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Human population growth as indicator for human-elephant conflicts in Rombo area, Tanzania

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Abstract

Conservationists need detailed information on human population growth and distribution in areas adjacent to protected areas. This information can help determine land use/land cover changes (LULCC), which affect the quality and quantity of elephant habitat and, thus, elephant populations. We assessed the influence of human population trends on demographic characteristics on the African elephant (*Loxodonta Africana*) population and related conflicts with people in Rombo, Tanzania. Data on household surveys, focus group discussions, site observations and human census records as well as reported human-elephant conflict (HEC) incidents were included. A Digital Elevation Model in GIS was used to produce a map showing spatial distribution of human population density along an altitudinal gradient in relation to LULCC and HEC status. We found that, over the past 40 years, the human population in Rombo area has been growing fast, with an increment of 128% from 1967 to 2012. The population density was low in lower altitudes (<1230 masl), which were strongly used for seasonal cropping and highly dominated by HEC (98%). Settlements expanded from 1987 to 2015 by 30%, particularly at higher altitudes. Most respondents only attained primary education (72%) and strongly depended on agriculture (99%) to sustain their livelihoods. We conclude that with the increasing human population and alteration of land use need interventions to sustain elephant conservation and livelihood of the people. We recommend the establishment of buffer zones for elephant conservation and tourism activities in the lowland areas.

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Introduction

Background of human population and natural resources

Human population growth and consumption of natural resources are associated with resource conflicts with wildlife (Redpath *et al.*, 2013). The rapidly increasing human population is projected to reach 11.2 billion people globally in the year 2050 (Borlaug, 2007; Cairns *et al.*, 2013). This will lead to an increased human population overlap with established wildlife territories (Ogutu *et al.*, 2016).

The resulting undesirable consequences will include habitat loss (encroachment and fragmentation), increased poaching, human-wildlife conflicts (HWC), as well as jeopardizing the viability of wildlife.

Human population increase also leads to overutilization of the natural resources, accelerating the threats to ecosystems and their services (e.g. timber, fodder and fuel). Hence, this trend further undermines the sustainability of the environment and biodiversity conservation (Emery, 2007).

Despite the fact that Tanzania has designated most of its land (36%,) (Mduma *et al.*, 2010) as PAs of various categories, wildlife and wildlife habitats are facing threats and conflicts with people due to high local human population increase. Cases of conflicts between humans and wildlife, especially with African elephants (*Loxodonta africana*), have been reported to increase in locations adjacent to protected areas (PAs), where the majority of poor human populations are located (Mduma *et al.*, 2010; Mwakatobe *et al.*, 2014; WCS, 2009).

Rural poor communities are highly depending on natural resources to meet their daily needs such as food, fuel, timber or clean water and, therefore, interactions and conflicts with wildlife are inevitable (Sinclair *et al.,* 2002). Hence, a critical assessment of the local human population growth in rural areas adjacent to PAs and its impact on conservation are essential in addressing the challenges related to biodiversity loss and livelihood development.

Biodiversity, livelihoods and Human elephant conflicts (HEC) in Rombo area

Humans have been cutting and clearing forests around Kilimanjaro including Rombo area for fuel and agriculture for centuries (Child, 1965) and the chagga home gardens (comprising coffee, banana and mixed trees) escaped deforestation because of their long-term sustainable supply of multiple ecosystem services (Soini, 2005). The home gardens, dominated by agroforestry, are now threatened by climate and environmental changes that have triggered shifts towards seasonal crops (Mmbaga *et al.*, 2017). A loss in home gardens has rendered ecosystem services and functions in an unsustainable way, leading to biodiversity loss and livelihood crises (Mmbaga *et al.*, 2017).

Little is known about the role that human population pressure and LULCC threats play in an ecosystem and the consecutive provision of ecosystem services. Historically, the Rombo area on Kilimanjaro, Tanzania, is known to be rich in biodiversity and elephants. Protected areas (PA) were established here at the beginning of the 20th century, and Rombo became an interface for elephant movements between these PAs (Afolayan, 1975). Subsequently, man has frequently been in conflict with elephants in the area, largely because of expanding human populations and their land demand for settlement and crop cultivation, challenged by human-elephant conflicts (HEC) (URT, 2013). This district is also known to have a rich agro ecological potential (URT, 2013). Although HEC are known to increase with increasing human population (Hoare, 1999), in Rombo area there is a lack of scientific data relating the human population numbers, demography, density and their characteristics with the quantity and quality of wildlife habitat and their contribution to the sustainability of the ecosystem.

With this study, we therefore wanted to relate human population density, growth and demographic factors with livelihood strategies, elephant population movement patterns and HEC so as to come up with good strategies to attain livelihood development and elephant conservation.

We intended to answer the following questions: How rapidly has the human population grown in Rombo? What is the spatial distribution of human settlements and activities along the altitudinal gradient of Rombo? What are the demographic characteristics of local people residing and farming in Rombo? And how these are related to Land use/cover changes (LULCC), elephant population and human elephant conflicts? We further inquired about the perception of people in terms of their vulnerability towards HEC with respect to gender and age. We combined data of 261 interviews with secondary data from the District wildlife offices and human population censuses (URT, 2013).

Material and methods

Study site

Our study site is located in Rombo District, North East Tanzania (3°09' S and 37°33' E; URT, 2013), which lies between Kilimanjaro National Park (KINAPA) in the northwest, and Tsavo West National Park (TWNP) in the South-East (Fig 1). We concentrated on the area outside of the protected sites of the district, here referred to as "Rombo area". Annual rainfall varied with elevation and exposure, ranging from 200 mm at 800 masl in the low lands to 2,000 mm at 2,100 masl in the settlements bordering KINAPA (URT, 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*) (URT, 2013).

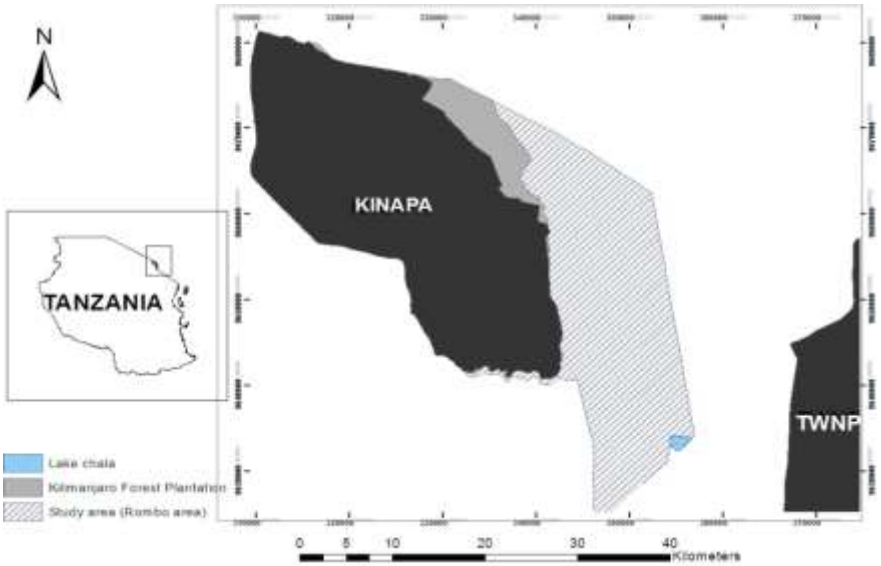

Fig. 1. Map of Rombo District showing the core study area, in north-eastern Tanzania surrounded by the two protected area; Kilimanjaro National Park (KINAPA) and Tsavo West National Park (TWNP). (Mmbaga *et al.,* 2017)

Data collection

Human population data were obtained from Rombo district profile (URT, 2013) and Tanzania census report (URT, 2013). Household interviews involved a total of 261 households (located at least 0.5km to 1km apart) across an altitudinal gradient. Extensive field observation of different land use/cover types and interviews were conducted by administering a semi-structured questionnaire to respondents aged 25 years and above, who had lived in the respective location for at least five years. Educational level, perceptions and awareness of respondents on patterns of population changes, age and sex vulnerable to HEC were captured. Focus group discussions were additionally conducted on five groups across divisions, with at least ten people per group (who were mainly elders of each division and could remember events in population transformation) in Rombo area.

Data analysis

Spatial analysis was performed using Geographical Information System (ArcGIS 10.4). Shape-files for study site boundaries and demographic characteristics were obtained from The National Bureau of Statistics (NBS; www.openmicrodata.worldpress.com).

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. A Digital Elevation Model (DEM) was used to generate the contour map of the study area and was overlaid with the population density map of the study area. The in-depth information obtained based on people's perceptions and attitudes were analyzed qualitatively using the Statistical Package for Social Science (SPSS 21).

Results

Human population and LULC trends

Over the past 40 years, the human population in Rombo area has been growing fast with an increment of 128% from 1967 to 2012 (Fig. 2), which is about 50% less compared to the entire country population growth, which increased by 265% over the same time period. Although the population is growing fast, the growth rate (GR) and House hold size (HHS) were found to decreasing.

In the years 1978, 1988, 1988-2002, 2002 to 2012 GR decreased slightly, with 2.4%, 1.6 and 1.4, respectively. Household sizes slightly decreased from 6 to 5 people per household between 2002 and 2012. With increasing human population, settlement expansions was found to rise by 30%, 54% and 60% in the years 1987, 2000 and 2015 respectively (Mmbaga *et al.*, 2017). Contrary to this, the area covered with seasonal agriculture decreased from 42% coverage in the year 1987 to 25% and 14% in the year 2000 and 2015, respectively. Agroforestry land decreased by 2% from the year 1987 to 2015, suggesting that the land area that was formerly used for seasonal agriculture and agroforestry was converted into settlements (Redpath *et al.*, 2013) (Fig 2).

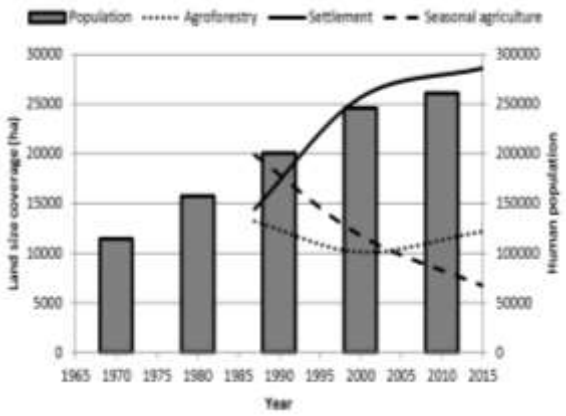

Fig. 2. Human population, settlement, agroforestry and seasonal agriculture trends in Rombo area.

Spatial distribution of human population density and distribution in relation to LULCC and HEC along the altitudinal gradient

The Rombo human population density has increased by 6% over the last ten years with similar trends across the study divisions (Fig. 3). In Tarakea division, the increment was 12%, in Mkuu 10%, in Mengwe 7% and in Useri 6%, in Mashati 2%.

The population density differed across the wards in Rombo area, with denser wards (≥1583 people / km^2) in higher altitudes (>1230 masl) and <12 people/ km^2 residing in lower altitudes (<1230 mals) (Fig. 4).

Land use/cover mostly changed in low land areas covering about (17,889 ha) and settlements expanded from upland towards lowland areas, which previously had few settlements and had been dominated by seasonal agriculture. Respondents also claimed that higher altitude lands were fully occupied by settlement, forcing the present and coming generations to settle in the lowland areas.

Most respondents (99%) in lowland areas reported to have received more neighbors in their residential areas over the recent 20 years and about 60 % of lowland area had been settled. These areas below 1230 masl and with low human population density were highly dominated by HEC (98%), while areas above this altitude and with high human population densities were an almost conflict free zone.

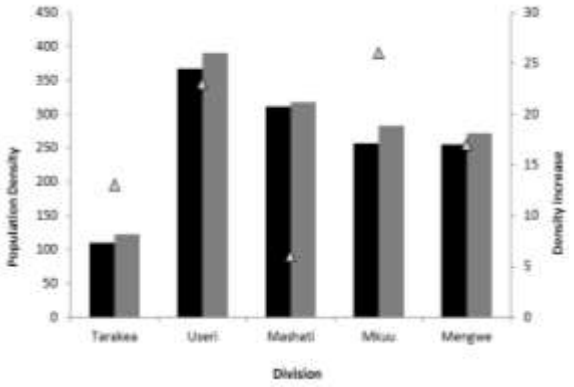

Fig. 3. Human population density increase (triangles in km²) across the divisions of Rombo area, as well as the entire human population density (in people/ km²) in the year 2002 (black bars) and 2012 (grey bars).

Education status, age and livelihood strategies of the respondents in Rombo

Education level of respondents differed significantly across the divisions ($P < 0.0001$, $X^2 = 200.13$, df = 2 and N = 261), whereby most respondents had primary education only (72%), followed by illiterates (27%) and with secondary education (ordinary level) (1%). No interviewee had attended advanced level secondary education or university education. The main economic activity of respondents was agriculture (85%), followed by business (9%), laborers (6%) and government employees (1%).

Respondents claimed to be engaged in other businesses, mainly brick mining, small shops, and other activities to supplement their income obtained from agriculture. Government employees were mainly primary teachers, nurses, and most of them (98%) were also involved in agricultural activities. In the lowland areas, about 99% of respondents completely depended on agriculture while in the highland areas, only 50% of respondents did so. Income from agriculture differed significantly across the divisions ($P < 0.0001$, $X^2 = 22.24$, df = 2 and N = 261), whereby the maximum earnings of 400 USD per household per season were achieved in Mengwe division while Mashati showed the lowest earnings of 250 USD per household per season. Income from other sources, max of 20 USD per month per household, did not significantly vary across the divisions of study ($P = 0.238$, $X^2 = 2.87$, df = 2, and N = 261).

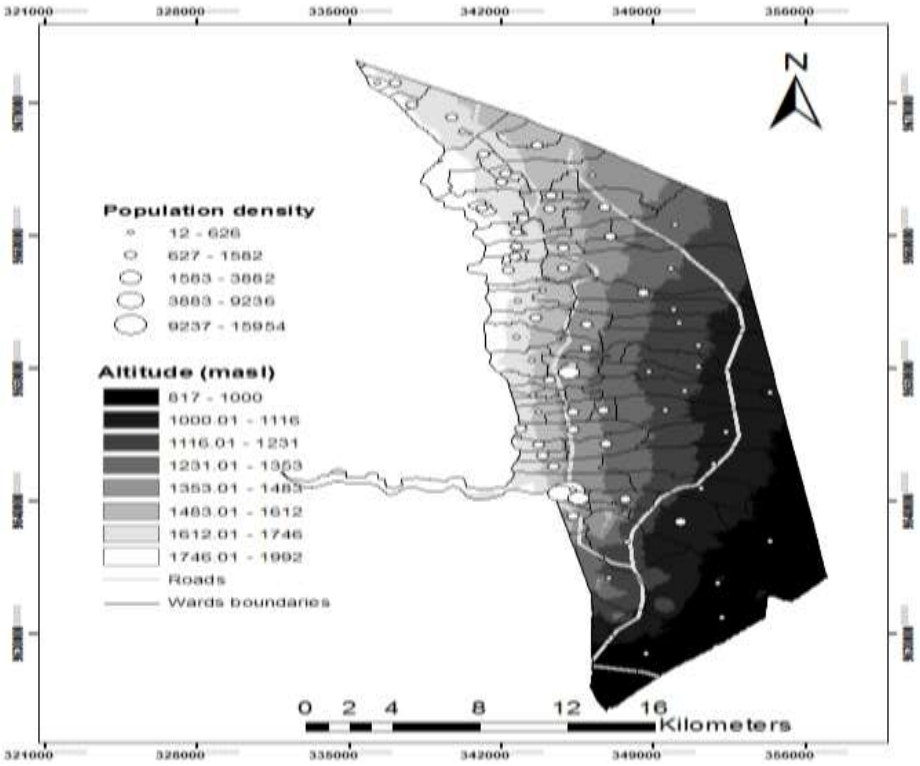

Fig. 4. Distribution of human population density across wards along the altitudinal gradient of Rombo area.

Perception on vulnerability to elephant attacks

There were 387 incidents of HEC throughout Rombo reported to the Wildlife Division office over a period of six years (1996-2011), with most incidents occurring in Mengwe and Mashati. Respondents claimed that HEC cases happened every year, especially in low land areas. The majority (46%) of the respondents declared that both sexes are vulnerable to elephants, which also agreed with the incident records, whereby there were only two cases of human beings killed by elephant (one man and one woman) over a period of six years. On the other hand, some (38%) respondents claimed females to be highly vulnerable because they are weak and cannot defend themselves compared to men, while few (16%) mentioned that mainly males were vulnerable because they heavily drink alcohol and walk at night, which is the time of elephant visits. Respondents also had a different perception towards age vulnerability, whereby the majority claimed older people to be likely victims due to their loss of vision and sound detection (60%), little potential for self-defense (35%) and drink and walk at night (5%) (Fig. 5).

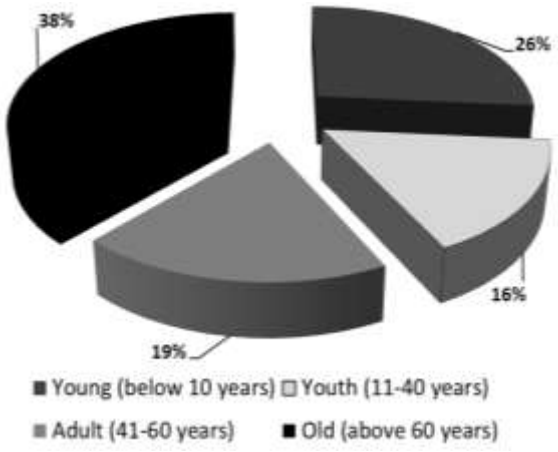

Fig. 5. Perception of the respondents on vulnerability to elephants based on age.

Discussion

Human and elephant population trends in Rombo

Human population growth has triggered severe land use/cover changes and increased the rate of utilization of natural resources, which has raised the pressure on the environment and, thus, elephant populations in Rombo.

The management of elephant populations and their conflicts with people has been a matter of key concern and the elephant mortality due to conflicts remains high (Chen *et al*., 2016; Ngene *et al*., 2013). Different studies have linked human population growth with increasing HEC.

For instance, Bal *et al*., (2011) recorded an increase of HEC intensity over the last 10 years in India, all of which were accompanied with a human population increase and the expansion of farms. Contrary to this, although human population has been growing (URT, 2013) and settlements have expanded by about 30% over the last three decades in the Rombo area (Mmbaga *et al*., 2017), HEC have been reported to be declining. This might be caused by an increase in human population density immediately adjacent to protected areas, which might suppress elephants coming out of their protected zones and lead to a blockage of migratory routes.

The average human population age (65%) in Rombo was rather young below 15 years (URT, 2013), which suggests that more LULCC is to be expected due to further expansion of the land for settlement for present and coming generations. The historical distribution of elephants and large mammals in Rombo area has been linked to human settlement, which reduced the elephant distribution range (which occurred between 1930 and 1965) to only few migratory elephant groups that would enter KINAPA from TWNP in the east (Afolayan, 1975; Child, 1965). This means that migration by elephants and other large mammals used to occur on a regular basis between KINAPA and TWNP in Kenya to the east but very little evidence was found that this migration still existed during this study interview and observations.

Human population density and HEC

During our study, the lowland areas with low human population densities ranging from 12-626 people/km^2 were highly dominated by HEC. In this area, humans have been competing with elephants by converting their habitat into farmland where they grow seasonal crops such as maize.

In upland areas, where human population density was above 626 people/km², elephant populations seemed to have disappeared, rendering these area conflict free zones. Elephant population in the Kilimanjaro ecosystem was reported to be about 1,500 individuals in 1963 (Child, 1965), thereafter decreased to 750 in 2002 (Munishi & Maganga, 2003) with a further decline to 450 in 2009 (Mduma, Simon; Lobora, Alexander; Foley, Charles; Trevor, 2010). Hence, over the last four decades elephant population decreased by about 70%, which might also contribute to the decreasing HEC. The decreasing elephant population might be caused by other reasons, including higher poaching activities by more people close to PA (Child, 1965; Mduma *et al*., 2010; Munishi & Maganga, 2003; Wasser *et al*., 2010). In pastoral areas with no farming, e.g., in the Mara of Kenya, wildlife numbers began to decline when human population densities reached 8-10 people/km², and about 90% of the wildlife disappeared when there are more than 75 people/km² (Wittemyer *et al*., 2008). Wildlife started to disappear when farms and settlements cover 25-50% of savanna landscapes in Kenya (Reid, 2012). In Ghana, savanna reserves that have lost a great number of mammal species over time are those with highest human populations around them (Wittemyer *et al*., 2008). Elephant numbers also dropped markedly in Zimbabwe in areas with more than 15-20 people/km² (Hoare & Du Toit, 1999), while in nutrient rich savannas in Kenya elephants persisted in areas with up to 80 people/km² (Reid, 2012).

Major income sources and education level

Our study showed that in the lowland areas of Rombo, people depended strongly on agriculture, and only 1% was involved in other activities. In sub-Saharan African countries, the majority of the human population depends on small-scale agriculture to sustain their livelihood, and in Tanzania agriculture contributes to the GDP by about 30% (Ahmed *et al*., 2009; Herrick & Beh, 2015). However, in these agriculture-dominated lowlands of Rombo, where especially maize is cultivated (Mmbaga *et al*., 2017), cropping is highly challenged by raids through elephants.

We found the majority of people in the study only visited primary education and many were illiterate, showing that the local population highly relied on natural resources to sustain their livelihood. Education level is known to be one of the key components to determine human behavior and dependency to natural resources (Baruch-Mordo *et al*., 2011). Across Africa, different conservation tools had been used to resolve HEC including electrical fences (Hoffmeier-Karimi & Schulte, 2015; Mutinda *et al*., 2014) and translocation (Baruch-Mordo *et al*., 2011), often with limited success (Mutinda *et al*., 2014). Therefore, considering altering human behavior by providing high levels of education, including conservation education as suggested by Baruch-Mordo *et al*, (2011) might be a promising long-term solution in sustaining livelihoods and elephant conservation in Rombo. On the other hand, in the lowland areas, which had high HEC but a generally low population density, establishment of buffer zones for elephant conservation and tourism activities might be possible. In these areas, co-existence may be achieved under agreement between local people, wildlife conservationists, and government authorities as the main stakeholders as has been shown in Mara region closer to Serengeti National Park where villagers dedicated the part of their land as wildlife management area and they are getting revenue out of ha through tourism.

Conclusion

Conflicts between humans and elephants are a problem throughout Africa and are often associated with human population growth. We found that the human population in Rombo area grew fast while elephant populations across the Kilimanjaro ecosystem had been decreasing over the past 40 years. Low population densities were found in lower altitudes, where recent settlements have expanded, leading to elephant habitat loss and, therefore, HEC hotspots. Respondents in these lowland areas had low education levels and completely depended on agriculture to sustain their livelihoods. We, therefore recommend the establishment of buffer zones for elephant conservation and tourism activities in these lowland areas.

In the lowlands, we thus claim that co-existence is possible under agreement between local people, wildlife conservationists and government authorities.

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