the area (Walpole *et al.,* 2004).

This highlighted the need for an accurate assessment of crop damages to determine the extent, spatial and temporal patterns of HEC in the study area. Scientifically collected HEC information to cover all dimensions (namely the extent, spatial and temporal patterns) is a vital pre-requisite for the management authorities to find better solutions to mitigate the problem.

The present study aimed to provide quantitative data on the extent, spatial and temporal patterns of HEC incidences in the villages adjacent the GIGRs and a small portion of SENAPA. The spatial and temporal trends are often vital prerequisites for effective management of HEC as it tells which areas are of high conflict and when the incidents intensify for immediate attention. Generally the study contributes to scientific knowledge and the information may be used by other stakeholders including policy makers, wildlife managers, researchers and scholars.

1.3. Objectives

1.3.1. General objective

The overall objective was to investigate human-elephant conflicts in areas adjacent to Grumeti-Ikorongo Game Reserves, northern Tanzania.

1. 3.2. Specific objectives

i. To identify and determine the patterns of HEC incidences in areas adjacent to GIGRs over the past four years (2006 - 2009).

ii. To determine the extent of damage caused by elephants to local communities living adjacent to GIGRs over the past four years (2006 - 2009).

iii. To identify the type of crops mostly damaged by elephants.

iv. To examine the effectiveness of the methods used to deter elephants from damaging crops and other properties.

1.3.3 Research questions

i. Which types of conflicts are mostly caused by elephants?

ii. What are the spatial and temporal patterns of human-elephant conflict incidents in the study area?

iii. What are the extents of damage caused by elephants to local communities in the study area?

iv. Which crops are mostly damaged by elephants in the study area?

v. What are the existing mitigation methods and their effectiveness to deter elephants?

1.3.4 Research hypothesis

Null hypothesis

The patterns and extents of human-elephant conflict incidences in areas adjacent to GIGRs are similar.

Alternative hypothesis

The patterns and extents of human-elephant conflict incidences in areas adjacent to GIGRs are not similar.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Elephant Population Trend

The recent elephant population estimates in Tanzania is estimated to 109 168 ± 6223 elephants counted from different ecosystems including the Serengeti ecosystem (TAWIRI, 2009). Historically, old census reports indicate the population of elephants in the Serengeti ecosystem to have increased from 500 individuals in 1961 to over 2500 in the late 1970s (Dublin and Douglas-Hamilton, 1987). However, the number dropped drastically to some 500 individuals by 1986 as the result of severe poaching. During that time, about 1500 elephants were illegally killed in SENAPA alone with about 500 individuals escaping to Maasai Mara National Reserve in Kenya which by then was heavily protected (Dublin and Douglas-Hamilton, 1987; Dublin, 1995). However, elephant population appeared to increase again and the number was estimated to be more than 2000 individuals by the late 1998. Later the population remained stable totalling 2500 individuals. The recent elephant population census estimates a total of 3068 individuals in Serengeti ecosystem (TAWIRI, 2003; 2006; 2009). The changes in elephant populations are possibly a result of both birth and immigrations of elephants from neighbouring ecosystems.

2.2 Elephant Distribution

Elephant has been observed to adapt to a wide range of habitats in tropical, sub-tropical, temperate, and desert areas (Parker *et al.,* 2007). Elephants can utilize similar habitats with human being, occupying areas with relatively adequate amount

of rainfall and soil fertility (Parker *et al.,* 2007). Their distribution is influenced by availability of water, shade, and feeds.

In the Serengeti ecosystem, elephant distribution appeared to be concentrated in the central, north and southern parts of SENAPA (Walpole *et al.*, 2004). However, in the mid 1990, some expansion was observed to the eastern areas of Loliondo Game Controlled Area (LGCA). By the year 2000 further expansion of elephant population was noted to the northwest part of the ecosystem. Population survey and monitoring activities conducted by the Grumeti Reserve Company has demonstrated the presence of resident elephants in both the GGR and IGR where significant numbers of elephants were observed along the woodlands of Grumeti and Robana rivers (Goodman, 2003). Elephant distribution monitoring program which started in 2003 reported a wider utilization of habitats within and adjacent to the unprotected landscape outside the two game reserves (Fig. 1).

Figure 1: Distribution of elephant sighting in and around GIGRs. (a) September – October 2003 (b) November - April 2003/04 in Grumeti and Ikorongo Game Reserve (Source: Walpole *et al.*, 2004)

2.3 Elephant Behaviour in HEC Situations

The African elephant herd composition includes bulls, cows and calves. Females usually remain in the family herd led by a matriarch (old female in a group) while adult males leave the herd on reaching sexual maturity at an average age of 14 years to join other bulls. Bull groups are usually smaller than family groups with a mean size of 2.4 elephants (Barnes, 1982). Males in musth usually travel longer distance than non-musth males for mating. A study by Hoare and du Toit (1999) showed a habitual crop raiding behaviour of relatively small groups of mixed herd of elephant ranging from 2 - 10 individuals. It has been shown further by Parker *et al.* (2007) that African elephants appear to have a natural preference to plant derivatives from *Gramineae* family that posses fewer spines, thorns, fibre and uniform ripening. Further studies on the feeding ecology of elephants indicate strong preference to

mature food crops. This preference is related to palatability, nutritive values, and lower secondary defences than wild browse plants (Nelson *et al.*, 2003). Example to this is depicted by a strong preference of elephants to rice and wheat crops at maturity stages, than observed to juvenile and medium growth stages in India (Yadav, 2003). Elephants are wide-ranging feeders, in natural condition Parker and Osborn (2001) observed them to select diet from about 140 different types of plants in the Zambezi valley in Zambia alone.

2.4 Types of Human-elephant Conflicts

In many parts of Africa local communities report conflicts with elephants as a significant cost of living adjacent to protected areas (Newmark *et al.,* 1994; Naughton-Treves, 1996; Weladji and Tchamba, 2003). The impacts of these conflicts may be direct or indirect. The direct effects caused to communities ranges from crop damages, loss of human life and injury, death or injury of livestock and damages to other of properties. However, elephant crop damage seems to be the major cause of conflicts particularly in situations where farming communities border the protected areas landscape. Questionnaire survey in Botswana indicated a high proportion of respondents to report on elephant crop damages as the major source of conflicts (Gillingham and Lee, 2003). Indirect effects associated with elephant presence reported by Hoare (2000) include interference and reduced rest to community members. In a broader context these problems finally result into reduced household income and food security to affected communities. On the other hand, severe retaliations to culprit elephants most invariably results into unsustainable wildlife conservation (Walpole *et al.*, 2004).

2.5 Factors that may Influence Human-elephant Conflicts

The magnitude, spatial and temporal trends of human elephant conflicts may be influenced by a number of factors:

(a) Soil degradation and other negative processes result in crops being planted in scattered patterns far from villages. This increases the area of interface between humans and elephants, thus increasing HEC (Hoare and Du Toit, 1999).

(b) Traditional migration routes of elephants that are disengaged by human activities such as farming activities and settlements, leads to change of behaviour in elephants and thus increases the level of conflicts (Kangwana, 1995).

(c) The increase in elephant numbers in protected areas following the CITES ban of ivory sales and improved anti-poaching measures in many elephant range states have resulted in some elephants losing fear to people (Kangwana, 1995; Tchamba, 1996; Naughton-Treves, 1998).

(d) State or hunting concession ownership of wildlife, coupled with bans on local hunting decreases tolerance of elephant crop-raiding (Sutton, 1998).

(e) Changes in land tenure, with a trend towards privatization, erodes traditional farming strategies based on joint properties and focus the impact of crop loss on individuals rather than communities. Similarly, in many places farmers have abandoned communal hunting, planting and guarding activities that once reduced crop loss to wildlife including elephants (Lahm, 1996).

(f) Availability of artificially maintained water sources that may attract elephants during drought periods (Sukumar, 1990; Sutton, 1998).

(g) Crop guarding by local farmers has decreased with men moving to cities to seek alternative employment, while children are increasingly involved in education (Lahm, 1996).

(h) People establishing farms close to protected area boundary pretending as farmers but actually they are poachers looking for easy access to wild animals (Lahm, 1996).

(h) Politicians are paying more attention to local citizens, who complain about crop raiding by elephants, thus increasing the profile and awareness of conflict (Kangwana, 1995).

2.6 Methods used to Mitigate Human-elephant Conflicts

The management of HEC has been researched and documented throughout Asia and African countries (Osborn, 2002; Parker and Osborn, 2006). Numerous mitigation measures to reduce HEC particularly elephant crop damages are employed, some have been rigorously tested. The following sub-sections summarize some of these methods.

2.6.1 Traditional methods

The traditional deterrent methods encompass all self-defence measures taken by local farmers to protect their crops from elephant damage (Hoare, 2001). Many of these strategies have been used for centuries and are still widely used, with local and regional variations. They range from chasing elephants off fields with noise and fire, and use of human effigies (scarecrows) such as pieces of clothes and rags tied to trees.

2.6.1.1 Crop guarding

Although this is not strictly a deterrent method, crop guards sleeping on watchtowers with some means of alerting the community to crop-raiding elephants (e.g. whistles) are an important part of any traditional deterrence system. Human effigies are used in many places, but elephants quickly become habituated to them (Hoare, 2001).

2.6.1.2 Noise making

Beating of drums or making noise of any kind is one of the most common strategies to scare elephant from crop fields. For example farmers around the Maputo Elephant Reserve in Mozambique used noise made by drumming on tins to frighten off elephants (Nyhus *et al.*, 2000). Variant to this method include whip-cracking to imitate gunfire as used in most African and Asian countries (Nyhus *et al.*, 2000) while bamboos burnt (causing them to 'explode') by communities around the Dzanga-Sangha Reserve in the Central African Republic showed a deterrent effect.

2.6.1.3 Use of fire

Most wild animals avoid fire. Fires around field boundaries or at elephant entry points to fields, serve as short-term deterrent, but are unsustainable for any length of time without large tracts of forest being cut down or fire breaks. Other materials can be burnt to increase the deterrent effect of fire. In the Democratic Republic of Congo, chilli seeds have been incorporated to fires, while in Zimbabwe 'brickettes' of elephant dung mixed with ground chillies were used to irritate elephants they inhale smoke from crop fields (Osborn and Rasmussen, 1995; Hoare, 2001). In Burkina Faso and Sumatra, expensive techniques in this aspect were the use of series

of kerosene lamps, flaming torches and powerful flashlights hanged on wooden poles around crop fields as deterrents (Nyhus *et al.*, 2000).

2.6.1.4 Traditional barriers

This is the most traditional form, which involve the use of bark ropes or string, often with tins and pieces of clothes and sometimes bells attached to it in a single or double rope strand to scare elephants from farms (Thouless, 1994; Thouless and Sakwa, 1995).

Most traditional methods are of limited use as deterrents usually, alleviate the problem temporarily, or shifting it to a neighbouring area (Tchamba, 1995; Tchamba, 1996; Nyhus *et al.*, 2000). The major problem associated with traditional methods, particularly in the longer term, is the ease, with which elephants become habituated (Osborn and Rasmussen, 1995; Sutton, 1998; Barnes, 1999; Hoare, 1999c; Nyhus *et al.*, 2000; O'Connell-Rodwell *et al.*, 2000). Elephants are intelligent animals thus after a period of exposure they overcome their fear of fire or noise or other disturbances, once they realize there is no real danger and they regard them as empty threats (Nyhus *et al.*, 2000).

Traditional methods are also typically difficult to quantify the socio-economic and psychological stresses on families and communities as they are often being used in combination with each other and sometimes other methods. However, as a counter-measure they have some deterrent effect in areas where no other crop defence

method is practiced, and mostly where elephants, do not continually challenge the deterrence system (Naughton *et al.*, 1999).

2.6.2. Disturbance methods

Disturbance methods are the 'traditional' realm of wildlife or local authorities, being the first step of the wildlife authorities when called on to supplement local traditional methods. These methods include the following:

2.6.2.1 Firing weapons

This technique is often employed when the elephants are of conservation or economic value. It is done by firing weapons over the heads of crop raiding elephants to scare and chase them off crop fields (Hoare, 2001).

2.6.2.2 Driving with aircraft, vehicle or people

The method involves use of a massive disturbance (e.g. people, vehicles and/or helicopters) to drive elephants away from a conflict zone. The technique has been tried with some immediate short-term success in Zimbabwe (Hoare, 2001) and western Serengeti, Tanzania (Brian, H. personal communication, 2006).

Disturbance methods in isolation provide only a local short-term relief before habituation. It require trained personnel and they can be dangerous because of proximity to the elephants also inability to move elephants far enough away over a large area or to prevent their return and resultant habituation. The method is very expensive especially when helicopters are used. However, they are generally easy to

apply, non-fatal for the elephants and the involvement of the wildlife authorities provides some public relations value to local communities (Hoare, 2001).

2.6.3. Killing problem elephants

Killing problem elephants have been widely used as a quick-fix solution to human elephant conflicts. It allows the wildlife personnel to demonstrate the use of firearms to appease the affected communities, while the communities generally believe it will provide a lasting solution as well as being an obvious act of revenge, coupled with the bonus of free or cheap game meat (Taylor, 1993; Hoare, 1999c; Taylor, 1999). Elephants are often shot on sight in damaged fields, mostly during the wet-season when crop-raiding is widespread. When a Problem Animal Control (PAC) unit is used, attempts are usually made to identify crop raiders or those caused human fatality (Hoare, 1999c).

Shooting ‘problem’ elephants often has short term effects with little effects to other elephants also it is difficult to identify the culprit(s) because it requires skilled personnel and can be dangerous to them. Its advantages are that, it is relatively cheap, quick, and it creates good public relations to the affected community through a bonus of free or cheap game meat (Hoare, 2001). Additionally, elephants tend to associate the practice when close to village areas as compared to being far away within the protected area.

2.6.4 Translocation

The method involves removal of the 'problem' animal(s) to an area where there will be reduced contact with people and their crops. It requires specialist experts' preparation of the costs to be involved, logistics and welfare of the animals. Additionally, preliminary studies need to be carried out on the social structure of the elephants to avoid its disruption effects to the family and on other elephants. The disadvantages of translocation are its expense, the need for skilled personnel, the potential distortion of population structure, and welfare concerns for the elephants being moved. It is also unsustainable solution as places to relocate problem elephants and inappropriate when the conflict involves migratory elephants, such as those reported in Kaélé, Cameroon, where they are only present during the wet season. However, its major benefit is that it has non-fatal effects to elephants when properly executed (Hoare, 2000).

2.6.5 Deterrent methods

It involves the use of specific repellents for elephants, both olfactory and auditory. Elephants have special receptors located within their respiratory track which detect irritant substances during breathing (Hoare, 2001). The use of irritants in chillies (*Capsicum frutescens*) has been the focus of many researchers as olfactory elephant repellents (Osborn and Parker, 2002; Paterson, 2007). Chilli-grease as a repellent has been tested with success in Tanzania, Kenya and Zimbabwe on simple traditional fences made around crops fields (Hoare, 2001; Malima *et al.,* 2004; Sitati and Walpole, 2006). Similarly, the noxious smoke from burning chilli bricks made from the mixture of grounded chilli and elephant or cow dung is also effective on

deterring elephants from crop fields (Osborn and Rasmussen 1995; Hoare, 2001; Parker and Osborn, 2006). The advantages are that, the technique uses simple technology, materials easily produced locally and it has short term noxious effects to elephants and does not accumulate in the environment.

Elephants can produce a wide range of calls, both audible and non audible to humans (McComb *et al.*, 2001). When calls which invoke alarm and flight are recorded and played back to elephants, they might serve as a deterrent (McComb *et al.*, 2001). The major drawbacks of this technique is that, the equipment required to record and play back the calls from elephants are complicated and very expensive as well as the identification of these alarms or infra-sound waves signals is dangerous (Osborn and Rasmussen, 1995).

2.6.6 Physical barriers

Trenches and moats have been used elsewhere in Asia and Africa with some success. In Sumatra, trenches of 2 m wide and 3 m deep were observed to be effective to prevent elephant entry in Way Kambas National Park, Sumatra (Nyhus *et al.*, 2000) while similar method reinforced with stone walls appeared to be effective in the Aberdares Mountain, Kenya. Like many other methods this also were found to be ineffective in the long run as elephants learnt to break down the walls and climb through (Woodley, 1965; Thouless and Sakwa, 1995). The main drawbacks of physical barriers are the large investment required for construction, their vulnerability to soil erosion and regular maintenance costs. Sometimes, elephants learn to kick the sides in to make crossing points. In the situation when these

methods become effective, they have high public relation value among the beneficiaries.

Electrified fence is another physical barrier perceived to be the best solution to HEC. The method provides exclusion of elephants to crop field and other man made structures. The major limitation to this technique is on the high initial and regular maintenance costs involved. In some areas, vulnerability of materials to theft increases the cost. They limit potential land use options by creating defined boundaries and break migration routes on areas used as wildlife movement corridors. The method when properly executed has high public relations value among beneficiaries (Thouless and Sakwa, 1995).

2.6.7 Compensation

The first reactions of a person whose properties have been destroyed by elephants are a request for compensation. This is especially true when the animals are legally or effectively owned by the state (Hoare, 2001). Compensation has been tried in some African countries such as Kenya and Zimbabwe. The schemes appeared to have a number of drawbacks as summarized by Hoare (2001):

(a) Failure to decrease the level of the problem (by not tackling the root cause).

(b) Immediate increase in claims, indirectly suggesting both corruption through bogus or inflated claims and a laxity of farmers' crop-guarding efforts.

(c) Complaints of unreasonably low payments and/or the inability to cover all claims.

(d) Unequal disbursement (e.g. only to some people), creating social disputes and resentment.

(e) Bureaucracy through cumbersome, expensive and slow administration brought about by the need to train assessors, huge areas to be covered and the verification needed for fraud prevention.

(f) Inability to quantify some socio-economic and opportunity costs for people affected by the threat of elephants and

(g) Lack of apparent end point.

2.7 Spatial and Temporal Patterns of Elephant Raiding Incidences

2.7.1 Spatial pattern

Elephant crop raids mostly invariably occur near protected areas boundaries or along migratory routes, prominent water sources and usually decreases with increasing distance from the protected area boundary (Nelson *et al*., 2003; Parker *et al*., 2007). In southern Tanzania, especially the miombo woodlands of Selous ecosystem, crop fields were reported to be more vulnerable to elephant raids the closer they were to the forest or elephant migratory routes (Malima *et al*., 2004). Stephenson *et al.* (2006) reported 57% and 83% of the damaged farms to be within 50 m from the forest edge in the year 2004 and 2005 respectively in Cameroon. In all these cases the proportion of farm raided appeared to decrease with increasing distance from forest edge or migratory route.

The distributions of elephant crop raids are also influenced by vegetation types and presence of fruiting trees in the forest. For example in Zimbabwe, elephants

damaged vegetable gardens along Zambezi riverine forest during the fruiting period of Masawu (*Zisiphus macrunata*). The trees are known to produce sweet fruits in dry season, which are preferred by elephants (Parker and Osborn, 2001). Many thick forests along the river banks also provide an ideal resting place for elephants during the day (Parker *et al*., 2007). Presence of cultivated crops definitely attracts elephants to eat crops.

In Uganda, particularly in the southern sector of the Queen Elizabeth Conservation Area, along the Ishasha and Ntungwe rivers, crop damage incidents were reported to concentrate within the flood plains (Keigwin, 2007). In southern part of Tanzania, areas bordering the Selous Game Reserve, crop fields located adjacent to the woodlands and within or along the elephant migratory routes were frequently raided by elephants (Malima *et al.*, 2004). Behavioural studies by McComb *et al*. (2001) indicated that, elephants have long memories and often utilize traditional movement routes and thus may return to areas where they remember having successfully raided in the past (McComb *et al*., 2001).

2.7.2 Temporal pattern

Human-elephant conflicts particularly crop raiding incidences are seasonal, high in the wet and low in the dry seasons due to elephant preferences to mature crops (Parker and Osborn, 2001). Malima *et al.* (2004), Osborn and Parker (2002) reported in areas where two cropping season occur two peak crop raiding incidences also observed. However, where perennial crops are grown along with annual crops, crop raids incidences occur throughout the year (Sitati *et al*., 2003).

2.8 The Extent of Human-elephant Conflicts

Stephenson *et al.* (2006) assessed HEC in Cameroon by use of interview schedule to local administrators, park staff, local residents, and consulting reports from the local agricultural services. The number of farms damaged by elephants ranged from 1 to 15 ha and none of the farmers lost their entire annual harvest to elephants.

In Uganda, HEC assessment system was carried out in the southern sector of the Queen Elizabeth Conservation Area, by adopting the African Elephant Specialist Group (AfESG) assessment protocol (Hoare, 1999a). Elephant crop raiding was found to be the main form of conflict. Elephants raided more palatable crops namely maize (*Zea mays*) (24%), cassava *(Manihot esculentum*) (15%), finger millet (*Eleusine coracana*) (11%), beans (*Phaseolus vulgaries*) (8%), sorghum (*Sorghum vulgare*) (6%), sweet potatoes (*Ipomea batatus*) (6%) and banana (*Musa domestica*) (6%) (Keigwin, 2007). In Trans-Mara, Kenya, over 60% of crop-raids by elephants resulted in damages between 10% and 25% of the standing crops. It appeared that, once elephants started to feed they tended to remain where they were rather than moving to other farmlands.

In south-eastern Tanzania, HEC assessment was carried out around villages in Rufiji, Kilwa and Liwale districts bordering the Selous Game Reserve (Malima *et al*., 2004). Many types of crops were reported to be damaged by elephants in 973 separate incidences recorded. Other forms of HEC reported included killing of two people and one injured by elephant. Four and 17 incidences were recorded of interference with people daily travel and damage of water sources respectively. During this period, 25 elephants were shot dead by wildlife personels. Crops mostly

damaged were maize, millet, bananas and mixed crops while fruiting trees such as cashew (*Anacardium occidentale*) and mango (*Mangifera indica*) appeared to be vulnerable to elephant raids during the dry season.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area Description

3.1.1 Location

The study area is located in Serengeti and Bunda districts which lie between latitude 1˚28′ and 3˚17′S and longitude 33˚50′ and 35˚20′E (Kaltenborn *et al.*, 2003) and involved an area covered by 24 villages that lie adjacent to the GIGRs and a small portion of SENAPA (Fig. 2).

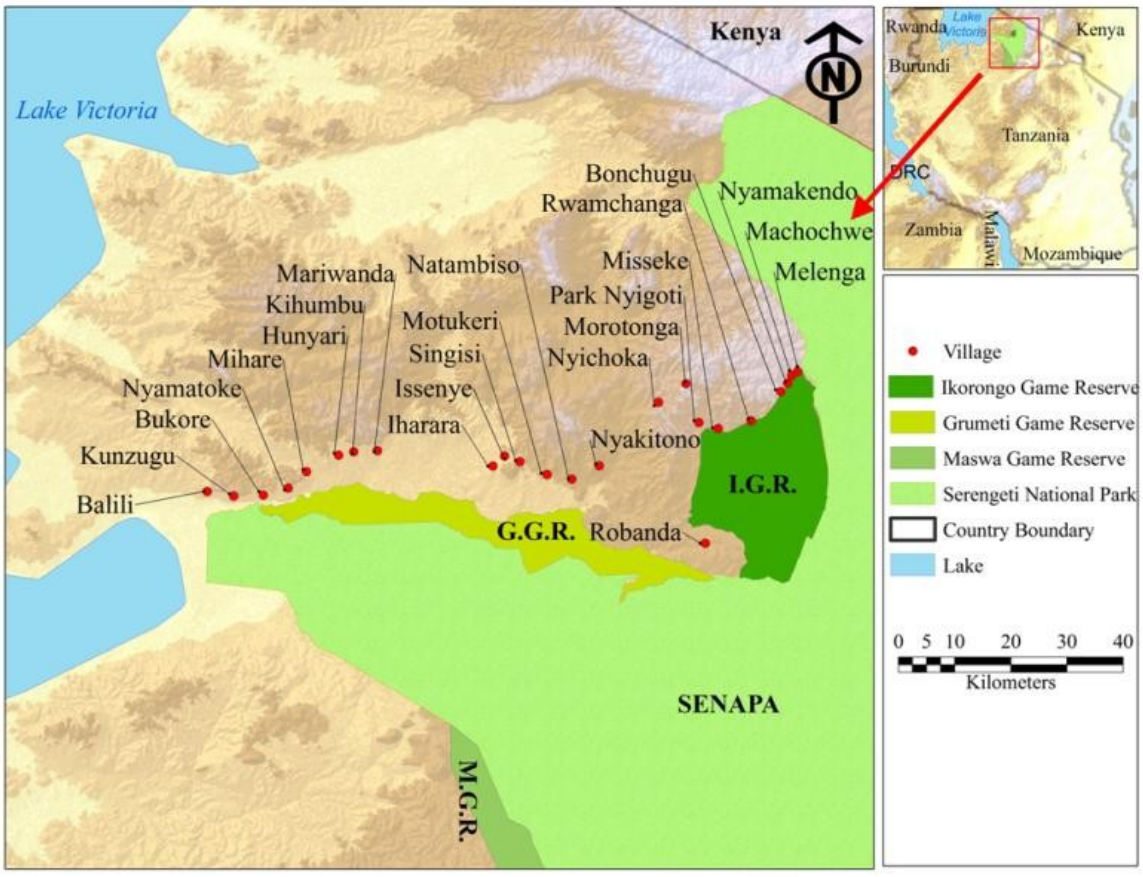

Figure 2: A map of the north-western part of Serengeti ecosystem showing the distribution of study villages adjacent to Grumeti-Ikorongo Game Reserves and Serengeti National Park

3.1.2 Climate

The study area exhibits bimodal rainfall patterns with the long rains falling from March to May and the short rains from November to December (Norton-Griffiths *et al.*, 1975). However, in certain years, the rains can fuse into one long period, particularly in the northeast, or sometimes the short rains can fail entirely, especially in the western areas of the ecosystem. The average annual precipitation ranges between 500 and 1200 mm, increasing gradually towards Lake Victoria. The annual temperature ranges from 25ºC to 29ºC (Norton-Griffiths *et al.*, 1975).

3.1.3 Soil and vegetation

The dominant soil type is black cotton soil. Riverine forests with closed canopy dominate the main river banks of Grumeti, Robana and their tributaries (Campbell and Hofer, 1995). The dominant tree species in the area are *Acacia seyal var fistula*, *Acacia tortilis, Acacia polycantha* and *Euphorbia candelabrum* while the dominant grass species are *Eragrostis cyndiflora, Chloris pychnothrix, Pennisetum mezianum* and *Themeda triandra* (Banyikwa and Lyaruu, 2003).

3.1.4 Human population and socio-economic activities

According to the Tanzania National census report of 2002, human population of Serengeti and Bunda districts were estimated at 176 609 and 143 105 respectively (URT, 2003). Majority of inhabitants are agro-pastoralists, relying on a combination of livestock keeping and subsistence farming for their sustenance.

Subsistence farming is characterized mainly by food crops such as maize, sorghum, cassava millet and to small extent cotton for cash crop. Cattle is the main livestock kept in the area others include goats, sheep, pigs, and donkeys, and aviary mainly poultry. Agriculture and livestock accounts for about 80% of the household income whilst the remaining emanates from off-farm activities such as subsistence and commercial hunting, charcoal making, and local brew making while in some cases, formal employment (Kideghesho, 2008).

3.2 Methods

3.2.1 Research design and sampling procedure

Both longitudinal and retrospective-prospective study designs were used to collect data during the entire study period (Kothari, 2004). For prospective data collections, field visits were conducted twice during the first and fourth week of a month. A purposive sampling technique was used to select 12 out of 24 villages whose centres were less than 5 km from the protected area boundary (Bluman, 1997; Kothari, 2004).

3.2.2 Data collection

A standardized HEC data collection and analysis protocol developed by Hoare (1999a,b) and adopted by the African Elephant Specialist Group (AfESG) for use in HEC situations in some African elephant range states (Hoare,1999c; Parker and Osborn, 2001; Malima *et al.,* 2004) was used. The present study adopted the same method to enable comparison with other elephant range states, and recommend management intervention strategies to minimize HEC. During the study, the

researcher trained four local enumerators to assess and record primary data particularly elephant crop raiding and other conflict incidence locations by use of a simple hand held Geographical Positioning System (GPS) device and to assess crop damages.

When elephant crop raiding incidents occurred, enumerators were informed through the existing village community communication networks and visited the incident site as soon as possible. On the site, the enumerator identified and recorded the type of conflicts, the name and locations of village in Universal Transverse Mercator (UTM) coordinates and other details on a standard elephant damage record form (Appendix I).

3.2.2.1 Assessment of elephant crop damages

Once crop damage occurred, the enumerator identified the type of crop raided, determined the area of the cultivated farm and damaged portion(s) by pacing. The age and quality of crop from damaged farm(s) were assessed and recorded using a method described by Hoare (1999a). Crop ages were determined and classified into three categories namely seedling (crop growth stage from emergence to pre-flowering stage), immature (crop growth stage from flowering to fruiting), and mature (plant growth stage after fruiting to the point of harvest), while the quality of undamaged crops were assigned three classes as poor (state of plant body under bad crop husbandry, poor soil fertility, disease and pest attack or unfavourable climatic conditions), medium (plants under average crop husbandry, soil fertility or climatic conditions) and good (plants growth conditions under optimal crop husbandry, soil fertility, favourable climatic conditions and absence of disease or pest attack). Age

categories for crops were assigned numbers 1, 2 and 3 for seedling, immature and mature growth stages respectively. Quality categories were also assigned numbers 1, 2 and 3 for poor, medium and good respectively.

3.2.2.2 Assessment of other incidences

Other types of serious incidences like, human death or injury, destruction of food stores or water structures, human activities interference, killing or injury of livestock and retaliatory killing of elephants were recorded as they occur using a similar protocol developed by Hoare (1999a). Existence of any mitigation methods used to deter elephants from crops and property damages were also recorded and the number of raiding attempts and damages inflicted by elephants were noted and recorded where possible (Appendix I).

3.2.3 Data analysis

The GPS point data projected into UTM coordinates were imported to Arc GIS (9.3v) for spatial analysis. The digitized shape files of the GGR, IGR, and SENAPA were assembled from maps provided by TAWIRI in order to provide a spatial map of HEC. Crop damages incidences were assigned six categories based on the percentages of damaged portion of the cultivated farm, categorized on the ranges of (< 5%; 6 - 10%; 11 - 20%; 21 - 50%; 51 - 80 %; and > 80%). Furthermore crop damage level were assigned three levels, low (< 5), medium (6 - 8) and high (> 9) by combining points for the age, quality and damage (Hoare, 1999b). The higher the damage score of combined points (age + quality + damage) for an incident, the more serious the damage observed (Hoare, 1999a). The total elephant incidents, serious

incidents and damage scores were ranked to obtain their ranks. The average of the three ranks gave the mean ranks. The number of elephant incidences, distances and size of damaged farms, type of conflicts and the mitigation methods used were imported into Microsoft excel and Statistical Package for Social Science (SPSS) program for calculating percentages and regression analysis. Area of farms cultivated and damaged portions were obtained from the calibrated enumerators paces in order to standardize the measurements.

Additional data for the past three years (2006 - 2008) collected using a similar method developed by Hoare (1999a) were retrospectively retrieved from the District Game Officers in Bunda and Serengeti districts and from research repository at Serengeti Wildlife Research Centre (SWRC) and Tanzania Wildlife Research Institute (TAWIRI). These data were merged and analysed together with the prospective data. Other information was obtained from Sokoine National Agricultural Library (SNAL) and internet sources.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Types of Human-elephant Conflicts

This study indicated the crop raiding by elephants to be the highest form of HEC in the study area for the past four years (2006-2009) (Table 1). This was followed by other forms of conflicts such as human interference, elephant, human and livestock kills including damaged water points. Other damages caused by elephants were on non crop plants such as indigenous trees and sisal plants.

Table 1: Proportions of type of human elephant conflicts in villages adjacent GIGRs and SENAPA as recorded from 2006 to 2009

Type of HEC	Frequency	Percent
Crop damaged	1618	89.00
Human killed	9	0.48
Elephant killed	20	1.00
Livestock killed	2	0.01
Destructed water points	2	0.01
Human interference	21	1.20
Others (damaged trees)	151	8.30
Total	**n = 1823**	**100.0 0**

During these years, a total of 1618 crop raiding incidences were recorded, with an average of 2 - 3 small plots damaged per incident. During this period nine people were killed by elephants including four farmers who were guarding their crop fields at night and five poachers encountered in the IGR but no report of injured people. About 20 elephants were killed by wildlife officers from districts or game reserve authorities in defence of people's safety in the event elephants resisted being driven off the crop fields or homesteads. Human interferences were encountered when

people were travelling on the road between Fort Ikoma and Park Nyigoti village to attend medical services at Fort Ikoma. The study also recorded incidences where elephants damaging water points during the dry season at Nyankimwa and Kihumbu dams found at Park Nyigoti and Kihumbu villages respectively, probably due to their proximity to GIGRs. This attracted elephants as source of water while a herd of livestock was encountered by elephants at Kihumbu village coming from Robana river to obtain water where two adult cows were killed by elephant. No any elephant incidences were recorded for damages of food stores during the study period. In some incursions elephant damaged non crop plants such as sisal plants planted as household or farm fences and indigenous trees particularly during the dry season. Comparisons with other results (Malima *et al.*, 2004; Parker and Osborn, 2001) have indicated similar diversity of human-elephant conflicts in the southern part of Tanzania and Zambia respectively.

4.2 Patterns of Human-elephant Conflict Incidences

4.2.1 Temporal pattern

In areas adjacent to GGR, IGR and SENAPA a peak of elephant crop damage incidences was greater at the transition period from wet to dry season (Fig. 3) and a small peak appeared again during the dry season between September to October. These time periods correspond with the crop harvest time (April to June) and availability of perennial root crops respectively. This indicates the preference of elephants to mature crops and seldom raid crops at seedling stages. The observed lower peak from September to October was linked with the maturity of root crops like cassava, some horticultural crops, sugarcane and banana along the Robana and

M ra river flood plains. Osborn (2004) and Chiyo *et al.* (2005) in Zimbabwe re l seasonal patterns of elephant crop raiding to be triggered by a decline in qu or availability of wild forage or by crop maturation in the nearby farms.

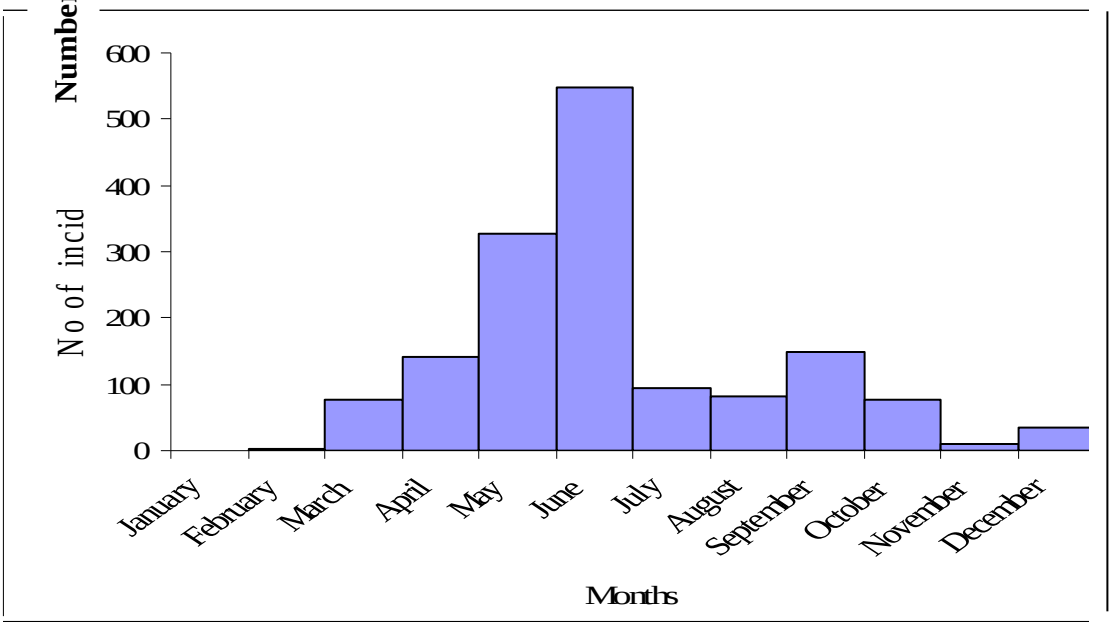

Figure 3: The mean monthly elephant crop damage incidences in areas adjacent to GIGRs and SENAPA as recorded from 2006 to 2009

Elephant crop raiding incidences did not occur on daily basis, elephants usually visited in groups ranging from 1 - 10 individuals and raided an area persistently every day for 1 to 3 nights raiding an average of 2 - 3 small crop fields within an incursion, and then disappeared for many days or weeks before returning again (Box 1).

Box 1: Elephant crop raid incidences in Rwamchanga village in Serengeti district

Between April and May, 2007 five incidences of elephant crop damage were recorded in Rwamchanga village. On 15, 18 and 20 April, elephant damaged a total of 66 small crop fields. They returned again on 10 and 26 May, and raided a total of 37 small crop fields of mainly maize and sorghum.

maize and sorghum.

Crop raiding was observed to be high during night time, starting from 1900 h to 2100 h depending on the distance of the farms from the elephant domicile zone. Most raiding incidents were reported to occur from 2200 h to 0200 h. Elephants were occasionally sighted resting in thick vegetations at the border to the protected areas and along the Robana river mostly between 1600 h to 1800 h. Sometimes when elephants successfully raided crop fields, they appeared to spend some hours in the same field although occasionally moved to a nearby crop field to continue feeding on preferred target crop.

4.2.2 Spatial pattern

This study indicated that, elephant crop damage spatial patterns clearly varied with distance from the crop farms to the nearby protected area boundaries. During the wet season when crops are mature, elephants appeared not to range far away from the protected areas. However, during the dry season, when crops are harvested elephants seemed to range far away from crop fields. Crop raiding incidences in areas adjacent to the GIGRs appeared to be confined in a narrow band away from the village centre bordering SENAPA and its buffer zones to game reserves (Fig. 4).

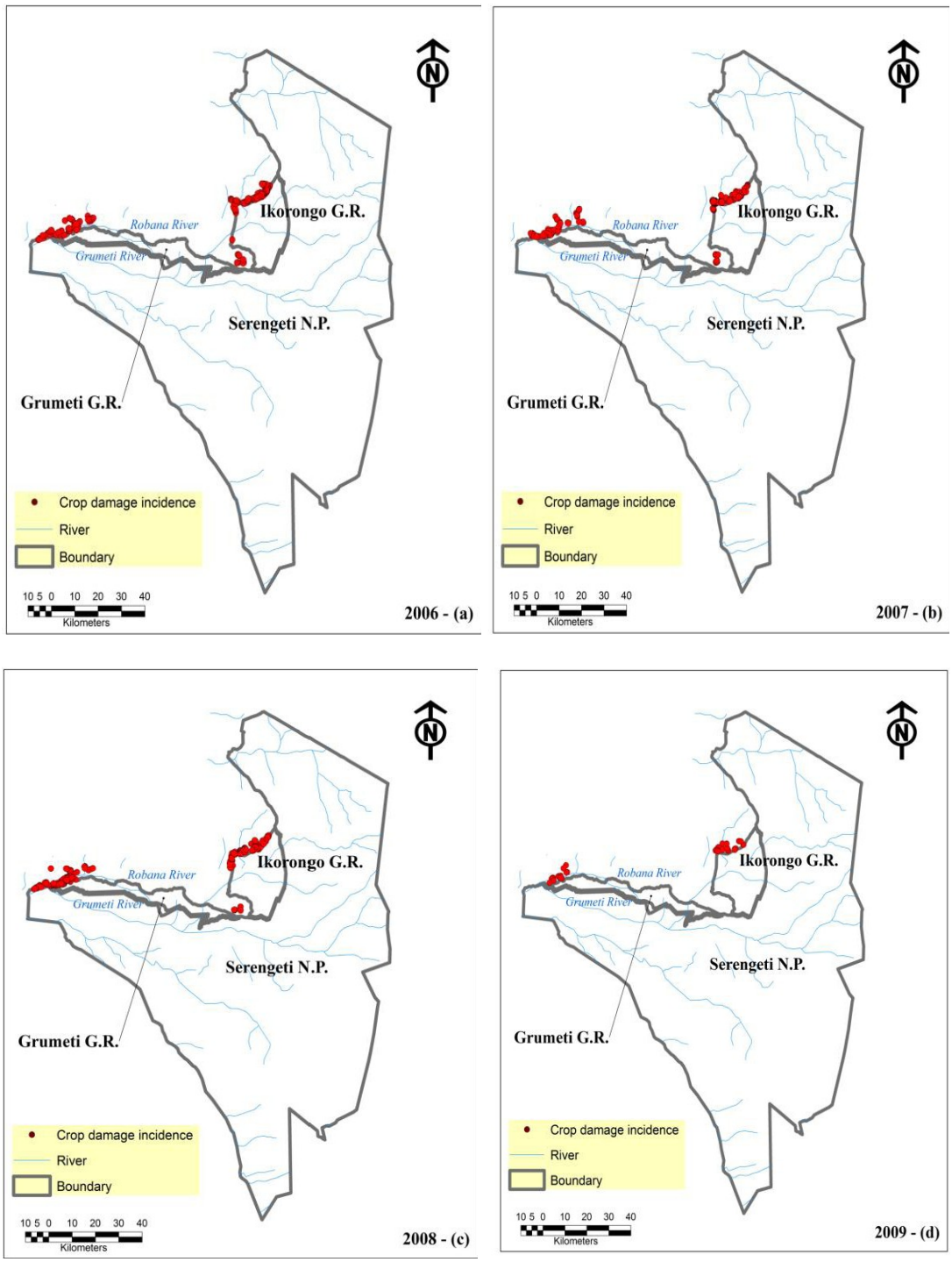

Figure 4: Spatial distributions of elephant crop damage incidences in villages adjacent to GIGRs and SENAPA as recorded from 2006 to 2009

For the period of four years (2006 - 09) the spatial distribution of crop raiding incidences showed a series of clumped conflict zones. Elephant raiding incidences appeared to be spatially clustered, with most crop damage incidences concentrated in Manchira and Ikoma wards particularly at Rwamchanga, Bonchugu, Miseke and Park Nyigoti villages respectively (Fig. 5). These areas are geographically located very close (0.02 to 0.50 km) to IGR boundary (Table 2). On the other hand, the areas within the IGR bordering these villages contains good elephant habitat and thus acts as a convenient domicile for problem animals. In contrast, Robanda village which is almost surrounded by all protected landscapes appeared to have lower crop damage incidences probably due to majority of the inhabitants practice less agricultural activities for their livelihoods (Kideghesho, 2008).

Table 2: Overall elephant incidence ranks per village adjacent to GIGRs and SENAPA in Bunda and Serengeti districts from 2006 to 2009

Districts	Ward	Villages	Distance from PA's boundary (km)	Total Incidents	Serious Incidents	Damage Score Points	Total Incidents Rank	Serious Incidents Rank	Damage Score Rank	Mean Rank
Serengeti	Ikoma	Robanda	0.50	68	1	68	9	4	9	7
		Park Nyigoti	0.50	309	2	309	1	3	1	1
	Manchira	Rwamchanga	0.02	286	4	286	2	1	2	1
		Bonchugu	0.03	159	0	159	5	5	5	5
		Miseke	0.02	231	1	231	4	4	4	4
Bunda	Hunyari	Mariwanda	5.00	0	0	0	12	5	12	9
		Kihumbu	3.00	37	0	37	10	5	10	8
		Hunyari	3.60	23	1	23	11	4	11	
	Chamrihо	Mihare	2.80	78	3	78	7	2	7	5
	Mcharo	Nyamatoke	0.50	265	1	265	3	4	3	3
		Bukole	0.50	69	0	69	8	5	8	7
	Kunzugu	Kunzugu	0.30	93	2	93	6	3	6	5
Total				**1618**	**15**	**1618**				

The three villages of Mariwanda, Kihumbu and Hunyari are located relatively at longer distances (from 3.00 to 5.00 km) away from the protected landscape thus experienced low incidences probably elephants were detected earlier before reaching to the crop fields. The other three villages of Mihare, Nyamatoke and Bukole had their farms located along the Robana river with distances ranging from 0.50 – 2.80 km from the GGR. Robana river marks the boundary between the GGR and the village areas whereby elephants use it as the sole source of water especially during the dry season. This proximity makes it easy for elephants to cross to village area to damage crops. Farms at Kunzugu village directly bordered the SENAPA boundary at a distance of about 0.30 km. The elephant migration route through Kunzugu village, a name originated from local language “Inchugu” (*Loxodonta africana*) crosses the Kunzugu hills to Salama village. During their routine migrations, elephants raid crop fields encountered en route.

The narrow band of clustered conflict incidences at all villages are related to the nature of subsistence farming system practiced by the local inhabitants in the area as reported by Kideghesho (2008) and the motivation to cultivate adjacent to the GIGR’s where the soil appears to be fertile. Equally, where there is elephant incursion into cultivated areas from a protected area, there is usually a front line of farms to which crop raiding is generally confined (Barnes, 2003). Barnes (2003) and Sitati *et al.* (2003) found that the spatial patterns of human-elephant conflict incidences are usually related to the underlying patterns of cultivation, focused particularly on the distances between farms and protected areas boundary, known elephant movement routes and/or water sources.

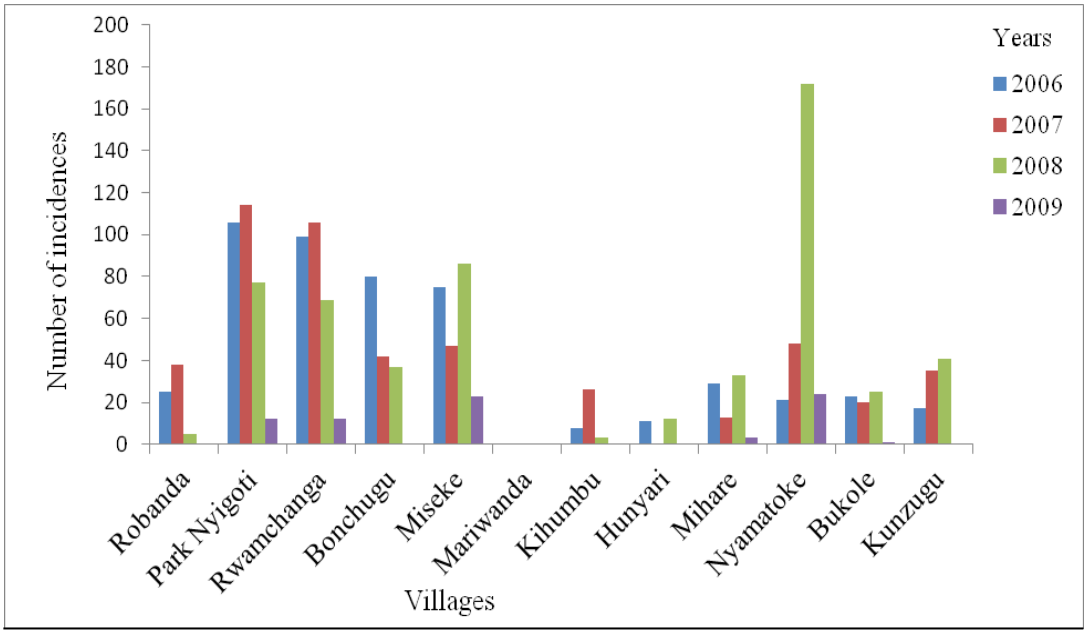

Figure 5: Elephant crop raiding incidences in some villages adjacent to GIGRs and SENAPA as recorded from 2006 to 2009

4.3 The Magnitude of Human-elephant Conflicts

The magnitudes of elephant crop damages in villages adjacent to GIGRs and SENAPA were not similar, they appeared to be largely influenced by the distances of the crop fields to the protected areas boundaries. Most of the raids were predominantly located in the farms closer to protected area boundaries as confirmed by the linear regression model where the crop damage incidences were inversely related to the distances from the crop fields to protected area boundaries ($r = - 0.84$, $p < 0.001$). Kanyatta (2006) reported a similar trend while studying HEC for farms around Wami-Mbiki Pilot Wildlife Management Area. In his findings, crop damage incidences appeared to decrease with increase in distance from the protected area boundary and vice versa.

For the period of four years consecutively (i.e. 2006-09) Manchira ward experienced the highest number of crop raiding incidences 42% (n = 1618), as well as higher damage score points with the lowest mean rank (Table 2). This observation is probably attributed to the fact that most crop fields were found nearly adjacent to IGR boundary. On the other hand, Hunyari ward that consist of Mariwanda, Kihumbu and Hunyari villages experienced the lower damage score points, with the highest mean rank. Strategic locations of these villages make them safe from elephant raiding activities. In these villages, farms are located at a relative longer distance of approximately 3.90 km from the protected areas. Villages in Chamriho, Mcharo and Kunzugu wards had an average damage scores points and average mean rank, with an exception of Nyamatoke village. In these villages, crop fields were located slightly closer (range of 0.50 to 1.00 km) from the protected area boundary. Interestingly, villages in the Ikoma ward in particular the Robanda village experienced the minimum number of crop raiding incidences regardless of its location of being encircled by the two game reserves and SENAPA. This is due to the fact that farmers at Robanda cultivate only small crop fields ranging from 0.25 to 1.00 ha per household due to presence of other alternative sources of income generation activities as reported by Kideghesho (2008).

In Ikoma ward particularly Park Nyigoti village appeared to have higher damage scores and the lowest mean rank probably due to the presence of Nyankimwa dam that directly attracted elephant as a source of water. Elephants raided mainly root crops (cassava) on their way to the dam particularly during the dry season as opposed to wet season where elephant primarily raided other crops. The higher the

number of elephant damage incidences the greater the damage scores and the lower the mean rank thus the higher the conflict level. The mean of the three ranks (namely total incidents, serious incidents and damage scores ranks) is very useful for the management decision to be prioritized according to the desired rank (Hoare, 1999a). Generally, the overall magnitude of crop damages was of medium category (Fig. 6).

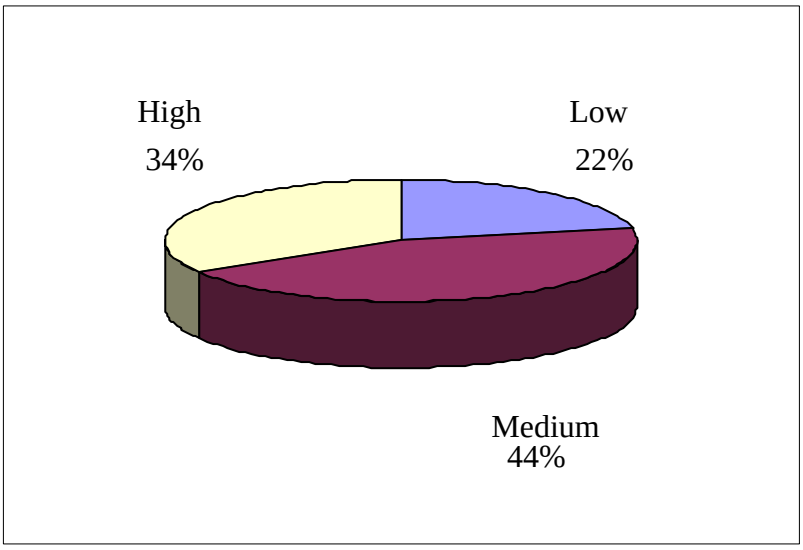

Figure 6: The overall levels of elephant crop damage incidences in villages adjacent to GIGRs and SENAPA recorded from 2006 to 2009 (N = 1586)

Comparison of the sizes of the damaged farms over years indicated significant differences in magnitude of damaged farms (F-test = 16.29, p = 0.001, df = 3), where the yearly sample mean of the damaged farm sizes for 2006, 2007, 2008 and 2009 were 4312.80 ha, 5555.60 ha, 8949.60 ha and 2660.00 ha, respectively. For the first two years the increase was probably attributed by the prolonged drought period that occurred in the year 2006 that might have resulted into reduced cultivated farms

in the area. However, the peak damage observed for the year 2008 was probably due to increased level of farmers' awareness of the importance of reporting elephant damage incidences after formulation of a dangerous animal damages consolation regulation under the Wildlife Act No.5 of 2007. (MNRT, 2007). On the hand, the shorter prospective data collection period (October to December) may probably explain the small proportion recorded in 2009 where only few incidences were captured on this short rain cropping period.

4.4 Elephant Crop Damage Preference

The present study indicates that elephants prefer certain crops to others and these preferences varied with the stages of crop growth (Fig. 7) and with season. For example, during wet season (February to May), elephants damaged more mature cereal crops mostly of medium quality (Fig. 8) particularly maize, millet, sorghum, root crops (sweet potatoes), and leguminous crops (beans, cowpeas, and pigeon peas) (Fig. 9). A crop like cotton was not eaten by elephants but was rather damaged through trampling when the animals pass through the fields. Perennial crops such as cassava, bananas, sugarcane, mango and pawpaw were mostly consumed during the dry period (June to January).

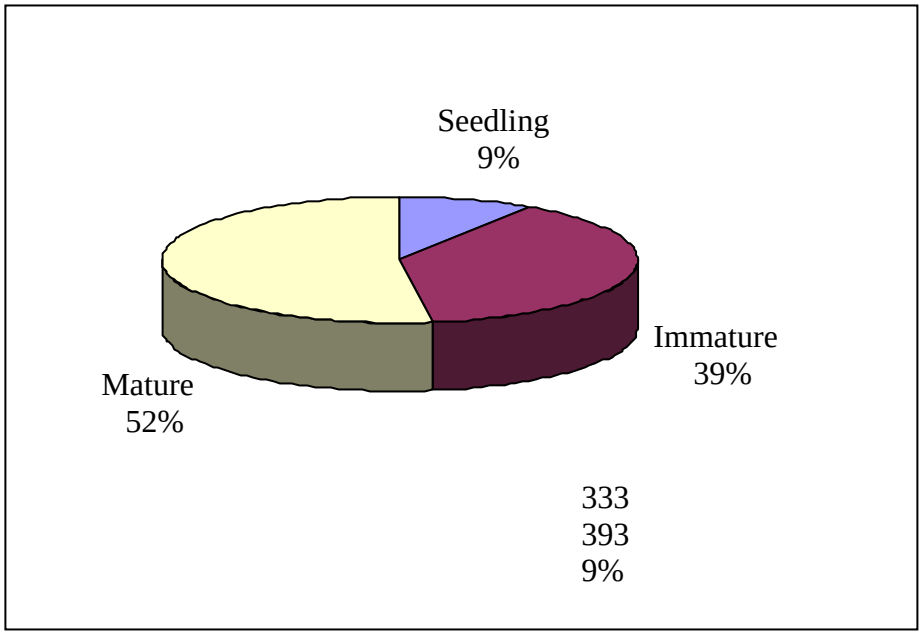

Figure 7: Elephant crop damage preferences with regard to stages of crop maturation (N = 1598)

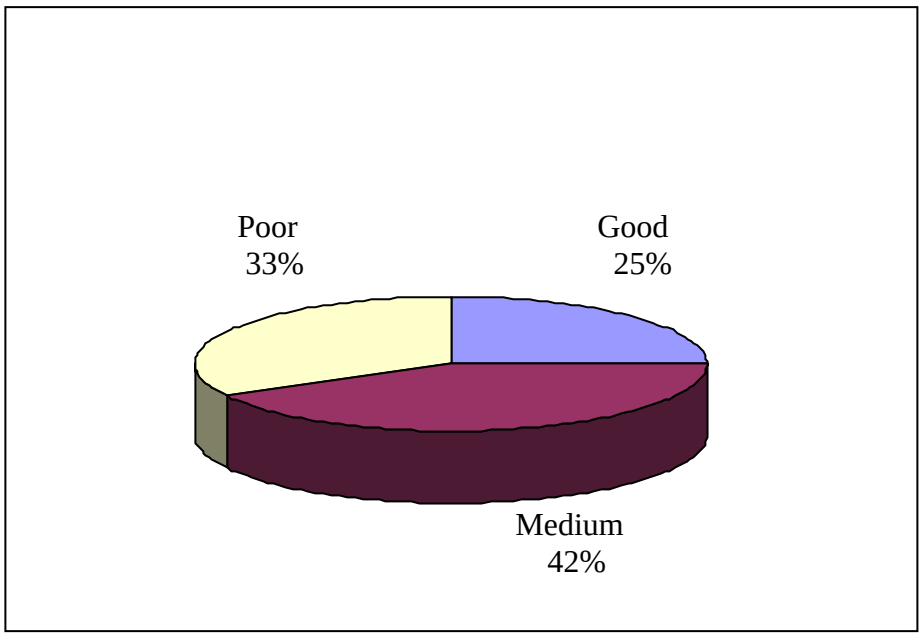

Figure 8: Elephant crop damage preferences with regard to crop qualities (N = 1618)

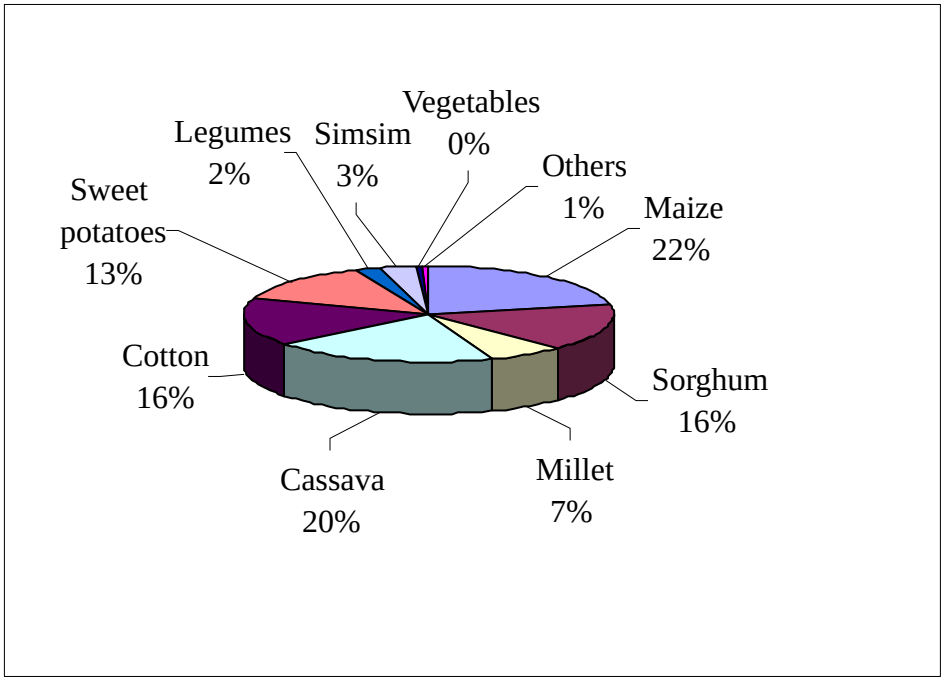

Figure 9: Proportions of crops damaged by elephants in villages adjacent to GIGRs and SENAPA (N = 1618)

More damages on cassava and cotton crops were frequently observed in the dry season mainly at Nyamatoke, Bukole and Kunzugu villages in Bunda district. These damages were related to the proximity of these villages to SENAPA separated by Robana river. Robana river is a good source of water to elephants and other wild animals. These villages have also been reported to be hotspots for human-carnivore conflict (Kalteborn *et al.*, 2003) as several cases of human and livestock attack by wild carnivores have been reported**.**

In Serengeti district and to a lesser extent in some parts of Bunda district, farmers carry out farming activities during the short rains starting from November to January. During this period, mixed crops such as maize, sorghum and horticultural crops are grown on small plots. However, during the 2005/06 cropping season, the

areas experienced a prolonged dry spell that extended up to February 2006. During this time, perennial crops such as mango fruits, bananas, sugarcane, and pawpaw appeared to be best alternative feeds to elephants. Interestingly, elephants were in some cases, observed to chew sisal leaves planted as barrier crops or household fences probably to obtain water.

4.5 Methods Used to Mitigate Human-elephant Conflicts

4.5.1 Traditional methods

The questionnaire survey conducted in different places of the study area recorded four types of HEC mitigation methods (Fig. 10). About 45% of the farmers used the traditional methods such as use of fire, night guard and noise making to deter elephants from their crop fields. A deterrent method that employed chilli as active ingredient was used by 7% of the farmers as the sole means to deter elephants from their crop fields. The remaining 48% of the farmers did not show any efforts to protect their crops.

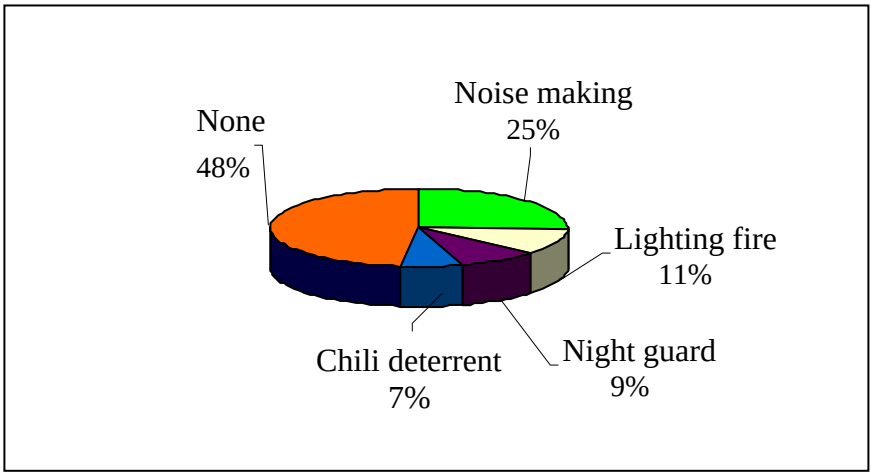

Figure 10: The proportions of mitigation measures employed by farmers to deter elephants in farms adjacent GIGRs and SENAPA (N = 1618)

In the study area farmers used more noise making technique by beating drums, whistling to deter elephants from crop fields especially during night time. The distance to the animal was maintained at not less than 100 m to avoid dangerous reaction from the culprit elephant. Some farmers used to tie dry grasses on long wooden poles up to 5 m and light it to scare raiding elephants. Some farmers collected dry logs and burned them on the peripheral part of the crop field or known entry route of elephant just to scare them combined with night guarding.

Traditional methods (noise making, lighting fire and night guards) of deterring elephants appeared not to be very successful. For example, during the 2008/09 crop season, elephant showed 96% success for a total of 628 raiding attempts that were recorded in that year. Literature shows that, with time elephants tend to habituate to traditional methods due to the fact that the methods are just empty threats since they cause no physical harm to them (Hoare, 2001; Nyhus *et al.*, 2000). Elephants thus tend to ignore and continue to damage crops.

Crop raiding appeared to be intense in areas very close to protected areas particularly the Rwamchanga village located close to the IGR boundary. The study showed that, farmers in this village were compelled to harvest their crops prematurely to avoid damage by elephants (Plate 1). This particular village had a big challenge to protect their crops. It was further noted that, elephants appeared to have developed a combat technique by invading crop fields without making noise. In most cases, farmers detected them while they already have caused damage or sometimes not until the next morning when the damage has taken place and the

elephants gone. Under this circumstance, it was difficult to deter elephants from crop fields.

Plate 1: A heap of prematurely harvested maize cobs at Rwamchanga village bordering the IGR in Serengeti district in 2008

The present study observed the great tendency of farmers to move and live in temporary shelters built within their crop fields in order to cope with crop raiding challenges brought by elephants especially from May to July (Plate 2). Similar practices have been reported by Naughton-Treves (1997) and Gillingham and Lee (1999) in high conflict areas of Uganda and Zambia respectively. Effective deterrence has been observed where elephants are detected early and prevented from entering the crop field (Hoare, 2000). Similarly, due to the potential danger that elephant may cause to people, sometimes farmers were forced to escape because of fear and leave their guarding post and farms.

Plate 2: A traditional hut used by local farmers to defend their crops at Bonchugu village in Serengeti district

4.5.2 Chilli deterrent method

In villages adjacent the GIGRs and SENAPA, the use of olfactory repellents particularly chilli was introduced in 2007 and has since then showed positive results in deterring elephants from crop fields. A chilli based method involves the use of the mixture of used engine oil and grounded chilli, pieces of clothes made up of cotton materials, sisal ropes and wooden poles of about 4 m. The mixture is smeared on the sisal ropes and pieces of clothes and later tied on pegged wooden poles placed strategically at an interval of 7 - 10 m each around the crop field (Plate 3). Also sun dried chilli bricks made up of a mixture of cow/elephant dung and grounded chilli then placed to burn on the peripheral part of the crop field producing noxious smell that has an intense irritating odour which deters elephants coming near.

Plate 3: Unraided maize farm at Rwamchanga village in Serengeti district protected by a chilli deterrent method

In this study few farmers (7%) adopted the chilli deterrent method (Figure 10). This method showed good protection against marauding elephants. Where properly used, elephants avoided chilli fenced farm by changing direction and invaded adjacent unfenced farms. Similar behavioural patterns have been reported by Malima *et al.* (2004) and Sitati *et al.* (2007) in southern part of Selous Game Reserve in Tanzania and Trans Mara in Kenya, respectively.

Since the inception of the chilli deterrent method, a fluctuation in successful raiding attempts had been noted. For example, in the 2007 and 2008 cropping seasons the number of successful raiding attempts by elephants were 92% and 87% respectively. This period corresponded with majority of the farmers employed traditional methods to deter elephants away from their crop fields. On the other hand, the unsuccessful raiding attempts for the 2007 and 2008 cropping season were 8% and 13%

respectively and corresponded to the time when farmers were already using chilli deterrent method. The positive responses from the chilli method as exemplified by elephants avoiding the chilli fenced fields and raided the unfenced nearby crop fields. Consequently the method created a positive altitude to most farmers in the study area. Thus, the method is recommendable for upscaling as it requires cheap, locally available materials and low technology for its application.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The present study showed elephant crop raiding to be a dominant form of conflict between people and elephants in villages bordering the GIGRs and SENAPA. The magnitudes of HEC were not similar across the villages as it was influenced by distances between village centres and the protected area boundaries. The overall level of crop damage was of medium category. More elephant raiding incidences were recorded in a narrow band bordering the protected area probably due to presence of fertile soils and palatable crops grown that attracted more elephants to raid. The peak crop raiding period corresponded with the harvest time and in most cases occurred at night. The spatial and temporal patterns observed in this study provide vital prerequisites to management authorities and other stakeholders for effective management of HEC. It indicates areas are of high conflicts and when the incident intensifies for immediate attention.

Majority of farmers practised some traditional mitigation methods which appeared to be in effective in preventing elephant attacks to their crop fields. Chilli deterrent method improved elephant protection to crop raids. The study concludes by calling for an integrated programme of monitoring, research and participatory mitigation measures using small scale and cost effective deterrent methods such as chilli method whereby HEC can be reduced to more tolerable levels.

5.2 Recommendations

In all circumstances where elephants range across cultivated landscapes, it is unlikely to completely abate HEC. Development of an integrated programme of early warning and participatory mitigation practices that use locally available materials and cost effective measures may significantly reduce HEC to a more tolerable level.

Research and monitoring should be pivotal and integral part of the early warning system in order to design appropriate interventions, evaluate their impacts and make the necessary modification or response to changing circumstances by encompassing the following core elements:

(a) Continuous monitoring of crop raiding to establish where and when it is happening, its intensity and how these factors change over time.

(b) Establishment of comparative mitigation trials that can be monitored for their effectiveness.

(c) Monitoring of elephant movements and distribution patterns using satellite telemetry in order to understand more about the dynamics of crop raiding within an elephant population focusing on identifying individuals and groups to establish the extent to which it dictates patterns of crop raiding, and provide a potential early warning system.

(d) Monitoring of local altitude and activities over time to discover the extent to which interventions have improved local support and tolerance, or change of people's livelihood.

On the other hand, reducing HEC mainly by reducing the temptations to crop raiding by involving villagers, management authorities and external supporting agencies like Grumeti Reserve Company and Frankfurt Zoological Society is recommended. This can be achieved by doing the following:

(a) Encourage villages adjacent to protected areas to develop clustered cultivation zones away from protected area boundaries and discourage scattered cultivations that are difficult to defend. Clustered farms should be guarded communally and where possible people must be encouraged to use effective mitigation method such as the chilli fence.

(b) Encourage villages along protected areas of GIGRs and SENAPA to plan ring cultivation with crops most preferred by elephants planted at the centre.

(c) Strengthen community education awareness through for example TANAPA outreach and other program to publicise the effectiveness of chilli deterrent method.

(d) Advise the government to link the formulated dangerous animal damage consolation regulation implementations with individual farmer efforts to defend their properties especially crops by use of effective chilli deterrent method.

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APPENDIX

Appendix I: Elephant damage record form

Form No.....

Village……...Sub-village…….Enumerator name…….
Date of damage……/……/……Date of reporting……/……/……
GPS No. (UTM) (1)……(2)……..……....
(3)……(4)……..

CROP DAMAGE ASSESSEMENT: LENGTH X WIDTH PACES

TYPE OF CROP	**AGE OF CROP** *(S/I/M)	**QUALITY OF CROP BEFORE DAMAGE** **(G/M/P)	**AREA OF CULTIVATED FARM**	**DAMAGED AREA** 1	**DAMAGED AREA** 2	**DAMAGED AREA** 3	**DAMAGED AREA** 4
			Length------ Width-------	Length---- Width-----	Length------ Width-------	Length------ Width-------	Length---- Width-----
			Length------ Width-------	Length---- Width-----	Length------ Width-------	Length------ Width-------	Length---- Width-----
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			Length------ Width-------	Length---- Width-----	Length------ Width------	Length------ Width-------	Length---- Width-----

Other serious incidents

Damage of food store----------

Damage of water structure----------

Human fear/interference----------

Death or injury of people----------

Kill or injury of livestock----------

Kill of elephant(s)----------

Others (mention)----------

Mitigation measures applied if any

Number of raiding attempts----------

Number of damage(s) inflicted----------

***Seedling/Immature/Mature, **Good/Medium/Poor**