
# Land Use Land Cover Change, Elephant Movement, and their Implications on Human-Elephant Interactions around Mkomazi National Park

**By**

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**Abstract**

Land Use Land Cover (LULC) changes have been a subject of high concern in recent decades due to rapid human population growth and some infrequent cases of natural processes. Invasion of human activities and settlements into spaces of land which were first wildlife habitat and/or wildlife migratory routes have caused habitat shrinkage for wildlife and thus, elevated human-wildlife interactions. African savanna elephants, a wide-ranging species listed as endangered by the IUCN red list have suffered from LULC which results in intolerable habitat and hence escalates human-elephant interactions, thus, conflicts.

The survey used remote sensing to analyse LULC changes around Mkomazi NP in districts of Rombo, Mwanga, Same, Korogwe, Lushoto, and Mkinga from 2000 to 2020. Then, in each district, three villages which are vulnerable to elephants were selected with the help of the District Game Officer. In each village, we surveyed elephant movement and occurrence in association with land use types such as agriculture and settlements. Through interviews using Focused Group Discussions (FGDs), Key Informants (KIs), and household questionnaires, we assessed the existing human-elephant conflicts in the villages.

This survey reports a substantial increase in agriculture and settlements from 2000 to 2020 for over one and a half to two folds from the starting year, 4 – 25.52% and 1 – 3.57% respectively. This shrinks wildlife habitat considerably making them intolerable. On the other hand, dense forests and shrublands have been decreasing around Mkomazi NP with water bodies remaining nearly constant.

Elephant movement and occurrence in the surveyed villages portray that elephants often occur in human-dominated landscapes and farmlands, however mostly during the night (*p = <<<<<<0.01)* to avoid overlapping with humans and minimise threats. This has resulted in the reported human-elephant conflicts for about 99% of respondents which solely negatively affected humans. Elephant crop-raiding was reported by more than 95% and property damage by about 75% of respondents with no retaliatory killing of elephants reported. Over 65% of respondents had a negative attitude towards elephants and the generalized linear model revealed the duration of stay and land use type (agriculture) to be the underlying reasons (*p = 0.013, p = 0.003* respectively*).*

The use of a combined approach to mitigate HECs was highly recommended through conservation education, beehive fences, response teams, and village game scouts. A land use plan is also very necessary to minimise the pressure on wildlife habitat areas which, in turn, reduces human-wildlife conflicts. This survey also reports limited findings on elephant movement, hence there is a need to carry out a migratory routes and dispersal areas survey.

**Keywords:** Elephant movement, human-elephant conflicts, LULC change, and Mkomazi National Park

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# 1.0 INTRODUCTION

Land-use and land-cover change (LULCC), a central component of global environmental change with direct implications for the Earth's climate, ecology, and human societies, is of great concern to national and international policymakers (Campbell et al. 2005, Msoffe et al. 2011). Land cover refers to the sum of all things that occupy the surface of land in an area. Land use refers to the utilisation of land in different activities by human beings and has always been the determinant of the former. Land use is always spatio-temporally dynamic mainly due to human activities and in some rare cases natural processes (Mmbaga et al. 2018). These dynamics include 25% of African land degraded and over the past three decades, as much as half of the tropical rainforests have disappeared and the remaining portions are tremendously lost at a rate of 7.5 million hectares per year (Mmbaga et al. 2018).

Several land use types are being established especially, recently with the finer analysis tools; these include, settlements, agriculture, vegetation (dense forest, forest, grasslands), and bareland. In Tanzania, assessments of LULC changes around Kilimanjaro NP in Rombo revealed an increase in settlements and a decrease in agroforestry lands (Mmbaga et al. 2017), whereas that of the Kitendeni corridor reported a more than 15 $km^2$ decrease in corridor area due to agriculture and settlement (Noe 2003). These rapid LULC changes on landscapes cause shifts in socio-ecological and environmental pressures which compromise the provision of ecosystem services for humans and habitat for wildlife, especially wide-ranging species like elephants (Mmbaga et al. 2017). The tip of the balance then results in dynamics of land use conflicts such as human-wildlife conflicts which include human-elephant conflicts (Sanare et al. 2022). The most documented drivers of LULC have been agriculture and human settlements (Noe 2003, Noe 2014, Mmbaga et al. 2017, Sanare et al. 2022).

Elephants are among the megafauna extant in three species; African elephants (*Loxodonta Africana),* Forest elephants (*Loxodonta cyclotis)* in Africa, and Asian elephants (*Loxodonta maximus)* in Asia in the wild. African elephants hereby described as elephants are a wide-ranging species with a home range size extending up to c. 6,000 $km^2$ (Poole and Granli, 2008), more importantly, Tanzania has about 32.4% of its land space set apart for conservation while elephants move about 50% of the country. This tells that elephants are significantly outside protected areas through dispersal areas, migratory routes, and wildlife corridors which are village lands not professionally managed and actively protected (Kikoti 2009, Newmark 2008).

In the past when agricultural expansion and settlements were minimal, these lands were suitable habitats and corridors for elephants. However, LULC changes through agriculture and settlements have hampered these habitats and routes and made them intolerable for elephants (Sanare et al, 2022). Consequently, as elephants move along these areas, they collide with humans by raiding

crops, destroying properties, and causing human injuries and even deaths. Humans sometimes retaliate against elephants, hence causing human-elephant conflicts (Hoare 2012).

Elephant distribution is among the dependable indicators of resource availability (minerals, pasture, water, crops, crown cover, and others) (Foley 2002). Recently, elephant distribution has been ascribed to be outside protected areas in areas with crops, on one hand, as crops have higher nutritional and mineral value, reduced chemical defences, and higher water retention, as well as close woodlands for protection, on the other hand (Foley 2002, Montero-Botey et al. 2024). This is even escalated by water shortage during the dry season in the Mkomazi NP forcing elephants to range outside the park seeking water. This puts more strain on communities through hunger, famine, discomfort, stress, and loss of properties, hence less productivity and poor livelihoods. In summary, there is a close interrelationship between socio-demographic characteristics of people, their overall population, LULC change, wildlife distribution, and human-wildlife conflicts, particularly human-elephant conflicts.

Mkomazi National Park was transitioned to the highest rank of protected areas in Tanzania in 2008 from Mkomazi-Umba Game Reserve. The park forms the most important part of the transboundary ecosystem of Tsavo-Mkomazi and is home to over 1200 elephants during the dry season from the last census of 2020 (TAWIRI 2020). Secondary data from communities around the park suggest that elephants move around the park, interact, and cause conflicts with people. This survey aimed to assess the impacts of LULC change and elephant distribution around Mkomazi and assess the implications of the two in escalating human-elephant conflicts around the park. This information is crucial for understanding the underlying reasons for the conflicts and suggesting suitable measures to minimise them. LULC change will also help to emphasize the conservation of reserved areas and proper land use while elephant distribution will provide information on hotspot areas for HECs in villages surveyed.

## 1.1 Objectives and Activities of the Survey

General Objective

The overall objective of the survey was to understand the LULC change and elephant distribution and their implications on human-elephant conflicts around Mkomazi NP.

Specific Objectives

i. To assess the LULC change for the districts around Mkomazi NP
ii. To map elephant movement in villages around Mkomazi NP
iii. To explore the human-elephant conflicts existing around Mkomazi NP

# 2.0 METHODOLOGY

## 2.1 Description of the Study Area

Mkomazi NP, located at 03°470S–37°450E and 04°330S–38°450E, was once a game reserve (allowing both consumptive and non-consumptive use) and is 3245 $km^2$ in size (Nyakunga et al. 2018, Mseja et al. 2020). It forms an important part of the Tsavo-Mkomazi ecosystem and provides essential refuge for about 1200 elephants during the dry season (TAWIRI 2000). The park falls within the Somali-Maasai region which is the centre for endemism, the Afromontane Forest region which is the centre for plant diversity and endemism, and the Zanzibar Inhambane region which is the region for endemism making it substantially unique (Homewood and Brokington 1999, Nyakunga et al. 2018). It is elevated 230 – 1630 m a.s.l with average annual rainfall ranging from 570 to 890 mm depending on the altitude making its climate semi-arid (Homewood and Brokington 1999).

Mkomazi exhibits bimodal rainfall due to the intertropical convergence zone's (ITCZ) seasonal migration. East Africa is usually dry in July when the ITCZ is at its northernmost point. Before the ITCZ reaches its southernmost point, it brings rain in October and November as it advances south. At the start, the ITCZ shifts back north every year, bringing more rain from March to early June (McWilliam and Packer 1999). The park vegetation comprises grasslands, bushland, brushlands, and woodlands (Mseja et al. 2015).

Mkomazi NP is surrounded by five districts (Mwanga, Same, Lushoto, Korogwe, and Mkinga) from two administrative regions (Kilimanjaro and Tanga). This survey also considered the Rombo district because of its landscape connectivity with Mkomazi through the Tsavo-Mkomazi ecosystem (fig 1). The area contains about 1.8 million people, and the dominant economic activities are agriculture and livestock keeping, small-scale mining, and small business enterprises (www.nbs.go.tz). The population of each district is shown in fig 3.

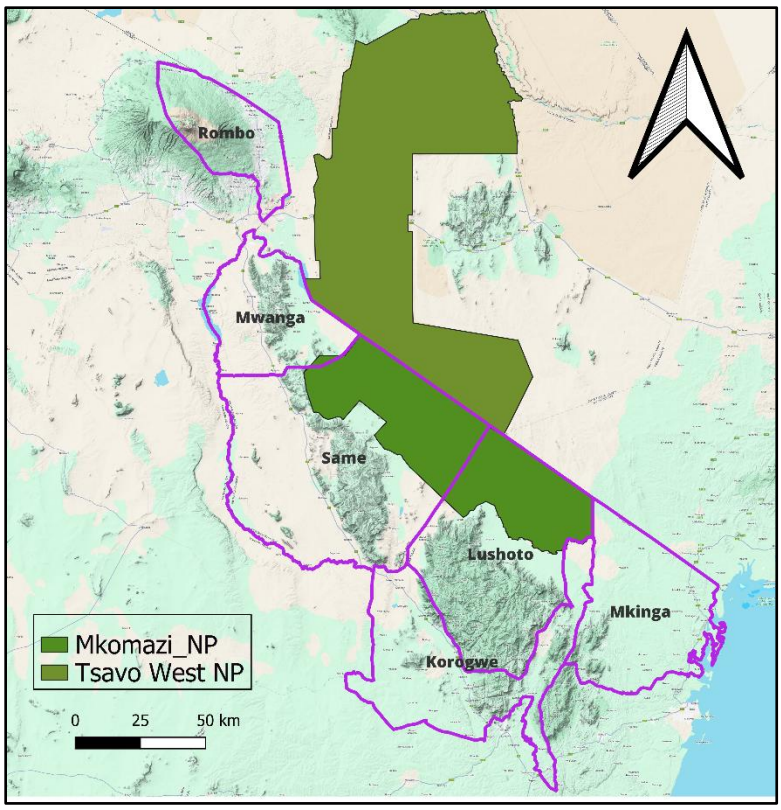


**Figure 1: Mkomazi National Park and its surrounding districts**

## 2.2 Survey Design

This survey was carried out during the late wet season up to the length of the dry season in 2024. The period was targeted because most crops ripen (Sitati et al. 2003, Montero-Botey et al. 2024) attracting more elephants to come out of the national park, this was essential to understand how elephants are distributed in villages around Mkomazi NP. Data was collected through satellite images, ground truthing, FGD, KI, and household questionnaires. Each of these methods is described thereafter. Before the survey, we tentatively discussed the HEC situation in a respective district by the DGO to discern the village experiencing HEC and purposively selected them. Based on time and financial constraints, we surveyed three villages per district making a total of 18 villages.

### 2.2.1 To assess the LULC change for the districts around Mkomazi NP

LULC changes were generated using satellite images from the Landsat 8 from the USGS (http://earthexplorer.usgs.gov). Images were downloaded following the period of the dry season in the study area since it was possible to identify agroforestry and the remaining bare lands were termed as seasonal agricultural lands (Mmbaga et al. 2017).

### 2.2.2 To map elephant movement in villages around Mkomazi NP

Ground truthing and site surveys. This method was used to answer the question of elephant distribution on the landscape. In each village, field surveys were carried out to identify areas where elephants had passed by assessing dung, footprints, tree scratch marks, and the live presence of elephants. GPS coordinates of the places were taken to map elephant spots and understand their distribution.

### 2.2.3 To explore the human-elephant conflicts existing around Mkomazi NP

Household Questionnaire

Purposive sampling was used to administer questionnaire interviews with respondents in which the local guide led us to the households intended for the interviews. In each district, 150 questionnaire interviews were administered; 50 questionnaires from each of the three villages. The consensus of 50 respondents per village was reached due to the homogeneity of responses and a recommended minimum of 30 respondents per site (Saunders et al. 2019, Mtongani et al. 2014, Kothari 2004). Therefore, a total of 905 questionnaires were conducted in the whole survey.

The context of the questionnaire interview was the demographic characteristics of respondents, the situation of HEC at the village and household level, the trend of HEC in the village, measures to mitigate HEC, and their attitudes towards elephant conservation. The prepared questions and their responses were filled into the prepared forms using Open Data Kit (ODK) collect version 2022.4.4 with the KoBo toolbox software.

Focused Group Discussions

In these communities, elders have witnessed the LULC changes, trends and aspects of HEC for a long time and have Indigenous knowledge and experience while youths are on the frontlines in helping their communities against elephant incidents. FGD helped to synthesise the collective data from the villagers about LULC change, elephant distribution in the village, HEC and the interaction between them. These FGDs were organized with the help of village leaders and we asked them relevant questions in the context of the survey; these were LULC change, elephant distribution and routes in the village, and HEC questions. With the consent from the group, we used phones to record the responses during FGDs.

Key Informants Interviews

In the context of the survey, personnel with professional knowledge and data on LULC change, elephant distribution and routes, and HEC in respective districts were necessary. Consequently, the District Game Officers were reached to provide the information on elephant distribution and HEC, District Land Use Officers were reached to provide information on LULC change, District Agricultural Officers were reached to provide information on crop losses from elephants and other sources, whereas District Development Officers were reached to provide information on

the social impacts of elephants in the villages. With the consent from the interviewee, we used phones to record responses during KIs.

## 2.3 Data Analysis

### 2.3.1 To assess the LULC change for the districts around Mkomazi NP

Images were imported into the ArcGIS Pro-3.4 then processed and analysed through cleaning, compositing, masking, clipping and mosaicking. Finally, image classification used the maximum likelihood function under supervised classification (Campbell and Whyne 2011). I classified the LULC types into bareland, shrubland, dense forest, water bodies, agriculture, and settlements similar to Noe (2003), Msoffe et al. (2008), Mmbaga et al. (2017), and Sanare et al. (2022). However, because of limited image availability, I could not get the images that form a complete block of the study area as far back as 1983 for analysis.

### 2.3.2 To map elephant movement in villages around Mkomazi NP

Elephant distribution across the surveyed villages was mapped using the QGIS software. Because of the robustness of the study area, I separated the distribution maps by districts and in some cases by villages with reference to human-dominated land-use patterns.

### 2.3.3 To explore the human-elephant conflicts existing around Mkomazi NP

Data in the Kobo toolbox server were imported to Microsoft Excel where cleaning and organising were performed. I then imported the cleaned and organised data into the SPSS software (IBM SPSS statistics 20) for extracting frequencies and generating crosstabulations. The final frequencies and organised data were coded using the R language in R Studio (R core team, 2023) for generating graphs and charts. For the survey data that involved association between variables, I used the Chi-square test of independence to inferentially test for the association between the variables. In some cases, the test involved more than two groups and the $\chi 2$ test detected a significant association among groups. In this case, Bonferroni correction was applied for comparison between groups. This helped to reduce the familywise type I error rate that could arise by analysing two groups separately (Beasley and Schumaker 1995).

In some variables, I used the $\chi 2$ goodness of fit test to verify if responses align with expected distributions (e.g., uniform preferences among groups) (Sanare et al. 2022). Moreover, using the demographic characteristics of the district, education level, duration of stay in the village, and the economic activities of respondents as predictor variables and the attitude towards elephants as a response variable, I performed the Generalized Linear Model (Binomial) using R language in R Studio (Dickman 2008, R core team 2023). FGD data were analysed using repeatedly listening and manually coding the responses. The coded responses were imported into the QC (QualCoder-3.5) software where multiple responses were generated. This helped to reveal the most frequent matters of concern and the central aspects of the FGD that were mentioned by the groups during discussions. I used a similar approach for the KI data.

# 3.0 RESULTS

## 3.1 To assess the LULC change for the districts around Mkomazi NP

Because LULC change is primarily driven by population trends, I first extracted the population trends of the 6 districts around Mkomazi NP from https://www.nbs.go.tz/. However, the population trends data I obtained were only for 2012 and 2022 which show a fair increase in human population for both districts except for Lushoto district which portrays a decrease in population between the years (fig 2).

The mapped LULC change indicates that agriculture and settlement have been increasing for over one and a half to twofolds from the starting year, 4 – 25.52% and 1 – 3.57% respectively (Table 1). Nevertheless, dense forests have been decreasing for most districts except for Lushoto district, water bodies have changed randomly with years in respective districts with an increase in Korogwe and Same and apparently stable state in Lushoto, Mwanga and Rombo and a decrease in Mkinga. The expansion of settlements and agriculture and their correlation with elephant distribution is clearly shown in figure 4 where elephants largely traverse farmlands, water bodies, and settlements escalating human-elephant interaction.

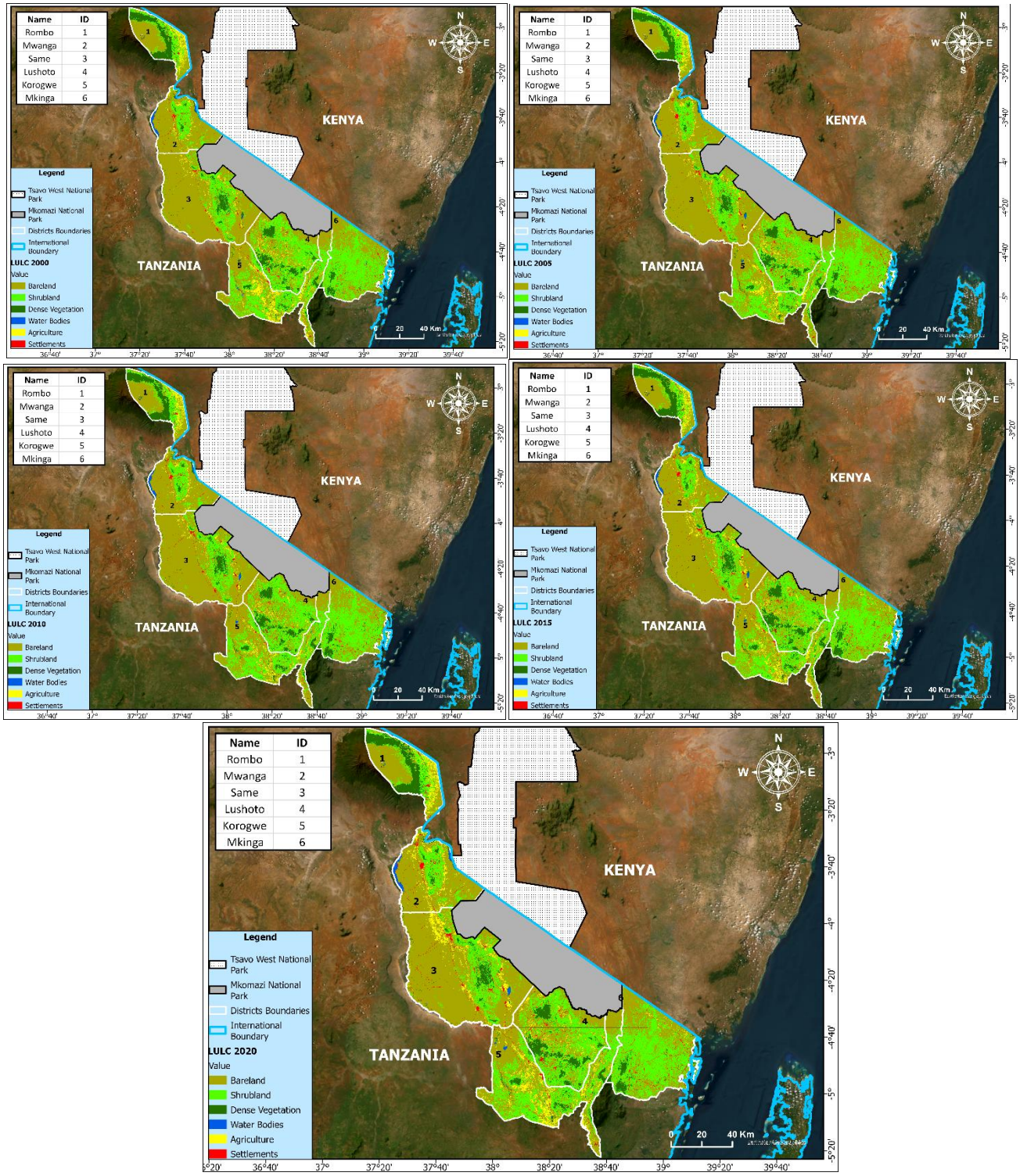


**Figure 2: Changes in Land Use of Land Cover around Mkomazi National Park; districts of Rombo, Mwanga, Same, Lushoto, Korogwe, and Mkinga. The maps are distributed into the delineated years of 2000, 2005, 2010, 2015, and 2020**

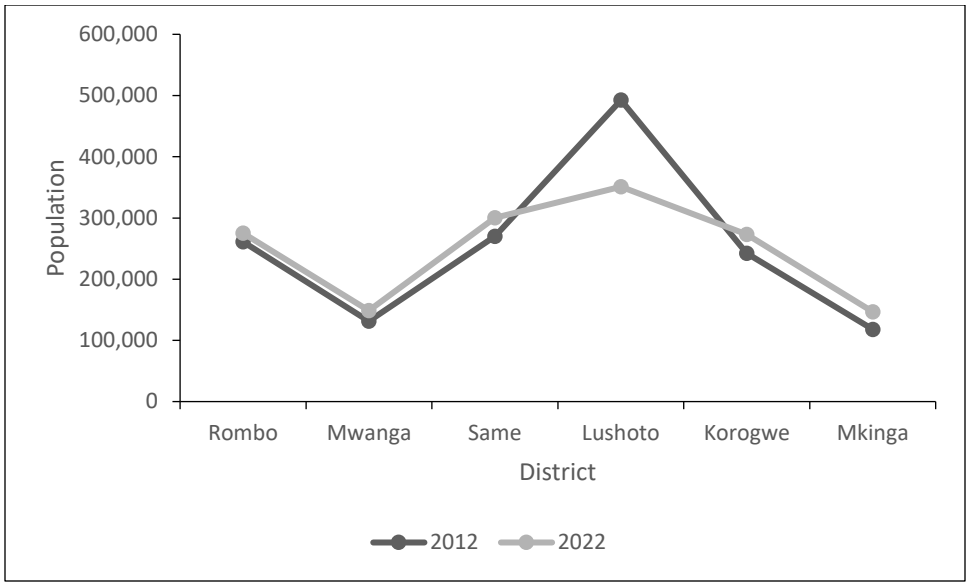


**Figure 3: Human population trends in districts around Mkomazi National Park from 2012 to 2022 (data source: National Bureau for Statistics)**

## 3.2 Elephant movement in villages around Mkomazi National Park

Elephant movement was mapped in association with land use land cover forms such as farmlands, village areas and water bodies. We relied on visible elephant signs to collect their occurrence coordinates. The results show that elephant occurrence in villages is considerably associated with water bodies and farmlands at a 1-5 km spatial scale (fig 4). These water sources included lakes, dams, and small tributaries.

In some villages, such as Mkomazi in Korogwe District (fig 4), elephants found refuge in thick and closed thickets during the day before they surfaced late in the evening and at night to seek water and raid crops.

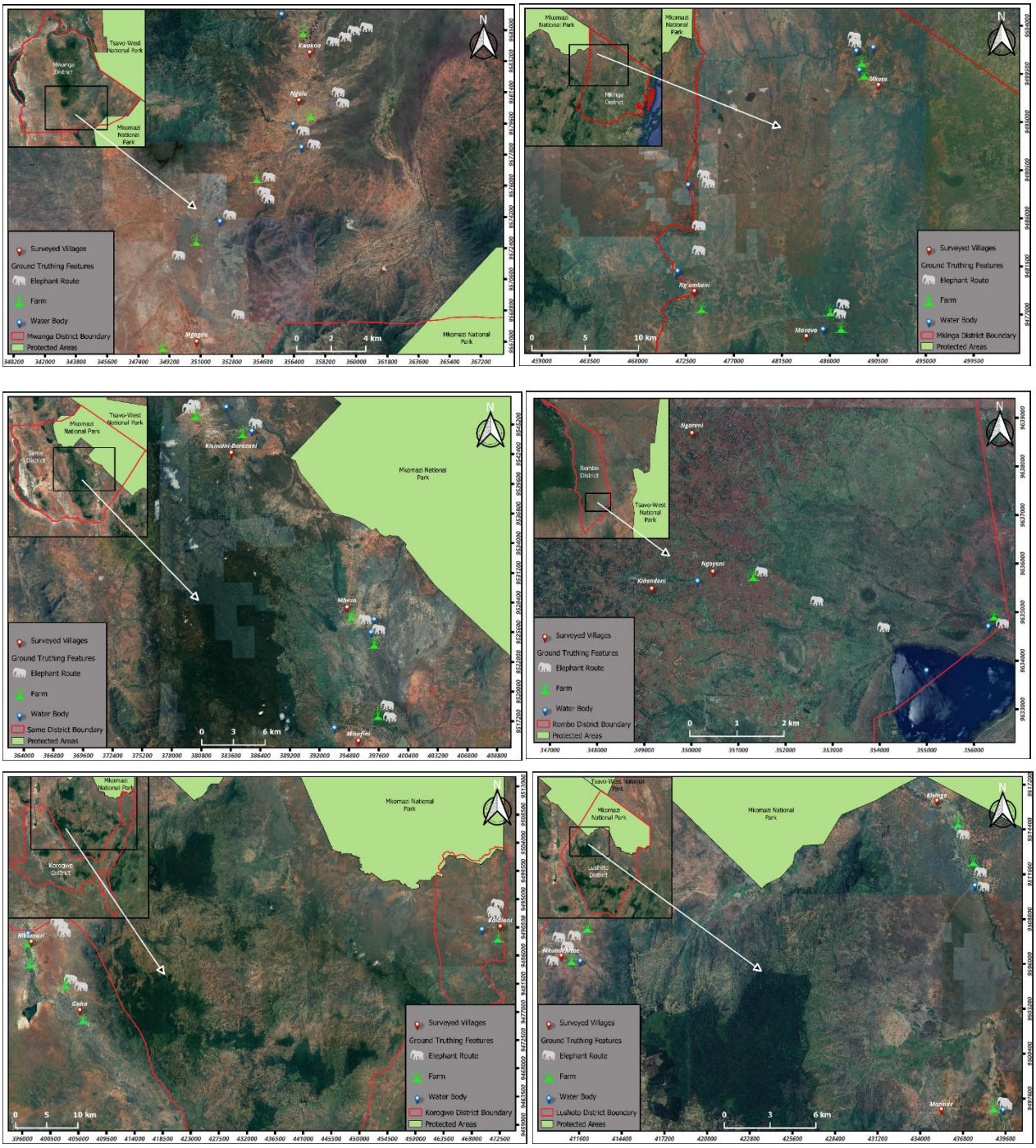


**Figure 4: Elephant occurrence in the surveyed villages around Mkomazi National Park; note the elephant signs denoting elephants, maize signs denoting farms and the sampled villages**

These results depict a considerable movement of elephants around community areas which poses a serious threat to the communities and in turn to elephants themselves. Moreover, our discussions during the FGDs and the KIs suggested that elephants still retained their historical routes and mostly came from Mkomazi NP and Tsavo NP for the Rombo district.

## 3.3 Human-Elephant Interactions and Conflicts around Mkomazi National Park

### 3.3.1 Demographic Characteristics of Respondents

A total of 905 respondents from 6 districts were interviewed during questionnaire surveys. Males were generally more than females in terms of sex, whereas in terms of education level, most respondents had primary education, and the least had tertiary education. The dominant livelihood activity was agriculture outnumbering other activities by far with most respondents substantially living in the study area for more than 10 years the fact that increased the validity of the HEC data they provided based on their long-term indigenous knowledge and experience. Table 2 shows the overall demographic characteristics of respondents across districts.

### 3.3.2 Forms of Human-Elephant Conflicts

895 (98.9%) respondents reported the presence of HEC in their villages. Analysis of the presence of HEC in relation to district and village was performed and the χ2 test of independence obtained a significant association between both districts and villages with the presence of HEC ( $\chi 2_{(0.05,10)} = 32.29, p = 0.00036$ *and* $\chi 2_{(0.05, 34)} = 55.587, p = 0.011$ respectively) (fig 5). χ2 posthoc test then revealed the Rombo district with its villages to be less affected by HEC unlike other districts' villages with $p = 6.67E\text{-}7$ and $p = 1.7E\text{-}5$ respectively.

The most existing forms of HEC were those affecting people's livelihoods and threatening their survival, unlike those threatening elephants such as retaliatory killings. Crop-raiding and property damage were the most frequently reported forms of HEC where human casualties through injuries and deaths by elephants were also reported (fig 6).

**Table 1: Demographic characteristics of respondents**

| Characteristics | Rombo | | Mwanga | | Same | | Lushoto | | Korogwe | | Mkinga | | Total % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number | (%) | Number | (%) | Number | (%) | Number | (%) | Number | (%) | Number | % | |
| **Sex** | | | | | | | | | | | | | |
| Male | 90 | 60 | 85 | 55 | 78 | 52 | 84 | 56 | 91 | 60 | 86 | 57 | 56.8 |
| Female | 60 | 40 | 70 | 45 | 72 | 48 | 66 | 44 | 59 | 40 | 64 | 43 | 43.2 |
| **Education level** | | | | | | | | | | | | | |
| No formal education | 19 | 13 | 10 | 6 | 25 | 17 | 58 | 39 | 47 | 31 | 39 | 26 | 21.9 |
| Primary education | 103 | 69 | 105 | 68 | 100 | 67 | 87 | 58 | 86 | 58 | 90 | 60 | 63.1 |
| Secondary education | 27 | 18 | 38 | 25 | 24 | 16 | 5 | 3 | 16 | 11 | 19 | 13 | 14.3 |
| Tertiary education | 1 | 0.007 | 2 | 1 | 1 | 0.007 | 0 | 0 | 1 | 0.007 | 2 | 1 | 0.8 |
| **Duration of stay in the village** | | | | | | | | | | | | | |
| > 10 years | 134 | 89 | 145 | 97 | 122 | 81 | 144 | 96 | 145 | 97 | 134 | 90 | 91 |
| < 10 years | 3 | 2 | 3 | 2 | 7 | 5 | 2 | 1 | 3 | 2 | 15 | 10 | 3.6 |
| 10 years | 13 | 9 | 7 | 5 | 21 | 14 | 4 | 3 | 2 | 1 | 1 | 0.007 | 5.3 |
| **Household size** | 4.9 | | 5.4 | | 4.6 | | 5.6 | | 5.4 | | 4.9 | | |
| **Livelihood activity** | | | | | | | | | | | | | |
| Agriculture | 143 | 96 | 150 | 97 | 149 | 99.3 | 129 | 86 | 125 | 83.3 | 135 | 90 | 91.8 |
| Livestock keeping | 3 | 2 | 3 | 2 | 0 | 0 | 19 | 13 | 13 | 9 | 4 | 2.7 | 1.7 |
| Business | 1 | 0.007 | 1 | 0.007 | 1 | 0.007 | 1 | 0.007 | 3 | 2 | 7 | 5 | 0.3 |
| Employment | 0 | 0 | 1 | 0.007 | 0 | 0 | 0 | 0 | 1 | 0.007 | 0 | 0 | 4.4 |
| Masonry | 2 | 1.3 | 0 | 0 | 0 | 0 | 1 | 0.007 | 0 | 0 | 0 | 0 | 0.3 |
| Mining | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 5.3 | 4 | 2.7 | 1.1 |
| Plumbing | 1 | 0.007 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.1 |

Moreover, elephants were reported as the main threat to the crops ($\chi 2_{(0.05, 4)} = 605.89, p = 2.2E\text{-}16$) with other factors such as climate, diseases, and livestock following elephants (fig 7).

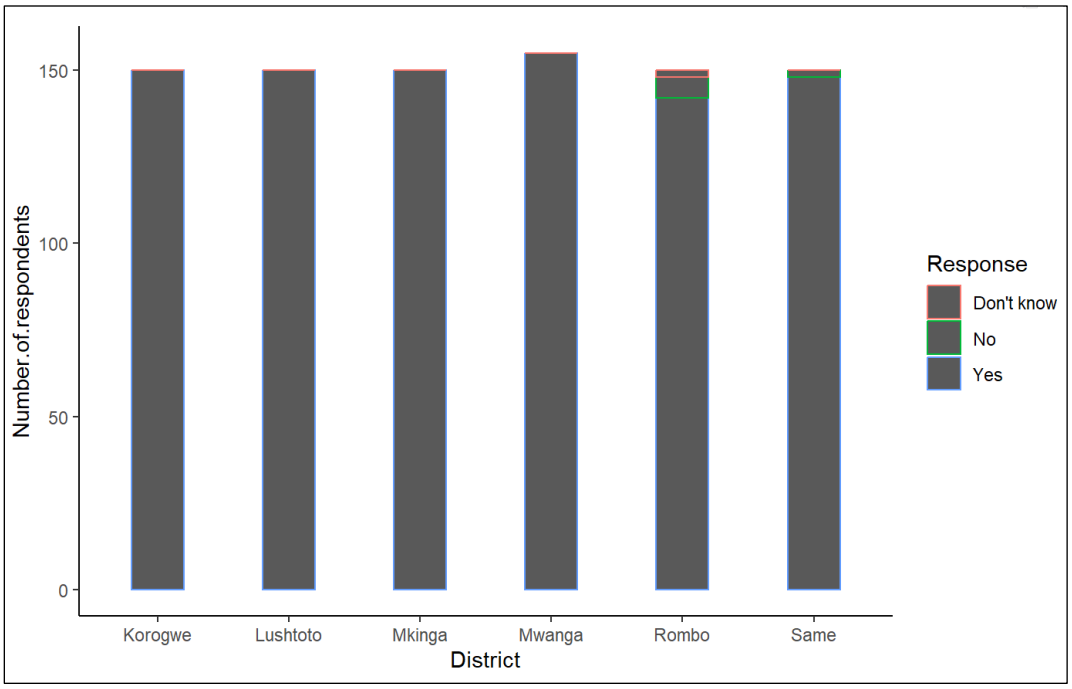


**Figure 5: Magnitude of the problem caused by elephants**

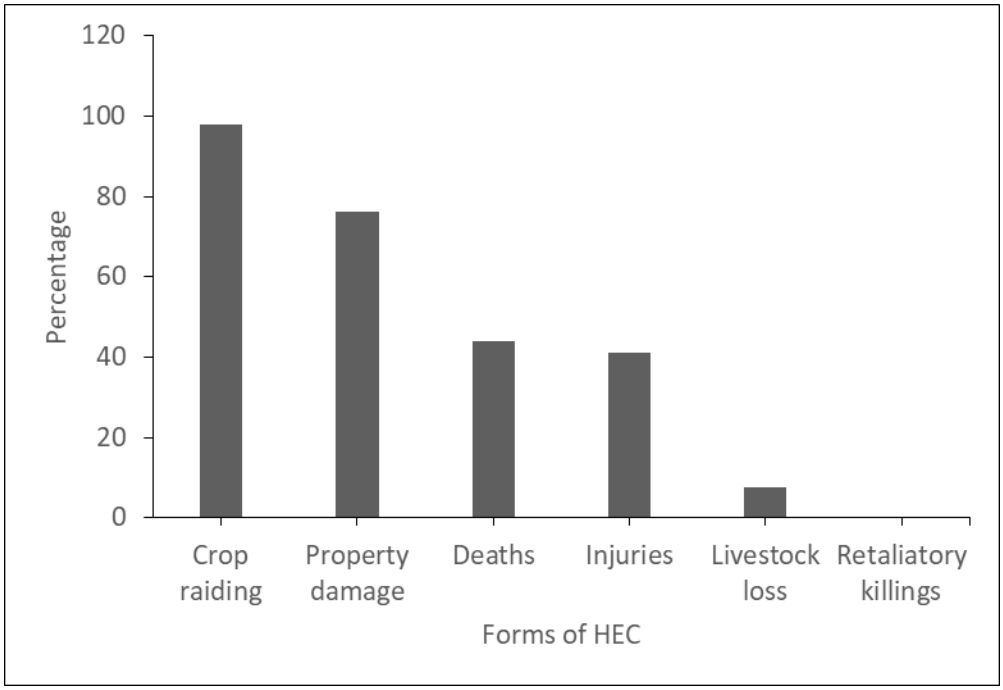


**Figure 6: Existing forms of human-elephant conflicts**

Elephants were reported to almost explicitly invading the villages and causing conflicts during the night unlike all other times of the day ($\chi 2_{(0.05,\ 2)} = 1296.25,\ p = <<<<<<0.01$) (fig 8).

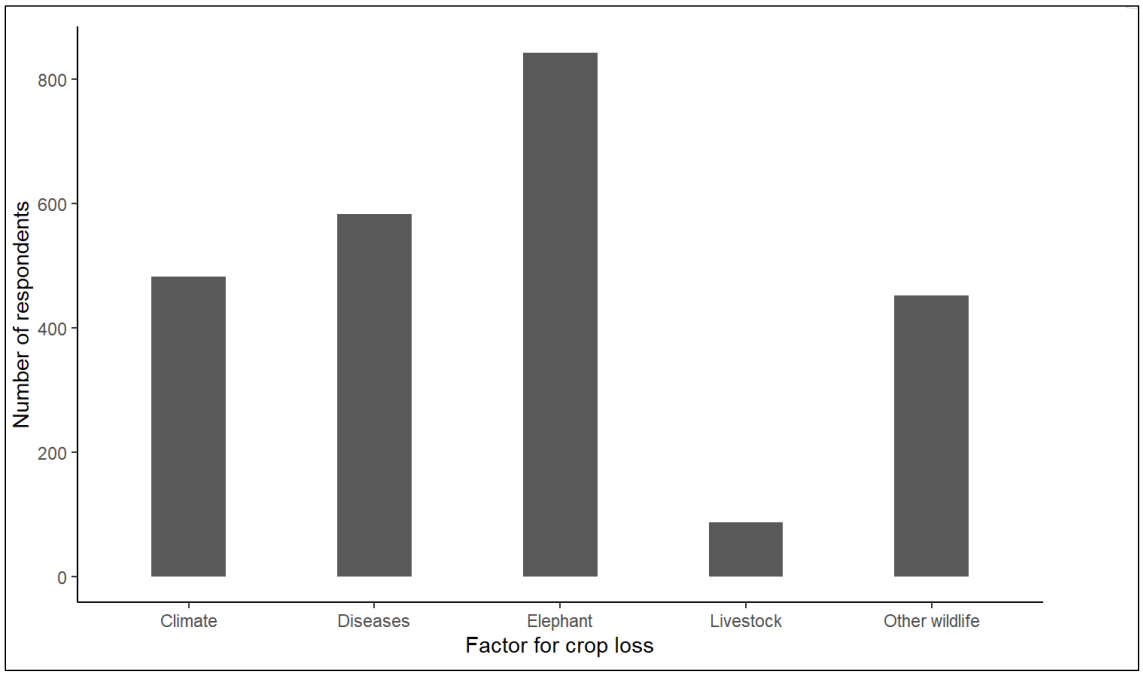


**Figure 7: Focusing on crop losses as a major form of human-elephant conflict; factors that lead to crop losses with elephants on the lead**

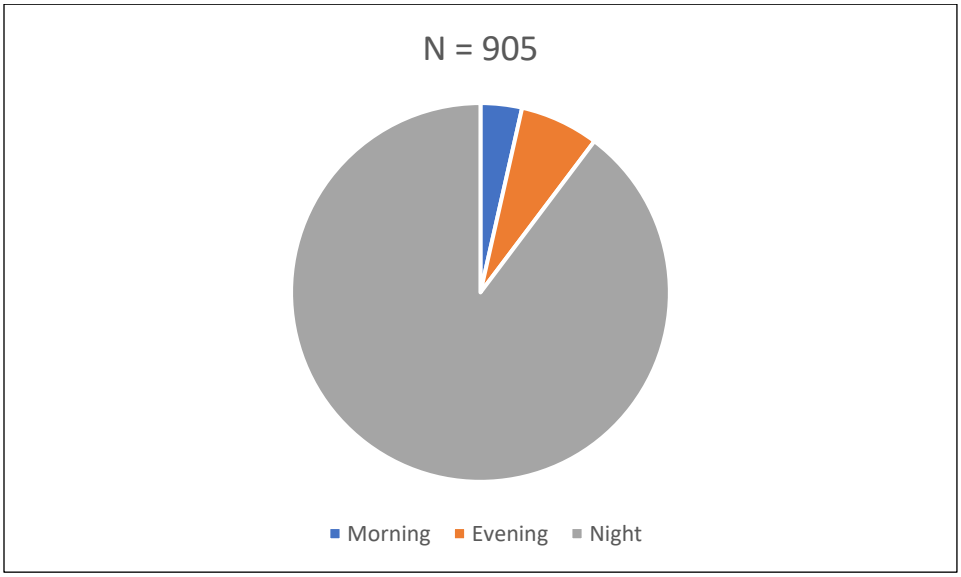


**Figure 8: Time of the day that elephants invade the villages**

3.3.3 Attitude towards Elephants and their Conservation

The majority of the respondents perceived elephants negatively and regarded them as a species causing loss. This attitude seemed to be independent of the villages and districts regardless of the levels of HEC the units were experiencing portraying not only the prevailing situation but also the historical viewpoint as a determinant of attitude (fig 9). The binomial GLM in R portrayed the duration of stay and livelihood activities of agriculture as significant predictors of people's attitudes towards elephants and their conservation (Table 3).

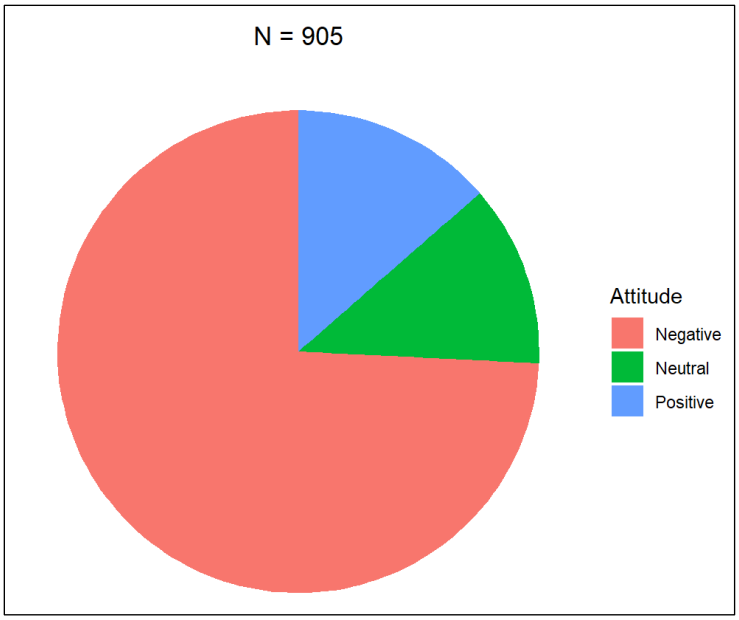


**Figure 9: Respondents attitudes towards elephants and their conservation**

**Table 2: Binomial Generalized Linear Model analysis results of variables determining attitudes towards elephants and elephant conservation (n = 905). ** indicates significance**

| Variable | Estimate | Std Error | Z score | *P* |
|---|---|---|---|---|
| District | 0.08469 | 0.05971 | 1.418 | 0.156 |
| Education Level | -0.22943 | 0.16671 | -1.376 | 0.169 |
| Duration of Stay | -0.90965 | 0.36795 | -2.472 | 0.013** |
| Livelihood activity; Agriculture | -1.76968 | 0.60326 | -2.934 | 0.003** |

3.3.4 Human-Elephant Conflict Mitigations

The most suggested mitigation measure was the provision of education on human-elephant coexistence along with other measures such as the use of fences (beehive fences, electric fences, and physical fences). Nevertheless, some respondents portrayed total ignorance of the methods to mitigate HECs and suggested that it is the role of the government to handle HECs and it is not their concern (fig 10). This was also revealed during the FGDs since most respondents argued that the primary role of managing HEC is not theirs but the governments.

Considering the use of fences to mitigate HECs as among the widely suggested methods, the majority of respondents suggested the use of beehive fences (53.5%) unlike, electric (23.7%) and physical fences (22.8%). This was also widely posed during the FGDs.

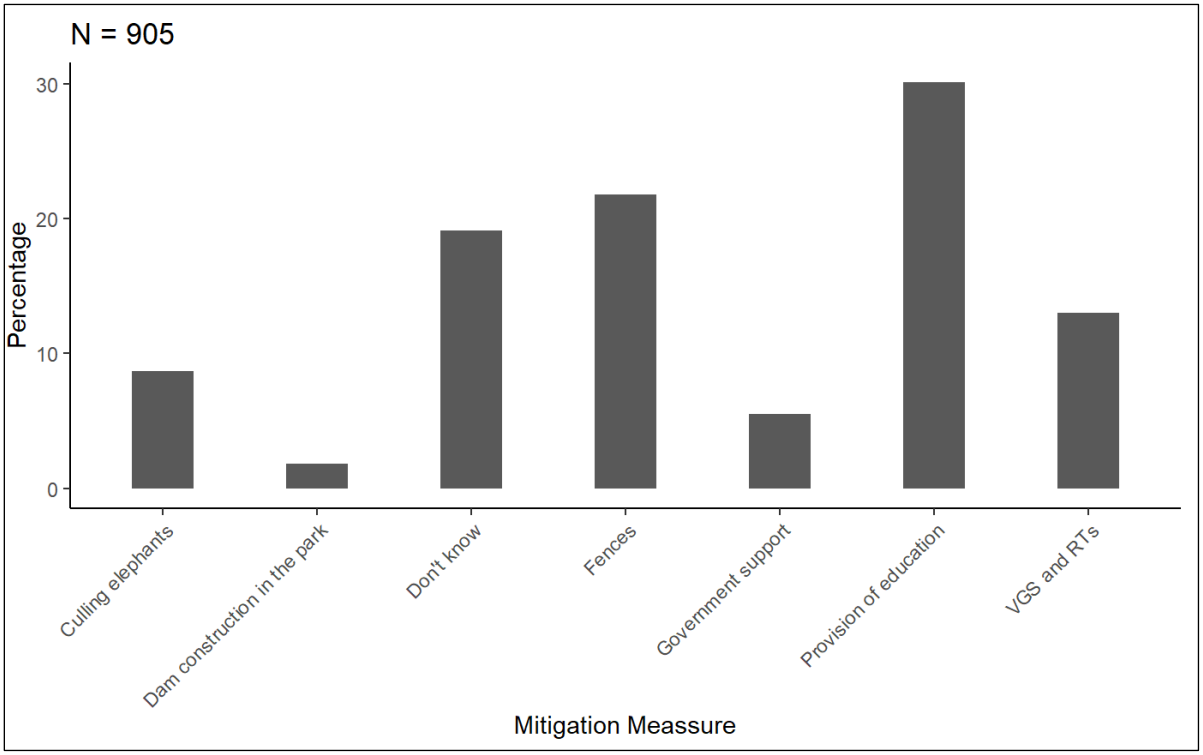


**Figure 10: Human-elephant conflict mitigation measures mentioned by respondents**

# 4.0 DISCUSSION

## 4.1 Land Use Land Cover Change around Mkomazi National Park

LULC changes around Mkomazi NP have been happening as per the hypothesis of this survey, such that, agriculture and settlements have expanded whereas dense forest and shrublands have declined. Empirically, land-use change has been significantly influenced by changes in land tenure, which have been brought about by state actions since the pre-colonial era, colonial, and post-colonial. Pastoralists were sparse and roamed freely during the pre-colonial era when the land was owned collectively and resources were plentiful. This allowed for the coexistence of wildlife and the sustainable utilization of rangeland resources (Peterson 1978; Voeten 1999). Then, pastoralists were denied access to several of their former important grazing areas during the colonial era due to large-scale plantations (Igoe 2000). Policies that promoted agriculture at the expense of pastoralists persisted after independence (Shivji 1998). The Villagization Policy of 1974, which obliged people to reside in nucleated villages, further enhanced the sedentarization of nomadic pastoralists.

People were further marginalized by the Investments Act of 1992, which promoted mining on rangelands. The Village Land Act of 1999 granted people greater control over their land use and hastened the pastoral communities' sedentarization even more (Tenga et al. 2008). Due to autochthonous growth, immigration from neighbouring areas in search of arable land (Campbell 1999), and young people drawn to mining (Igoe 2000), these changes in land tenure caused a significant increase in the population. As portrayed by the changes in population from 2012 to 2022, it is worth noting an increase in settlements at the expense of retaining natural habitats (Noe 2014).

Inarguably, agricultural and settlement expansion have depleted the natural habitats including the revealed dense forests and shrubs (Noe 2003, Msoffe et al. 2008). This translates into the shrinkage of wildlife habitat which, in turn, forces wildlife to traverse along human-dominated landscapes as they move longer distances in search of limited resources (Mmbaga et al. 2018, Sanare et al. 2022). This results in heightened interactions between wildlife, especially elephants and people leading to frequent and severe cases of human-elephant conflicts (Sanare et al. 2022). This is proved by the distribution maps that we obtained revealing that elephants in the villages were mostly sighted in the farms and settlements of people.

Despite the heightened human-elephant conflict, LULC changes also lead to the blockage of migratory routes and wildlife corridors (Venter et al. 2016; Mace et al. 2010) which is also a topic of global interest, however, beyond the scope of this survey.

## 4.2 Elephant Movement in the Surveyed Villages around Mkomazi National Park

Elephant distribution in the villages was closed associated with farmlands and water bodies present in the villages. Several pieces of evidence reveal that elephants are water-dependent species (Sukumar 2003, Sitati et al. 2003, Montero-Botey et al. 2024), the fact that water is scarce in Mkomazi NP might be an accelerator of elephants' presence of village lands seeking water.

However, the presence of farmlands might supplement the seeking for water behaviour of elephants by maximizing the gains while minimizing the energy required if both are found near each other (Foley 2002, Smit et al. 2022).

When the elephant distribution maps were overlaid on the trends of LULC change maps, it was clear that elephants' movement paths lie in the areas that are currently settlements and farms of people. This pattern was equally found by Sanare et al. (2022) and Noe, (2003). It is therefore critical that land use types have already converged with former wildlife habitats creating wildlife-intolerable habitats and/or wildlife-attractant habitats at the expense of fear, risks, and losses to both.

### 4.3 Human-Elephant Conflicts around Mkomazi National Park

This survey found that only one out of every ten people in the villages sampled was not aware of the presence of elephant-related losses in their villages. Not surprisingly, the MNRT, (2022) also reports that elephants are the most problematic animals with over 99% incidences of all human-wildlife conflicts and at an increasing rate since 2018. However, spatial variations still exist such that, in districts such as Rombo only historical existence of elephant-related losses were mostly reported and only extremely a few recent incidences. The case of the Rombo district was best explained by the shifting elephant migratory routes which ended up affecting the Mwanga district through Mkomazi National Park in 2020 (Rombo DGO, Pers. Comm.). This is clearly captured by the results since villages in the Rombo district were found to have significantly fewer HECs.

Agriculture was the main and the dependent socio-economic activity of residents around Mkomazi NP and yet elephant crop-raiding was the most prevailing form of HEC. Elephants are mega-herbivores feeding more than 2% of their body weight daily and spend more than 16 hours (Lessing 2007). Encountering an opportunity to satisfy their quest within a few hours seems to be the solution to their energetics problem although at the expense of risks (Scheijen et al. 2019, Smit et al. 2022). Moreover, studies have ascribed the love of elephants towards crops due to higher nutritional and mineral value, higher fibre and water content, and minimum to zero secondary compounds of cultivated crops (Chiyo et al. 2005, Ogunjobi et al. 2018). No wonder, our respondents claimed it is very difficult and almost impossible to chase elephants away from a farm that they have started raiding unlike, the one that they have not yet started. Night time was the most vulnerable time for elephant cop-raiding and factors such as safety through temporal shift of activity with humans have been ascribed (Nahonyo 2009, Smit et al. 2022, Hoare 2012). No retaliatory killing was reported and this is a good sign that people are still willing to coexist with elephants, however, early interventions are necessary to maintain the willingness.

Climate change, livestock, diseases, and other wildlife such as vervet monkeys were also mentioned as threats to crops, however, elephants were a significant threat. Elephants were perceived as an unmanageable threat and respondents regarded this problem as an abandoned problem where the government only cares about elephants and not the people (Hoare 2012). Consequently, the attitudes of the majority toward elephants were negative because elephants

were perceived as destroyers and murderers (Dublin and Hoare 2004). More importantly, since most respondents were farmers and witnessed elephant destructions for over ten years a sense of anger and hostility seemed to exist same as that reported by (Hoare 2012). Regardless that most respondents had a limited understanding of the relationship between HECs and LULC changes, our interviews with GDO and land use planning officers revealed clearly that LULC change is the underlying cause for HECs.

# 5.0 CONCLUSION

## 5.1 Land Use Land Cover Change around Mkomazi National Park

Land use and cover changes have been observed, with a general increase in agriculture and settlements and a general decrease in dense forests, where other variables remain apparently constant. Inarguably, these changes are a result of the increasing human population and hence activities that reduce the habitat, dispersal areas, and migratory routes viable for wildlife.

## 5.2 Elephant Movement in the Surveyed Villages around Mkomazi National Park

These results depict a considerable movement of elephants around community areas which poses a serious threat to the communities and in turn to elephants. When overlaid with LULC shapefiles, elephant movements were found in peoples' farms and settlements which were formerly natural habitats. Moreover, our discussions during the FGDs and the KIs suggested that elephants still retained their historical routes and mostly came from Mkomazi NP and Tsavo NP for the Rombo district.

## 5.3 Human-Elephant Conflicts around Mkomazi National Park

Crop-raiding was the most dominant form of human-elephant conflict followed by property destructions. Most respondents claimed that elephants inflict hunger, famine, stress, and restraint preventing them from engaging in socioeconomic activities, hence hindering prosperity. On the other hand, no elephant has been reported injured or killed through retaliation a fact that calls for interventions to maintain the willingness to coexist with elephants. HEC mitigation measures were highly ascribed necessary through a combined approach of beehive fences, nature education, and the use of rapid response teams. Tentatively, this combined approach was preferred because of its nature and livelihood benefits.

Generally, I quote one of my respondents saying "We really suffer from this what they call the national treasure and pride (elephant) yet those who realise its treasury and pride do not bother about the sufferings we endure; our crops are raided, houses destroyed, food stores stolen, us and children denied peace to carry on our daily activities, our brothers die, and relatives injured yet no elephant has been killed in retaliation. What they do not know is that the fate of most of this species lies in our hands because we are the ones who live with them, encounter them, and spare them; everything has got limits and the limit to our patience about elephants is very about to an end. We ask the government and other stakeholders to know that we, the people are also valuable and are in pain because of elephants; we need help."

# 6.0 RECOMMENDATIONS

## 6.1 Land Use Land Cover Change around Mkomazi National Park

- Stakeholders should act on this rapidly changing LULC through formulation and implementation of Land Use Plans in order to address to restore lands around Mkomazi and prevent further reckless extensive use of lands.

## 6.2 Elephant Movement in the Surveyed Villages around Mkomazi National Park

- It appears from the survey that there are elephant migratory routes around the villages that we surveyed and respondents suggested that some elephants have become residents of village areas while others just pass by. This calls for a survey of existing elephant routes around northeastern Tanzania and their conservation challenges.

## 6.3 Human-Elephant Conflicts around Mkomazi National Park

- There is a great need to introduce HEC mitigation measures which also address community livelihoods such as beehive fences with an added advantage of harvesting and selling bee products such as honey. This method has been tested and proved to be effective (>71%) in reducing elephant crop raiding (King et al. 2012, Save the Elephants, Kenya; TEF, Tanzania).

- These mitigation measures should use combined approaches with education, response teams and village game scouts because elephants learn and habituate to methods. This will also help to build a generation that understands elephants and can rationally coexist with them (Hoare 2012).

- Except for the Rombo district, villages in all other district deserve to in the list of priority villages for HEC mitigation measure projects.

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APPENDIX 01: Table 3: Land Use/ Land Cover Changes (in ha and % coverage) between 2000 and 2020

| | LULC coverage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| LULC classes | 2000 | | 2005 | | 2010 | | 2015 | | 2020 | |
| (Korogwe) | ha | % | ha | % | ha | % | ha | % | ha | % |
| Bareland | 96418 | 36 | 167882 | 52 | 168077 | 52 | 165744 | 51 | 153723 | 48 |
| Shrubland | 120014 | 46 | 115509 | 36 | 113995 | 35 | 110480 | 34 | 112041 | 35 |
| Dense forest | 29291 | 11 | 13181 | 4 | 14490 | 4.5 | 16274 | 5 | 13744 | 4.3 |
| Water bodies | 13.8 | 0.005 | 339 | 0.1 | 518 | 0.16 | 559 | 0.2 | 1362 | 0.4 |
| Agriculture | 10397 | 4 | 19077 | 6 | 18782 | 6 | 22466 | 7 | 33733 | 11 |
| Settlements | 4466 | 1.7 | 3325 | 1 | 3452 | 1.1 | 3791.6 | 1.2 | 4710 | 1.5 |

| LULC classes (Lushoto) | LULC coverage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2005 | | 2010 | | 2015 | | 2020 | |
| | ha | % | ha | % | Ha | % | ha | % | ha | % |
| Bareland | 96418.8 | 37.0 | 97516 | 37.4 | 97667.7 | 37.5 | 98091.8 | 37.6 | 97831.6 | 37.5 |
| Shrubland | 120014.9 | 46.1 | 120851 | 46.4 | 119538.7 | 45.9 | 111838.1 | 42.9 | 112502.4 | 43.2 |
| Dense forest | 29291.5 | 11.2 | 29014.6 | 11.1 | 30373.6 | 11.7 | 37196.2 | 14.3 | 32909.2 | 12.6 |
| Water bodies | 13.8 | 0.0 | 0.7 | 0.0 | 0.5 | 0.0 | 3.1 | 0.0 | 4.2 | 0.0 |
| Agriculture | 10397.8 | 4.0 | 8483.5 | 3.3 | 8125.7 | 3.1 | 8368.6 | 3.2 | 11388.6 | 4.4 |
| Settlements | 4466.2 | 1.7 | 4737.2 | 1.8 | 4896.9 | 1.9 | 5105.2 | 2.0 | 5967.0 | 2.3 |

| LULC classes (Mkinga) | LULC coverage | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2005 | | 2010 | | 2015 | | 2020 |
| | ha | % | ha | % | Ha | % | ha | % | ha |
| Bareland | 112516.8 | 41.54 | 111353.2 | 41.11 | 111149.4 | 41.03 | 111319.1 | 41.09 | 111589.3 |
| Shrubland | 142455.0 | 52.59 | 142749.9 | 52.70 | 140436.6 | 51.84 | 137159.9 | 50.63 | 137688.4 |
| Dense forest | 9853.5 | 3.64 | 12804.3 | 4.73 | 14950.2 | 5.52 | 16233.2 | 5.99 | 13984.0 |
| Water bodies | 2566.2 | 0.95 | 147.7 | 0.05 | 179.0 | 0.07 | 208.8 | 0.08 | 269.7 |
| Agriculture | 146.1 | 0.05 | 143.2 | 0.05 | 357.5 | 0.13 | 1734.5 | 0.64 | 2416.8 |
| Settlements | 3358.0 | 1.24 | 3697.2 | 1.36 | 3822.7 | 1.41 | 4240.1 | 1.57 | 4947.3 |

| LULC classes (Mwanga) | LULC coverage | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2005 | | 2010 | | 2015 | | 2020 |
| | ha | % | ha | % | Ha | % | ha | % | ha |
| Bareland | 138937.3 | 71.66 | 138640.1 | 71.50 | 137912.1 | 71.13 | 136694.0 | 70.50 | 132210.5 |
| Shrubland | 32484.9 | 16.75 | 32321.6 | 16.67 | 32570.2 | 16.80 | 31554.0 | 16.27 | 31878.26 |
| Dense forest | 5959.4 | 3.07 | 8049.4 | 4.15 | 7104.0 | 3.66 | 8176.1 | 4.22 | 6255.407 |
| Water bodies | 7159.2 | 3.69 | 5322.2 | 2.74 | 6005.0 | 3.10 | 5737.6 | 2.96 | 6630.77 |
| Agriculture | 6355.7 | 3.28 | 6080.9 | 3.14 | 6759.0 | 3.49 | 7945.6 | 4.10 | 12315.83 |
| Settlements | 2992.9 | 1.54 | 3475.2 | 1.79 | 3539.2 | 1.83 | 3782.1 | 1.95 | 4598.673 |

| LULC classes (Rombo) | LULC coverage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2005 | | 2010 | | 2015 | | 2020 | |
| | ha | % | ha | % | Ha | % | ha | % | ha | % |
| Bareland | 17924.5 | 35.08 | 17979.3 | 35.19 | 17477.8 | 34.21 | 17016.2 | 33.30 | 16472.5 | 32.24 |
| Shrubland | 17726.5 | 34.69 | 17872.1 | 34.98 | 17784.4 | 34.81 | 16528.9 | 32.35 | 17764.8 | 34.77 |
| Dense forest | 1181.8 | 2.31 | 1541.2 | 3.02 | 1584.5 | 3.10 | 2815.4 | 5.51 | 2015.8 | 3.95 |
| Water bodies | 105.7 | 0.21 | 105.1 | 0.21 | 106.4 | 0.21 | 107.6 | 0.21 | 107.7 | 0.21 |
| Agriculture | 12815.7 | 25.08 | 12094.6 | 23.67 | 12619.6 | 24.70 | 13037.6 | 25.52 | 12913.7 | 25.27 |
| Settlements | 1342.9 | 2.63 | 1504.7 | 2.94 | 1524.2 | 2.98 | 1591.2 | 3.11 | 1822.5 | 3.57 |

| LULC classes (Same) | LULC coverage | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 2000 | | 2005 | | 2010 | | 2015 | | 2020 | |
| | ha | % | ha | % | Ha | % | ha | % | ha | |
| Bareland | 330926.2 | 76.95 | 331507.0 | 77.08 | 330384.0 | 76.82 | 327975.7 | 76.26 | 317000.1 | 1 |
| Shrubland | 69145.5 | 16.08 | 68544.4 | 15.94 | 68521.0 | 15.93 | 64957.7 | 15.10 | 66968.6 | 1 |
| Dense forest | 15759.8 | 3.66 | 15989.5 | 3.72 | 15776.4 | 3.67 | 18678.0 | 4.34 | 15567.0 | |
| Water bodies | 462.6 | 0.11 | 725.9 | 0.17 | 896.5 | 0.21 | 895.4 | 0.21 | 1234.3 | |
| Agriculture | 9454.8 | 2.20 | 8202.8 | 1.91 | 9129.9 | 2.12 | 11865.4 | 2.76 | 22009.3 | |
| Settlements | 4322.4 | 1.01 | 5101.7 | 1.19 | 5363.4 | 1.25 | 5698.9 | 1.33 | 7292.0 | |

**Plate 1: Field photos of the team during FGDs and household interviews; from top left- Ngoyoni village, Misufini village, Mkundimtae village, Mavovo village, and Goha village in the bottom left**

**Plate 2: Field photos of elephant occurrence, crop-raiding, and property destruction by elephants in the surveyed villages; from top left is Mkomazi village, Misufini village, Kisiwani village, Kivingo village, Mazinde village, and Mkundimtae village in the bottom right**


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