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How dynamics and drivers of land use/land cover change impact elephant conservation and agricultural livelihood development in Rombo, Tanzania.

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Abstract

Land use/ land cover (LULC) change affects the provision of ecosystem services for humans and habitat for wildlife. Hence, it is crucial to monitor LULC particularly adjacent to protected areas. In this study, we measured LULC change in Rombo, Tanzania, an area with high potential agro-ecological zones that is dominated by Human Elephant Conflicts (HEC). We used remote sensing and geographical information system (GIS) techniques, questionnaires and village meetings to assess spatio-temporal patterns of the LULC changes in the study area. Using Landsat imagery, digital elevation model and ground truthing, we classified and monitored changes in LULC from the year 1987 to 2015. We found that within Rombo settlements were increasing while agricultural and agroforestry lands were decreasing and respondents' perceptions varied along the altitudinal gradient. Patterns of HEC and LULC were observed to change along the gradient and the later threatened the agricultural land and ecological integrity for elephant habitat, leading to high tension and competition between elephants and people. This research offers baseline information for land use planning to balance wildlife conservation with livelihood development in Rombo and highlights that managing the impacts of LULC changes on HEC and elephant habitat loss is a matter of urgency.

Keywords: African elephant, Kilimanjaro, Land use Land cover change, GIS and Remote Sensing, Habitat loss

1. Introduction

Land use change can greatly alter the provision of ecosystem services such as food, water, and forage for wildlife. Agricultural production in Tanzania is the dominant economic activity in which more than 80% of the country's population is dependent upon and contributing to more than 50% of gross domestic product (GDP). Globally, the conversion of native grasslands, forests, and wetlands into croplands, tree plantations, and developed areas has led to vast increases in production of food, timber, housing, and other commodities but at the cost of declining ecosystem services and biodiversity (Yanda and Shishira, 2001). This conversion is occurring at the rate faster than originally thought, and as much as half of tropical rain forest, for example, disappeared in the past three decades, its remainder is continuously being destroyed at a rate of at least 7.5 million ha per year (Yanda and Shishira, 2001). Recently, forest clearing is happening on a massive scale, leading to widespread soil erosion, excessive evaporation and reduced biodiversity. For example, during the 1990s the global forest area was reduced by approximately 2.4 % which is 94 million ha, and over 60 % of Asia's mangrove areas have been cleared for aquaculture (Lockwood and Maslo, 2014).

Conservation of wildlife requires a complete knowledge of species habitat preferences (Prakasam, 2010) and land use changes outside Protected Areas (PAs) have significant effects to wildlife, which requires large home range. For instance, in the Trans-Himalaya Region of Nepal land use changes shifted blue sheep (*Pseudois nayaur*) foraging to lower elevations, which attracted snow leopard (*Panthera uncia*) from their higher-elevation habitats to lower sites, resulting in severe human-wildlife conflicts (Aryal *et al.*, 2014). Further, in the Masai Mara-Serengeti ecosystem, a 25% decline in seven wild ungulate populations due to land use changes dominated by wildlife poaching and human-wildlife

conflicts was reported in Kenya (Ogotu *et al.*, 2009; Ogotu *et al.*, 2014; Verchot *et al.*, 2015). Generally, the conservation and management of African elephants, *Loxodonta africana*, has faced policy- and decision-makers with challenges due to this species' migratory nature and large habitat requirements outside conservation areas (Graham *et al.*, 2009). Elephants represent keystone species with significant roles in ecological dynamics (Harich *et al.*, 2016) and, therefore, their persistence outside PAs is important to the conservation of other elements of biodiversity (Baxter and Getz, 2005). On the other hand, adjacent to PAs and in migratory routes where there are human settlements, human wildlife conflict is a serious problem, especially crop raiding and related risks to life and livelihood (Mwakatobe *et al.*, 2014). Elephant kills in these migratory areas have commonly been reported (Mariki *et al.*, 2015). Furthermore, the information on which managers base their decisions is largely biased towards protected habitats, often neglecting the importance of dispersal areas for wildlife such as agricultural land (Harich1a and Treydte, 2016). Therefore, information of land use/land cover outside protected areas is essential for assessment of wildlife habitat and identification of their potentially preferred areas (Bailey *et al.*, 2015).

Land use and land cover are two separate terminologies, which are often used interchangeably (Prakasam, 2010); land cover reflects the biophysical state of the earth's surface, including the soil material, vegetation and water while land use refers to the utilization of land resources by human beings (Kavitha *et al.*, 2012). Land use / land cover (LULC) are dynamic in nature and provide a comprehensive understanding of the interaction and relationship of anthropogenic activities with the environment (Prakasam, 2010). With the increasing human population and its impact on environment, there is a need to balance conservation with infrastructure and agricultural development. Particularly in eastern Africa, the human population is increasing rapidly (Rudel, 2013), calling out for cross-cutting views on both biodiversity conservation and agricultural production.

The area around Kilimanjaro National Park, in particular Rombo, is highly fertile and has high agricultural potential (Soini, 2005). Hence, human agricultural activities are in strong conflict with African elephants residing in the areas adjacent to the National Parks. The major challenge is how a balance between conservation of wildlife and human development and, thus, co-existence can be achieved. Studies relating to current and future land use/cover changes (LULC) as well as their influence on human-elephant conflicts (HEC) are lacking. In order to meet the increasing human needs and wildlife conservation goals, information on past and present LULC and its shifts over time is essential for the selection, planning and implementation of the land use schemes so as to minimize tensions and conflicts while promoting livelihoods development. This study, therefore, intended to capture information on the dynamics and drivers of LULC change in Rombo, Kilimanjaro Region, Tanzania, by answering the following questions: (1) What are the major land use types existing in Rombo area?, (2) How have these land use/cover types changed over the last three decades?, (3) How are these changes related to the trend of HEC?, (4) What are the perceptions of the local people on the trend of different land use/cover changes in relation to HEC along an altitudinal and land use type gradient?. We applied a combination of techniques such as interviews, gray literature, participatory field assessments and satellite images. This information will help different stakeholder authorities in land use planning and establishment of land-use policies that can provide buffer zones and corridors for attaining coexistence between elephants and humans.

2. Material and Methods

2.1 Study site

Our study site is located in Rombo District in North East Tanzania (3°09' S and 37° 33' E; URoT, 2013), which lies between three protected areas, namely Kilimanjaro National Park (KINAPA), North Kilimanjaro forest plantation in the northwest, and Tsavo West National

Park (TWNP) in the South-East. This study concentrated outside these protected areas (KINAPA and forest plantations) of the district, here referred as “Rombo area” (Fig. 1). Annual rainfall varies with elevation and exposure, ranging from 200 mm at 800 masl in the low lands and 2,000 mm at 2,100 masl in the settlements bordering KINAPA (URoT, 2013). Rainfall is bimodal with long rains from March to June and short rains from November to December, which also defines the two cropping seasons of the area (Soini, 2005). The main economic activity for the local people is agriculture, with the majority of people (90%) cultivating coffee (*Coffea arabica*), banana (*Musa sp*), maize (*Zea mays*) and common beans (*Phaseolus vulgaris*) (URoT, 2013). Human population in Rombo area is about 260,963 people, having increased by 30% between 1988 and 2012 (URoT, 2013).

2.2 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 1987, 2000, and 2015, respectively. Rombo area extends over two different Landsat paths and rows. Images with spatial resolution of 30 meters were downloaded from United States 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 (1987, 2000, and 2015) were obtained within same time of year (ranging between 30th January and 29th February). Shapefiles for study site boundaries were obtained from The National Bureau of Statistics (NBS) available at (<https://openmicrodata.worldpress.com>). Natural forest and forest plantation shapefiles were obtained through (<http://www.esri.com>).

Satellite images of different years were imported in ArcGIS (version 10.3) 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 37S prior to analysis. Image processing and analysis included image cleaning, compositing, masking, clipping and mosaicking (ArcGIS guide, 2016). 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 and 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 and Wynne, 2011). Visual interpretation and digital image classification were then combined using GIS functions. Four land use classes were defined in the study area which included: (1) Agroforestry (comprising mixed perennial crops such as banana, an coffee, interspersed with tall trees species such as *Grevillea robusta*, *Persea Americana*, *Albizia spp.*, *Citrus sinensis*, *Azadirachta indica*, *Cassia siamea*, *Mangifera indica*, *Cordia holstii*, *Prunus persica* and *Annona squamosal*); (2) Settlement (comprising any type of buildings); (3) Seasonal Agriculture (seasonal cultivated lands, open areas, grasslands, bush lands, bare lands and livestock grazing) and (4) Water bodies (permanent lakes and rivers). Training sites were determined and signature files were created to be used in the classifications by using ArcGIS (version 10.3). The classified images were compared with 100 direct ground truthing points across the study area and modified accordingly. For the year 2015, land use map ground truthing was done by using the error matrix technique (Reis, 2008). Additionally, to improve the accuracy on the historical images of the year 1987 and 2000 interviews with local people were conducted. In order to refine and analyze the data at a much finer scale, the LULC classification and analysis were done across five divisions: Mengwe (17474 ha), Mkuu (9176 ha), Mashati (8827 ha), Useri (7591 ha) and Tarakea (4783 ha). Frequent human elephant

conflicts (HEC) had been recorded here and previously mentioned as one of the big challenges to agricultural production in this area (TAWIRI, 2010; URoT, 2013).

2.3 Household interview and focused group discussion

Household interviews involved a total of 261 households (located at least 0.5 km to 1 km apart) located in divisions across an altitudinal gradient (lower and high lands) guided by major roads of Rombo as main transects. Extensive field observations and interviews were conducted by administering a structured questionnaire to respondents aged 25 years and above, who had lived in the respective location for at least five years. Perceptions and awareness of respondents on: current land use types of Rombo area in relation to HEC, the influence of humans as well as the trend of different land use types over the years and reasons why land use types have changed were captured. The GPS location of households and their field locations was recorded (Garmin 64s) across the altitudinal gradients. Focus group discussions were additionally done with at least ten people (who were mainly elders of each division and could remember events in land transformation) in Rombo area. The discussions were distributed across the study site divisions and were guided using the checklist of questions related to land use change and its drivers as well as their effect on the human-wildlife interactions in the area.

The in-depth information obtained based on people's perceptions and attitudes were analyzed qualitatively and these analyses and graphical presentations were performed using Statistical Package for Social Science (SPSS 21). To generate a map, spatial analysis was performed using Geographical Information System (ArcGIS 10.4), where GPS coordinates from household surveys on the interaction with elephants and shape-files of Rombo district boundaries were imported into Arc map, geo-referenced to the World Geographical System (WGS) 1984 coordinate system and projected to Universal Transverse Mercator (UTM) Zone 37S prior to analysis. To convert point data to raster data the Inverse distance weighted

(IDW) interpolation tool was used. A Digital Elevation Model (DEM) was used to generate the contour map of the study area to overlay with elephant interaction map of the study area.

3. Results

3.1 Land use / land cover (LULC) classes and changes in Rombo area

In Rombo, seasonal agriculture covered the largest area in the year 1987, followed by settlement and agroforestry while in the years 2000 and 2015, settlement occupied the largest area compared to other land use/cover types (Table 2, Fig.2). Settlements remarkably increased from the year 1987, when they covered about 30%, to 2000 and 2015, when it occupied 54% and 60% of the entire land, respectively. There was a consistent decrease in seasonal agricultural land from a 42% coverage in the year 1987 to 25% in the year 2000 and 14% in the year 2015. Settlements expanded from upland towards lowland areas, which previously had few settlements and had been dominated by seasonal agriculture (Fig.2). Settlements increased by about 30% over the past three decades (between 1987 and 2015) while seasonal agricultural land decreased by about 28% and agroforestry decreased by 2%, suggesting that the land area that was formerly used for seasonal agriculture and agroforestry was converted into settlements (Table 3).

3.2 LULC changes across divisions

Across the five divisions of Rombo area, settlement changes between 1987 and 2015 most strongly increased by 47% in Mengwe, followed by 35% in Mkuu, 23% in Mashati, 22% in Useri and 17% in Tarakea (Fig. 3). Seasonal agricultural land decreased within the same period most strongly in Mengwe with 49%, followed by 33% in Mkuu, 21% in Mashati, 12% in Useri and 7% in Tarakea. Agroforestry decreased in all divisions except for Mengwe, where it increased by 2% (Fig. 3). Hence, in the four divisions (Mkuu, Mashati, Useri, Tarakea), the former agricultural and agroforestry land was converted to settlements while in Mengwe former agricultural land was converted to settlement and agroforestry (Fig. 3).

3.3 Perceptions of respondents on the trends of LULC changes

More than 200 respondents reported an increase of settlement areas (residential homes, schools and hospitals) and decrease in seasonal agricultural areas (Fig.4). Respondents' perceptions also varied along the altitudinal gradient, whereby 84% and 16% of the reported increased settlements were found in lowland (below 1230 masl) and highland areas (above 1230 masl), respectively. The results from the interviews also indicated that 76% of the current residential areas (settled lands) were formerly used for agriculture. This also varied across altitude whereby 30%, 45%, and 25% of the current settled land in the lowland areas had been colonized 30, 20 and 10 years ago, respectively,. In the upland areas, 87%, 8%, and 5% of the current settled land had been colonized 30, 20 and 10 years ago, respectively. This was confirmed by the village meetings where about 90% of the members agreed that before the 1980s' about 80% of the settled lands in lowland areas were used for seasonal agriculture. Due to limited space for residential areas in the uplands, settlements had been extended towards lowland areas in the recent years. The results of the interviews and meetings are consistent with those generated by our LULC change detection analysis in Table 3 and map in Fig. 2 which shows.

3.4 Respondents awareness on HEC and interactions with elephants

Interactions amongst people and elephants varied along the altitudinal gradient; in lowlands interactions were common and current, while in the highlands interactions were described as a historical event (Fig. 6). All respondents (100%) in lowlands were aware about HEC and about 96% had encountered elephant problems in their farms at least once within the last five years. In these areas, elephants were reported to come from Tsavo West National Park (TWNP) in Kenya to Rombo, invaded cropped lands and went back to Kenya. In the highland areas, about 69% of respondents were aware of HEC issues in Rombo area and 30% of

respondents encountered elephants on their farms at least once in five years, albeit farms were located in lowland areas but not in highland areas. Additionally, respondents aged above 50 years in the highlands reported to have seen elephants before the 1980s' crossing from the TWNP to KINAPA forests but afterwards they were only localized in the lowlands. The lowland areas of Rombo are characterized by savanna habitat, which is a typical environment for diversity of wildlife ranging from small to large mammal species (Ricci *et al.*, 2009). In the lowlands, the dominant agricultural crop was seasonal, especially maize (*Zea mays*), which is highly attractive to elephants, while in highland areas the major crops were coffee (*Coffea arabica*) and banana (*Musa sp.*), which seemed less attractive to elephants in our area. Respondents also reported that the frequency of elephant visits in lowland areas has decreased over time (Fig.4). Elephants were most frequently (31% of the cases) found in farms (seasonal agricultural lands), around settlements (23%) and on roads (20%) while water areas and grazing land were less frequently visited by elephants (11 and 15%, respectively) (Fig. 5), which was also confirmed by members of the meetings.

4. Discussion

4.1 Historical LULC of Rombo

In our study, the Chagga farming systems in highlands were dominated by agroforestry including Arabica coffee, banana and intercropped trees as well as dense settlements. The lowland areas is a characteristically savanna area and agricultural production here is predominantly seasonal crops including maize (*Zea mays*), millet (*Eleusine coracana*) and beans (*Phaseolus vulgaris*) with scattered settlements. Most residents in the highlands of Rombo area reported to make daily trips to the lowland farms during cropping seasons. Highland farms are owned by the Chagga tribe and inherited within a particular family from generation to generation (Grimshaw and Forley, 1990). In contrast, at the lowlands areas, land is individually owned and can be sold and bought (Soini, 2005). Hence, we observed the

high level of land use changes in these lowland areas, which had changed from bush lands to seasonal agricultural lands since the 1960s (Soini, 2005) and now were converted to settlements.

Historically, significant land use changes in the slopes of Mount Kilimanjaro including Rombo area started to occur in the late 19th century with the arrival of missionaries and early colonialists (Soini, 2005). Rombo, like other parts on the slopes of Mount Kilimanjaro, has been known to be productive land for people and animals due to beneficial climatic conditions and fertile soils (Grimshaw and Forley, 1990; Soini, 2005). The competition for areas available for biodiversity conservation (e.g. elephants) and human development such as agriculture and settlements destroyed elephant habitat, and blocked the wildlife (elephant) migratory routes. The population dynamics of wildlife (e.g. of a variety of large mammals) is also determined by the relationship they have with the humans in their habitat (Baillie *et al.*, 2004). In the lowland areas (called savanna) other wild animals e.g. baboons, monkeys often forage in the grasslands and raid crops (Ricci *et al.*, 2009). Olive baboons prefer human crops as they are easily obtainable food (Boulton *et al.*, 1996). While this species was also reported to inflict damage to crops, baboon conflict with people is disproportionately lower than that caused by elephants particularly in terms of nature and magnitude, hence humans can adapt to a wide range of other wildlife species but not so easily with elephants.

The numbers and distribution of elephants and large mammals in Rombo has been inversely related to the amount of habitat destroyed after human settlement, which reduced the elephant distribution range between 1930 and 1965 and left few migratory elephant groups that would enter KINAPA from TWNP in the east (Child, 1965; Afolayan, 1975). Nowadays, elephants and human interests in this area seem to be notoriously irreconcilable, especially where crops are cultivated close to protected areas.

4.2 Recent LULC changes

Our study has indicated that settlement expanded by about 30% almost within the same period of 28 years. Even small increases in settlement areas may have significant impacts on PAs and wildlife in general (Bailey *et al.*, 2015) because settlements relative to other LULC are more permanent and resource intensive (McGranahan and Satterthwaite, 2003). Rombo area had a continued human population increase of 30% over the past 25 years with human population densities of 471 people per km² and the land's carrying capacity has been exceeded by 7 people per ha instead of recommended 5 people per ha (URoT, 2013). With this rate of population increase more agricultural land is likely to be converted to settlement and, thus, reducing elephant dispersal area. In pastoral areas with no farming in the Mara of Kenya, wildlife numbers begin to decline when human populations reach 8-10 people per km², and about 90% of the wildlife disappears when there are more than 75 people per km² (Wittemyer *et al.*, 2008). Globally, urban populations are projected to increase in the coming few decades, with much emphasis in Africa (Cohen, 2003) and a likely increase in Rombo area (URoT, 2013), threatening the survival of the isolated elephant populations in KINAPA and TWNP. Generally, wildlife starts to disappear when farms and settlements cover 25-50% of savanna landscapes (Reid, 2012). In our study area, about 75% of the land was covered by settlement and seasonal agriculture in the year 2015. This has also been shown by studies in other areas and in Ghana, for example, where savanna reserves surrounded by many human settlements have lost a large number of mammal species over time (Wittemyer *et al.*, 2008). Different from other Rombo divisions in our study area, Tarakea and Useri had a high rate of decrease in agroforestry. These two divisions are neighboring the Kilimanjaro forest plantation with favorable rainfall and fertile soil, which attract human populations and settlements with the interest to cultivate seasonal crops inside the forest plantation. This might further result in potential encroachment into elephant habitats and increased poaching.

Studies by Karanth *et al.* (2006), Luck (2007), Wittemyer *et al.* (2008) and (Bailey *et al.*, 2015) argued that the growth of human populations around protected areas may have strong negative impacts on large mammals and biodiversity through illegal hunting, deforestation and habitat encroachment but the magnitude of this trend is context-specific and contingent on the nature of the landscape and the effectiveness of border protection.

4.3 Elephant population

We found in our study that migration by elephants and other large mammals used to occur on a regular basis between KINAPA and TWNP in Kenya but, currently, there is little evidence of these movement patterns. Farmers also claimed that the frequency of elephant visits declined and medium to large-sized mammals such as baboons, bush pigs and warthogs increased on their fields. A study by Kyale (2006) in the same ecosystem also indicated strong and significant association patterns of poaching-induced elephant mortality. Previously, elephants and other large mammals occurred at high numbers in Rombo, particularly in the southern part of Kilimanjaro and in the lowland areas bordering TWNP (Child, 1965; Afolayan, 1975). Due to increasing habitat fragmentation, encroachment and poaching for ivory trade some studies reported a declining elephant population in the KINAPA ecosystem from 1200 elephants in 1970s (Afolayan, 1975) to about 750 in 2003 (Munishi and Maganga, 2003) and 450 in 2010 (TAWIRI, 2010). Although loss of habitat due to agriculture and human settlements (Okello and Kiringe, 2004) has been argued to be a major long-term threat to the survival of elephants *in situ*, the ultimate direct threat to elephant survival has been identified as poaching for ivory trade before and after the colonial era (Leader-Williams *et al.*, 1990; Burton, 1999; Heltberg, 2001).

4.4 Human Elephant Conflicts (HEC)

Rombo district, which encompasses high potential agro-ecological zones and encompasses about 58% of protected land, has had a high level of conflicts between humans and elephants (Mmbaga *et al.*, 2017 *under review*). We found HEC dominating in lowland areas of Rombo, where the major land use type was seasonal agriculture dominated by maize, which was highly preferred (in 82% of cases) by elephants compared to other crops (Mmbaga *et al.*, 2017 *under review*), congruent with findings by Hoare (1999) and Mwakatobe *et al.* (2014). The (seasonal) agricultural land in Rombo in the lowlands are frequently experiencing conflicts dominated by elephant crop raiding (99%) and sometimes even leading to human death (1%) (Mmbaga *et al.*, 2017 *under review*). Degrading impacts on protected area resources due to adjacent cropland and settlement intensification is likely to drive elephant population to local extinction (Davis and Hansen, 2011; Bailey *et al.*, 2015), threatening the elephant population and their dispersal, as we might see in Rombo area in the future. Therefore, with the existing LULC changes and HEC condition in our study area, establishment of land-use policies that provide potential buffer zones and corridor land is crucial. This may minimize the HEC and benefit human livelihood while attaining conservation of wildlife (elephants) and their habitat in the dispersal areas.

5. Conclusion

Our fine-scale critical assessment of the contribution of spatio-temporal LULC changes on HEC is important to conservationists if we are to meet the challenges related to wildlife population loss and attaining sustainable conservation goals. Our study has indicated that in Rombo area lowland areas human development such as agriculture, settlements and infrastructure development actually destroyed elephant habitat, and blocked the wildlife (elephant) migratory routes in highland areas and remaining with HEC in lowland areas close to TWNP. These areas were dominated by frequent HEC although in recent years, elephant

visits in village lands have been reported to decline. In these lowland areas, coexistence is likely to occur and people may benefit from elephants if the mechanisms for sharing the profits from wildlife tourism are in place. While short-term management measures such as crop rotations and alternative crops to reduce HEC should be prioritized in areas bordering protected areas, patterns of human population and settlement expansion should be taken into account when planning for long-term HEC mitigation measures. Generally, in areas of common interest/shared resources between wildlife and people, establishment of land-use policies that provide buffer zones, wildlife corridors and benefit sharing with local people is also essential. This will reduce impacts of anthropogenic activities and ensure sustainability of wildlife conservation and livelihoods.

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Figure 1: Map of Rombo District showing the core study area, in north-eastern Tanzania surrounded by the two protected areas; Kilimanjaro National Park (KINAPA) and Tsavo West National Park (TWNP).

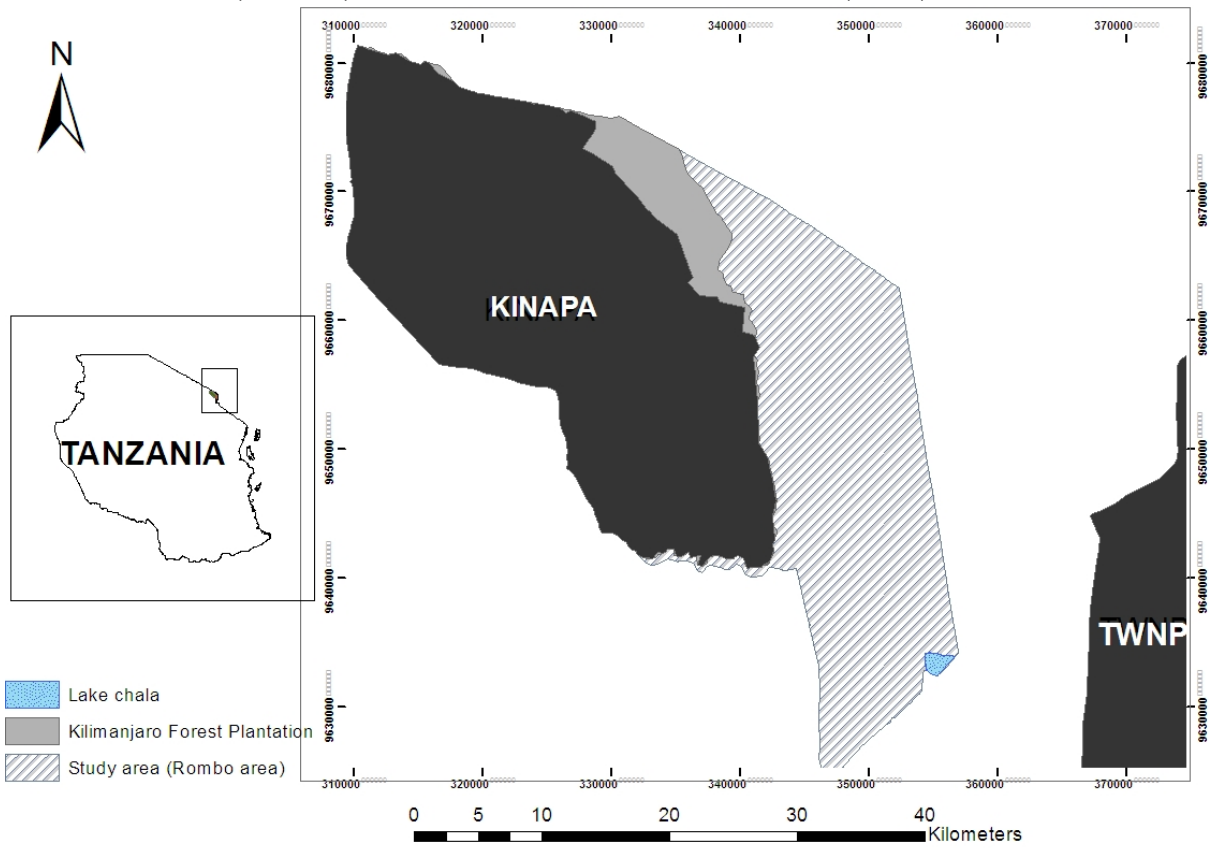


Figure 2: Land use / land cover (LULC) types in the years 1987, 2000 and 2015 in Rombo area

(A=Mengwe Division, B= Mkuu Division, C = Mashati division, D = Useri division, E= Tarakea Division)

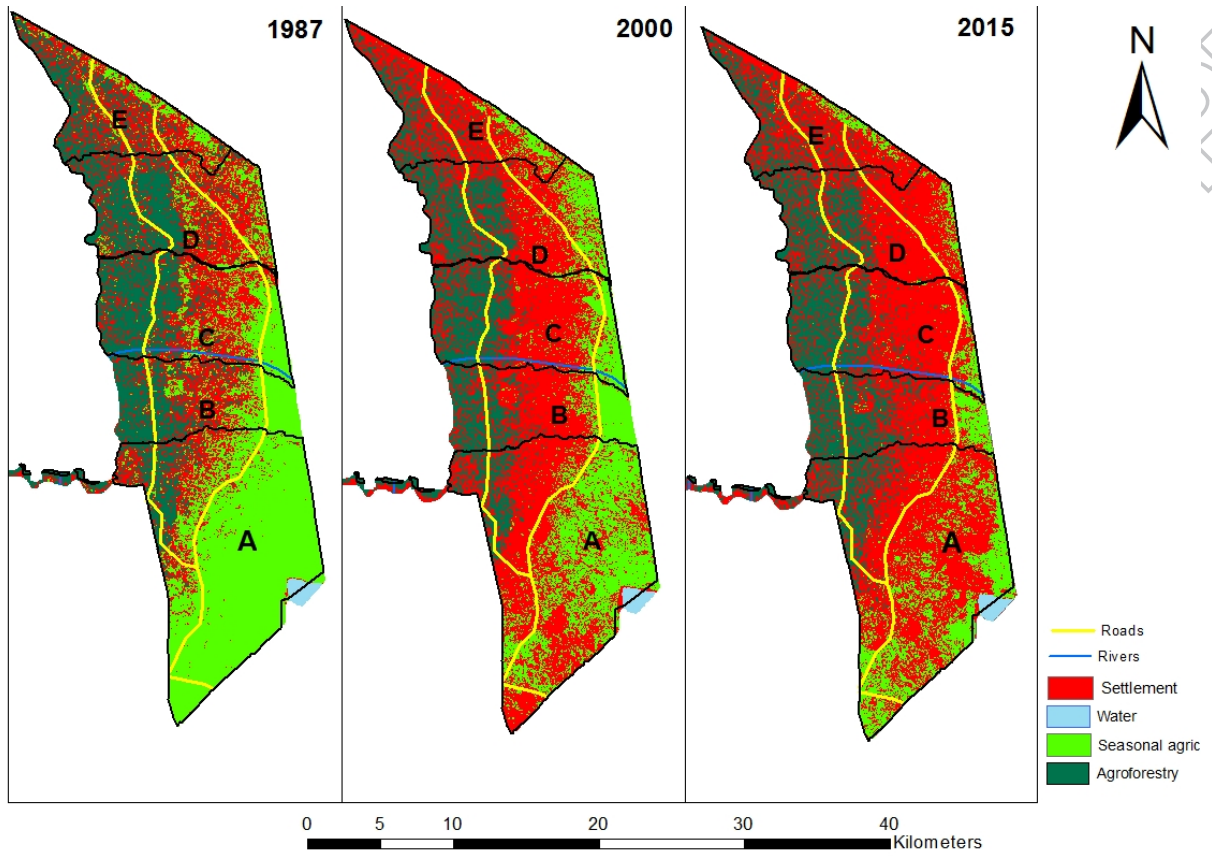


Figure 3: Land use / land cover (LULC) change across five divisions in Rombo area from 1987 to 2015.

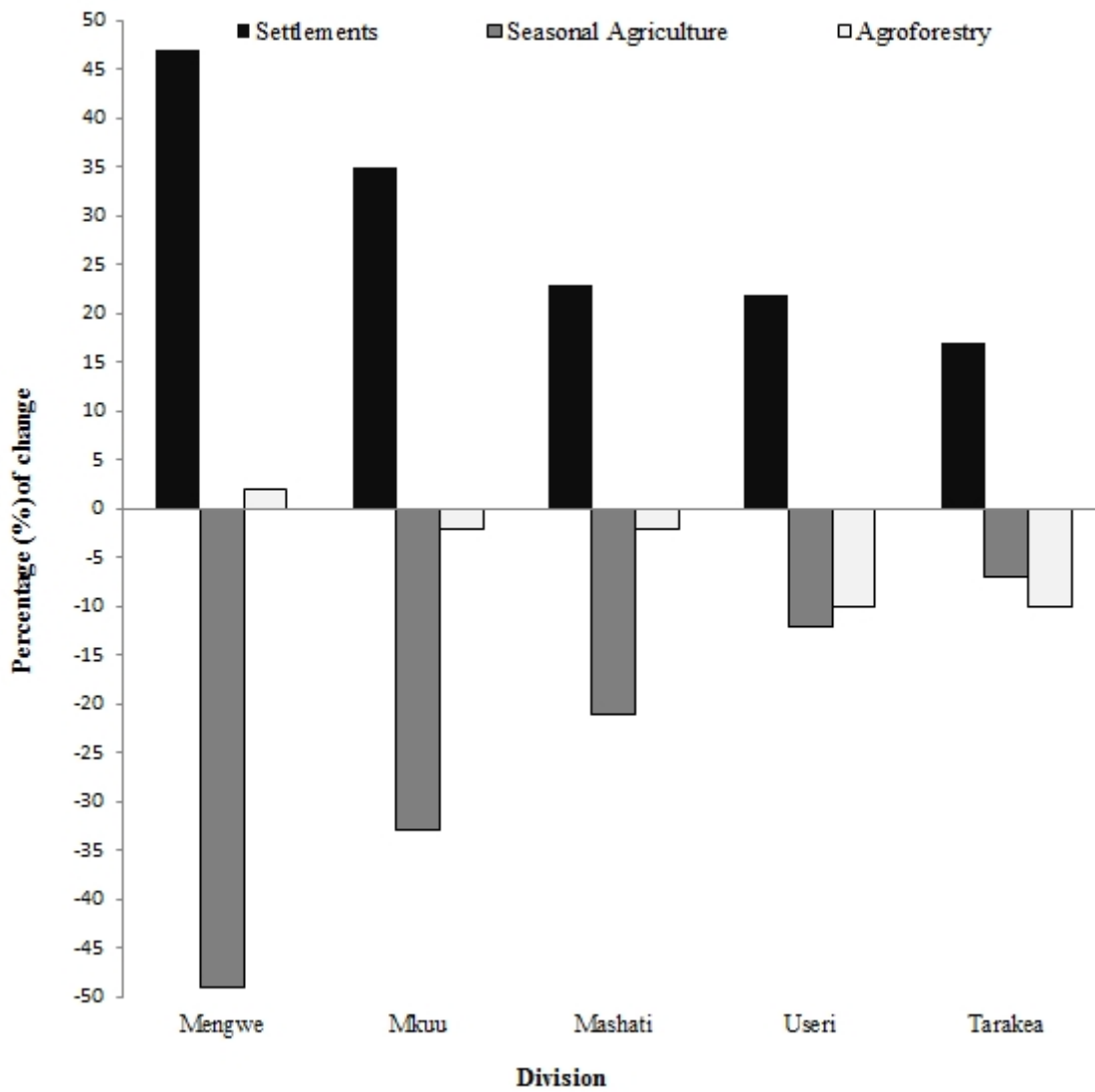


Figure 4: Perception of respondents towards changes in different land use / land cover (LULC) types and in the frequency of elephant visits over the last six years (N=261)

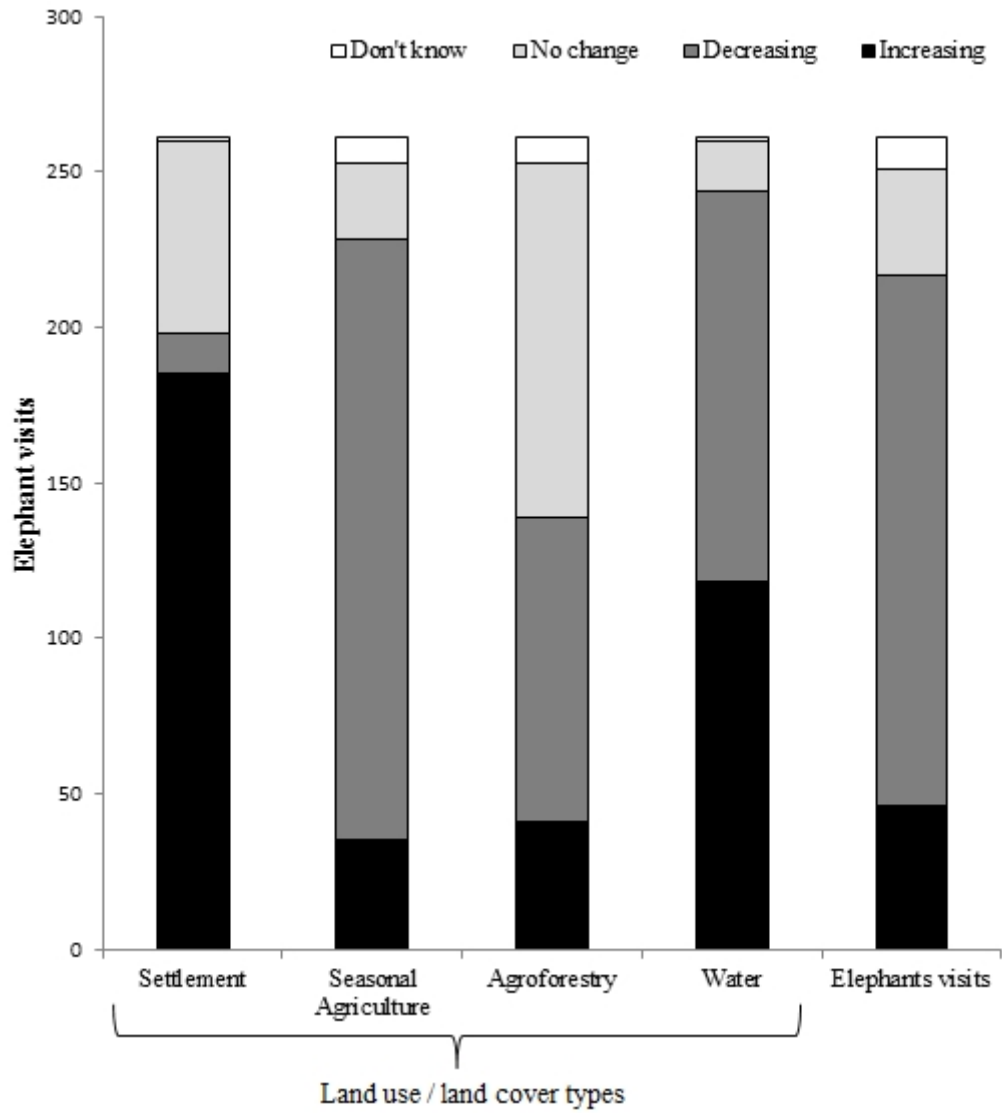


Figure 5: Perception of respondents towards the frequency of elephant visits in different land use types (N=261)

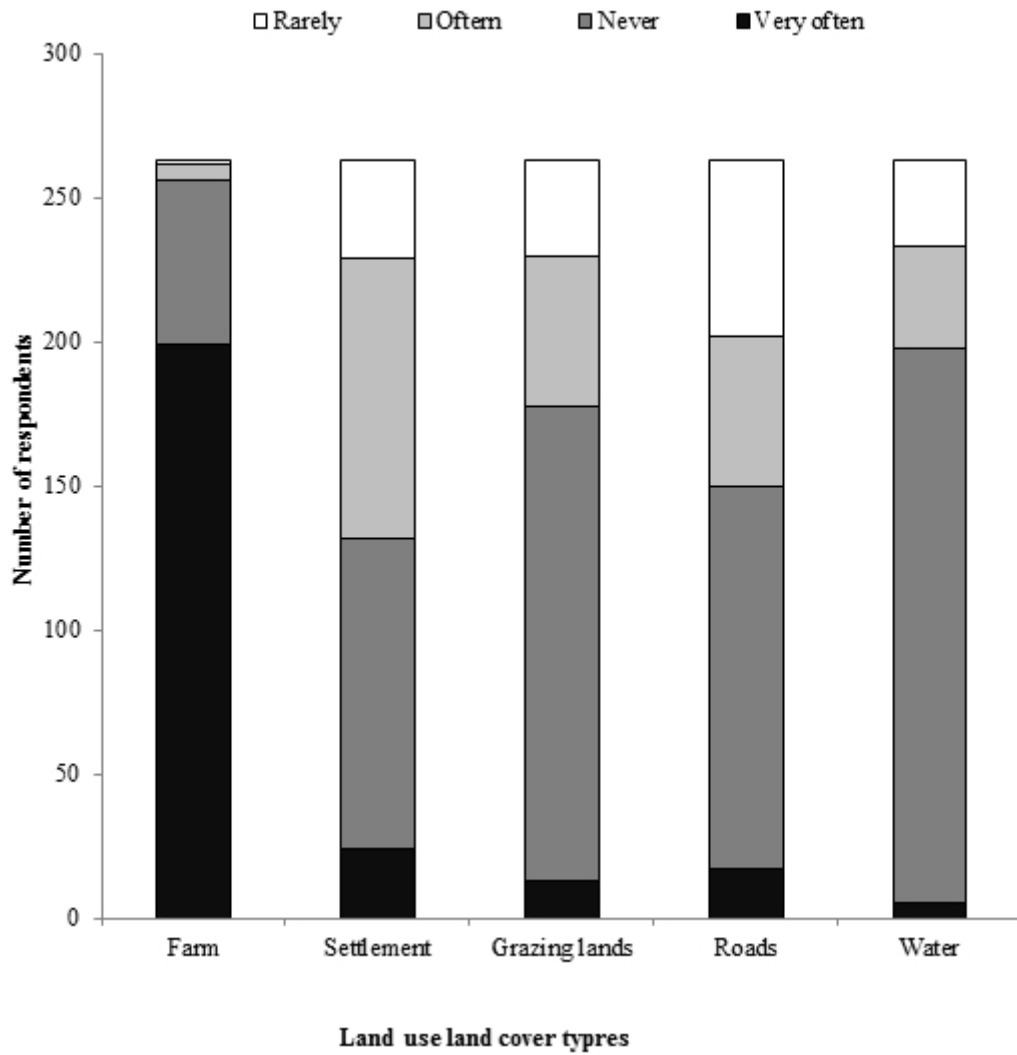


Figure 6: Status of Human Elephant Interaction along the altitudinal gradient.

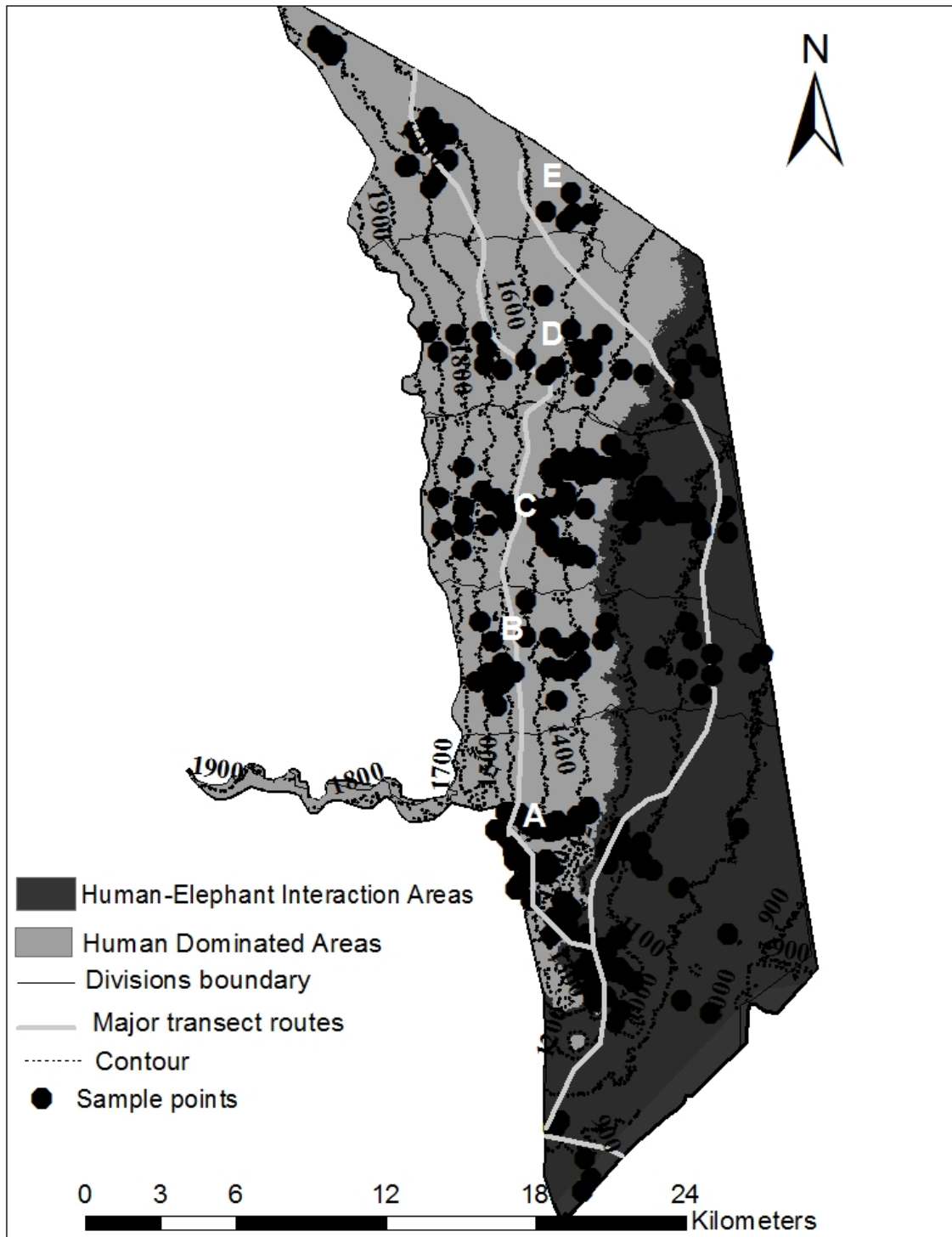


Table 1: Satellite image descriptions (*Source:* <http://earthexplorer.usgs.gov>)

Year	Position	Description				
		Path	Raw	Space craft ID	Sensor ID	Date acquired
1987	East	167	62	Land Sat 5	TM	18/02/1987
	West	168	62	Land Sat 5	TM	25/02/1987
2000	East	167	62	Land Sat 7	ETM	29/02/2000
	West	168	62	Land Sat 7	ETM	21/02/2000
2015	East	167	62	Land Sat 8	OLI TIRS	30/01/2015
	West	168	62	Land Sat 8	OLI TIRS	06/02/2015

Table2: Land use / land cover (LULC) types in ha and % in Rombo area from the year 1987 to 2015

LULC Types	1987		2000		2015	
	ha	%	ha	%	ha	%
	Agroforestry	13224	27.6	10126	21.2	12217
Settlement	14450	30.2	25660	53.6	28599	59.8
Seasonal Agriculture	19893	41.6	11784	24.6	6757	14.1
Water	284	0.6	281	0.6	278	0.6
Total	47851	100	47851	100	47851	100

Table 3: Changes in land use / land cover (LULC; in ha and %) across Rombo area

Year	1987 to 2000		2000 to 2015		1987 to 2015	
LULC Type	ha	%	ha	%	ha	%
Agroforestry	-3098	-6.5	2091	4.4	-1007	-2.1
Settlement	11210	23.5	2939	6.1	14149	29.6
Seasonal agriculture	-8109	-17.0	-5028	-10.5	-13136	-27.5
Water	-3	-0.0	-3	-0.0	-4	-0.0