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Analyzing the Geospatial Patterns of Hidden Impacts from Human-Elephant Interactions in the Bunda District, Tanzania

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ABSTRACT. The geographic information systems were used to analyze the spatial context of hidden impacts in the Bunda District, which is a Tanzanian community with high annual incidents of human-elephant interactions, to understand their location, distribution, density, and relationships relative to Grumeti Game Reserve and the Serengeti National Park. These are indirect impacts and largely unreported adverse effects resulting from human and elephant interactions. Hidden impacts usually go unnoticed and unreported due to the lack of visible damage. Spatial studies on human-elephant interactions have focused on environmental to socio-economic perspectives rather than spatial aspects of hidden patterns. This study analyzed the distribution, proximity to protected areas, kernel density and hotspots analysis of hidden impacts. It identified 327 hidden impacts, categorized into the abandonment of farms, marriage problems, delayed school attendances and restriction on movement. It ascertained the highest number of incidents (18.35%) from Kihumbu village and the lowest from Nyangere village (0.01%). Abandonment of farms constituted the largest number (77.4%) while marriage problems formed the lowest number (0.6%) of hidden impacts. The most hidden impacts occurred between 0 and 2,000 meters from the boundaries of protected areas. There was higher concentration of hidden impacts in villages bordering Grumeti Game Reserve than Serengeti National Park. The significant statistical level of adverse hidden impacts occurred in Kihumbu village. Imprecisely execution of tourist hunting operations could presumably be the causing factor for the high concentration of hidden effects nearby Grumeti Game Reserve. The conceptual and graphical presentations of the hidden impacts, in this study, provide conservation stakeholders with insights into the existence, severity and distribution of the impacts relative to protected areas. However, researchers recommend for a comprehensive study to understand the spatial characteristics of other types of hidden impacts adjacent to protected areas.

Keywords: Bunda district, coldspots, Geographic Information Systems, Grumeti Game Reserve, human-elephant conflicts, hidden impacts, hotspots, Kernel density, Serengeti National Park, trophy hunting

1. Introduction

Human-elephant interactions (HEI) are a major conservation challenge (Parker et al., 2007), causing injuries and deaths to humans, livestock and African elephants (Loxodonta africana), as well as destruction of elephant habitat, and human property (Mduma et al., 2010; Rahman et al., 2010). In addition to these more obvious impacts, there are hidden impacts of HEI (Madden, 2004). Such adverse effects usually go unnoticed and unreported due to a lack of visible or obvious damage or interactions (Barua et al., 2013). The impacts include fear of injury or death, restrictions on people's movement (particularly at night), competition for water resources, poor health, and nutrition status, and competition for livestock grazing fields. Elephants reduce school attendance for children due to fear, disrupt families, interrupt sleep and affect the ability to collect firewood and fruit. Guarding of crops or properties at night increases the possibility of suffering from diseases, such as malaria (Hoare, 1999; Parker et al., 2007; Barua et al., 2013). These hidden impacts often outweigh the more obvious interactions, particularly in the number of people affected, and have a significant influence on perceptions of local residents towards elephant conservation (Messmer, 2000). However, the quantification of hidden impacts or secondary impacts of HEI into understandable economic context is particularly challenging (Lamarque et al., 2009).

Under certain circumstances, hidden impacts may destabilize local community initiatives and commitment towards sustainable rural development (Parker et al., 2007), especially by undermining efforts dedicated and directed towards poverty reduction (Messmer, 2000). Incidents, such as restrictions on people's movements, marriage problems, psychological problems, malnutrition and inability to collect non-timber forest products (NTFPs) may significantly affect residents. The hidden impacts complicate community capability, material resources, social resources and typical daily activities (Madden, 2004). The extent and severity of hidden impacts depend on various factors (Lamarque et al., 2009). One of the most significant factors is the ability of people to cope with, recover from the stress, and shock

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resulting from these impacts (Cooper, 1998; Dimsdale, 2008). Khumalo and Yung (2015) have described the consequences of both stress and shock to people's livelihood and food security. Besides emotional tension and shock, hidden impacts reduce the willingness of people to coexist with elephants (Osborn, 2004), which causes impediments to sustainable conservation through community-based conservation regimes.

Moreover, the stress and shock of hidden impacts create adverse effects on community wellbeing, ability to work, and relationships (Dimsdale, 2008). Ongoing stress causes undesirable health impacts on communities when agencies mismanage elephant-related conflicts (Messmer, 2000). Continuous exposure to stressful events may gradually shift humans into a chronic stress state. Consequently, people may experience permanent changes in emotions, physiology, and behavior (Khumalo and Yung, 2015). Physiological stress complicates their natural immuneity and makes them more susceptible to diseases and death (Dimsdale, 2008). African elephants are not the only perpetrators of hidden impacts in Tanzania. Many wild species, such as lions, spotted hyenas, bears and jackals, cause adverse hidden effects to humans in the forms of fear and restricted human movements (Baldus, 2004; Woodroffe et al., 2005; Treves, 2007).

People usually become intolerant and unsupportive of elephant management when interaction costs are higher than benefits (Treves et al., 2007). Unknown consequences resulting from interactions between humans and elephants are well understood, but a good understanding of their spatial patterns and configurations are lacking. Geographic and scientific components of hidden impacts are crucial in understanding their distribution, concentration, and proximity to environmental features because most of the management decisions humans make have a spatial context. In this study, geographic information systems (GIS) were used to analyze the spatial context of hidden impacts in Tanzania's Bunda District to understand their location, distribution, density, and relationships relative to Grumeti Game Reserve (GGR) and the Serengeti National Park (SENAPA).

The understanding of the distribution, location, and concentration of hidden impacts may help relevant authorities and stakeholders acquire a geographical outlook of HEI. A concise spatial knowledge of the problem may facilitate a timely and accurate decision-making process in mitigating the adverse impacts because GIS unveils graphical and conceptual geographical information of hidden impacts required during planning, policy devising and decision making. The spatial information provides a deep understanding of causal mechanisms and processes of geographically referenced patterns of hidden impacts (Vanleeuwe, 2010). The majority of geospatial studies on HEI have only focused on spatial analysis of direct impacts, particularly elephant deaths and injuries, crop damage and human deaths and injuries, this study has exceptionally deployed GIS to identify, sketch and verify the geographical configuration of the hidden or direct impacts to examine the effects of spatially explicit factors on the distribution of HEI. The selection of a study area based on the high frequency of elephant damage and the proximity of this area to protected areas. Bunda district has the highest incidence (approximately 500 annual events) of human-elephant interactions in Tanzania (Mduma et al., 2010). The district borders Serengeti National Park and Grumeti Game Reserve. The two protected areas form part of the Serengeti ecosystem, one of the few ecosystems in Tanzania with relatively stable elephant populations (TAWIRI and KWS, 2014).

2. Materials and Methods

2.1. Description of the Study Area

Bunda is the home of more than 25 ethnic groups. The most dominant and common tribes in the area are Kurya, Ikoma, Jita, Sukuma, Ikizu, Natta, Isenye, Zanaki, Zizaki, Ngoreme and Taturu. The main economic activity within the region is subsistence agriculture, which accounts for about 80% of the people's annual income (Kideghesho and Mtoni, 2008). Farmers normally grow maize, millet, cassava, and sorghum as food crops and cotton

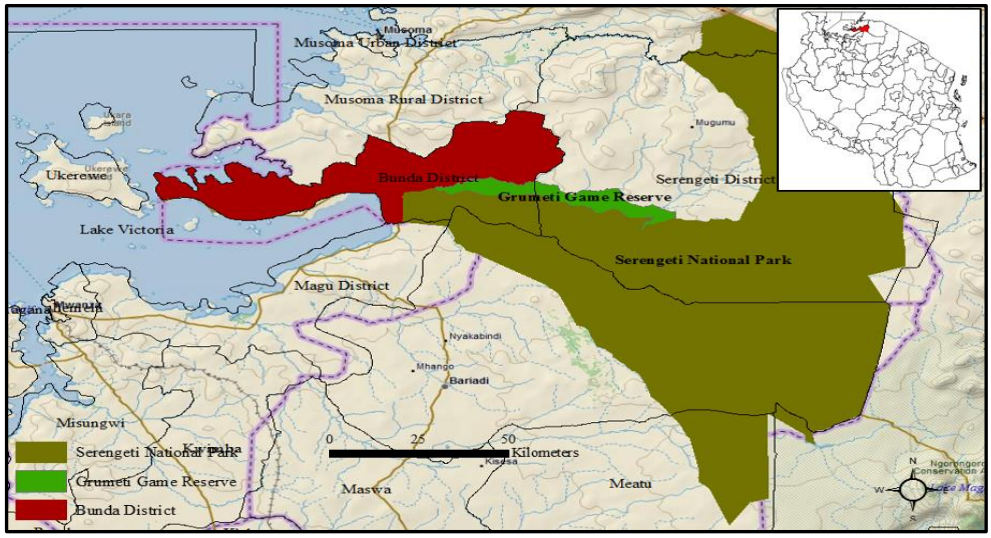

Figure 1. The Bunda District, Serengeti National Park, and Grumeti Game Reserve.

as cash crops. Furthermore, people keep sheep, goats, and cattle (Walpole et al., 2004). The majority of inhabitants are peasants, fisherman, livestock keepers, and small-scale traders. The Bunda District had the highest human population density in Tanzania of about 200 people per km^2, and annual population growth of about 3.0% (URT, 2013). The District is in the western part of the Serengeti ecosystem lying between latitude 1°30′ and 2°45′ S, and longitude 33°39′ and 34°05′ E. It is about 3,088 km^2. The district has contributed a large part of its land surface to wildlife conservation. Lake Victoria occupies about 200 km^2 of the area, and the Serengeti National Park occupies 480 km^2. In that case, the Serengeti ecosystem makes up about 40% of the district's surface area (see Figure 1).

2.2. Data Collection

The data were collected from Bukore, Balili, Mcharo, Mihale, Hunyari, Kihumbu, Kunzugu, Kyandege, Mariwanda, Mugeta, Nyamatoke, and Nyangere villages. In Tanzania, a village is a small community in a rural area made up by inhabitants, infrastructure, forests, farms and geographical features, governed by a legally established local authority (URT, 1982). Proximity to protected areas and the high number of incidents of crop damage were the main criteria for the selection of the villages (Mduma et al., 2010). In this study, hidden impacts refer to indirect impacts, the impacts that are indirectly caused by elephants but because they are unseen. Scientists hardly study indirect impacts and local people barely regard them as impacts from elephants. The impacts are regarded hidden because neither conservationists nor villagers talk about them, their mitigation measures and means of assessment. Hidden impacts include declining health or nutrition status, and children with reduced school attendance. People affected by hidden impacts included those who were highly indebted (as a result of elephant damage), with disrupted family bonds, individuals with interrupted sleep, people who could not collect firewood and fruit, those who suffered diseases while guarding crops or property at night and people who abandoned farming activities because of elephants (Parker et al., 2007; Lamarque et al., 2009; Barua et al., 2013). A study adopted the purposive sampling technique to identify and record households and farms with hidden impacts (Singh, 2014). Researchers conducted a participatory survey to assess the households and farms with hidden impacts. Researchers convened village meetings to identify the household representative whose family and farms were affected by hidden impacts. Through community meetings, it was possible to descrybe the types and characteristics of hidden impacts at length to villagers.

Villagers, particularly village leaders, participated in identification and description of hidden impacts in their village. Due to complexity and nature of hidden impacts, third party experts (wildlife officers, agricultural officers, medical personnel, village leaders, and community development officers) clarified and confirmed a nature of these impacts. The study identified and collected both historical and current patterns of hidden impacts for six months. The study was only interested in identification of the actual location of each incident not in the extent of impacts. A handheld Garmin GPS receiver recorded the locations (X, Y coordinate) of verified current and previous signs (within one year) of a pattern of hidden impact. The data were collected for six months. From the collected information, it was possible to create a hidden impact GIS layer in ArcGIS 10.5. All incidents were reviewed and confirmed before entering them into a database. Spatial data concerning the locations and types of hidden impact were recorded using a handheld GPS receiver. Impacts related to households were spatially recorded at each respective household, while agricultural patterns were recorded in farms and grazing areas. It is safe to acknowledge that the quality of geospatial data is representative, as the survey and informal interview were conducted in the language, the species and areas best understood by the participants. The participants were well informed on the aim and objective of the study before participating in the survey. This avoided exaggerations of the responses as they were also informed that the study was not for compensation of property and life loss resulted from HEI. Moreover, the principal researchers also participated in the identifycation and collection of the patterns of hidden impacts. This made it possible to relate what is in the survey and the reality of the study area. However, low levels of participation, perception and attitudes, communication barriers and resistant leaders were some of the obstacles hindered local people participation in the research. A few local people offered inadequate participation because they were involved in the similar projects in the past, which were unsuccessful.

2.3. Data Analysis

A shapefile of the Serengeti National Park (SENAPA), Grumeti Game Reserve (GGR) boundaries and villages were obtained from the headquarters of Serengeti National Park and the Lincoln University GIS server. Four types of hidden impacts were recorded: "no farming" (NF), "no school attendance" (NS), "restricted movements of adults" (NM) and "marriage problems" (MP). In this study, "no farming" refers to farms or households abandoned by local people after several incidents of elephant damage. In the same way, "no school attendance" means the decision of parents and students to not attend school for fear of possible elephant attacks as they go to school. "Restricted movements of adults", means the decision of adults to reduce their movements away from their households for fear of elephant encounters. "Marriage problems" meant pair bond and family-related problems emanating from HEI, such as the breakup of family relationships after a prolonged absence due to farm guarding. ArcGIS 10.5 was used to perform geospatial analysis of hidden impacts (Gibin et al., 2008). Kernel Density Analysis was used to identify areas with a concentration of hidden impacts in the study area. For accurate distance measurement between hidden impacts and the edge of the protected areas, all shapefiles were projected into the Arc_1960 UTM Zone 37S coordinate system. A 5,000 m buffer width was used around park boundaries because it conformed to the size of currently recommended buffer zones (conservation corridor as used in this study) for SENAPA and GGR. A proximity analytical tool was used to determine the distance of each hidden impact incident to either SENAPA or GGR. After projection, the Near Tool computed the distance for each pattern of hidden impact to the edge of

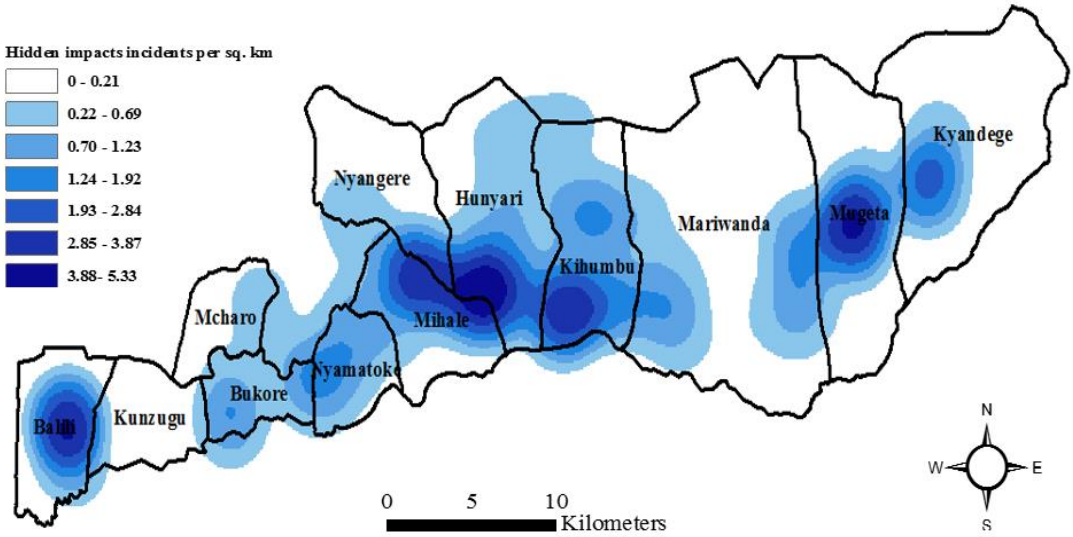

Figure 2. Hidden impacts incidents per square kilometer.

SENAPA and GGR (protected areas). Hotspot analysis was carried out using the Gedis-Ord G* algorithm for each hidden impact pattern (Getis, 1992). The resulting z-scores and p-values associated with the hotspots provided the probability of clustering of hidden impacts. The hotspot analysis tool assessed each hidden impact in the context of the clustering of that impact. The hotspot analysis used the village shapefile to identify the locations of statistically significant hot spots and cold spots. The analysis used Z scores and P values to identify villages with statistically significant hotspots hidden impacts. The village polygon features, including each village with its surrounding farms and wilderness (12 villages) were combined with incident points using the spatial join tool in ArcMap. The resultant polygons contained a new field with the number of hidden impacts for each village.

3. Results

3.1. Impacts of Protected Areas on Hidden Impacts

A study recorded 327 hidden impact from 12 villages over six months. The highest number of incidents (77 (23.53%)) were recorded in Kihumbu village, and the lowest number of incidents (four (0.01%)) were recorded in Nyangere village. "Abandonment of agricultural farms and housed" had the highest incidence (77.4%), while Marriage Problems (MP) had the lowest 2 (0.6%) incidents. In the case of proximity, spatial analysis revealed that the majority (40.3%) of hidden impacts occurred between 0 and 2,000 m from the boundary of Serengeti National Park and Grumeti Game Reserve. Most of the incidents occurred within 5,000 m of the buffer zone. In the case of the type of hidden impacts, the identification and recording of "no farming", and "no walking in the village" impacts peaked in areas between 0 and 2,000 m from the boundary of protected areas and declined along with increased distance from the areas. However, "no school attendance" peaked between 4,000 and 6,000 m from the protected areas. Researchers identified and recorded "marriage problems" between 0 and 2,000 m from the edge of protected areas, though there were no "marriage problems" in the areas beyond 2,000 m from the boundary of Serengeti National Park and Grumeti Game Reserve.

3.2. Kernel Density Analysis

Kernel Density Analysis is a technique for generalizing the location of incidents to entire areas (Gibin et al., 2008). It measured the density of the hidden impacts in the district. Kernel Density Analysis identified five major concentrations of hidden impacts in Mugeta, Balili, Hunyari, Mihale, Mariwanda and Kihumbu villages (Gibin et al., 2008). The largest concentrations were in Hunyari, Kihumbu, Mugeta and Balili villages (see Figure 2).

3.3. Hotspot Analysis

The hotspot analysis identified the statistically significant hotspots and coldspots of hidden impacts in the study area. The statistically significant hotspots of the hidden impacts were identified in Kihumbu and Hunyari villages and statistically significant coldspots in Balili, Kunzugu, Bukore and Mcharo villages. According to the hotspot analysis tool, the significant hotspots of hidden impacts were near Grumeti Game Reserves and coldspots near the Serengeti National Park (see Figure 3).

4. Discussion

Hidden impacts are complex and require social, economic, medical, environmental and economic knowledge to understand and mitigate them. In this study, researchers were able to identify and record four types of hidden impacts: delayed school attendance, restricted movement of adults, marriage problems and reduced or abandonment of farming activities. Limited know-

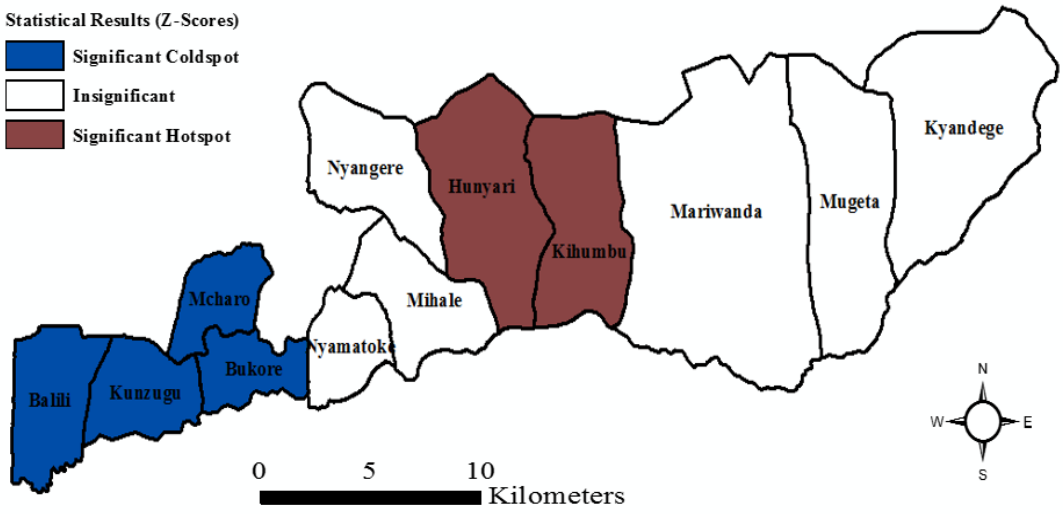

Figure 3. Statistical test results of hotspots (reds) and coldspots (blue) in the study area.

ledge, time and resources restricted our abilities to identify and record other types of hidden impacts such as psychological impacts and suffering from diseases. Reduction or abandonment of agricultural activities ranked as the most noticeable hidden impact in the district. According to the villagers, people abandoned both their farms and houses to avoid routine agricultural loss from elephants. The majority moved to near villages and communities, while some people moved to other villages with low elephants' incidents in the same community to establish new households. In the same way, some people shifted from agriculture to other socio-economic activities, including charcoal burning, fishing, mining, and small businesses. However, it is important to understand that farmers may also abandon their farms because of lack of market skills and information, high transaction costs, poor production, poor transport to the market, uncontrollable diseases and poor farming skills (Khapayi and Celliers, 2016).

In the Bunda District, many communities have one only public primary school (Hartwig and James, 2010). Consequently, children have to walk for several hours to and from schools. With elephants around, schoolchildren's safety is at risk. In those situations, parents restrict children's school attendance to avoid possible attacks from elephants. Delayed school attendance by children affects their academic performance and mental development (Hancock et al., 2013). Despite the geographical and technological challenge, if unreported in advance to school administration, no "school attendance" means an unauthorized absence. Analyzing the impacts of elephants on school attendance and academic performance is beyond this study. However, it is important to understand that elephant disturbance is not the only factor influencing delayed school attendance in the district. Hancock et al. (2013) found that highly mobile students and pupils, students whose families have low education levels, whose parents have a low-income level and students with low socio-economic index, all had low school attendance level and poor academic achievements.

Elephants also restrict adult movement. With elephants present, it is often difficult for social and economic gatherings to be held. Elephants limit local access to fetching water, firewood, fruits, medicinal plants, vegetable, and mushrooms. Elephants restrict community movements to some locations during different hours of the day. During the night, humans do not leave their houses for fear of elephant attacks. It is not because elephants are more likely to attack at night than a day but it is difficult to avoid elephant encounters at night due to darkness. Restricted movement, generally, for prolonged periods, has physical, psychological and socio-economic impacts on people. Restricted movements caused by elephants may affect an entire household's health by confining them to their home and affecting their physical, mental and social well-being (Boruchovitch and Mednick, 2002). When elephants enter the village area, the collection and preparation of basic human needs become difficult. The absence of indoor plumbing facilities makes the situation more dangerous. Many households have outdoor plumbing services, requiring family members to leave the main dwelling for hygienic issues during night and day. For adults with adequate knowledge of elephant encounters, accessing outdoor plumbing facilities during the night will be the last option due to the maximized possibility of encountering elephants near the house.

Elephants may cause marriage problems to farmers. Villagers reported two cases in Bukore village when men complained about unfaithful wives, which occurred when the men spent time away from homes guarding their cereal farms against elephant damage. Due to numerous elephant incidents in the district, men usually spent most of their time protecting their agricultural fields against elephant invasion. Therefore, husbands and wives experience significant damage to self-image, personal confidence, feelings of abandonment, betrayal of trust and disruption of relationships among family members (Charny and Parnass, 1995). In the case of family support, a husband gradually loses his routine family attention and responsibilities due to

extended periods away from home. No cases of wives complaining of the infidelity of husbands while supposedly guarding their crops were recorded, although women only made up a small proportion of respondents.

Hidden impacts mainly affect people residing near protected areas, notably, the majority of individuals residing between 0 and 3,000 m from the boundaries of the Serengeti National Park and Grumeti Game Reserve. The proximity of human occupations to protected areas intensifies the frequency and magnitude of hidden impacts (Okello et al., 2014). Many human settlements and activities in the district occur within the buffer zone of the protected areas. These are ecological zones designed purposely for minimizing the negative impacts on neighboring communities and protected wildlife populations (Ebregt and Greve, 2000). Increasing the distance of human settlements from the buffer zone may largely reduce hidden impacts incidents because the increased interface between agricultural areas and elephant habitat magnifies the occurrences of hidden impacts (Desai and Riddle, 2015). Customary and government laws prohibit human occupations and destructive human activities in the buffer zones. Buffer areas usually extend 5,000 m from the boundary of protected areas. In the study area, the majority of farms and human residents are within these buffer zones (Desai and Riddle, 2015). Therefore, the reduction or eradication of hidden impacts can be difficult due to the presence of people and anthropogenic activities proximity to protected areas and within conservation corridors. The findings show a significant decrease in the patterns of the adverse effects outside the buffer zone, which supports the need for enforcing the buffer zone for the substantial reduction of the impacts.

Communities neighboring Grumeti Game Reserve experienced significant hotspots of hidden impacts. Residents bordering Serengeti National Park experienced significant coldspots of hidden impacts. The analysis revealed significant hotspots in Hunyari and Kihumbu villages. Grumeti Game Reserve and Serengeti National Parks vary concerning their management authorities and conservation policies. As an example, Grumeti Game Reserve allows tourist hunting while Serengeti National Parks strictly prohibits hunting of any description. Hunting operations in Grumeti Game Reserve are presumably a contributing factor for the significant hotspot in Kihumbu and Hunyari villages because uncontrolled trophy hunting degrades wildlife habitats (Leisanyane et al., 2013). As it reduces direct and indirect the types and number of keystone species whose importance to the ecosystem's structure, composition and function are disproportionately large relative to their abundance (Nuñez and Dimarco, 2012). Habitat degradation affects the availability of environmental resources for elephants. When habitat loss significantly reduces the quality and size of habitat within their home range, elephants will raid crops and ultimately become habitual crop raiders (Desai and Riddle, 2015).

In this study, a data collected from local villagers and a GIS approach enabled a better understanding of the hidden impacts in a geographic context by recording where the patterns occur, measuring the proximity of hidden impacts to protected areas, measuring their geographic distributions in the study area and understanding the extent of their concentrations. If properly used, the attained geographical knowledge about hidden impacts may change the way people understand and manage the HEI in the Bunda District. In a similar way, such knowledge is essential for landscape and regional planning towards sustainable conservation. Using local people to identify the types and collect the locations of hidden impacts was crucial because local people understand the severity of hidden impacts better than researchers do.

5. Conclusion

GIS provided geographical knowledge about location, distribution and concentration of hidden impacts in the Bunda District. A study ascertained four types of hidden impacts. Abandonment of agricultural farms and houses was the major hidden impact in the district. Most of the hidden impacts occurred within buffer zones, where conservation laws promote environmentally friendly activities, especially in the areas that bordered Grumeti Game Reserve. There was a lower level of hidden impacts in communities bordering the Serengeti National Park than Grumeti Game Reserve, possibly due to tourist hunting, as poorly executed trophy hunting activities usually affect the quality and quantity of the environmental resource (Burke et al., 2008). The conceptual and graphical presentations of the of hidden impacts, in this study, provides the conservation stakeholders insights into the existence, severity and distribution of the impacts relative to the Grumeti Game Reserve and the Serengeti National Park.

However, it is safe to point out that, like many spatial studies, data quality, quantity and geographical errors influenced this study. The collection and analysis of spatial data occurred in 12 administrative villages. The selection of participating villages based on their proximity to SENAPA and GGR not on either frequency or magnitude of hidden impacts. Such selection introduced some geographical issues as the government of united republic of Tanzania defines village boundaries for administrative not conservation purposes. In that case, it was essential to consider both geographical location and the magnitude of elephant crop damage for each participating village. In addition, time constraints, the willingness of participants to participate in the study, expertise on identifying hidden impacts and geographical challenges of the study area may have affected the quality and quantity of the geospatial data used for conclusion. Moreover, some villagers needed incentives to participate in the surveys. Such challenges hindered the availability of reliable data used for spatial analysis.

It would be useful to further identify and explore other types of HEI hidden impacts, especially regarding the socioeconomic impact on the district. Such studies would require a long-term investment in time, expertise and financial resources. Conducting research on hidden impacts is complicated because it requires a multidisciplinary research team, including medical experts, conservationists, financial experts, community development experts, economists, veterinarians, psychologists and valuers, and adequate time to cover all types of the impacts occurring in the district. It would also be useful for a research team to conduct a similar study in another district with similar HEI

incidents for comparative reasons. It is equally important for the study to investigate the type and extent of the hidden impacts that affect elephants and other wildlife species. The study ascertained many hotspots of both hidden impacts and elephant crop damage in the communities neighboring the game reserve. However, the study failed to record the distribution and configuration of the incidents as the location where the hidden impacts are recorded may be different from where the hidden impacts occurred. For example, a human might encounter an elephant and manifest hidden impacts at their home rather than where the encounter occurred.

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