Assessment of human elephant interaction, land cover, and land use changes and the potential need for citizen science around the Rukwa-Lwafi Game Reserve, Tanzania

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Executive Summary

Coexistence between people and elephants is a significant conservation challenge around Rukwa and Lwafi Game Reserve Rukwa Tanzania. Farmers around the two reserves like many other farmers living adjacent to protected areas have continued to suffer huge losses resulting from elephants and other wildlife menace without adequate solution to mitigate the problem. Increasing agropastoral immigration into remote areas of western Tanzania have hugely contributed to changes in land use making the area prone to crop destruction by elephants. While it is known that human elephant conflict existed in this area and several factors contributed to this, it has never been quantified over time for these two reserves. The objective of the study was to assess human elephant interaction, land cover, and land use changes between 1990, 2000, and 2020 in two districts Mpanda and Nkasi in which the two reserves exist in and the potential need for citizen science among communities bordering Lwafi Game Reserve.

To better understand the nature and extent of these conflicts, we conducted intercept surveys (n = 201) with local villagers around the Rukwa and Lwafi Game Reserve in western Tanzania (started September 18, 2021 and ended in October 15) and we managed to directly visit 12 villages and out of these, we conducted surveys in nine villages and consulted through phone, in person meeting with Game Reserve officers to consult about the situation of HEC in 25 other villages.

Through the survey, we aimed to gather information on forms and distribution of HEC, its relationship with land cover and land use changes, and the social and economic effects of elephants' invasions on people's livelihoods and the willingness of these communities to Public Participation in Scientific Research (PPSR). A total of 201 interviews were conducted including both villagers and their leaders in nine villages. Land use and land cover mapping and change detection were done using satellite images of 1990, 2000 and 2020. Supervised classification and on-screen delineation approach were used for feature extraction. Geo-referencing and ground verification surveys were done after preliminary photo interpretation.

Results revealed high levels of crop depredation, increasing agricultural activities, ineffective methods of conflict mitigation in villages surrounding the protected areas, increased changes in land use and land cover due to increased human activities. Efforts to mitigate human-wildlife conflict could emphasize an enhanced awareness and introduction of introduction 'multi-value' and low-cost farm-based elephant deterrents that are affordable and applicable among the locals to reduce cases of crops raids among these particular socio-demographic groups.

Acknowledgment

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Introduction

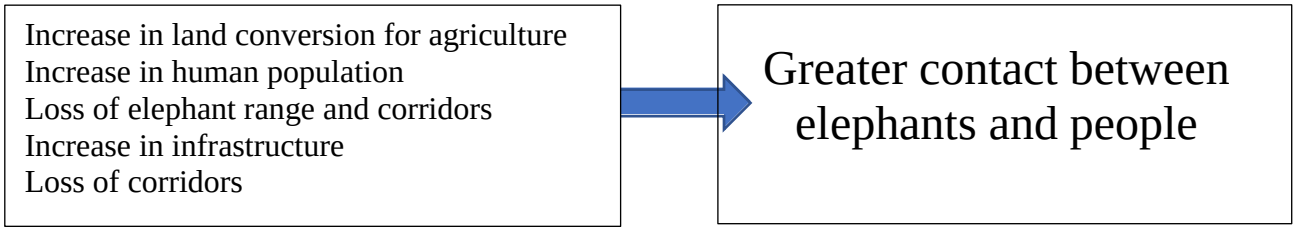
Human elephant conflict occurs throughout the African range and has been reported in most of the 37 elephant range states of the African continent in both savannah and forest situations and also in all 13 Asian range countries of the wild Asian elephants (Gross et al. 2017). Elephant conservation is a national priority in Tanzania (Mduma et al. 2010), as this country holds the largest population of elephants in East Africa (50,400 elephants in 2015), despite a serious and ongoing poaching crisis that has reduced the elephant population by more than 50% since 2009 (Thouless et al 2016). In addition to their important ecological role as keystone species, elephants are recognized as an important source of national income via nature and wildlife tourism. Over 1 million people visit Tanzania's Protected Areas every year, contributing to a rapidly growing tourism industry that constitutes 14% of Tanzania's GDP (WTTC 2015).

However, elephants can also have negative impacts on people and livelihoods, especially in communities that share space and resources with elephants. Impacts can include damage to crops, pipes and food stores, socio-economic disruptions such as increased need for night-time guarding of farms, competition over the use of limited water resources between elephants and people, killing of livestock by elephants, and human injury and mortality caused by elephants (Ngure 1995; Thouless 1994; Kangwana 1996). In agricultural areas, elephant crop-raiding is the primary form of HEC, and results in crop losses that negatively affect food and livelihood security (Kangwana 1996). Though a variety of wildlife species depredate on crops (including wild pigs, antelopes, birds, rodents, elephants, hippopotamus and certain species of primates are known to feed on human crops where they live in close proximity to cultivated lands (Shafi & Khokhar 1986; Conelly 1987; Boulton et al. 1996; Kharel 1997), and species other than elephants often cause the greatest crop losses (Fungo 2011), elephants are usually perceived as the most serious cause of human-wildlife conflict due to the scale of damage they are capable of causing and the potential physical threat they pose to humans (Kangwana 1996).

HEC also has negative consequences for elephants, as it can prompt retaliatory or Problem Animal Control (PAC) killing (Dublin and Hoare 2004); between 1989-2009, it is estimated that an average of 300 elephants were killed annually for PAC in Tanzania (CITES CoP15 Prop. 4 2009), though the actual number of elephants killed for PAC showed a sharp decreasing trend in 2007-2009 (Mduma et al. 2010). HEC may also foster tolerance of poaching among people who feel powerless to prevent elephant crop-raiding, and perceive no tangible benefits from protecting elephants. HEC creates anger towards elephants from the communities who live with them because they can ruin people's livelihoods. Such anger undermines support for elephant conservation, and has led to farmers killing elephants or turning a blind eye to poaching in retaliation for the damage they have caused. HEC contributes significantly to farmers' negative attitudes towards wildlife and conservation as they look at wildlife as a liability to them (Conover & Decker 1991).

Given these negative consequences of HEC for people and elephants alike, mitigation of HEC should be a conservation priority in areas where people coexist with elephants.

Causes of Human Elephant Conflict



Reasons for greater contact between elephants and people

As a species with large range requirements and migratory behaviour (Douglas-Hamilton et al. 2005), elephants spend considerable time outside of Protected Areas. Although Tanzania's Protected Area network covers over 30% of the country, elephants' range over at least 41% of the country (AED 2012). As such, there is potential for conflict when elephants come into contact with people outside PAs.

Furthermore, the human-elephant interface at which conflict can occur may be expanding due to rapid demographic, socio-economic and land-use change in Tanzania (Devisccher 2010). Tanzania's human population has almost doubled since 1978, from around 17.5 million people (1978 Census National Bureau of Statistics) to a projected 51.8 million in 2014 (World Bank). In addition to the pressures of population growth, internal migration of rural people driven by access to available and productive land may lead to increased settlement and land conversion around PAs, though a study of migration patterns to National Parks did not find evidence for PA-driven in-migration (Salerno et al. 2015).

Human-elephant conflict appears widespread in Tanzania (Figure 1), particularly in regions bordering PAs and in wildlife corridor areas (Mduma et al. 2010). In a survey of District Natural Resource Officers conducted for the Tanzania Elephant Management Plan 2011-15 (Mduma et al. 2010), sixty districts reported HEC events for the period 2007-2009, of which 60% reported serious or very serious HEC.

In Tanzania, between the four financial years from 2011-2012 to 2014-2015, 11,846 acres of crops were raided by problem animals and the government spent about 856,333,000 TZS (USD 713,611) in consolation (Munuo W. 2016; WD, 2015). HEC occurs wherever people and elephants coincide, and poses a serious challenge to wildlife managers, local communities and elephants alike. Increasing human populations and expanding agriculture have increased the potential for conflict between humans and elephants in many regions. Elephants have been compressed into ever-smaller areas and their traditional migration routes have been cut off or reduced. Kitendeni corridor providing link between Mount Kilimanjaro and Amboseli National Park in Kenya is a good example. This corridor has shrunk from 21 km^2 in 1952 to 5 km^2 in 2001, resulting in a reduction of wildlife habitat and increasing human–wildlife conflicts (Noe, 2003).

Negative impacts of elephants on people mostly occurs in adjacent communities that live close to the natural habitats were the elephants live. Considering the rapid increase in human population that has increased human needs, there has been a resultant expansion of human activities which in many cases have encroached into wildlife areas (which are the last suitable habitats remaining), especially by local communities living around protected areas. In situations where such areas have a significant population of elephants, HEC are bound to occur. In many cases, as a result of HEC, people lose their crops, livestock, property, and sometimes their lives. HEC has been a big problem to a huge number of people in many parts of the world.

Elephants have increased contact with humans due to changes in land-use (i.e., fragmentation of habitats because land is converted for crop cultivation, settlement, and livestock grazing) (Nelson et al. 2003). Also, National parks created under colonial governments were established to exclude local people and protect the areas as wildlife sanctuaries. As a result, these landscapes ―became frozen in time. This exclusion led to local people resenting wildlife, especially dominant wild species like elephants, because native people thought animals enjoyed economic, land-use, and political advantages that were unavailable to them (Anderson and Grove, 1987). This has contributed to ―determinedly hostile attitudes towards elephants (Lee and Graham, 2006).

General objective

The general objective of this project was to investigate the impact of human elephant conflicts (HEC) on agro-based livelihoods, analyze land cover and land use changes for the period 1972-2019, community willingness to participate in citizen science to understand trends in HEC, and find solutions to this problem. Outcomes of this study will provide an understanding the complex conflicts between elephant conservation and human livelihoods around RLGR and inform strategies to mitigate human elephant conflict in this and other areas.

Project Activities

In order to achieve overall objective, we identified a number of activities to be conducted during the project period and they are;

I. To identify land cover and land use changes through analysis of online acquired images of the indicated years.
II. To identify crops grown in the area and crops mostly preyed by elephants and those not used by elephants.
III. To identify willingness of the community to participate in citizen science
IV. Attitudes toward crop raiding elephants and human-wildlife conflict more generally
V. To understand views/satisfaction/concerns regarding existing HEC mitigation strategies across villages, specifically with respect to how farmers currently protect their crops from wildlife and more specifically elephants
VI. To understand perception of change in land use and land cover, and attitudes regarding these changes
VII. To identify visions for the future with respect to human elephant coexistence, food security

Methodology

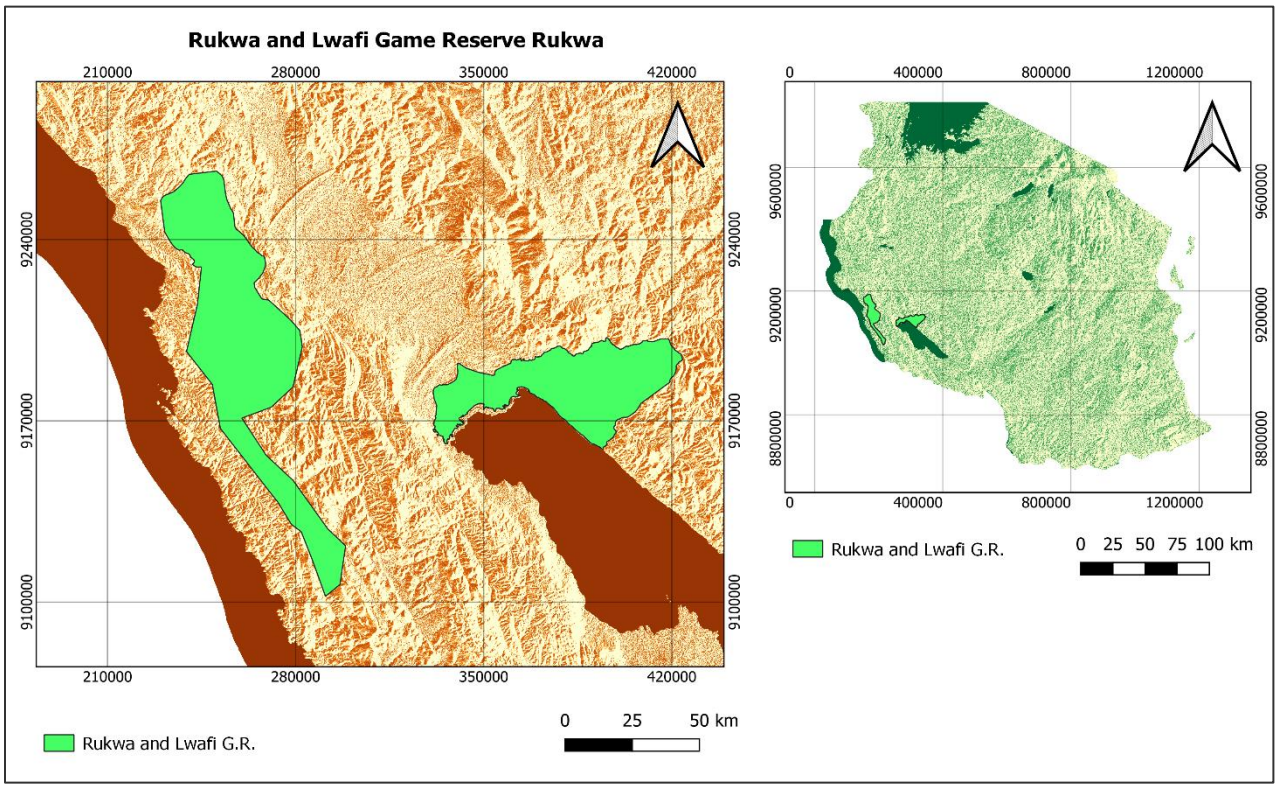
Study area

The study area is located on the Katavi – Rukwa Landscape in Western Tanzania. Rukwa (494 km2) and Lwafi (2228.2 km2) Game Reserves are crucial protected areas in western Tanzania providing critical ecosystem services for the surrounding regions, and a potential magnet for the growing trade in African photographic and hunting tourism. These two GRs border Katavi National Park and are surrounded by several forest reserves which are also important areas hosting many species including elephants. The landscape is home to approximately 4600 elephants in 2018 (TAWIRI, 2019) a decline from approx. 6400 elephants in 2009 (Mduma et al. 2010) among other species of wildlife. Habitats of RLGR are a mix of miombo woodland, shrub land, and savannah grassland providing a suitable home for a wide variety of animals. Demographic changes in the area have led to changes in land use and land cover, forest cover density and an increased interaction between people and wildlife (Salerno et al. 2014). Around the Lwafi Game Reserve exists, the Loazi -Ntantwa- Lwafi wildlife corridor which offers a long stretch of connectivity to elephants and other wildlife to across the Northern Zambia section.

Rapid population increase around Tanzanian protected areas, marked ecological changes in Rukwa-Katavi Regions, dramatic losses of biodiversity in and around these reserves, and ongoing immigration of different ethnic groups into the landscape (Salerno, 2016) has created specific

challenges such as human elephant conflict around wildlife buffer zones, corridors, and dispersal areas. As throughout Tanzania, most district government has little power and resources to address human wildlife conflict (Salerno et al. 2017), such that village officials (and the village environmental committee) are unable to prevent wildlife raiding farms in village land. Without fomenting political disturbance, it is nowadays critical to get baseline information on the extent of HEC, land cover, land use change, and local engagement, if novel community based human elephant conflict mitigation strategies are to be developed, as endorsed by my collaborators (Genda et al. 2021).

The main economic activity for the local people is agriculture and livestock keeping but seasonal food security is a serious problem for many households in the area (Hadley et al. 2007). The human population in Nkasi District was about 281,200 in the last census (URT, 2012) with a population growth rate of 4.5% and National Bureau of Statistics, the population recently estimated to have increased to 333,771 (NBS, 2017). Mpanda District has about 118,150 people (URT,2012) with a population growth rate of 4.9% and currently, the population is projected to have increased to 210,572 (NBS, 2017).



Map showing Rukwa and Lwafi Game Reserve. The study was conducted in villages bordering these two reserves.

Image acquisition, processing and analysis

We used Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM) and Landsat 8 Operational Land Imager (OLI) imagery to analyze land cover change of the years 1990, 2000 and 2020, respectively. Nkasi and Mpanda areas extend over two different Landsat paths and

rows. Images with spatial resolution of 30 m were downloaded from the US Geological Survey (USGS) Earth Explorer (http://earthexplorer.usgs.gov). The images were selected based on crops growing calendar as previously used by Canute et al. 2015. The authors selected the images based on the dates when the crops were maturing, but our study selected the images using the dates of off cropping. This is due to the fact that during dry season, it was possible to identify agroforestry and the remaining bare lands were termed as seasonal agricultural lands (Table 1). All images (1990, 2000 and 2020) were obtained within same time of year. Shapefiles for study site boundaries were obtained from The National Bureau of Statistics (NBS) available at (https://openmicrodata.worldpress.com). Satellite images of different years were imported in QGIS (version 3.18.2) for processing and analysis. The geographic coordinate system was defined to the World Geographical System (WGS) 1984 and projected to Universal Transverse Mercator (UTM) Zone 36S prior to analysis. Image processing and analysis included image cleaning, compositing, masking, clipping and mosaicking. In this study, natural color bands were used. Three Landsat images were classified by using the maximum likelihood function, which is the most common decision rule among the supervised classification (Campbell & Wynne, 2011). It is also considered to give very accurate results (Reis, 2008) because each pixel is assigned to the class to which it has a highest probability of belonging (Campbell & Wynne, 2011). Visual interpretation and digital image classification were then combined using GIS functions. Seven land use classes were defined in the study area which included: Forests, agriculture, built-up, swamp, water, shrubland and grassland. Training sites were determined and signature files were created to be used in the classifications by using QGIS (version 3.18.2). The classified images were compared with over 40 direct ground truthing points across the study area and modified accordingly.

Household interviews

To better understand the nature and extent of these conflicts, we conducted surveys (n = 201) with local villagers around the Rukwa and Lwafi Game Reserve we recorded about 37 villages bordering these two reserves. During the project, we directly visited 12 villages and out of this we administered questionnaires in 9 villages and consulted through phone, in person meeting with Game Reserve officers about the situation of HEC in 25 other villages which did not show serious incidences of HEC – some rarely recorded at least one incidence of elephants passing through village land once in three years.

The households were selected from nine elephant roaming villages by visiting at least 25 households per village (located at least 0.5-1 km apart) with the accompaniment of a village council committee representative. We approached residents at their homes and only proceeded with the survey if the interviewee has a good experience or history of HEC of their household and mostly targeted father, mother or the eldest son of the age above 18. During the survey, respondents were informed about the aim of the surveys and asked for their consent to conduct the surveys. All the respondents were asked on their willingness to participate in the survey; and a few refused. Questionnaire prior to constructing the survey, we first conducted a pilot survey of local individuals in Mpimbwe we approached villages officials and several households bordering Mpimbwe Wildlife Management Area. From this pilot survey, we refined and produced a final version of a questionnaire used in nine villages.
The team that assisted in data collection was trained and also participated in the pilot survey to make sure they are well versed with the questionnaire and understand how to properly fill the data sheet and other information including GPS points. Data were entered in Ms. Excel where they were cleaned and then coded. Then entered in Statistical Package for Social Science version 20.0 (SPSS) where frequencies and proportions were run. Categorical variables were analyzed using Chi-square/Exact fisher test.

Phone and Experts consultation

We contacted village representatives from **25** distant villages that could not be easily reached to confirm incidences of HEC. All the villages reached through phone consultation gave minimum information of the situation of HEC in their villages for instance some indicated at most one incidence of elephants passing through the village land in two years and caused no damage to crops.

The village selection, data collection activity, analysis and presentation were conducted smoothly because we initially consulted experts working in the project area. They showed maximum support and helped us meet all targets for each identified activity. The list of consulted experts include;

1. Mr. Asubuhi Kasunga – Lwafi GR Manager
2. Mr. Shaban Matwili – Nsimbo District Game Officer (Mpanda)
3. Mr. Christopher - Rukwa GR officer
4. Mr. Cedric Mashauri - Lwafi GR officer

RESULTS IDENTIFIED AFTER DATA ANALYSIS

Sociodemographic characteristics of the participants

A total of 201 participants were interviewed in this project, whereby majority were males (69.5%). More than half (58.7%) of the participants were from Nkasi district. Most of the participants' age (50.8%) ranged from 21-40 years and more than three quarter (66.9%) were head of the households (fathers) Table 1.

Table 1: Sociodemographic factors of the participants

Variable		**Nkasi, N=118**	**Mpanda, N=83**
	Category	**n (%)**	**n (%)**
Age	21-40	60(50.8)	29(34.9)
	41-60	50(42.4)	34(41)
	61-80	7(5.9)	18(21.7)
	>80	1(0.8)	2(2.4)
Sex	male	82(69.5)	62(74.7)
	female	36(30.5)	21(25.3)
Position in the family	father	79(66.9)	60(72.3)
	mother	36(30.5)	21(25.3)
	son	3(2.5)	2(2.4)

Most cultivated crops in two districts

Our findings of the HEC indicated that maize is the major seasonal food crop grown in the area among villages of Mpanda district while for those of Nkasi district is beans. Other main crops grown in the area include, cassava, sweet potatoes, paddy and sunflower. These are crops that are favored by both communities residing in these areas, the Pimbwe, Fipa and Sukuma. They are also grown widely in recently acquired farms that still have good soil fertility.
Some crops such as millet, carrot, peas and cotton are less grown in the area as only few of these areas have all season water sources to support their growth and especially villages bordering Lwafi Game Reserve (Figure 1).

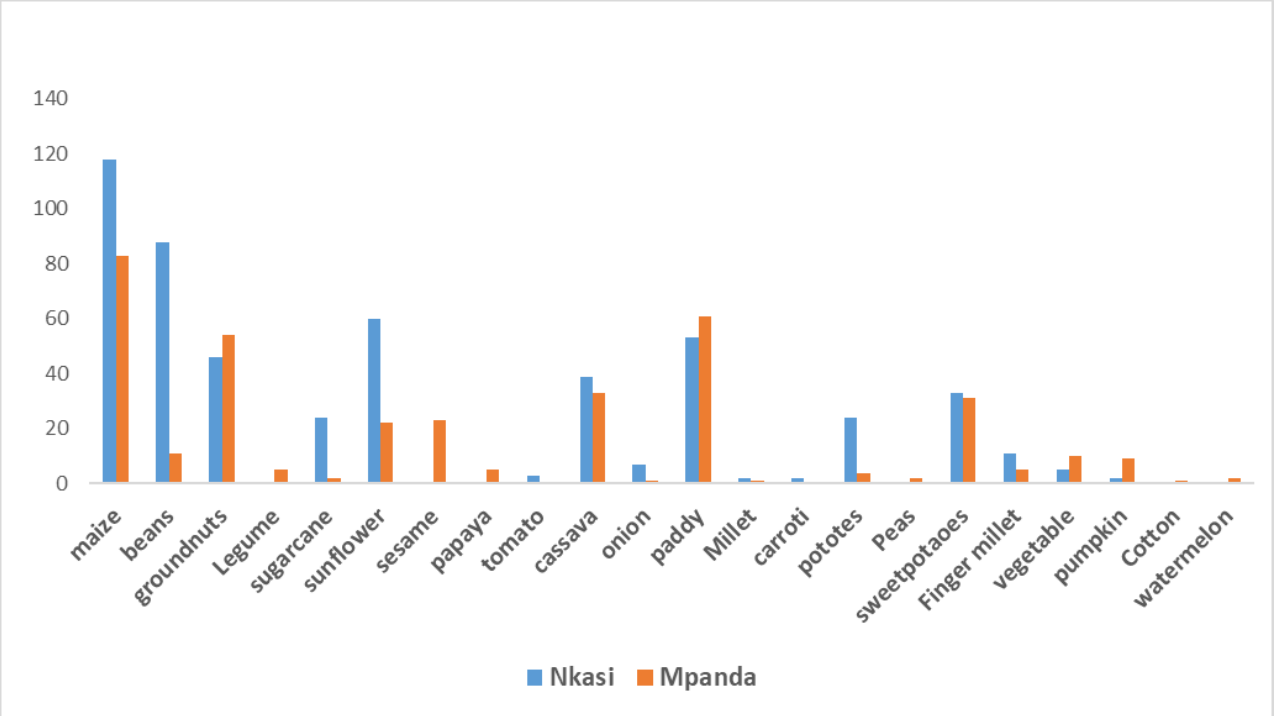


Figure 1: most cultivated crops in both districts

Threats to food shortage

We have also explored on the possible threats to food shortage in the surveyed areas. From the data collected in the surveyed villages, we also identified threats to food and ranked them and from the results, wildlife has been identified as a major threat to crop losses in the surveyed villages. Some farmers in Sitalike, Kizi and Paramawe also cited drought as their primary threat to agriculture, and crop losses from wildlife was the second greatest threat.

Farmers also cited other lesser factors which contributed to food shortage in the surveyed villages and they include; inadequate transport facilities, floods, pests, livestock and farm inputs (fertilizers).

In Figure 2 below, crop losses from wildlife were ranked the highest and this has been reported in villages such as Sitalike and Igongwe which reported incidences of roaming elephants in both the wet and dry season. Livestock is also a challenge during the wet season due to shrinkage of grazing areas. Also, most villages do not have clear land use management plan and because of tough restrictions to graze in wildlife areas, they end up allowing livestock into farmlands. Most of the villages that do not directory border the game reserve, reported slightly lower incidences of crop losses from wildlife and cited other factors such as floods in the lower parts of Sitalike (Situbwike sub village), transport challenges in the upper part of China which is hilly and roads are barely impassable (Figure 2).

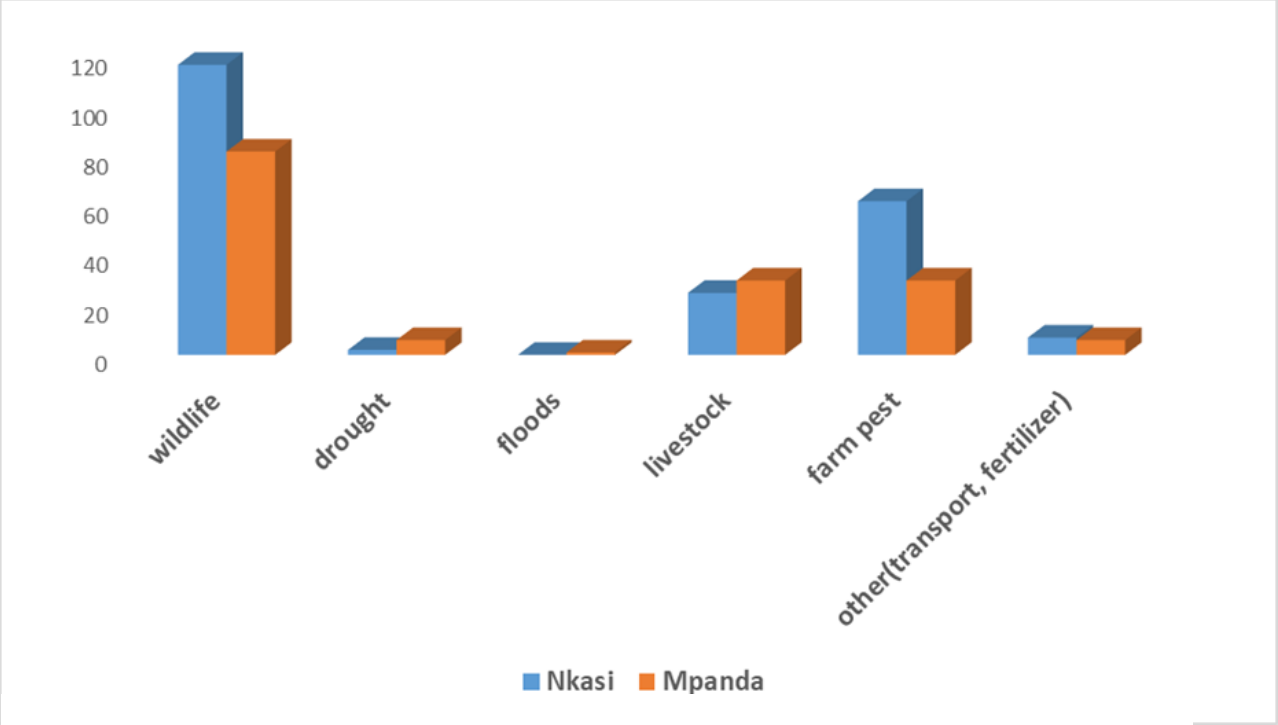


Figure 2: threats to food shortage

Most disturbing animal in both districts

From our questionnaire, we also narrowed down to specific animal that has been reported to the source of crop loss in the area and farmers reported several animal species. In the surveyed villages bordering the two reserves, elephants were ranked as the primary source of crop loss in all the nine villages and hippopotamus as the secondary cause of crop loss and only reported in the three villages of Mpanda district. High incidences of hippopotamus within village land were highly reported in Sitalike village and this could be due to its proximity to several rivers along its border with Katavi National Park. Rice farmers in Sitalike reported high incidences of hippos in their field and no form of mitigation has been trialed as most of them fear the animal. In far remote villages bordering Lwafi Game Reserve for instance China village, other wildlife such as bushbucks, wild pigs and vervet monkeys were cited as the secondary source of crop loss (figure 3).

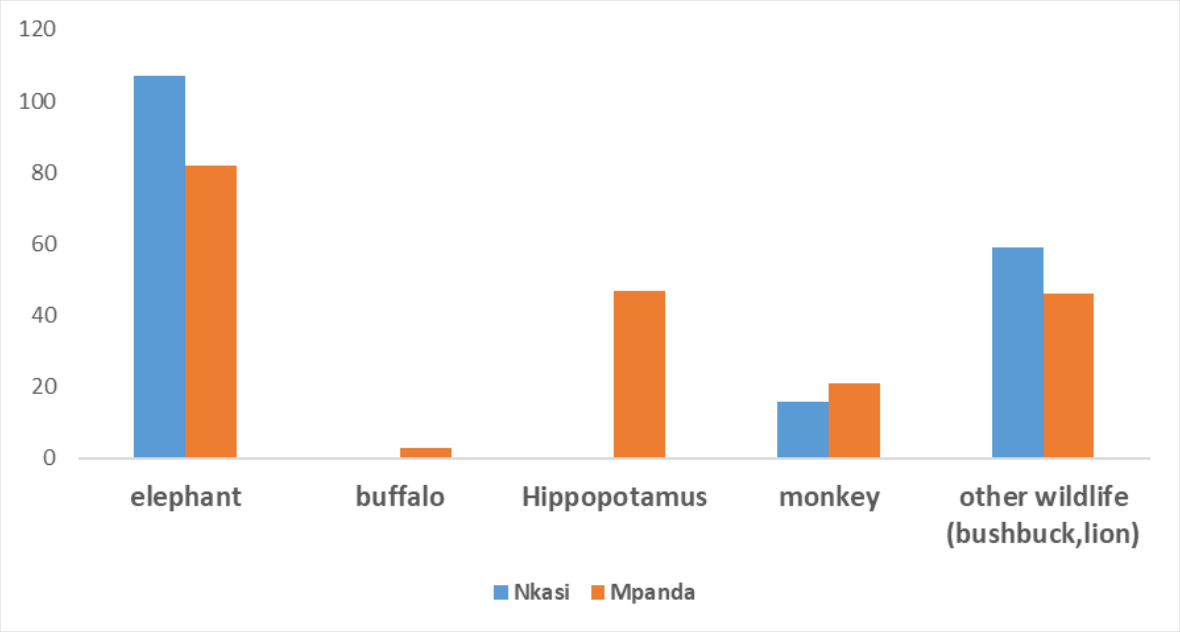


Figure 3; most disturbing animals in both districts

Damages caused by elephants

Data from the 9 surveyed villages showed crop destruction is the primary damage caused by elephants in which for Nkasi is 97.5% while for Mpanda is (98.8%). Additionally, in villages such as Sitalike, Igongwe and Matandalani, farmers reported huge incidences of fruit tree damage and mostly mangoes and guavas and banana plants were most affected by elephants. Some farmers also reported incidences of damage to food store and mostly elephants targeted food stores and maize mills houses where maize residue and flour is stored. This has been widely reported in Sitalike and specifically in the far subvillage of Situbwike (Table 2).

Table: 2 *Damages caused by elephants

	Nkasi, N=118	Mpanda, N=83
	n (%)	n (%)
Crop destruction	115(97.5)	82(98.8)
Fruit trees damage	57(48.3)	66(79.5)
Hardening soil	7(5.9)	15(18.1)
Damage to food storage	4(3.4)	17(20.5)
Damage to farms	12(10.2)	17(20.5)
No damages	1(0.8)	0(0.0)

***Response based on multiple choices**

Seasonality of the problem

Data collected from the surveyed villages were also used to investigate seasonal patterns in elephant crop-use. From the figure below, (Figure 4), farmers reported high incidences of crop loss in the wet season for Nkasi District villages while in villages of Mpanda, the problem seem to occur in all seasons. Second Figure 5, crop-loss events were said to occur during the late wet season when most farm crops have ripened (January to March) and harvesting months (April to June). In three villages of Mpanda District (Sitalike, Matandalani and Igongwe) incidence of crop loss was high in the driest month of year, September while those in China (Nkasi District) also reported some incidences of elephant activities in the September as they practice all year farming as most rivers from Lwafi Game Reserve provide water all year round. September is one of the driest months of the year in this landscape and elephants roam freely in village land in search of extra food and water (Figure 4).

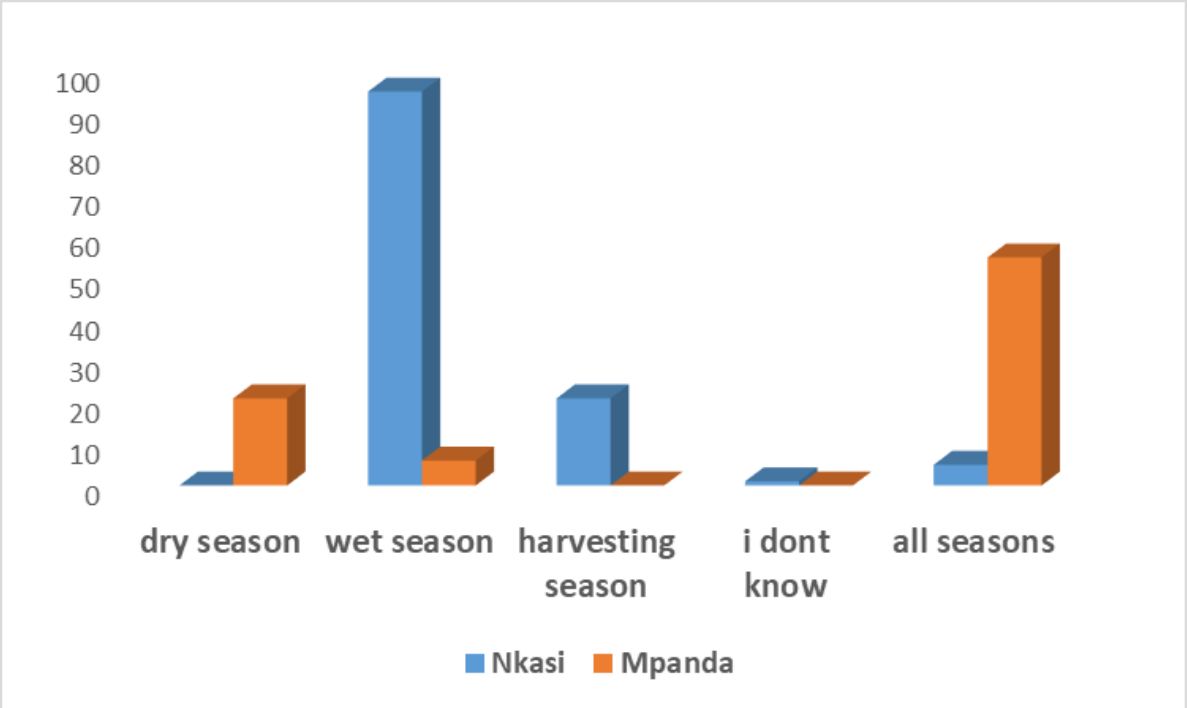


Figure 4: seasons elephants most occur

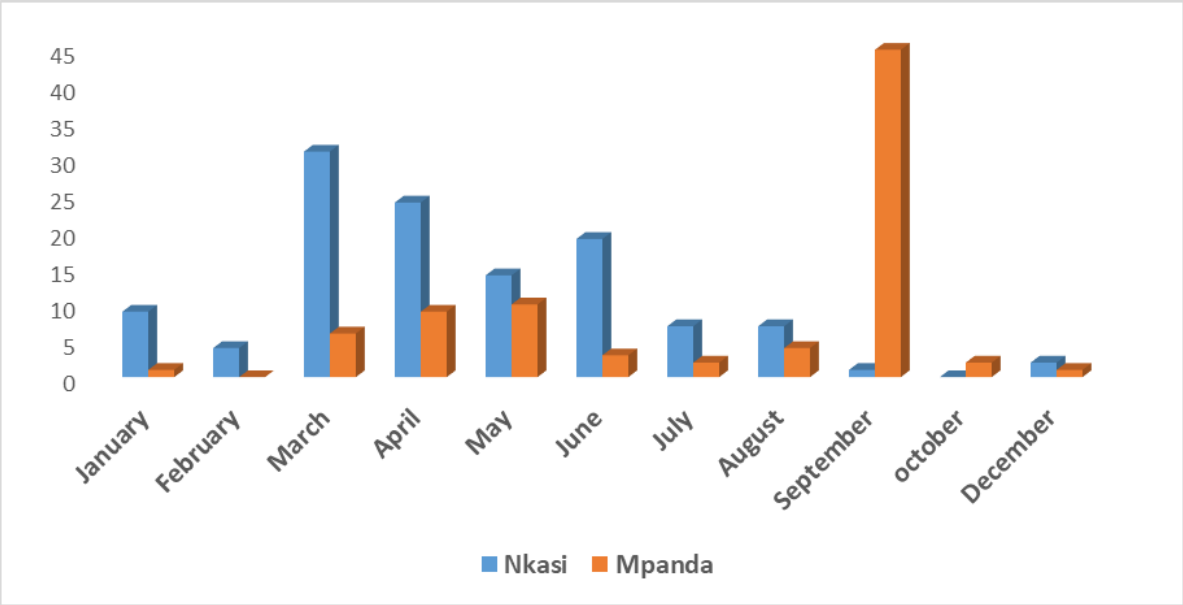


Figure 5: last time the crops were raided by elephants in year 2021

Crops which are most raided by elephants and why?

The major crops consumed by elephants are maize and rice, with maize being reported as the most frequently consumed crop all the nine villages as it is grown in all villages as staple food. Paddy has been reported in four villages – Sitalike, Ipanda, Mkole and some parts of China villages (Figure 6).

Other crops destroyed by elephants are sugarcane, banana, cassava and sweet potatoes. Some crops are grown in very small scale but are also prone to elephant damage for instance millet, pumpkins and cabbage. Crops that are not used by elephants are sunflower, sesame, tobacco and onion but cases of elephants destroying them by stepping on them has been frequent as well. Some of these non-palatable crops are also grown within other palatable crops and they are affected during the elephants' raids. This is why sunflower and sesame has appeared in the figure 6. We also asked farmers on why some crops are being mostly used by elephants and 41.3% of the farmers cited that it is the most grown crop in the area (Table 3).

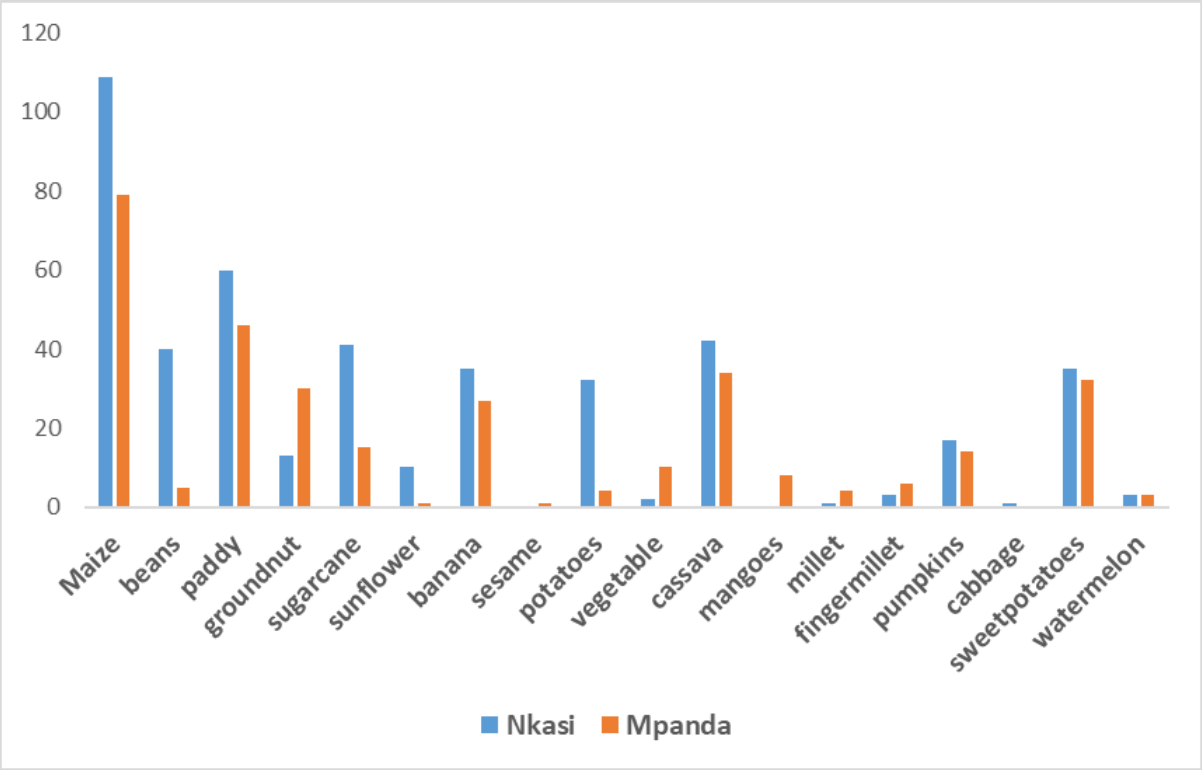


Figure 6: Crops which are most raided by elephants

Table 3: Reasons why elephants prefer these crops in both districts

	Frequency (N=201)	Percent
They are very common crops in the village and available in plenty	83	41.3
They are sweet and attractive	46	22.9
available in dry seasons	5	2.5
hunger	2	1
I don't know	65	32.3

Land Use Changes, Land Cover Changes and Human Elephant Conflict

From the survey conducted in these two districts, (table 4) shows reasons for increase in crop raiding incidences in the villages. The highest percentage (33.1% and 50.6%) indicates changes in land use; cited increase in settlement areas (residential homes, schools, and schools) and farmlands where most areas formerly occupied by wildlife are now farmlands and this increased interaction between people and wildlife. Another factor (seasonal shortage of food and water for wildlife) was mentioned as the secondary cause of crops raid. Some farmers for instance those in Sitalike, Matandalani and Igongwe cited those elephants are attracted to small gardens, fruit trees and banana plants in village land during the dry season. A few farmers who moved into the area recently did not know the reason for crop raids in their village.

Table 4: Reasons for elephant's crop raid in the villages

*Reasons for elephants raiding farms	Nkasi (%), N=118	Mpanda (%), N=83
Changes in land use - most former wildlife areas are now occupied by people	39(33.1)	42(50.6)
Seasonal shortage of food and water for wildlife	33(28.0)	26(31.3)
Encroachment of people and livestock into wildlife areas has increased contact between people and wildlife	14(11.9)	3(3.6)
This is a new village and I moved into this area recently	6(5.1)	1(1.2)
Others	25(21.2)	14(16.9)
I don't know	8(6.8)	3(3.6)

***Response based on multiple choices**

Change in area of the various land cover types

This chapter presents and discusses the changes in various land cover/land use types of the year 1990, 2000 and 2020. It also presents and discusses the current different human activities that have resulted to the observed changes.

The results from the supervised classification of the images shown in map 001-003 indicate losses and gains in various land use and land cover types. From table 4, it is apparent that the area covered by indigenous forest reduced drastically between 1990 and 2000; with an increase in area for farmlands and bare land. The results of 1990 shows and intact forest patches but has been decreasing over years due to changes in land cover and land use among the two analysed districts which the two reserves and its adjacent surveyed villages.

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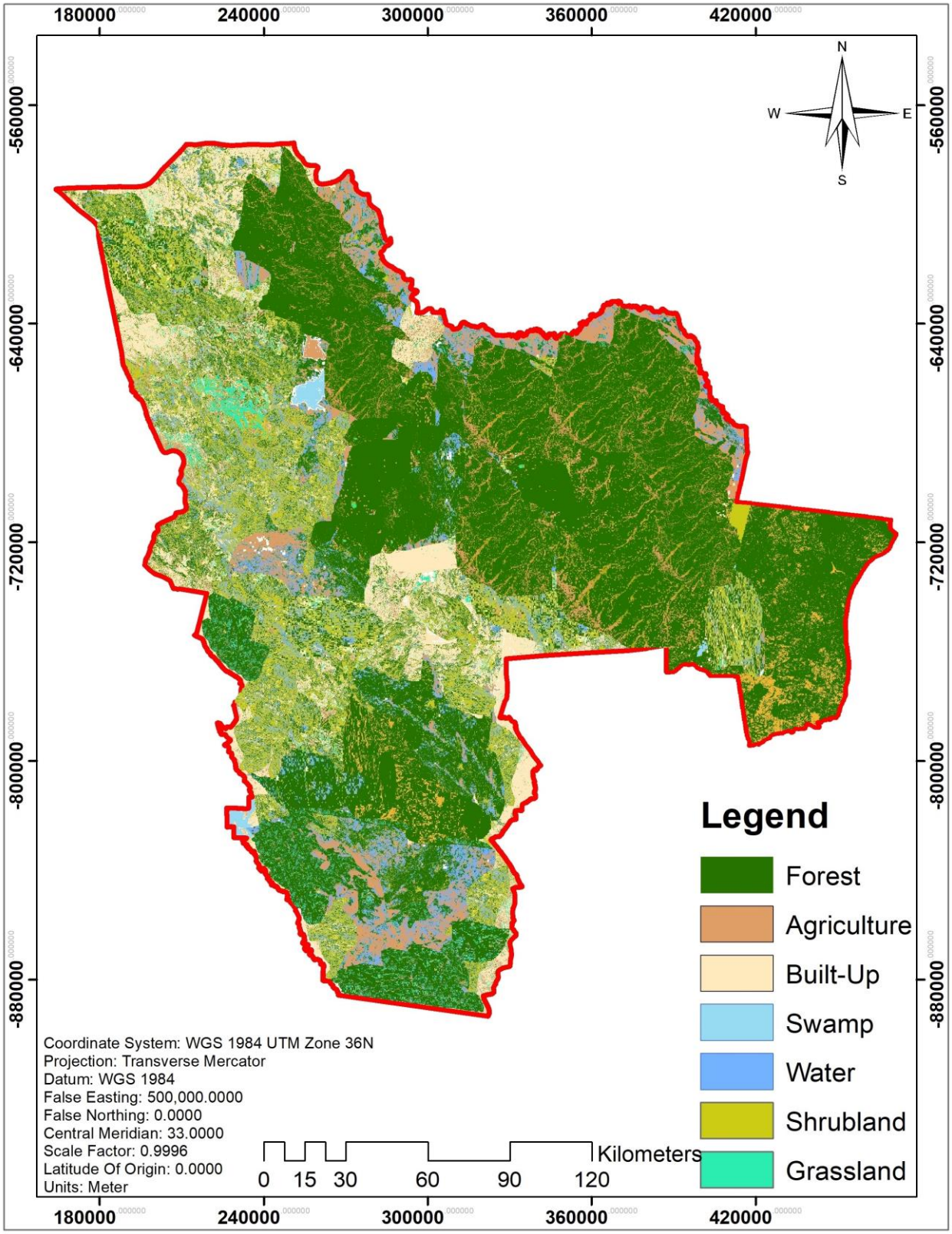
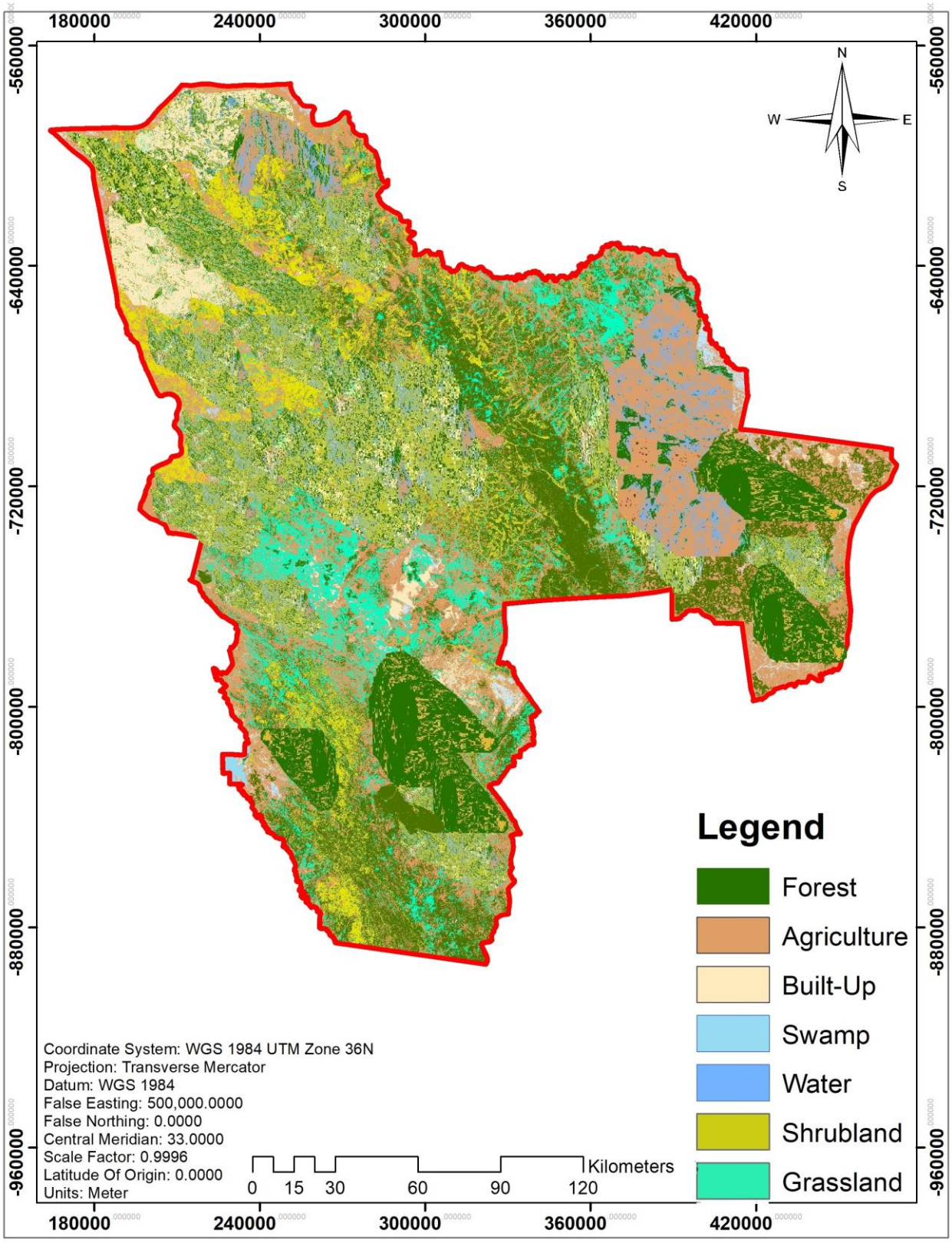
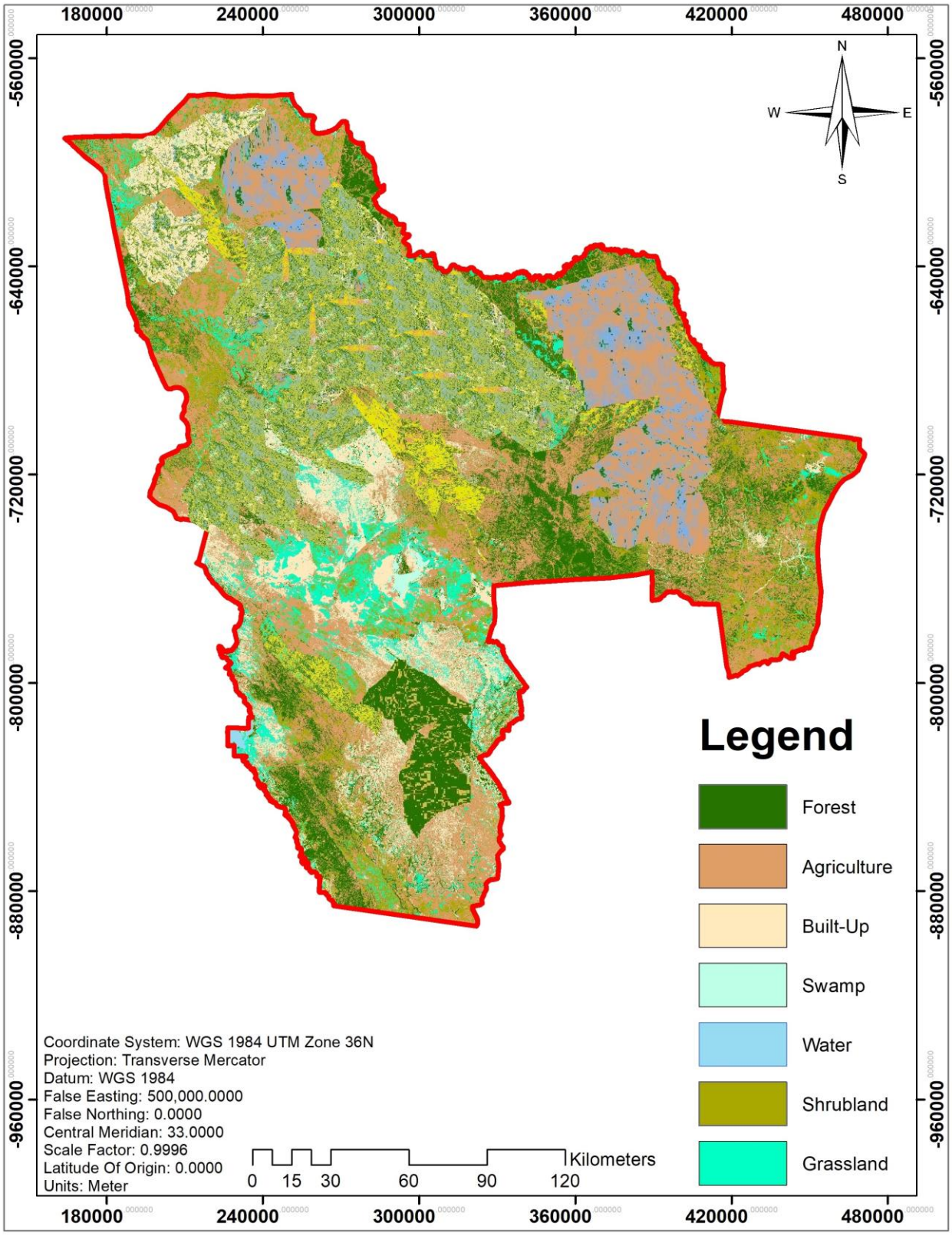


Map 001: LULC map for year 1990



Map 002: LULC map for year 2000



Map 003: LULC map for year 2020

Table 5: Area statistics of LULC maps for years 1990, 2000 and 2020

	Year wise area in km^2		
LULC Type	**1990**	**2000**	**2020**
Forest	12917.547	12165.547	11593.547
Agriculture	16731.8857	16835.8857	16980.8857
Built-up	5117.3978	5203.3978	5355.3978
Swamp	584.6524	575.6524	452.6524
Water	283.6197	205.6197	58.6197
Shrubland	8004.0086	8182.0086	8524.0086
Grassland	3470.2557	3941.2557	4144.2557

Table 6: Change area analysis of LULC maps for periods between 1990-2000, 2000-2020 and 1991-2020

LULC Type	**1990-2000**		**2000-2020**		**1991-2020**	
	Area					
	km^2	**%**	**km^2**	**%**	**km^2**	**%**
Forest	-752	-44.8153	-572	-33.9667	-1324	-39.3813
Agriculture	104	6.197855	145	8.610451	249	7.406306
Built-up	86	5.125149	152	9.026128	238	7.07912
Swamp	-9	-0.53635	-123	-7.30404	-132	-3.92623
Water	-78	-4.64839	-147	-8.72922	-225	-6.69244
Shrubland	178	10.60787	342	20.30879	520	15.46698
Grassland	471	28.06913	203	12.05463	674	20.04759

Contribution of local resident to research through citizen science

HEC still exist in the area and more aspects still need to be studied over time while searching for the best solution to enhance coexistence. Due to limited resources, there is need to come up with a strategy to incorporate local input to further gather HEC-related and other wildlife data while fostering public input and engagement. We interviewed the local residents (n = 201) to explore the feasibility and utility of expanding our initial survey effort to create a more comprehensive and sustainable framework for monitoring human-wildlife interactions based on Public Participation in Scientific Research (PPSR) principles.
Many local residents seem to be attracted by this idea and willingly shown interest to participate in this project and one of the driving factors is the high level of HEC. Some believe they will get solutions if they participate in sharing information on HEC. A small number that said NO were expecting tangible benefits and some afraid that if they constantly share the information, it might lead to their relocation.

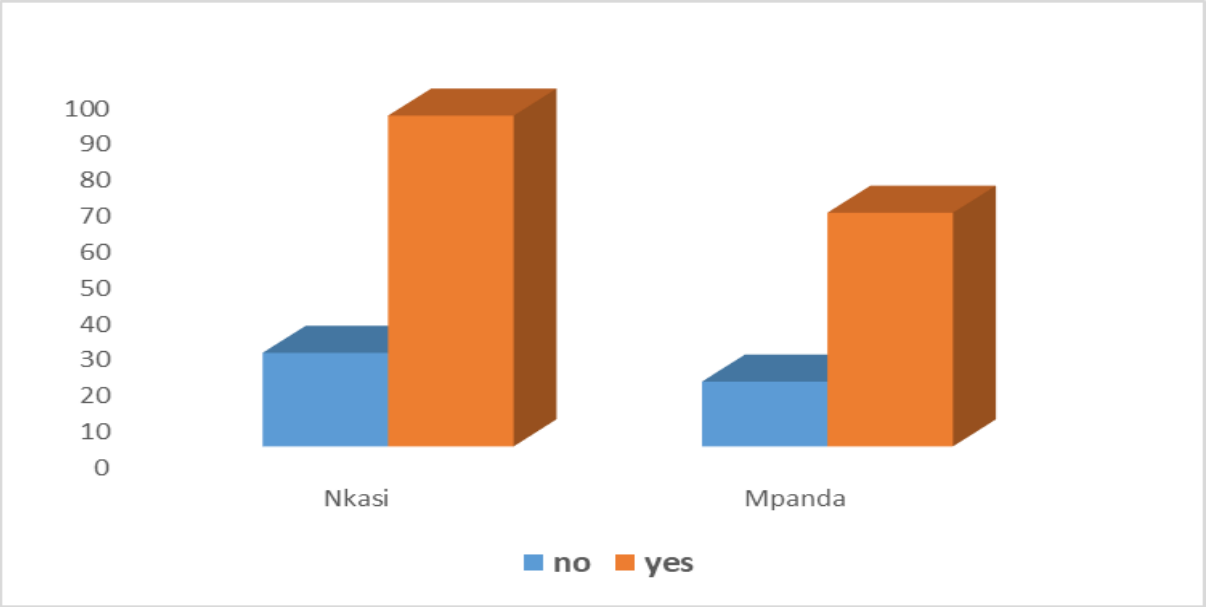


Figure 7: willingness to participate in citizen science

Human elephant conflict Mitigation

Crop protection strategies and effort used by farmers in these two areas.

With the existence of the conflict, farmers also brought in some efforts to safeguard their farms from elephants. During the survey, we also asked farmers to mention strategies used to protect crops against elephants. The table below (table 7) shows different methods highlighted by farmers as mitigation strategies to protect crops from elephants. During the survey, we were also lucky to witness and capture some methods. In both districts, all farmers interviewed at least applied crop protection strategy suggesting the problem is and farmers are will to adopt appropriate methods to protect crops from elephants.
Traditional crop protection methods mentioned by the interviewed farmers include guarding using dogs, creating unpleasant mixtures to deter elephants, make noise to chase away elephants, chasing elephants using fire and this method seemed not too ineffective as most of these farmers still raised concerned on crop loss from elephants. A section of farmers from Sitalike and China have trialed chili fencing while some from Sitalike trialed beehive fencing

after they received training from experts in 2020. Also, some have tried traditional crop protection methods and after they failed, they opted to be reporting the problem to the authorities and sometimes relies on protection from park rangers.

Table 7: ways most used to prevent elephant crop raid

* **Ways to prevent crop raid**	Nkasi (N=118)	percentage	Mpanda (N=83)	percentage
Creating unpleasant mixtures to deter elephants from farms	0	0	1	1
Guarding farms using dogs	6	5	2	2
Make noise to chase away elephants	60	51	50	60
Chasing elephants using fire	25	21	36	43
Chili fencing	1	1	4	5
Beehive fencing	0	0	1	1
Reporting to the authority	2	2	1	1
Joint family farm guarding during farming and harvesting season	13	11	12	14
Protection from park rangers	1	1	3	4

***Response based on multiple choices**

Suggested ways to stop crop raiding in the villages in both districts

We have also asked farmers on what they think should be done to crop raiding elephants as a way to stop them from the damage caused in farms. A larger percentage (87%) of the farmers recommended on non-lethal methods of managing problem elephants – meaning despite the problem of consistent crop use by elephants they can still see their value. Only a section (8%), especially from Sitalike and Igongwe who experience HEC on both wet and dry season recommended on problem animal control through killing as they perceive it will reduce the number of elephants roaming in village land.

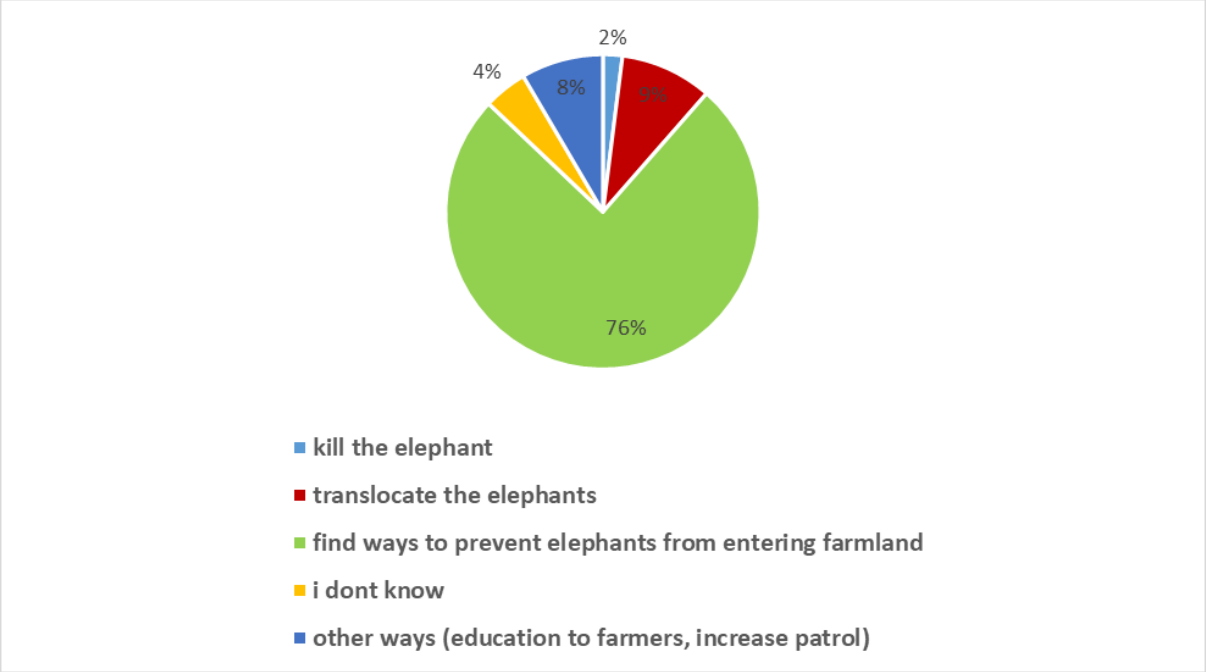


Figure 8: suggested ways to stop crop raiding in the village in both districts

Reporting and assistance in response to crop losses

In all the villages that we surveyed by questionnaire that reported crop losses, interviewees were asked about current responses to crop-loss incidents from elephants, including if crop losses were being reported, and if assistance had been received in response. Approximately over half of farmers (66.9% of farmers in Nkasi and 72.3% of farmers Mpanda) from the nine villages (Table 8) said that they report crop-loss incidents to local authorities, usually the village government, district game officer, Village environmental council, Village agricultural officer, Katavi National Park, Lwafi game reserve, wildlife researcher, Rukwa Game reserve. A section of farmers (16.1% in Nkasi and 3.6%) indicated that they have received assistance from a wildlife authority as a result of reporting crop losses from elephants (Table 8). This assistance most often took the form of rangers chasing elephants away from the village, and providing advice on how to avoid encountering elephants.

Table 8: Crop raid reporting

Variable	Response	Nkasi (%)	Mpanda (%)
Do you report a crop raid?	no	39(33.10)	23(27.7)
	yes	79(66.9)	60(72.3)
Where do you report			
	village government	55(46.6)	43(51.8)
	district game officer	0(0.0)	0(0.0)
	Village environmental council	0(0.0)	0(0.0)
	Village agricultural officer	8(6.8)	10(12.0)
	Katavi National Park	0(0.0)	7(8.4)
	Lwafi game reserve	21(17.8)	0(0.0)
	Wildlife researcher	0(0.0)	0(0.0)
	Rukwa Game reserve	0(0.0)	0(0.0)
Do you receive assistance?	no	99(83.9)	80(96.4)
	yes	19(16.1)	3(3.6)

Recommendations

Identifying immediate actions to mitigate HEC for some priority areas

Human-elephant conflicts (HEC) are regarded one of the most crucial threats to livelihoods and in conservation of elephants and their habitats. Therefore, there is an urgent need to come up with immediate solutions to intervene the problem. And because the surveyed areas are large and at the moment we cannot implement mitigative strategies in all villages, we highly recommend immediate intervention in three main villages; ***Sitalike, Igongwe*** *and* ***Matandalani*** which are all based in Mpanda District and bordering Rukwa Game Reserve and Katavi National Park.

From the study, we recommend a number of immediate actions to reduce the conflict;

1. ***Train communities on ways to promote existing traditional beekeeping industry as an innovative approach to deter elephants from agricultural fields but also as an alternative method of population profitability****; This will be achieved through selecting and training local monitors who will be referred to as 'Elephant Conservation Ambassador' and the wider community, purchase of 60 beehives for constructing a model beehive fence for as initial elephant deterrent, training on ways to diversify income through beekeeping, capacity building for multipliers and revision of local management plans for elephant protection*
2. ***Strengthening existing informational and educational campaign among small farmers and students from schools on behavioural ecology and land use of elephants to continue reducing incidences of elephant attacks.*** *This will be achieved through – development of a Swahili booklet '**Elephant Conflict Mitigation Workshop and Training**, **visual animations, weekly community live radio show and Media/social media engagement** to help train, raise awareness and changing the behaviour of the local population. We will also facilitate existence of village-based elephant monitoring groups (ECAs), evaluation of the effectiveness of existing education and outreach approaches.*
3. ***Support advanced training and peer-to-peer exchange for 15 highly affected farmers from the three villages with farmers elsewhere in Tanzania -*** *in **collaboration** with existing partners, this will be achieved through selecting 15 highly affected farmers from eight villages to visit Tanzania Elephant Foundation (TEF) and Southern Tanzania Elephant Program (STEP) projects around Selous Game Reserve to study farmers led projects aimed at reducing human elephant conflicts. This approach facilitates sharing experience, methods and challenges at different sites but our farmers will heavily benefit from this as it is a new component to them.*

Communicating the results and further Steps taken so far to help reduce human elephant conflict

Radio session

I held two radio sessions with a local radio, Mpanda FM to communicate results of the project. The radio reaches all the villages of Mpanda District and parts of Nkasi District. This is an ongoing program and we expect to have five more programs covering different topics on elephant ecology and behaviour and conflict mitigation methods.


Picture 1: : A radio session with Mpanda FM

Production of a human elephant conflict information pack

We have developed a booklet entitled 'Elephant *Conflict Mitigation Workshop and Training*' that will be distributed to the community for educational purposes. The booklet is currently under review and will soon be produced and distributed to farmers groups and school's library.

Educational brochures

We have also produced 3000 copies of elephant brochures to supplement the booklet which might not be enough to the community. This is shared during outreach and film show events in the target villages.

Picture 2: Community members with elephant brochures

Conservation education in schools

We have also reached seven schools and shared with students about the project and specifically on human elephant conflict, the source and possible mitigation measures. We also engaged students in a number of activities including modelling elephants using clay and drawing elephants and their habitats and this attracted a high student's participation.

Picture 3: A film show event in schools and students with an elephant drawing

Awareness and Film shows

We have also conducted 12 outreach events and film shows reaching of 1250 community members to further advance their knowledge on elephant ecology and behaviour and conflict mitigation approaches. This is an ongoing program and we target to reach all the nine villages that have shown significant incidences of human elephant conflict.

Picture 4: Conservation film show in Sitalike village

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