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Impacts of Elephant Crop-Raiding on Subsistence Farmers and Approaches to Reduce Human-Elephant Farming Conflict in Sagalla, Kenya

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IMPACTS OF ELEPHANT CROP-RAIDING ON SUBSISTENCE FARMERS AND APPROACHES TO REDUCE HUMAN-ELEPHANT FARMING CONFLICT IN SAGALLA, KENYA

By

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ABSTRACT

As human and elephant populations grow in Kenya, elephants increasingly leave parks to eat farmers' crops while foraging, which creates epicenters of human-elephant conflict (HEC). This conflict compromises farmers' food and economic security, impedes elephant conservation initiatives, and threatens the safety of humans and elephants. In recent years, the situation has been exacerbated by drought and national-level infrastructure development that bisects key elephant habitat. Although researchers have widely studied elephant populations, few have examined the cultural, economic, and emotional effects of HEC on subsistence farmers. This project utilized a mixed methods approach to address this knowledge gap and understand the lived experiences of Wasaghala farmers in Lower Sagalla, Kenya. These farmers live adjacent to Kenya's largest elephant population in Tsavo East National Park and regularly experience elephant crop-raiding. This research was conducted in partnership with Save the Elephants, a non-profit that studies elephant-crop raiding in Lower Sagalla. This project complements their research by facilitating greater understanding of complex human-elephant interactions and providing insight into the role that agricultural crops play in elephant crop-raiding. Personal interviews were conducted with a purposefully chosen sample of farmers, community leaders, and regional experts to understand their perspectives on cultural, agricultural, and economic dimensions of HEC in Lower Sagalla. Topics covered included regional history of HEC, impacts on farmers, elephant deterrent strategies, and farmer agricultural decision-making. Additional data were collected from an on-farm experiment that examined how crop palatability impacts elephant crop-raiding behavior. It aimed to determine if moringa and sunflowers are less palatable to elephants than maize, and if growing these crops can reduce crop loss due to elephant crop-raiding. Results from all data concluded that HEC creates widespread suffering for farmers in Lower Sagalla, that they are unable to adequately address this issue on their own, and that there is a need for the development of novel HEC mitigation strategies. Additionally, results suggest that crop palatability influences elephant crop-raiding behavior and that growing crops that are less palatable to elephants, but beneficial to farmers, may play a role in reducing crop loss and increasing farmers' economic and food security. The research concludes with management recommendations to reduce elephant crop-raiding and improve human-elephant co-existence.

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LIST OF ABBREVIATIONS

EBP	Elephants and Bees Project
HEC	Human-Elephant Conflict
HWC	Human-Wildlife Conflict
KWS	Kenya Wildlife Service
SGR	Standard Gauge Railway
STE	Save the Elephants
TME	Tsavo-Mkomazi Ecosystem

CHAPTER 1: INTRODUCTION

As human populations increase and development fragments habitat, human-elephant conflict (HEC) has become increasingly common (Thouless 1994). Human-elephant conflict is defined as an interaction between elephants and humans and/or their goods, livestock, land, or property that negatively impacts one or both parties (World Wildlife Fund 2017). In serious instances it may lead to loss of human and/or elephant life (Thouless 1994; Warren et al. 2007). HEC occurs internationally and negatively impacts both human and elephant populations. Throughout Kenya, various types of HEC occur including: property destruction, poaching, resource competition, habitat fragmentation, and crop-raiding (Sitienei et al. 2014).

This research project focuses exclusively on human-elephant farming conflict, which occurs when elephants crop-raid farmers' fields. Crop-raiding, the destruction of agricultural cultivars through consumption, trampling, and uprooting, threatens farmers' economic and food security (Mackenzie & Ahabyona 2012). In some communities, human-elephant farming conflict also limits children's access to education and fosters resistance towards wildlife conservation initiatives (Hill 2015; Mackenzie & Ahabyona 2012; Sitati et al. 2005; Thouless 1994). Although research has acknowledged these hardships, few studies have examined the extent to which elephants negatively impact farmers and community-level dynamics, and additional research is necessary.

In the face of increasing human-elephant farming conflict, farmers and conservationists are searching for effective strategies to improve human-elephant co-existence. In their fields, farmers utilize numerous techniques to deter crop-raiding elephants including shouting, lighting fires, banging iron sheets, keeping guard dogs, and building fences (Davies et al. 2011; Graham

& Ochieng 2008; Gunaryadi et al. 2017). However, few elephant deterrent techniques have proven to be universally effective.

Although important to limit crop damages when elephants enter fields, it is also crucial to understand what drives elephants to raid crops in the first place and which crops are most attractive to elephants. Research suggests that elephants crop-raid because crops taste good and are nutrient dense (Chiyo et al. 2005; Osborn 2004). Previous studies have shown that chilies (*Capsicum annuum*) are not attractive to elephants (Webber et al. 2011). However, chilies are not ecologically viable or culturally appropriate for cultivation in all communities. Therefore, additional research is necessary to assess the palatability to elephants and cultural appropriateness of other potentially non-palatable crops.

To address these knowledge gaps, creative organizations with intimate knowledge of wildlife ecology, as well as local socioeconomic and cultural traditions, are implementing research to expand understanding and develop practices that benefit both humans and elephants. For this project, I partnered with one such organization, Save the Elephants (STE), to conduct research on the experiences of farmers living with crop-raiding elephants and the potential of non-palatable crops to reduce elephant-crop raiding behavior in Kenya.

The idea for this project began in March 2015 during my internship with Save the Elephants (STE). I was interested in the stories I heard from staff members and farmers about living in a community that is regularly raided by elephants and about the potential of crops to influence elephant crop-raiding behavior. So, I returned to examine these questions for my graduate studies. This research shares the lived experiences of subsistence farmers by exploring the cultural, social, and economic contexts of elephant crop-raiding in Lower Sagalla and its impacts on farmers, their families, and the community as a whole. It also considers whether or

not crops that are non-palatable to elephants and valuable to humans can reduce the frequency and severity of elephant crop-raiding. Overall, this project aims to decrease elephant crop-raiding and the human-elephant conflict it creates by building upon STE's ongoing beehive fence research and community engagement (King et al. 2017).

My objective for this project was to provide a case study of human-elephant farming conflict in Lower Sagalla. First, I wanted to share the experiences of Lower Sagalla farmers to facilitate an in-depth understanding of how crop-raiding impacts their daily lives. I wanted to elucidate farmers' perceptions of elephant-crop raiding, its economic and social impacts, and farmers' elephant deterrent techniques. Secondly, I wanted to determine if two crops anecdotally discussed in the community as non-palatable to elephants, sunflowers (*Helianthus sp.*) and moringa (*Moringa olifera*), are less palatable to elephants than local staple maize (*Zea mays*) and if planting these less palatable crops can decrease elephant crop-raiding. Additionally, I hoped to understand whether or not these crops were ecologically suited for Lower Sagalla and if their cultivation could benefit local farmers.

This project aimed to meet these objectives by addressing the following research questions:

1) What is the history of human-elephant farming conflict in Lower Sagalla and how has this conflict changed over time? What factors are driving this change?
2) What are the economic, psychological, and social impacts of elephant crop-raiding on farmers in Lower Sagalla?
3) What methods have farmers historically used to reduce elephant crop-raiding and/or deter elephants? What methods do farmers use today, and how do they decide which methods to use?

4) Which crops do farmers grow during each rainy season, and what factors are most important in making this decision?
5) Which crops are less palatable to elephants than maize? Can planting non-palatable crops such as sunflowers and moringa instead of maize reduce the severity of elephant crop-raiding damage (e.g. consumption and trampling)?
6) Are sunflowers and moringa ecologically, economically, and culturally viable alternatives to growing maize?

The first four research questions were addressed by conducting in-depth informational interviews with community members and key stakeholders. Data from interviews and on-farm experiments were combined to answer the last two research questions.

By partnering with Save the Elephants and working closely with local farmers throughout the research process, this project examines the cultivation of crops that are not only effective at reducing elephant crop-raiding, but also valuable and of interest to community members. Including local farmers' experiences, opinions, and goals in this conversation can foster the creation of novel crop-raiding mitigation strategies.

Once a greater understanding of farmer perceptions of and experiences with elephant crop-raiding is established this insight can be shared with wildlife management officials and incorporated into the creation of effective community conservation plans and elephant deterrent techniques. Additionally, knowledge about elephant crop selection while foraging and relative crop palatability has the potential to improve local farmers' abilities to mitigate elephant crop-raiding behavior while increasing farm production and profitability. Overall, I hope this research will provide other communities and conservationists in Kenya and beyond with valuable

information to assist in the creation of ecologically-effective and socially-beneficial human-elephant co-existence strategies.

CHAPTER 2: LITERATURE REVIEW

In this chapter I examine the pre-existing research pertaining to human-elephant farming conflict. First, I briefly outline the history of wildlife conservation legislation in Kenya to place contemporary human-elephant farming conflict within the broader context. Then, I explain continent-wide and Tsavo-specific elephant population trends. Next, I discuss human-elephant farming conflict and how it negatively impacts subsistence farmers. I then describe strategies that farmers use to deter crop-raiding elephants and mitigate crop damages. Finally, I examine how agricultural practices influence elephant crop-raiding behavior and explore the potential of crops that are non-palatable to elephants to reduce crop-raiding damages.

Historical Kenyan Wildlife Management

Kenyan wildlife has been heavily managed at a national level since British colonialism in the early 1900's. In this section I describe the history of wildlife legislation in Kenya. In 1895, the British seized control of modern-day Kenya as part of the East African Protectorate. Widespread wildlife mismanagement, the spread of rinderpest caused by early European settlers, and the introduction of firearms caused a sharp decline in wildlife populations (Akama 1998; Smith & Kasiki 1999). Therefore, soon after taking control of Kenya, the colonial government enacted wildlife management legislation that created game reserves and heavily regulated access to and usage of wildlife (e.g. hunting trophies), especially by indigenous Kenyans (Chongwa 2012; Didi 2013).

In the mid-1900's colonial wildlife management began focusing on the creation and management of protected areas (Chongwa 2012). European and American conservationists met in the 1920's and 1930's and pressured colonial governments to enact legislation to protect

natural habitats in African colonies (Akama 1998). In 1945, at the urging of British conservationists, the British government established The National Parks Ordinance in Kenya (Akama 1998; Didi 2013). Under this legislation, the colonial government assumed ownership of and management responsibility for all Kenyan wildlife and established protected areas.

The creation of national parks aimed to protect wildlife populations; however, it negatively impacted indigenous Kenyans by ignoring their traditional land use practices and eliminating their ability to manage natural habitat and wildlife populations at a community level. Although colonial sport hunting and land mismanagement was largely responsible for the decline in wildlife populations and habitat quality, the colonial government blamed indigenous land use (Akama 1998). So, they created protected areas that separated human settlement and wildlife with clearly demarcated boundaries and removed indigenous peoples from protected areas (Akama 1998; Smith & Kasiki 1999). For example, when Tsavo East National Park was established in 1948 to promote tourism, recreation, and research, the indigenous people of Tsavo, including the Orma and Watha, were pushed off the land and considered outlaws (Kasiki 1998; Smith & Kasiki 1999; Steinhart 1994). Elephant hunting, previously an important and sustainable part of Watha culture, was criminalized and reclassified as "poaching"; many indigenous Kenyans were imprisoned for hunting (Akama 1998; Smith & Kasiki 1999).

The trend of national-level wildlife management continued after Kenya gained independence in 1963 (Chongwa 2012). Kenya adopted the Wildlife (Conservation and Management) Act in 1976, established the Kenya Wildlife Service in 1989, and made them responsible for managing Kenya's wildlife (Didi 2013). In 1977, the government passed legislation that ubiquitously banned both sport and subsistence hunting in Kenya (Didi 2013;

Steinhart 1994). Through this legislation, Kenya adopted a preservationist approach that minimized community-level involvement in wildlife management (Didi 2013).

Most recently, Kenya adopted the Wildlife Act in 2014. This new legislation aimed to address shortcomings of previous wildlife legislation and to increase community participation in wildlife management (World Wildlife Fund 2014). It provides county governments and local communities with the legal ability to participate in wildlife management when animals are outside protected areas (Ogutu et al. 2016). Although the outcomes of this legislation remain to be seen, this shift may enable communities to have a more active voice in wildlife management and play an important role in reducing human-wildlife conflict within their region.

Elephant Population Trends

As the world's largest terrestrial mammal, the African elephant **(***Loxodonta africana***)** is an iconic species. Populations are currently found in thirty-seven Sub-Saharan African countries (Beaune et al. 2013). African elephants are renowned not only for their large body size, but also for their ecological impacts and complex social structure. They are considered a keystone species because "of their comparatively large individual body size and population biomass," which results in "the consumption of more woody vegetation by elephants than by all other large herbivore species combined" (Skarpe et al. 2014:33). As a keystone species, elephants mold the landscapes in which they live and provide ecosystem services crucial to the survival of other species (Landman et al. 2008). They are important seed dispersers and cause trophic cascades that impact community composition and nutrient cycling (Blake et al. 2009; Haynes 2012; Pringle 2008; Skarpe et al. 2014).

However, human activity threatens many African elephant populations despite their ecological importance and large body size. Poaching for the global ivory trade is one of the greatest threats elephants face. Wittemyer et al. (2014) estimated that in 2011 alone approximately forty thousand African elephants, or 7.7% of the total elephant population, were killed for the global ivory trade. High levels of poaching coupled with a low overall population growth rate (λ of 0.971 in 2011) have led to a net population decline (Wittemyer et al 2014). In addition to poaching, African elephant populations are threatened by habitat fragmentation and land use change due to encroaching human settlements (Bouche et al. 2011). Bouche et al. (2011) estimated that in the past forty years these combined factors have caused West African elephant populations to decline by ~33% and Central African elephant populations to decline by ~76%. Without targeted conservation and anti-poaching efforts, it is likely these trends will continue and may lead to local extirpation. Additionally, the African Elephant Status Report in 2016 estimated that the number of African elephants has declined by 104,000-114,000 since the previous report in 2007 (Thouless et al. 2016).

A similar trend of decline was observed in Tsavo during the late 1800's and early 1900's. The introduction of firearms led to rampant hunting of elephants for the global ivory trade and caused a sharp population decline (Smith & Kasiki 1999). Over time, Kenya's wildlife legislation and the creation of national parks and reserves protected elephants and allowed their numbers to increase. However, severe drought, an increase in the global ivory price, and a decrease in Tsavo National Park law enforcement in the 1970's led to a sharp elephant population decline (Smith & Kasiki 1999). According to count data, elephant populations in Tsavo East and Tsavo West National Parks declined from 22,174 in 1973 to 4,327 in 1988 (Ngene et al. 2017).

Today, despite continent-wide declines, elephant populations in Tsavo East and Tsavo West National Parks have been increasing since the 1990's (Smith & Kasiki 1999). According to Smith and Kasiki (1999:14),

> The Tsavo ecosystem is an area of 43,000 km^2 found between the 2° and 4°South and the 37.5° and 39.5°East . . . The core of this area is formed by TsE [Tsavo East] and TsW [Tsavo West] NPs in Kenya, which together occupy about 21,000 km^2 . . . and the Mkomazi Game Reserve (MGR) which occupies about 5,000 km^2 in Tanzania.

The Tsavo ecosystem hosts Kenya's largest African savannah elephant (*Loxodonta africana africana*) population (McKnight 2015). In 2011, this ecosystem was home to approximately 12,570 elephants, one third of Kenya's total elephant population (McKnight 2015). In 2017, the Kenya Wildlife Service and Tanzania Wildlife Research Institute conducted aerial counts of elephants in the Tsavo Mkomazi Ecosystem. In contrast to marked declines in Central and Western Africa, they found that across the Tsavo ecosystem the elephant population has increased 15.1% since the previous aerial survey in 2014 (Ngene et al. 2017). They attributed the population growth to the reduction of poaching in the region. Furthermore, southern Tsavo East National Park (located adjacent to Lower Sagalla) had the greatest elephant density with 7.0 elephants/km^2. In the second densest region, Tsavo West National Park, they only observed 2.99 elephants/km^2 (Ngene et al. 2017).

Elephants in Tsavo, as elsewhere, live in a highly dichotomous social structure with males being solitary and females living in matriarchal groups with their offspring (Fernando et al. 2012). Since 1989 elephant populations have been monitored and behavior recorded within the Tsavo ecosystem by Dr. Barbara McKnight's Tsavo Elephant Research team. Their study site encompasses one-third of Tsavo East National Park, and they currently monitor 215 independent bulls as well as 190 adult females and their offspring (McKnight 2015). Individuals are identified

from photographs using descriptive terminology and studied to understand elephant social and foraging behaviors (McKnight 2015).

Increasing elephant populations in the Tsavo-Mkomazi Ecosystem is a victory for Kenyan conservation efforts. However, for farmers living adjacent to the ecosystem's protected areas, including Tsavo East National Park, these elephants threaten their livelihoods. In the next section I define human-elephant farming conflict and explain how it negatively impacts subsistence farmers.

Human-Elephant Farming Conflict

Human-elephant farming conflict is prevalent throughout Africa and occurs when elephants eat farmers' crops while foraging to meet their large caloric needs. As large herbivores, the average elephant consumes 250-300 pounds of foliage per day (International Elephant Foundation 2018). They are mixed feeders that both browse and graze; elephants rely on fruit as well as grass and shrubs for their diet and nutrition (McNaughton et al. 1988). Elephant crop-raiding is especially serious for farmers living adjacent to protected areas; these farmers consider elephants to be one of the most serious causes of crop damage (Hoare 2015; Megaze et al. 2017). For example, one study assessed the frequency and severity of crop-raiding damage caused by a wide variety of species. They found that although signs of elephants were minimal, the majority of participants reported that elephants damaged their crops (84%) and soil (71%) (Harich et al. 2013). Additionally, seventy-percent of participants reported elephants drinking their water (Harich et al. 2013).

Elephant crop-raiding is problematic for farmers due to its severity rather than its frequency (Hoffmeier-Karimi & Schulte 2015). This is because even if elephants do not crop-

raid a farm very often, one visit can compromise a farmer's successful harvest for that season. The severity of elephant crop damage creates epicenters of human-elephant farming conflict that most detrimentally impact subsistence farmers, that is, farmers whose production matches their consumption with little or no surplus (Sitati et al. 2005). Large, poorly guarded farms are most susceptible to elephant crop-raiding (Sitati et al. 2005).

Negative Community Impacts

Although it is widely understood that elephant crop-raiding damages harvests, minimal research has been conducted on the extent to which human-elephant farming conflict negatively impacts subsistence farmers. In this section, I provide an overview of the existing research. First, I examine the economic impacts of crop-loss. Then, I discuss the high opportunity costs of protecting crops from elephants. Finally, I explore how human-elephant farming conflict fosters resistance to conservation efforts.

Crop Damage

Elephants negatively impact subsistence farmers by damaging the crops they rely upon for their livelihoods and food security. In just one night, a family group, which averages nine elephants, can destroy a farmer's entire field (Wittemyer 2001). Elephant crop-raiding behavior varies seasonally, and the period of most severe crop-raiding is often during peak ripening, just before crops are ready to harvest (Chiyo et al. 2005; Sitienei et al. 2014; Thouless 1994). This poses a serious threat to subsistence farmers' economic stability and undermines their earning potential (Hedges & Gunaryadi 2010; Mackenzie & Ahabyona 2012; Sitati et al. 2005; Sitienei et al. 2014). For example, research by Sitati and Ipara (2012) found that elephants preferentially

ate mature maize. Additionally, a study in Uganda found that "household financial losses [from crop-raiding] averaged US $74 over the six-month study, a substantial loss given the median household income was US $503" (Mackenzie & Ahabyona 2012:77). These financial losses may render families unable to pay necessary expenses. Additionally, damages caused by wildlife crop-raiding cause greater food insecurity in communities adjacent to protected areas (Harich et al. 2013). Loss of income and food security caused by elephant crop-raiding compromises farmers' abilities to meet their families' basic needs.

Childhood Education

In addition to directly undermining farmers' economic and food security, successfully preventing crop-raiding often requires diligent field guarding to scare away elephants. The time and energy requirements for successfully protecting farms are especially high when proper fencing is not in place (Sitati et al. 2005). Unfortunately, children are often needed to protect these fields (Mackenzie & Ahabyona 2012; Thouless 1994). This family responsibility detrimentally impacts children's access to education. Mackenzie and Ahabyona (2012:77) found that "sixty percent of survey households reported children under the age of eighteen guarding crops". The majority of children guarded crops two days a week (presumably on non-school days); however, other children guarded crops three to seven days a week during the peak-raiding season. In Tanzania, sixty-percent of students reported missing school to guard crops (Mackenzie & Ahabyona 2012). Regular school absenteeism degrades children's academic performance. Studies showed that students living in communities that experienced regular elephant crop-raiding scored worse on national exams than students living in communities not impacted by wildlife. (Mackenzie & Ahabyona 2012; Sitati & Ipara 2012). Over time, poor academic

performance may limit children's employment opportunities or their ability to pursue higher education (Smith & Kasiki 1999).

Resistance to Conservation Initiatives

Due to its negative impacts on farmers and their families, elephant crop-raiding often fosters animosity towards elephants and protected areas and can create resistance to elephant conservation initiatives (Sitati et al. 2005). These feelings are intensified when farmers are not compensated for crops lost to raiding by protected animals, such as elephants. A farmer quoted by Mackenzie and Ahabyona (2012:77) highlighted this sentiment, saying, "If a thief pays for his sins, then animals should be speared and killed if there is no compensation [for crop raiding]". In many places, community members bear the costs of protecting elephant populations without feeling they gain any direct benefits from conservation.

Animosity is directed towards elephants because they are the immediate cause of economic hardship and food insecurity. However, Hill (2015) explains this is because farmers are often unable to direct their anger towards the conservationists or park officials managing elephant populations. Thus, addressing human-elephant farming conflict is not just about reducing the costs of living with elephants (e.g. crop damages) but also about resolving conflict between human groups such as subsistence farmers and park managers.

Small-scale farmers are often unable to address these underlying causes of human-elephant farming conflict. Therefore, they focus their energy on minimizing crop damages by deterring marauding elephants. In the following section, I examine different strategies that farmers employ to reduce elephant crop-raiding damages.

Elephant Deterrent Strategies

The implementation of effective elephant deterrent techniques is essential to reduce crop loss. Therefore, farmers consider a variety of factors to determine the best approach for protecting their farms. Unsurprisingly, farmers utilize deterrent methods they view as highly effective (Noga et al. 2015). They also select methods that have minimal labor requirements; for example, many farmers adopted the use of chili briquettes because they are easy to use (Graham & Ochieng 2008; Hsiao et al. 2013; Noga et al. 2015). Additionally, Hsiao et al. (2013) found that farmers consider whether or not deterrent methods are affordable, reduce the need for human guarding, and alert farmers in advance of the animal's arrival. Novel elephant deterrent methods were more attractive to farmers when they could be tested on a small scale prior to implementation on an entire farm parcel (Noga et al. 2015). Conversely, household maintenance (e.g. adding grease to chili fences), local politics, and insecurity discourage farmers from adopting some elephant deterrent techniques (Graham & Ochieng 2008).

Based on the aforementioned criteria, farmers choose to employ a wide variety of strategies to protect their crops. Traditional elephant deterrent techniques include shouting, banging, lighting fires, throwing stones, and guarding via watchtowers (Davies et al. 2011; Graham & Ochieng 2008; Gunaryadi et al. 2017). One study found that making noise and fire were the most commonly used elephant deterrents (Davies et al. 2011). Although these methods are widely used, farmers are concerned that these traditional methods (e.g. fire) will lose their efficacy as elephants become habituated and that crop damages will increase as a result (Davies et al. 2011; Sitati et al. 2005). In extreme instances, communities have observed that none of their strategies effectively deter crop-raiding elephants (Thouless 1994).

To maximize deterrent efficacy, researchers have compared the effectiveness of both traditional and newly introduced elephant deterrents. For example, Davies et al. (2011) compared the effectiveness of chilies, electric fences, and spotlights when each was used separately and when each was combined with making noise. They found that deterrent methods were most effective when used independently rather than combined with making noise because noise caused elephants to panic and inadvertently damage crops by trampling on them (Davies et al. 2011). Another study observed that traditional field guarding methods (e.g. watch towers) were highly effective when coupled with early warning systems (e.g. trip sirens) that detected elephants; adding chili-based repellents did not increase its efficacy (Gunaryadi et al. 2017). Additionally, Sitati and Walpole (2006) observed that chili-grease ropes successfully deterred crop-raiding elephants.

Other studies have shown that some novel deterrent methods do not reduce elephant crop-raiding behavior. Graham and Ochieng (2008) did not observe any significant declines in elephant raiding behavior following the implementation of experimental techniques including chili fences, cow bells, chili dung briquettes, banger sticks, and watchtower and torch. Additionally, when Hedges and Gunaryadi (2010) tested the effectiveness of traditional guarding techniques when used alone and when combined with chili grease ropes they discovered that adding chili grease ropes did not reduce elephant crop-raiding. A likely cause of chili grease's ineffectiveness was that it often had to be reapplied due to heavy rains. Sitati and Walpole (2006) showed that non-electric barriers are ineffective at deterring crop-raiding elephants. Due to the ineffectiveness of these deterrent methods, several researchers have recommended the continued use of traditional field guarding techniques (Hedges & Gunaryadi 2010; Osborn & Parker 2003; Sitati & Walpole 2006).

On the other hand, farmers often identify electric fences as being highly effective at deterring crop-raiding elephants (Noga et al. 2015; Van Eden et al. 2016). However, electric fences are cost-prohibitive for most subsistence farmers (Thouless 1994). For example, Gunaryadi et al. (2017), found that the total crop loss in twenty villages over two years was $12,000 and that one kilometer of electric fencing costs $9,000. Therefore, although electric fences may be viable options for large-scale cash crop farms or ranches they are less practical for subsistence farming communities. Similarly, thunder flashes are financially inaccessible for many small-scale farmers (Sitati & Walpole 2006). Due to the ineffectiveness of many novel elephant deterrent techniques and the inaccessibility of electric fences, organizations continue to develop innovate solutions to address human-elephant farming conflict.

One such innovation is Save the Elephants' (STE) use of beehive fences in the rural communities of Lower Sagalla, Taita Taveta County, Kenya. Since 2009, STE has worked with local communities to select farms that are most vulnerable to elephant crop-raids for fence installation. A beehive fence consists of beehives that are suspended between posts, connected by wire, and surround an agricultural plot. These fences rely on elephants' natural avoidance of honeybees to deter them from entering agricultural areas (King et al. 2007; King et al. 2009; King et al. 2011; King et al. 2017).

Previous research shows that beehive fences are a cost-effective and socioeconomically-sensitive approach to protecting farmers' fields and livelihoods as well as elephant populations (King et al. 2011; King et al. 2017). The installation and upkeep costs of beehive fences is significantly less than that of electric fences, which makes them more accessible (King et al. 2017). Additionally, beehive fences provide farmers with a valuable secondary income through

the production of honey and increase regional pollinator activity, which motivates farmers to maintain their beehive fences (King et al. 2017).

Overall, Lower Sagalla farmers are supportive of beehive fences. The rapid spread of the method within the community demonstrates farmer acceptance of and support for this deterrent method, and anecdotes suggest that farmers believe beehive fences effectively reduce elephant crop-raiding (King et al. 2017). However, at another study site, Noga et al. (2015) found that farmers were not interested in using beehive fences as an elephant deterrent; they believed that bees sleep at night when elephants are most likely to crop-raid. Additionally, farmers noted that beehive fences are expensive to implement, and they were unclear on the installation process. However, these farmers were interested in pursuing beekeeping as a separate economic activity (Noga et al. 2015).

Agriculture and Elephant Crop-Raiding

While beehive fences can deter elephants once they arrive at a field, elephants may still damage property or raid a neighboring farm. Therefore, to mitigate crop-raiding at the community level and foster human-elephant co-existence it is important to understand what makes crop-raiding attractive to elephants. It was previously thought that elephants raid farmers' fields due to nutrient deficiencies in natural forage; however, Chiyo et al. (2005) found that elephants crop-raid because they prefer some human cultivars to natural forage. According to Osborn (2004:326), “Elephants appear to be selecting the maximum amount of highly nutritious food available to them throughout the year.” In many instances, crops are that highly nutritious food. Elephants forage selectively when crop-raiding; they preferentially eat maize, bananas, and

beans while avoiding other crops (e.g. chili pepper, garlic, Irish potatoes) (Gross et al. 2015; Thouless 1994; Webber et al. 2011).

Planting crops that are non-palatable to elephants but beneficial to humans has the potential to reduce human-elephant farming conflict (Chiyo et al. 2005). Examples of human-wildlife coexistence such as the differential utilization of cashews by humans and chimpanzees illustrate that selecting crops that are undesirable to or differently utilized by wildlife can help mitigate occurrences of human-wildlife conflict (Hockings and Sousa 2012). However, minimal research has been done on elephant foraging selection while crop-raiding or crop palatability to elephants. Webber et al. (2011) suggest that some crops are less palatable to elephants including chilies, peanuts, and ginger. Additionally, Gross et al. (2015) compared differences in elephant crop-raiding on plots planted with maize (a known elephant favorite) and plots planted with potentially non-palatable crops (ginger, onion, garlic, and lemongrass) that have innate chemical defenses. Results showed significantly less crop damage in non-palatable crop plots (Gross et al. 2015). These findings suggest that growing crops that are non-palatable to elephants in communities with high rates of elephant crop-raiding may reduce elephants' attraction to enter agricultural fields. Thus, planting non-palatable crops has the potential to decrease the frequency and severity of elephant crop-raiding.

Several researchers have proposed the planting of crops that are non-palatable to elephants in buffer zones around communities to reduce human-elephant farming conflict (Chiyo et al. 2005; Osborn & Parker 2003). However, minimal research has been done on the role crops might play in mitigating elephant crop-raiding behavior and to assess whether or not buffer zones would effectively deter elephants. Additional research is necessary to understand if non-palatable crops can influence elephant foraging behavior.

Although crops like chilies and ginger may be profitable and reduce elephant crop-raiding, they are not suitable for planting in Lower Sagalla due to the hot and dry climate and cultural preferences. Therefore, this research looks to understand elephant foraging selectivity and crop suitability in Taita Taveta County, Kenya and to determine which non-palatable crops are of socio-economic interest to local farmers and ecologically appropriate.

Farmer Involvement

Although a variety of strategies have been employed to deter crop-raiding elephants including: fires, chili pepper fences, sirens, etc., few have proven universally effective (Hedges & Gunaryadi 2010; King et al. 2010; Osborn & Parker 2003). Thus, multi-faceted approaches and participatory planning processes are necessary to mitigate human-elephant farming conflict (Noga et al. 2015). Sitati et al. (2005) recommended a three-step approach to reducing crop-raiding that included early detection, increased field guarding, and use of active deterrents.

Preventing human-elephant farming conflict depends upon understanding not only elephant crop-raiding but also farmers' viewpoints, priorities, and agricultural practices. The support and involvement of local farmers in elephant conservation is essential to the creation and implementation of successful human-elephant conflict mitigation strategies. Hsiao et al. (2013:570) highlight the importance of local stakeholder involvement: "farmers' perceptions of raiding wildlife are influenced by observable raiding events, previous interactions with wildlife, and cultural beliefs, all of which can affect how conflict mitigation strategies are executed and received locally". Therefore, considering community stakeholder experiences and values when developing effective strategies to mitigate HEC is critical to both farmer livelihoods and elephant conservation efforts. This research project aims to build upon previous research by working

directly with farmers to make sure their opinions of and experiences with elephant crop-raiding are incorporated into conversations about human-elephant farming conflict and used to create innovative solutions.

Partner Organization and Setting

For this research project I partnered with Save the Elephants (STE), a Nairobi-based non-profit organization for whom I served as an intern during 2015. For twenty years STE has conducted important interdisciplinary research and participatory projects that foster human-elephant co-existence in Kenya and around the world. Their initiative, Elephants and Bees Project (EBP) focuses on researching beehive fences as a crop-raiding deterrent. However, their objectives also include understanding beehive fences' impacts on native pollinator populations, traditional wildlife knowledge, and mapping elephant movement. This knowledge is then incorporated into community education and outreach efforts.

Since 2009, STE has worked with farmers in Sagalla, Taita Taveta County, Kenya, located between Tsavo East and Tsavo West National Parks. [Appendix A] The natural habitat is composed primarily of acacia-commiphora woodland and grassland (Smith & Kasiki 1999). Sagalla is located within the Tsavo Conservation Area ecosystem and is comprised of seven sub-villages located atop and at the base of Sagalla Mountain. In this paper, Upper Sagalla refers to sub-villages atop Sagalla Mountain, and Lower Sagalla refers to sub-villages at the base of Sagalla Mountain. Sagalla was established by Wasaghala (i.e. Taita or Kishamba) people who migrated from the Congo Forest (King 2010). Save the Elephants first installed two pilot beehive fences in the sub-village of Mwakoma in 2009, but thanks to the project's success and

widespread community support, twenty-five beehive fences have since been installed in Mwakoma and later neighboring sub-village Mwambiti since 2015.

Small-scale agriculture is the primary source of income in Sagalla, and the majority of farmers cultivate for subsistence (Smith & Kasiki 1999). They farm one to three acres of land and predominantly grow maize, cassava, watermelon, cowpeas, and green grams (Taita Taveta County Government 2015). Some people also raise cows, goats, and chickens (King 2010). Despite high levels of agricultural activity, the region has low soil fertility, which limits the production potential of some crops (Smith & Kasiki 1999).

Widespread agriculture, Lower Sagalla's close proximity to Tsavo East National Park, and high elephant population density within the national park have placed Lower Sagalla farmers on the frontline of human-elephant farming conflict. Tsavo East National Park is largely unfenced; elephants enter and exit the park freely. They travel across private and public lands while foraging and are often attracted to Lower Sagalla by farmers' nutrient-dense crops. Thus, Lower Sagalla farmers experience high rates of elephant crop-raiding. Due to Save the Elephants' positive community relationships, my own prior experience working in Sagalla, and the high incidence of crop-raiding, I conducted my research in the Lower Sagalla sub-villages of Mwakoma and Mwambiti. In the following section, I explain my research methodologies and timeline.

CHAPTER 3: RESEARCH METHODS

I utilized a mixed methods approach to address my research questions. The first part of my research questions, pertaining to the human dimensions of crop-raiding, was investigated using an interpretive social science approach (Neuman 2003). By exploring farmers' actual interactions with elephant crop-raiding and their understanding of it, this approach enabled me to document farmers' viewpoints towards elephant crop-raiding. Furthermore, this approach facilitated an in-depth understanding of how crop-raiding impacts farmers' decision-making processes including deciding what to plant in their farms and which elephant deterrent methods to use. I utilized semi-structured interviews as the main method for gathering and interpreting farmers' experiences with farming and elephant crop-raiding.

The second part of my research questions, which crops are non-palatable to elephants and how crop palatability impacts elephant crop-raiding behavior, were explored through a positivist approach (Neuman 2003). By employing quantitative data, empirical observation, hypothesis testing, and numerical analysis this approach endeavored to discover stable, predictable relationships between elephant behavior and particular crops. For my research, I utilized a classic scientific experimental design to ascertain relationships between elephant crop-damage (i.e. consumption and trampling) and crop type. This chapter is divided into two sections, one about the semi-structured interviews with farmers and the other about on-farm experiments. Both sections discuss my overall research approach and then describe my data collection and analysis.

My research is an in-depth examination of elephant crop-raiding in Lower Sagalla, Kenya between August 2016 and July 2017. As such, it provides extensive information about farming decision-making and crop palatability to elephants during two growing seasons. However, the small sample size and short time frame limit the ability of these findings to be generalized

beyond this case study. Additional research is needed to test these findings under additional circumstances.

This project aims to build upon Save the Elephants' ongoing research and community engagement by utilizing a mixed method approach, which enables me to address both the human and elephant facets of human-elephant farming conflict. I hope to understand farmers' experiences with elephant crop-raiding and their decision-making processes regarding elephant deterrents and agricultural practices, especially crop selection. In addition, I want to determine if the crops sunflowers and moringa are less palatable to elephants than maize and are culturally, economically, and ecologically appropriate alternatives. Overall, I hope my findings will aid in creating ecologically-just solutions to human-elephant conflict that promote human dignity and support biologically-sound conservation practices.

Site Preparation

In August 2016, I met with the Elephants and Bees Project (EBP) research team to describe my project objectives and proposed research plan. I also met with Mwakoma's sub-chief to understand his perspective on human-elephant conflict (HEC), explain my project's methods and objectives, discuss opportunities for collaboration, and receive his support before implementing my project. Mwambiti's sub-chief was on leave, so Mwakoma's sub-chief attended the meeting on behalf of both villages.

Prior to my arrival in country, the Kenya Wildlife Service (KWS), which runs Tsavo National Park, approved my proposed research project and wrote me an affiliation letter. In September 2016, I was formally introduced to Tsavo East National Park's senior wardens. At each meeting, I explained my research project, gave them copies of my project proposal and

KWS affiliation letter, and discussed ways that my research and KWS's projects could complement one another. The meetings were successful, and the wardens gave my project their support.

Semi-Structured Interviews

I addressed the first part of my research questions, on the history and social components of crop-raiding, by conducting semi-structured interviews with community members to comprehend the social, historical, agricultural, economic, and cultural contexts of crop-raiding in Lower Sagalla and to provide an opportunity for subsistence farmers to have their voices heard in my thesis. My approach highlights farmers' perspectives and experiences, which are essential to addressing elephant crop-raiding and the HEC it creates. It also aides in creating solutions that are locally acceptable. With a greater understanding of farmer perceptions and experiences, my goal is that others such as STE can utilize these insights to create effective strategies to address HEC. In this paper, human-elephant conflict is defined as an interaction between humans and/or their goods, livestock, or land and elephants that negatively impacts one or both parties.

Prior to conducting my semi-structured interviews, I created an interview guide based on my research questions. My interview questions were divided into the following topics: Personal Background; Farming in Sagalla; Crop-raiding Impacts; Deterrent Strategies; Beehive Fences; Non-palatable Crops; and Additional Income Sources. [Appendix B] Supplementary questions on Sagalla history were added for community leaders or other key informants with in-depth knowledge of regional history. Separate interview guides were created for key informants at Save the Elephants (STE) and neighboring non-governmental organizations.

In my interviews, I utilized both close-ended and open-ended questions. The close-ended questions allowed me to quantify crop-raiding phenomena (e.g. months when elephants crop-raid) while the open-ended questions facilitated frank discussion and provided the opportunity for interviewees to share their lived experiences and personal anecdotes. After developing my interview guide, I pre-tested my interview guide for clarity, comprehension, and thoroughness with two community members and three STE interns outside my case study. The necessary revisions were incorporated into my final interview guide.

Interview Process

I started by interviewing the ten farmers participating in my on-farm experiments and Elephants and Bees Project staff members. Throughout my interview process, I utilized snowball sampling to expand my interviewee pool by asking each participant to recommend additional people for me to interview. This sampling approach worked well for my research; however, snowball sampling does not yield random population samples and may limit access to some portions of the population (Etikan, Alkassim, and Abubakar 2015).

The recommendations I received via snowball sampling led me to conduct additional interviews with local experts including community leaders and respected elders. These interviews provided more in-depth knowledge about community history, farming practices, elephant deterrent strategies, and non-palatable crops. In total, I conducted thirty-one interviews. Twenty-six interviews were with past or current farmers in Lower Sagalla. Eighteen were male, six were female, and two interviews were conducted with couples. Length of farming experience in Lower Sagalla ranged from ten to fifty-six years. Farm size ranged from five to thirty acres. [Appendix C] I also conducted five interviews with employees at local NGO's; hereafter referred

to as “regional experts”. These interviews provided additional big-picture insight into human-elephant farming conflict and on-going community engagement and research efforts within the region.

Before starting each interview, I briefly outlined my research project and summarized the topics that would be covered during the interview to each person I intended to interview (herein called “participant”). Furthermore, I explained that being interviewed was voluntary and that all responses would remain confidential. I also answered all questions that the participant had about my research project, the topics to be covered, or the rights of research subjects. Prior to starting the interview, each interviewee granted their verbal consent to participate and signed an Informed Consent Form (ICF) that had been approved by the University of Montana Institutional Review Board. [Appendix D]

Interviews were conducted during June and July 2017, scheduled in advance at the convenience of the interviewee, and lasted between 0.75 and 3.5 hours. I conducted interviews at the location where the interviewee was most comfortable. For most interviewees, this was their home; however, a few interviews were conducted at EBP’s office or another location. Although I preferred to conduct closed interviews with only my interpreter, the participant, and myself present, the presence of other individuals depended on the interviewee’s comfort level. For example, one participant invited her immediate family to attend the interview and listen to her responses to learn more about Sagalla History. In two instances, a husband and wife insisted on being interviewed together.

Use of an Interpreter

English is the third language for many in Lower Sagalla; so English fluency is not prevalent. Therefore, I worked closely with a university-educated interpreter fluent in both English and Swahili. He is not from Sagalla and did not have any previous relationships with community members. This helped mitigate any biases and allowed interviewees to respond openly without worrying their interview responses would negatively impact a personal relationship. Furthermore, having a male Kenyan interpreter helped counterbalance my biases as an American woman.

Prior to conducting my interviews, my interpreter and I extensively discussed both my research objectives and interview questions to reduce any misunderstanding or mistranslation. Next, we reviewed the interview guide carefully together and modified any language that did not easily translate into Swahili. My interpreter then translated the interview guide into Swahili, which helped ensure that questions were asked verbatim in each interview. To further improve the interview guide's translation, we conducted practice interviews in Swahili prior to interviewing project participants. For each interview, I asked my interpreter to translate the interviewee's responses as close to verbatim as possible. We strove to maximize translation validity; however, the potential for mistranslation is a drawback of working with a translator. Additionally, the presence of an additional person (i.e. the translator) might have influenced participants' responses.

Interview Coding & Analysis

I digitally recorded each interview, and my interpreter and I both wrote extensive notes throughout each interview. At the end of each day, my interpreter and I debriefed the interviews

by comparing notes; we paid close attention to anything out of the ordinary and non-verbal communication (e.g. discomfort or hesitation in discussing a topic). After completing my fieldwork, I listened to each recording and wrote comprehensive notes on each interview. I directly transcribed compelling quotes. Then, I sorted my notes by research topic (e.g. non-palatable crops) and assigned each interviewee a two-letter code to use during my analysis.

Next, I reread my notes and examined them for overarching themes. I created Excel worksheets for each of my main interview topics: Sagalla History, Land Use, Human-Elephant Conflict (HEC), Social and Emotional Impacts of HEC, Economic Impacts of HEC, Elephant Deterrents, Beehive Fences, and Non-Palatable Crops. As I reviewed each interview's notes, I wrote down every incidence when an interviewee's response coincided with a topic. For each reference, I noted the two-letter interviewee code and the line number of the reference. In my interview notes, I highlighted the references for each topic in a different color. Next, I reviewed my worksheets to determine which topics were most frequently discussed and divided them into themes and sub-themes. Finally, I arranged these themes and sub-themes into an outline that addressed my overarching research questions. I recorded responses to each close-ended question on a separate Excel worksheet and created tables detailing the responses. In the following chapter I report the findings from my interviews and the insight they offer into regional human-elephant farming conflict.

On-Farm Experiments

To explore the interactions between crop palatability and elephant crop-raiding behavior, I implemented a classic scientific experimental design. I hypothesized that crop palatability influences elephant crop-raiding behavior and that elephants preferentially raid fields with

palatable crops (e.g. maize, watermelon) over fields planted with less palatable crops (e.g. sunflower, chilies). To test my hypotheses and minimize experimental error, I utilized a randomized complete block design with ten replicates (as described below). I predicted that a smaller proportion of non-palatable crop plants (moringa and sunflowers) would be consumed and/or destroyed than my control crop (maize).

Crop Selection

To select my experimental crops, I consulted a variety of sources. I started by referencing the existing scientific literature to determine which crops were previously tested for their palatability to elephants. Next, I met with Elephants and Bees Project staff and local farmers to determine if any crops grown in the community are often undamaged by crop-raiding elephants, which may suggest they are less palatable. Finally, I met with a local agriculture expert at a nearby NGO to discuss other crops that may be non-palatable to elephants but beneficial to humans. We also considered regional climatic appropriateness, seed accessibility, and market availability.

After concluding my background research, I selected maize as my control crop because it is a well-established elephant favorite and has been utilized by prior research studies in this capacity (Gross et al. 2015; Parker & Osborn 2006). I chose sunflowers (*Helianthus sp.*) and moringa (*Moringa olifera*) as my experimental crops because anecdotal evidence from my meetings suggested that both crops are climatically appropriate, of interest to the local community, and farmers can consume it or sell it in the market. Furthermore, both crops have a similar growth form to maize, and their attraction to elephants was untested.

Experimental Sites

Following community leader and KWS approval, I worked closely with local Elephants and Bees Project (EBP) staff to identify possible farmers to partner with for my on-farm experiments. Possible sites were considered based on the farm's history of elephant crop-raiding and its location within the community as well as the farmer's relationship with EBP (i.e. are they open to participating in EBP's projects). As part of the selection process, I visited all the farms with beehive fences to assess farm size, location, and amount and location of land located outside the beehive fence. The farm's level of beehive fence maintenance (e.g. number of hives missing lids, number of dead posts) was used as a proxy for the farmer's ability to follow through on their commitment to a project. While I had originally intended to work with an equal number of beehive fence and non-beehive fence farms, I ultimately selected nine beehive fence farmers and only one non-beehive fence farmer. I reached this decision because beehive farms are those most frequently visited by elephants in the community, and these farmers have previously demonstrated their openness to working with EBP. Additional farms were considered but excluded due to either their lack of elephant crop-raiding activity, history of hostility towards EBP, or lack of available farmland.

After compiling a list of possible locations, I visited each farmer to briefly explain my proposed research project, answer any questions, and invite them to an informational meeting. Of the ten farmers invited, all expressed interest in participating and attended the information session I hosted at EBP's office. At the meeting, I explained my project objectives, outlined my experimental design, and facilitated a discussion about the potential of crop-type to influence elephant crop-raiding behavior. At the meeting, I also described my proposed strategy to compensate farmers with rainwater catchment systems for their participation. I worked closely

with EBP's Project Officer to coordinate meeting logistics and create the agenda. Throughout the meeting, he also interpreted between English and Sagalla (the local language) for non-English speakers. The meeting was highly successful; every farmer was interested in participating. I scheduled follow-up visits with each farmer to discuss the research project further and determine the exact location of the experimental crop plots on his/her farm. Of the ten farmers originally selected for participation in my project, one was unable to participate due to intra-family conflict. A substitute farmer was selected based on the same criteria as the original ten. The ten selected farmers had been farming between ten and forty-seven years and actively farmed between five and fifteen acres of land. Seven heads of household were male and three were female.

In the fortnight following my meeting, I conducted individual follow-up visits. While at each farm, I answered any additional questions the farmer had about the project and explained and completed Informed Consent Forms. Working closely with each farmer, we selected the site for my experimental farm plot on his/her property by considering land availability, pathways of previous crop-raiding elephants, and proximity to his/her home. To maximize possible elephant activity in my experimental plots I placed them in fields where elephants had previously crop-raided farmers' crops (e.g. maize, green grams). I mitigated the deterrent effect of human presence by establishing my experimental plots as far as possible from the farmer's home.

After selecting the experimental site, I marked three crop plots (one for each test crop). Each plot measured five meters by five meters. Plot size was determined by consulting with EBP staff and deemed large enough to attract elephants but small enough to be manageable. The three plots were arranged linearly and oriented north-south or east-west depending on land availability. An 8.5-meter buffer zone, where nothing was to be planted, was established between each of the crop plots; this dimension was selected based on previous research studies (Gross 2015). Due to

land scarcity within the community and the small size of individual's land holdings it was not possible to create an 8.5-meter buffer around the perimeter of the entire experimental area, so a one-meter buffer was established. [Figure 1] Before planting, plot treatments were assigned using a randomized complete block.

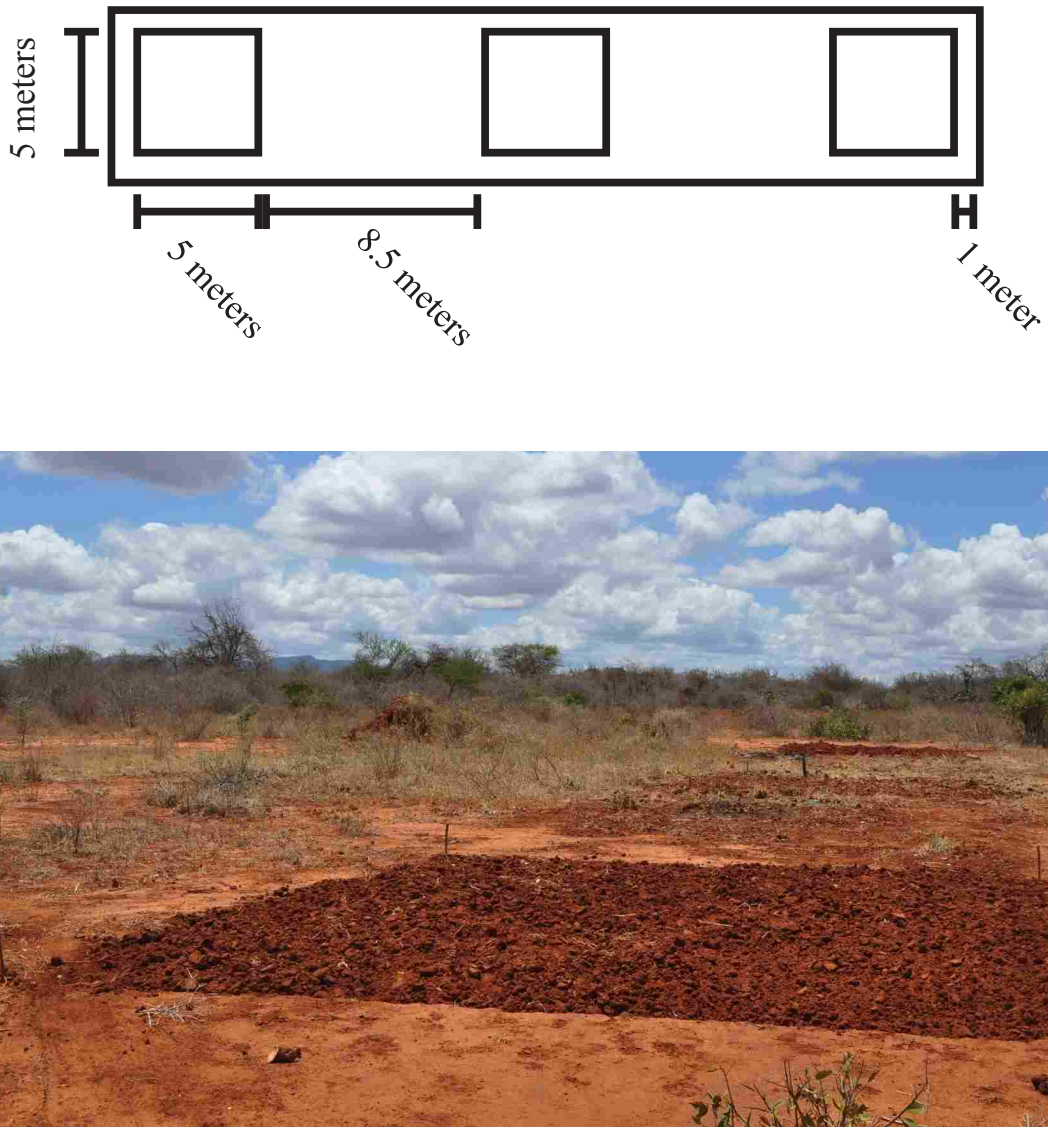


Figure 1: On-Farm Experimental Plot Arrangement (Top: Diagram of plot spacing; Bottom: Photo of experimental plots)

In a recent paper by King et. al (2017), they considered how bees influence elephant behavior within ten meters of a beehive fence. To mitigate the confounding influence of beehives on elephant behavior, I located my experimental sites at least fifteen meters away from beehive fences. After selecting the experimental site, arrangements were made with each farmer to clear the study site of all vegetation and till each five meter by five meter crop plot. Payment was determined on an individual basis, based on local pay norms and the amount of work necessary to prepare the study site for planting, and ranged from five hundred to 1,500 Kenyan shillings. I purchased maize seeds in Voi and sunflower seeds in Nairobi, and a nearby NGO donated the moringa seeds. Due to their slower growth rate, I established a tree nursery of more than six hundred moringa saplings at the EBP research center in mid-September 2016, approximately four weeks before the anticipated start of the rainy season.

Based on spacing recommendations, I cultivated fifty individuals in each moringa plot and one hundred individuals in each of the maize and sunflower plots. In each maize and sunflower plot, I established ten rows of ten individuals, with half meter spacing between each row and each plant within the row. [Figure 2] I determined the number of seeds and planting depth for each crop by consulting with local farmers. Sunflower and maize seeds were planted by digging a shallow two to four-inch hole at each designated location. Seeds were then added to the hole (four to five maize seeds or seven to ten sunflower seeds) and covered in one to two inches of soil. Due to their larger size, only fifty moringa individuals were cultivated in each plot. In each moringa plot, five rows of ten plants were established with one meter spacing between each row and half meter spacing between each plant within the row. [Figure 3] To facilitate recordkeeping on individual plant health, every plant in each plot was assigned a

number. The plant in the top left (in relation to Sagalla Hill) was plant number one. The plants were numbered from left to right within in row, and rows were numbered from top to bottom.

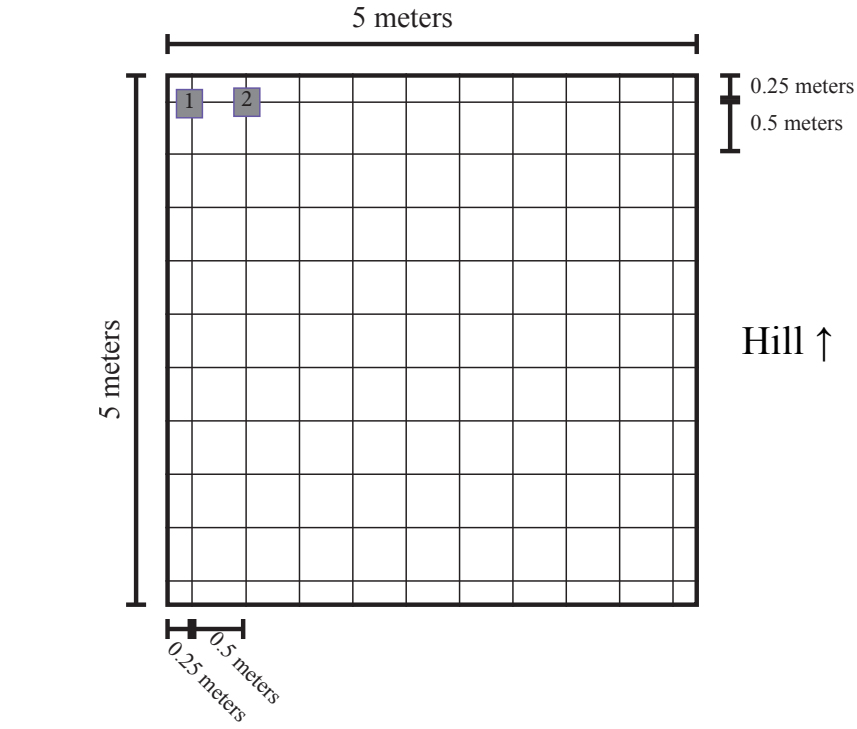


Figure 2: Sunflower and Maize Plot Planting Design (Top: Planting diagram; Bottom Left: Photo of sunflower plot; Bottom Right: Photo of maize plot)

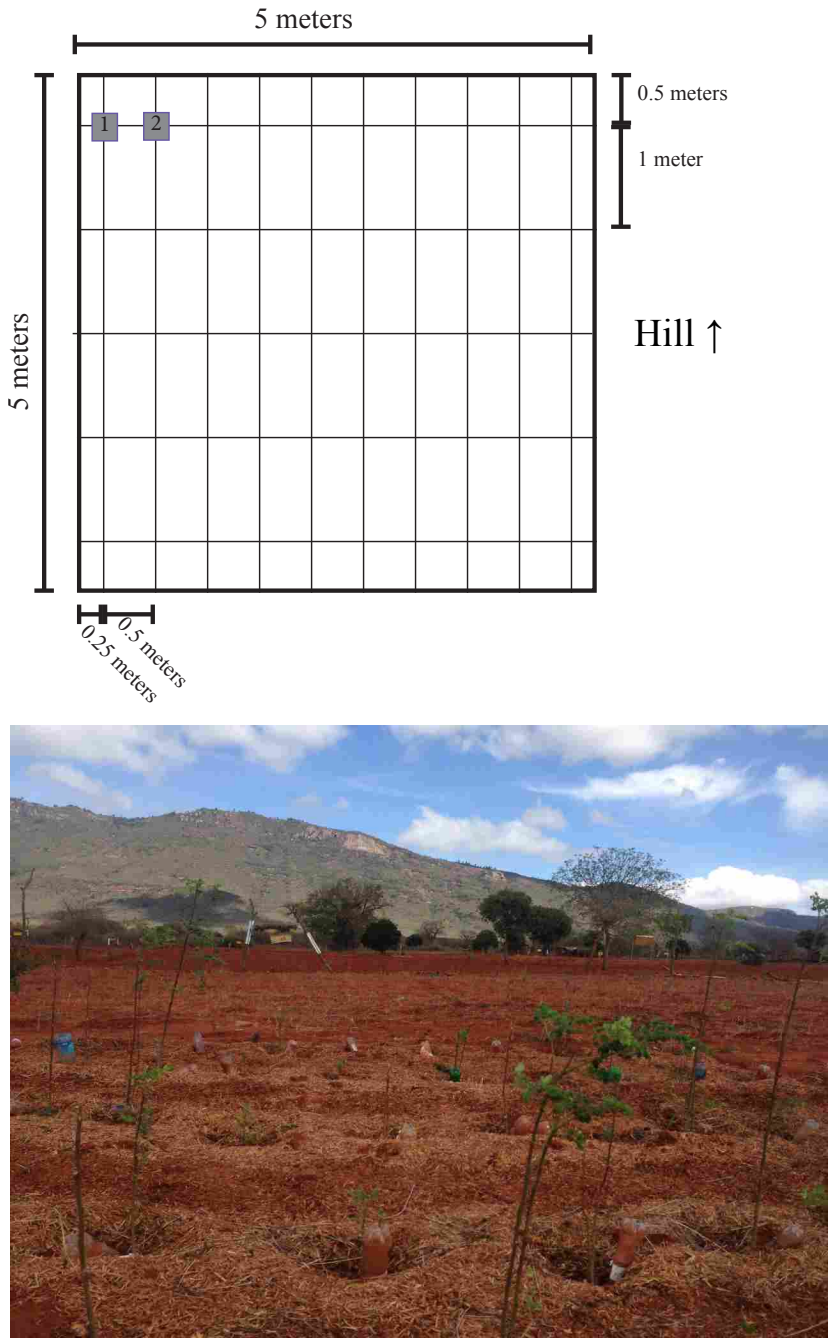


Figure 3: Moringa Plot Planting Design (Top: Planting diagram; Bottom: Photo of moringa plot)

Plot Establishment

Using the methods outlined above, I planted maize and sunflower seeds at each farm between mid-October and mid-November 2016, prior to the start of the rainy season. To determine planting dates and simulate local farming timelines, I consulted with each farmer about his/her farming practices and planted the sunflowers and maize during the same week the farmer planted his/her maize. Presumably due to bad seeds, none of the sunflowers planted in October and November germinated. Therefore, I purchased a new batch of seeds from a local farmer and replanted all sunflower plots during the second week of December.

Prior to planting at the experimental plots, some moringa saplings in the nursery died due to overwatering and abnormally hot temperatures; only 420 moringa saplings survived. To compensate for reduced saplings numbers, the remaining saplings were evenly divided among the ten experimental sites. At each farm, the moringa plot was planted with forty-two saplings, and seeds were planted in the eight remaining planting locations. The locations of the eight seed plantings within each site were determined using a random number table. To maintain consistency and maximize transplant survival, all moringa were planted in the last two weeks of November, after the start of the rainy season.

Experimental Data Collection

Whenever a crop-raiding event occurs in Sagalla, the raided farmer calls Elephants and Bees Project (EBP) so EBP staff can collect data on the number and sex of raiding elephants and record the elephants' routes through the community. EBP staff notified me whenever elephants crop-raided one of my study sites. At my non-beehive fence site, the farmer contacted me

directly to report elephant activity at her farm. After being notified about a crop-raiding event, I visited the farm within twenty-four hours to collect data on the incident.

Upon arriving at the farm, I spoke with the farmer, and he/she summarized recent elephant crop-raiding activity and described elephant movement on the farm. As part of this summary, I worked with the farmer to draw a map showing the elephant's pathway(s) including entry/exit points and direction of movement. Particular attention was paid to elephant movement near the experimental plots. The farmer also reported details about the elephants he/she saw and the time of the crop-raid. During these crop-raid assessments, I worked with EBP's elephant tracking experts to determine the number and sex of the crop-raiding elephants, based on farmers' anecdotal accounts and elephant footprints and dung boluses.

After conferring with the farmer about the overall crop-raiding impacts, I assessed the severity of damage to my experimental plots. I collected data systematically using my Crop Status Assessment Form. [Appendix E] I evaluated the overall status of the plants by first determining the average age of the crops. They were categorized as either seedling (immature plants less than twenty-five centimeters tall), intermediate (taller than twenty-five centimeters, but not flowering) or mature (exhibiting flowers or fruit). Next, I recorded the condition of the crops before the raid as bad (<33% of plants in good health), medium (33-67% of plants in good health), or good (>67% of plants in good health). Plant health considered insect harm, foraging damage, and environmental stress; an individual plant was in good health if it was present and not significantly impacted by (i.e. not in danger of dying from one of the above factors). Pre-raid condition was determined by consulting previous data sheets.

Next, I collected data on the health of each individual plant. The condition of each plant was recorded in accordance with pre-determined criteria. Plant criteria were developed prior to

data collection by consulting with EBP's elephant tracking and farming experts. Together we generated a list of likely crop impacts and practiced recognizing them. The following list of plant criteria were developed:

Good (G): Plant is in good health and unaffected by any of the conditions described below.

Never Sprouted (NS): Seeds were planted at this location, but never germinated. The cause is unknown.

Insect Damage (ID): Insects or signs of insects (e.g. droppings, webs, foraging damage) are visible on the plant and the leaf area has been significantly reduced (>50%).

Environmental Impact (EI): Lack of water caused significant (>50%) leaf death, signified by dry and brittle leaves and stems and dry cracked soil at the base of the plant.

Elephant Trampling (ET): An elephant stepped on and damaged the plant, as evidenced by the presence of elephant footprints on the plant, broken/damaged stems, and elephant dung.

Elephant Foraging (EF): Removal of plant foliage by an elephant, characterized by large clumps of vegetation removed at a low level and elephant footprints and dung.

Uproot, Elephant (UR): Ripping out of a plant by an elephant, plants were often found adjacent to the plot, frequently accompanied by ET, EF, and elephant footprints and dung.

Missing (M): Plant was previously recorded as present but could not be located. The cause of disappearance could not be determined.

Foraging Damage (FD): Defoliation of unknown cause, either livestock or wild ungulate. Caused by unreliable farmer reporting, unclear footprints, and camera traps showing multiple species.

Trampling Damage (TD): Trampling of unknown cause, either livestock or wild ungulate. Caused by unreliable farmer reporting, unclear footprints, and camera traps showing multiple species.

Rodent Damage (RD): Seeds or seedling was removed from soil by squirrel, rat, or other wild rodent, as evidenced by dig marks, empty seed casings, and farmer reports.

Baboon Foraging (BF): Uprooting of seedlings by baboons, as evidenced by farmer reports and dig marks.

Livestock Trampling (LT): A cow or goat stepped on the plant, as evidenced by the presence of hoof prints on the plant and dung.

Dead (D): Plant exhibits evidence of death including loss of all foliage, broken or dry and brittle stems, or uprooting. Whenever possible, the cause of death was recorded, as determined by examining the plant and the plant's health recorded on the previous data sheet.

A plant was considered impacted by one of the conditions if the condition altered the plant's overall fitness. For example, a plant recorded as "EF" exhibited severe enough elephant foraging that the damage was likely to kill the plant. If a plant was strongly impacted by more than one factor (e.g. elephant trampling and elephant foraging) both statuses were recorded. When it was difficult to determine which animal caused the foraging or trampling damage, the damage was recorded as "trampling damage" or "foraging damage". In addition to categorizing individual plant health, I also recorded general observations about the crops plots (e.g. dung in plot, dry soil) and photographed crop damage. [Figure 4]

Figure 4: Elephant Crop-Raiding Damages (Top: Foraging; Bottom: Uprooting)

Camera Traps

I installed two Bushnell Essential E2 camera traps at each farm to provide a secondary data source about plant health designations, especially in cases of foraging or trampling damage. [Figure 4] They also provided information about the demographics (e.g. age, sex) of crop-raiding elephants. At each farm, the cameras were located on opposite ends of the plots to maximize the area covered by the cameras. Whenever possible, they also covered known elephant pathways. Each camera was installed 1.5 meters above ground on a post or tree and approximately five meters from the experimental plots.

Following each crop-raiding event, I exchanged the SD cards from every camera as part of my routine data collection. If no crop-raiding event occurred, I exchanged the SD cards and tested the battery life of each camera trap every two weeks. After collecting SD cards, I reviewed each image and saved any containing elephants or other crop-raiding animals (e.g. baboons, goats, waterbuck, etc.). Images were sorted by location and animal and filed accordingly. Elephants and Bees Project interns recorded the images in a comprehensive spreadsheet for future evaluation.

Figure 5: Camera Trap Photo of Crop-Raiding Elephants Eating Maize (January 2017)

Data Analysis

Following my fieldwork, I entered the plant health statuses from each farm into a separate Excel worksheet. After reviewing my data set, I decided to focus my analysis on two points in time: mid-January and late March 2017. I chose mid-January because the majority of elephant crop-raiding events occurred between December seventeenth and January twentieth. During this time elephants raided nine out of ten farms. Coincidentally, I departed Kenya for the USA on January twentieth. Therefore, analyzing crop status on the date closest to January twentieth captures the cumulative crop-raiding damage from this time frame and is the last experimental data that I personally collected. For my second point in time, I chose late March

because it is the last data point for each plot during the growing season. This demonstrates the proportion of each crop survived to the end of the growing season and was harvestable.

Additionally, these two timeframes enabled me to address four key questions that complemented my interview research.

1) In January, was there a difference in intentional elephant damage among crop types?

2) Was there a difference in elephant-cause mortality among crop types at the end of the growing season (March)?

3) Was there a difference in available harvest (i.e. the number of plants alive) among crop types at the end of the growing season (March)?

4) Was there a difference in germination rate among crops by mid-January?

To facilitate data analysis, I condensed my plant health statuses to six categories: good, alive with accidental elephant damage, alive with intentional elephant damage, dead (killed by accidental elephant damage), dead (killed intentional elephant damage), and dead (other cause of death). Foraging and uprooting were considered intentional elephant damage; trampling was considered accidental elephant damage. The other categories (e.g. insect damage, baboon foraging) were condensed because they do not inform my primary research questions. Although condensing these categories obscured non-elephant impacts, doing so made it easier to isolate trends in elephant damage.

Then, I entered my data into SPSS and coded it according to crop type and farm identification number. To account for variable germination rates among crop plots I calculated the proportion of plants that germinated at a plot within each of my six plant status categories rather than using the number of plants. To determine whether or not there were statistically

significant differences between groups, I compared them using Kruskal-Wallis and post-hoc pairwise comparisons.

This statistical analysis provided key insight into differences in intentional elephant damage and germination rates among crop type. I selected Kruskal-Wallis because as anon-parametric test it is able to account for my small sample size and non-normal data distribution. However, a limitation of this statistical approach is that it is unable to account for differences caused by farm location or famer plot care (e.g. frequency of watering, soil type).

Farmer Compensation

Because water access is a major challenge in Lower Sagalla, I installed a five-hundred-liter rain barrel and gutter system at each farmer's house (valued at 140 USD) as compensation for participating in my project. During my research period, farmers agreed to water my experimental crops with any rainwater collected. After the close of my project, each farmer retained ownership of the rain barrel and gutter system. Two farmers had previously received rain barrels and gutters from Elephants and Bees Project (EBP), and on the recommendation of EBP's project leader they were not given an additional rain barrel. At the end of the experiment, farmers also retained any remaining harvest from my experimental plots to consume or sell in local markets. The moringa remained where they had been planted, and their management was handed over to the farmer.

Research Limitations

Due to a family emergency, I suddenly departed Kenya in mid-January 2017, during my field season, and did not return until early April. Prior to my departure, I trained my field

assistant and other EBP staff on my data collection procedures and left them with all the materials necessary to continue my on-farm experiments. When my field assistant departed in February, she handed my project over to another EBP intern. Although my field assistant trained the new intern on my research procedures, the new intern sometimes failed to precisely follow my research methods (e.g. did not complete the Elephant Damage Assessment) and did not write notes about plant health.

Furthermore, throughout the field season, Lower Sagalla experienced lower than average rainfall. Only 2.2 millimeters of rain fell in January 2017 (King, unpublished data). This lack of rainfall negatively impacted my experimental crops and by mid-January, the plants were showing signs of drought stress (e.g. dry and brittle stems and leaves). To compensate for the lack of rainfall and hot temperatures, I hired two community members, one each in Mwakoma and Mwambiti, to water each experimental plot three times a week. The supplemental watering was intended to boost plant growth and allow them to reach maturity, thus increasing the attraction to crop-raiding elephants. In the beginning, both community members regularly watered their assigned plots. However, as the drought's severity worsened, it became increasingly difficult to obtain enough water to water the plants, and the community member in Mwambiti failed to regularly water the plants. The lack of regular watering ultimately killed many plants in Mwambiti.

Additionally, I had planned to collect a second season of crop-raiding data from March to July 2017 and replanted all my experimental plots in March 2017. However, a drought occurred, and the anticipated rains never arrived. Between March and July 2017 only 66.1 millimeters of rain fell in Lower Sagalla (King, unpublished data). I continued to work with two community members on watering my experimental plots; however, there was not enough locally available

water to support regular watering of my crops. Therefore, the seeds planted in March 2017 never germinated. Presumably due to the lack of both crops and natural forage, elephant activity in Sagalla was much lower than anticipated between March and July 2017, and no data was collected.

This study provides insight into the relative palatability of sunflowers, maize, and moringa to crop-raiding elephants in Lower Sagalla from August 2016 to July 2017. While these findings may be applicable to other settings, the study's short time frame and small-scale limit the ability of these findings to be generalized. Thus, further research is necessary before my findings can be applied to additional sites.

CHAPTER 4: RESULTS

In this section I present findings from both my semi-structured interviews and on-farm experiment to address my research questions. I start by relaying the settlement of Lower Sagalla and how human-elephant farming conflict has changed over time. I then focus in on contemporary human-elephant farming conflict and explore the numerous ways in which it negatively impacts farmers and communities in Lower Sagalla. Next, I examine the strategies farmers utilize to deter elephants and mitigate these negative impacts. Then, I share how farmers make decisions about which crops to grow and where to plant them. In addition, I look at how relative crop palatability may influence elephant crop-raiding behavior. I focus on the cultural, ecological, and economic viability of two potentially non-palatable crops, sunflowers and moringa, to reduce elephant crop-raiding behavior.

In each sub-section I utilize direct quotations from my interviews to address each topic and illustrate salient points. To protect participant anonymity and provide reference to the individual interview, the participant code and date of the interview are included in brackets after each quotation. All information was gathered from my personal interviews and on-farm experiment or from external publications, as cited.

Wasaghala History in Lower Sagalla

To fully understand contemporary HEC in Lower Sagalla, it is essential to begin by considering the community's history. The Sagalla Hill was settled hundreds of years ago when the Wasaghala (also known as Kishamba) a sub-group of the Taita began living in Upper Sagalla. According to a farmer, "Taita people are a Bantu-speaking group that originated in the Congo a long time ago, hundreds of years ago. Even now some of the language is shared. As

they traveled, some chose to settle atop Sagalla Hills." [6, 6/9/17] The Wasaghala established permanent dwellings in Upper Sagalla and eschewed settling in Lower Sagalla because it was undeveloped bush land and home to dangerous wildlife, including lions, hyenas, rhinos, and leopards. A farmer explained,

> I cannot tell the year when it was first settled because my fathers were here; my grandfathers were here . . . but long-ago people did not settle here in this land. People settled up the mountain because this one was a wildlife zone. Every kind of animal species was here: lion, hyenas, rhinos, most everything. [9, 6/15/17]

This danger dissuaded the Wasaghala from settling in Lower Sagalla before the mid-1900's.

However, as the human population increased and land availability and forage quality decreased in Upper Sagalla it became increasingly difficult to support the burgeoning community. So, Wasaghala herdsmen looked to Lower Sagalla. A farmer noted,

> It [Lower Sagalla] was a place of herding. Only herdsmen kept *bomas* [corrals in Swahili] here. Everybody had their homes up there . . . people would come down to take care of the cattle and when they have finished, then they would go up there. [10, 5/31/17]

Soon afterwards, others began growing crops in Lower Sagalla. According to one farmer, "Land was scarce on top of the mountain . . . the population had increased . . . the soil fertility was being washed away every time it rained. So, there was lot of soil erosion." [14, 6/15/17] The farmers descended in the morning and returned to Upper Sagalla each evening. A farmer explained, "So every time they would come down. At six they would migrate to the top of the mountain." [9, 6/15/17] Another farmer remarked, "Land was very scarce atop the mountain and people were increasing. Then again, food was so much minimal. So, when the first people settled here, they came to do farming and go back." [3, 6/16/17] When people commuted to and from their farmland, they also transported resources between Upper and Lower Sagalla;

> Ladies would carry water from the top of the mountain because there was no water here . . . After finishing, they would carry whatever they have back to the mountain along with

> firewood. They collect firewood here and carry it all the way, top of the mountain. [9, 6/15/17]

This continued for several decades.

Although the Wasaghala began grazing and small-scale farming in Lower Sagalla, wildlife deterred permanent settlement. According to a farmer, "Women feared to stay there because of the animals . . . It was risky." [12, 6/8/17] At this time, human-elephant conflict was rare in Lower Sagalla. A farmer shared, "People knew nothing about elephants because were having two to three people here who were only herding. Incidences of elephants were not so frequent as of now." [1, 6/2/17] Although the Wasaghala only rarely encountered elephants, livestock grazing led to conflict with predators. According to a farmer,

> That time there was no elephants conflict. It was only the rhinos and, uh, *simba* [lion in Swahili], lions and leopards . . . this animal that laughs, the hyenas . . . the rhino . . . there were no elephants . . . and of course the baboons during the day. They're the only animals that you'd have human conflict. [10, 5/31/17]

Due to the risk of encounters with dangerous animals, most herders were men. A farmer explained the danger,

> If darkness fell early and you are not found on top of the mountain it's rather you stay down, just near the mountain. Now, they'd face a problem. A lion or a hyena would always attack their livestock, pick one cattle and eat. All that would be left were the carcasses . . . so you would fight with the lion or whichever animal had taken the cow, and after chasing the animal away, whatever remains of it, maybe it ate half, and you'll eat to finish it up. Because it's their livelihood. It was their food. [9, 6/15/17]

Livestock predation not only threatened the herdsmen's safety but also their livelihoods and food security.

Over time, the constant movement up and down Sagalla Hill became tiresome for the Wasaghala. According to a farmer, "They did that, and it was a bit of a challenge, a hardship . . . People started settling . . . They decided fully it's just time to settle here, it's our land." [9, 6/15/17] So, in the 1930's the first people moved from Upper Sagalla and settled in caves on the

side of Sagalla Hill to improve their access to Lower Sagalla's farmland and pasture. A farmer noted,

> I was born in the middle of the mountain near the rocks, and after I was born there, my father was a herdsman, a livestock keeper. So, he was grazing his cattles, and so I came up grazing cattles also . . . So, I took after my parents, herding. [3, 6/16/17]

After living in the caves, some people began settling in Lower Sagalla in the mid-1900's. A farmer remarked, "They came down from the cave to Mwambiti." [9, 6/15/17] However, Upper Sagalla remained the center of Wasaghala culture. For example, "There was a rule that people would not bury. When somebody dies, they would not bury here. Anybody dead would be carried up to the hills to be buried up there." [10, 5/31/17] These rules discouraged permanent settlement in Lower Sagalla.

Between the 1940's and 1980's few people lived in Lower Sagalla, and wildlife was problematic in the sparsely settled community. A farmer remarked,

> Early fifties is when the women started to come to stay with their husbands . . . They started bringing up their children here. When you come, you come and make a shed, just a shed for you to stay. And they are not putting mud like this; they are just putting sticks all around. Then you stay there inside and your cattle outside there, and they used to stay with *pangas* [machetes in Swahili] for their protections, weapons for their protections, for animals. [12, 6/8/17]

Although other human-wildlife conflict was common, the Wasaghala rarely saw elephants. A farmer explained, "When we were kids, you would not spot an elephant. You would only be told by your parents or, you know, those elders, that an elephant stepped here by seeing maybe the footprint of an elephant." [22, 6/2/17] Another farmer remarked, "Before you could just find someone thirty years old and he's not seen an elephant footprint." [3, 6/16/17] Low human population density, nominal farming activity, and infrequent human-elephant interactions meant crop-raiding was rare and the first settlers experienced minimal human-elephant conflict.

However, when the Wasaghala settled in Lower Sagalla rhinoceros were common. According to a farmer,

> Rhinos, they were plenty . . . but they are no longer here . . . They were also as destructive as an elephant, though the impact was minimal for me. For the rhino, he walks alone, which is an advantage . . . They crop-raided, but at an insignificant level. They were not as stubborn as elephants. [9, 6/15/17]

Another farmer noted,

> There were no elephants. What we had of plenty were rhinos. Rhinos were in plenty at that time when they started settling here . . . There were so many and every time you had some ox peckers cry, you'd know it's a rhino which is nearby. So, it's warning you of danger. And rhinos, the good thing with them, they did not crop-raid. They only fed on bush and forest. [26, 6/1/17]

Rhinoceros infrequently foraged on crops but threatened people's safety when they traveled in the bush land.

Land scarcity and soil erosion atop Sagalla Hill made farming in Upper Sagalla less productive and accelerated settlement in Lower Sagalla despite the threat of wildlife. A farmer noted, "They were on top and then migrated to the lower part after quite a while. On the top, they found that the soil is not so much productive." [22, 6/2/17] The Wasaghala were also drawn to Lower Sagalla by more reliable harvests and new crops. One farmer shared, "The problem is that the land was so small, and it did not satisfy their needs. Therefore, my parents decided to come on this parcel of land, so they can farm at a better huge portion of land and have more food." [13, 6/6/17] Another farmer remarked,

> My father, he is the one who started, and we just followed [in] 1956 . . . because the land there is scarce. And another thing, when it rains they were faced with challenges; the soil is washed away . . . My dad came farming here because you can plant plenty of crops here including maize, including pigeon peas, peas and all that, whereas you cannot do that on top of the hill. [17, 6/12/17]

The ability to plant different crops offered farmers greater food security and access to additional income sources.

In Lower Sagalla farmers could also utilize new farming technologies. Upper Sagalla's hills limited farmers to cultivating by hand. However, Lower Sagalla's flat topography could be plowed using a tractor or oxen. According to a farmer,

> This place is more productive in terms of growing of crops than up there because this place is fertile. At the same time, you know, you can use ox plows, which is driven by cows, so it's more economical. Nowadays, people use tractors. So instead of farming half an acre, you can have even three or two . . . up there you have to till using a hoe, but down here you can use a tractor. [21, 6/10/17]

These advantages led to successful harvests. A farmer noted, "He [my father] was among the first settlers . . . they harvested maize and *pojo* [green grams in Swahili] . . . because they harvested a lot, and people from up-mountain, after seeing that, they were motivated to come down." [20, 6/7/17] The initial settlers' success inspired others to relocate as well.

Lower Sagalla's plentiful pasture and flat landscape offered the Wasaghala better livestock grazing as well. According to a farmer,

> You can't keep goats . . . up there. Even if you keep a cow, where will you? There is no green pasture. The *shamba* [field in Swahili], the garden is very small, maybe half an acre. So, you can only have two or three cows. [24, 6/7/17]

Another farmer shared, "My grandmother did farming on top of the mountain. She came down here in 1961, before we got independence . . . because of her cattles. My grandmother had cattles, so she settled here." [16, 6/5/17] Larger pastures meant the Wasaghala could graze more livestock and increase their potential livelihood.

In contrast to the congestion of Upper Sagalla, Lower Sagalla was largely undeveloped. Land in Lower Sagalla is held in a community-level title deed and unoccupied land was available for settlement. According to a village leader,

> It was a free land for Kishamba [Wasaghala] people. So, wherever you choose to clear nobody would come to hinder you. It was just free land . . . it is an indigenous land. Everybody was free to clear . . . there was no conflict. [10, 5/31/17]

Settlement in Lower Sagalla was unregulated by community leaders. A farmer explained, "Land was not allocated by anyone. Our forefathers, after noticing the potential of this land in Lower Sagalla, they would just come and take whichever portion for farming." [3, 6/16/17] Therefore, families were able to claim large parcels and increase their farming activity.

In the 1980's, infrastructure improvements further catalyzed resettlement in Lower Sagalla. According to a village leader,

> When the people increased . . . decided to construct a school rather than all these children going up the hills to school up there . . .That was 1980 . . . the primary school was constructed . . . Most people now came down. [10, 5/31/17]

The school enabled families to pursue Lower Sagalla's economic opportunities without sacrificing their children's education. In addition, the roads and water access improved. A farmer remarked,

> People could not settle here because of water was an issue. It was a big problem . . . Up there, there are many springs . . . Here it was dry, there is no water. If they had to get water, they had to walk kilometers . . . '80's there, they started to think of getting the water from up the springs and bringing it down. They decided to fundraise. They fundraised. They bought pipes. They connected water from up there. That was '90's now. They got water down here. [6, 6/9/17]

Better infrastructure reduced the challenges of living in Lower Sagalla and made resettlement increasingly appealing to the Wasaghala.

As the initial success of Lower Sagalla's first farmers encouraged others to relocate as well, human-elephant conflict became increasingly problematic. According to a farmer, "When we were young, we would spot elephants at a very long distance. We didn't know very much about elephants, but then during the era of independence . . . elephants were a bit now starting to crop-raid." [5, 6/6/17] The foraging opportunities of agricultural crops drew elephants to the community. According to one farmer, "Farming is what attracted elephants." [20, 6/7/17] Another explained,

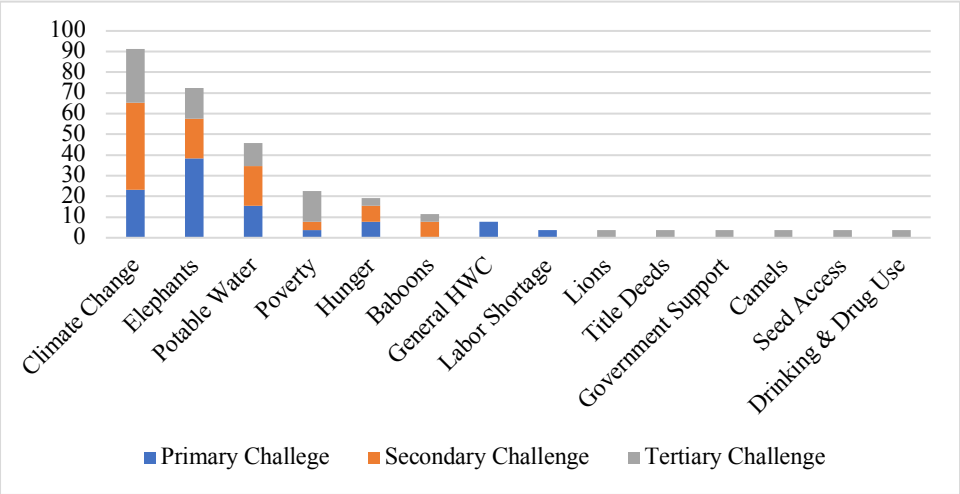
> [Before] not many people were planting . . . So, I would say . . . what has contributed most to the increase of elephants coming in should be actually because of many people planting here. So, elephants could just smell it, some different food here, so they come for that. [6, 6/9/17]

As agricultural activity and elephant populations increased in Lower Sagalla, so did human-elephant farming conflict.

Contemporary Challenges of Farming Lower Sagalla

The farmers I interviewed continue to struggle with human-elephant farming conflict today. To understand how it compares to other issues they face, I asked them to share their opinions about the three greatest challenges currently facing their community. One farmer highlighted the immensity of his challenges, "The challenges are so tiring. Which one should I say?" [9, 6/15/17] A village leader summarized the two biggest challenges of living in Lower Sagalla, "People are doing good in farming, but the problems are elephants and drought." [12, 6/8/17] My survey results substantiated her claim. [Table 1] Overall, nineteen (n=26, 73.1%) farmers reported elephants as one of the community's top three challenges: primary challenge (10, 38.5%), secondary challenge (5, 19.2%), and tertiary challenge (4, 15.0%). Elephants were second only to climate change and drought, which was mentioned by twenty-four (92.3%) farmers. Other top challenges mentioned were the lack of potable (drinking) water (12, 46.2%), poverty (6, 23.1%), and hunger (5, 19.2%). [Table 1]

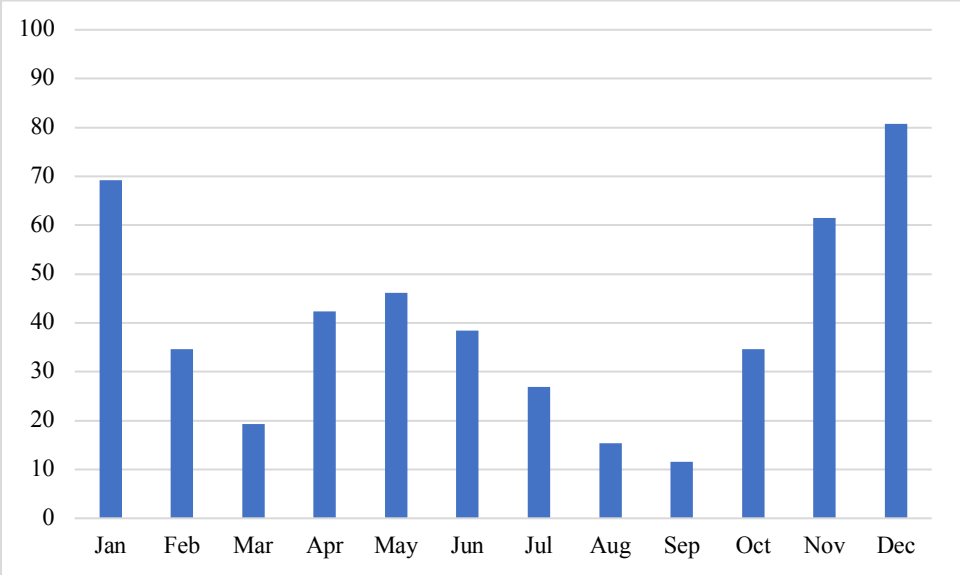
Table 1: Farmer Identified Challenges of Farming in Lower Sagalla (%) (n=26)



Drivers of Contemporary Human-Elephant Farming Conflict

To better understand farmers' experiences with human-elephant farming conflict, I asked those participating in my study during which months elephants tend to raid their farms. The greatest proportion of farmers in my sample (n=26) experienced elephant crop-raiding in November (n=16, 61.5%), December (n=21, 80.8%), and January (n=18, 69.2%). [Table 2] Several observed that the frequency of elephant crop-raiding behavior directly corresponds to the crops they planted. A farmer remarked, "The biggest problem [of elephant crop-raiding] is when we have maize." [6, 6/9/17] This suggests elephants preferentially visit farms during the months when corn is in the field and almost ready for harvest, i.e. November through January.

Table 2: Farmers' Perception of the Months with the Worst Elephant Crop-raiding (%) (n=26)



In addition to understanding when they experience elephant crop-raiding, I also gathered farmers' views on what drives regional human-elephant farming conflict. Commonly mentioned causes were elephant behavior, community expansion, elephant population growth, and elephant malice towards human. I explore each driver in this section. There were no clear patterns between participants' demographics and responses.

Elephant Behavior

During my interviews, farmers shared several ways in which they thought elephant behavior causes crop-raiding. I start by sharing participants' views on elephant foraging behavior. Then, I examine their views on the influence of crop nutrition. Finally, I relay topics farmers brought up: how widespread drought impacts natural forage availability and elephant behavior.

Many agreed that elephants' natural behavior drives them to crop-raid; they enter farmers' fields because they are hungry and looking for food. A farmer remarked, "You cannot

read an animal's mind, but all I know is everybody or every living being needs food, and that is why elephant maybe would come from where it's coming from just to eat food in my land." [2, 5/29/17] Foraging elephants do not know which crops are wild and which are cultivars. Another farmer explained, "Nature is the source of conflict. It's nature of elephant. You know, elephant is a wild animal. Through its raiding, or through its feeding it feeds on the wrong crops." [20, 6/7/17] A third farmer remarked,

> An elephant is just an animal, and it's a senseless animal, an animal without, you know, brain or something. So, an elephant cannot tell that I am going to eat on his farm or whichever farm. An elephant goes anywhere knowing that it's feeding on its food. It doesn't know that it is yours, never . . . when you go there chasing it he is wondering, 'Why this man is pushing me when I am eating my food?' . . . An elephant is so innocent in eating. [17, 6/12/17]

A local expert shared this viewpoint; he remarked, "The animals are innocent and try to avoid people, but they eat what they find, and they don't know that this crop belongs to so-and-so and that he works very hard to get it." [27, 6/8/17] This suggests that when elephants crop-raid they are following their biological drive to forage.

Several farmers elaborated and noted that elephants preferentially eat cultivars because they are palatable. Elephants choose the most flavorful foods; sometimes they happen to be farmers' crops. A farmer explained, "They [elephants] come because of food. And when they come they find it is good food, nutritious . . . They like it." [11, 6/1/17] Another farmer added, "It [an elephant] is just like us. I like eating rice, I like eating *ugali* [maize porridge in Swahili]. So, they also know which crops taste good." [24, 6/7/17]. EBP's Project Leader substantiated this claim,

> They [crops] taste great. It just is yummy. They [elephants] are sentient, amazing animals so they will selectively choose the more delicious food that tastes good on their tongue. They have big taste modules like any of us. So a tomato will taste great, and they will come back for it. They might not be starving to death, but they just like the flavor. [28, 6/23/17]

Elephants are incentivized to regularly crop-raid because crops are appetizing.

Cultivars are not only tasty, but also more nutritious than natural forage. According to a farmer, "Maize is more sweeter than grass . . . peas are more sweeter than, more nutritious. So, they come for the nutrients." [21, 6/10/17] Nutrient deficiencies in their natural diet may compel elephants to seek highly nutritious crops. A farmer remarked, "Elephants come in here because of some deficiency in their nutrition. What they take out there is quite different from the crops that we grow. So, they are attracted by the content in the crops." [6, 6/9/17] EBP's Project Leader shared a similar viewpoint, "Crops are highly nutritious. That's why humans eat them. That's the attractant. And then of course, once they [elephants] have tasted it, then it's a habit." [28, 6/23/17] This suggests elephants may start raiding crops due to nutritional deficiencies but continue out of habit.

In addition, elephants may forage on nutritious crops because drought has decreased natural forage. The vegetation inside the national parks, on which elephants previously relied, is no longer available. A farmer noted,

> There is not enough food inside the park. Maybe that is the reason and sometimes it's very dry inside the park. Maybe they are coming here because of water and there are also some crops, which are not found inside the park and maybe it's good for the elephants. [18, 6/10/17]

Another farmer shared, "You'll find a group of ten [elephants], a group of twenty, but there's nothing to eat . . . they're being pushed to where there is some green land so that they can have some food." [10, 5/31/17] It appears that during a drought, elephants leave the park and enter farmers' fields because they are one of the few places elephants can find nutritious food.

Unfortunately, the crops elephants find palatable and nutritious are the same ones that farmers rely on for their livelihoods. A farmer noted, "Elephants eat everything that the human

being eats." [10, 5/31/17] She later elaborated, "The elephants are there just after the crops, and so I am there to protect my crops. So, we find ourselves conflicted." [10, 5/31/17] Elephant foraging behavior drives them to target cultivars, which oftentimes fosters hostility between elephants and farmers.

Human Settlement

Human activity in Lower Sagalla has also contributed to elephant crop-raiding behavior and regional HEC. Human settlement in the region altered the landscape and made it increasingly difficult for elephants to forage. The most commonly mentioned human-based drivers of elephant crop-raiding were range mismanagement, community location, and human population growth.

Prior to large-scale settlement in Lower Sagalla, some farmers interviewed agreed that community-level range mismanagement set the stage for contemporary crop-raiding. Poor land stewardship (e.g. overgrazing) in the 1950's denuded Lower Sagalla of its foliage. According to a farmer,

> [Before] they [elephants] were not spotted here, the vegetation was plenty. So, they would just feed over there [in the bush land] and that was enough for them. But of today, there is no vegetation. There is no grass because they [the Wasaghala] were doing a lot of burning . . . I had friends who had lots of cattles . . . So, they finished everything, every vegetation. It was cleared. [9, 6/15/17]

He then explained how this has led to rampant crop-raiding today,

> Today there is no vegetation that is putting the elephants away or satisfying them. That's why they're coming to the fields to crop-raid. When we were beginning to farm here, elephants would be spotted, but they wouldn't come to crop-raid . . . But after a while, is when they started now entering into the fields due to lack of satisfaction because there is no longer food for them . . . They [Wasaghala] burned hundreds of acres in the 1950's. There was no range management in terms of keeping livestock. They [the herdsmen and cattle] would just moving, eating everything. So that is what killed the vegetation. [9, 6/15/17]

As the Wasaghala burned the landscape to create livestock pastures they destroyed the foliage on which elephants relied. Without their natural forage, elephants are increasingly driven to forage cultivars.

In addition, elephants crop-raid because Lower Sagalla was established on elephant habitat. A farmer remarked,

> This is a corridor. The elephants . . . have been passing through here . . . They are moving towards this direction to come and look for fodder and, uh, food. So, they normally pass and where we are is their path, indefinitely, since then. [21, 6/10/17]

Another farmer noted, "My farm was placed right on the migratory corridor of elephants. So, every time they are passing there, they crop-raid. It's a behavior for them." [15, 5/31/17] Conflict with humans appears to occur when elephants try to use the landscape in the same manner as before and encounter human settlement. A farmer commented,

> Elephants have no mistake. They should just come and eat as usual because it is their food also . . . I wouldn't put a blame on elephants. I'd put a blame on people who came down because they were living on top and this one was an elephant area. So why did they come down? [8, 6/14/17]

However, this farmer revealed that his opinion is not widely accepted in the community; he said, "I can't speak like that when there are many of us because I may even be chased away." [8, 6/14/17] Although human settlement has played a role in generating regional HEC, it is not recognized in the community, and those who acknowledge it are hesitant to discuss it with others.

As the human population grows, the community "footprint" for infrastructure, farming, and cattle grazing is likely to encroach on more elephant habitat. According to a Mwakoma community leader,

> The population has increased so much . . . through both immigration and birth rate. Currently, I am holding a population of 345 . . . during 1972, we had a population of less than a hundred people . . . around two hundred [in 2007]." [23, 6/13/17]

A similar trend is happening in Mwambiti. According to the sub-chief, "The number [Mwambiti population] is going up . . . we are about seven hundred . . . Ten years ago, there were about five hundred." [21, 6/10/17] The population is not increasing only through birthrate, but also because land scarcity and declining soil fertility in Upper Sagalla drives farmers to relocate to Lower Sagalla. A community leader noted, "Some of them are coming from up there and some of them are born just here." [18, 6/10/17] The population is increasingly rapidly and is unlikely to change.

Rapid population growth in Lower Sagalla has increased the number of farms and caused the community to expand outward. A community leader remarked, "Land is finished nowadays; you cannot acquire new one." [21, 6/10/17] Community members have claimed all land within Lower Sagalla for agriculture and development. A local expert explained the immensity of this issue,

> This place was occupied by wildlife before people. Now people have encroached, and they keep encroaching. There is no control of where people should occupy and where they shouldn't. The animal corridors are literally blocked by homesteads and farms, and the animals are innocent, just roaming the way they used to do one hundred, two hundred years ago when there was nobody. But now the fact that people are building, blocking the corridors. It is them that have really encroached in the home of animals. [27, 6/8/17]

Continued expansion of Mwakoma and Mwambiti may increase agricultural activity and diminish elephant habitat, thus further intensifying elephant crop-raiding.

Elephant Population Growth

In addition to human population growth, the regional elephant population is also increasing. In 2017, Kenya Wildlife Service and Tanzania Wildlife Research Institute found that elephant population has increased 15.1% since the previous aerial survey in 2014 (Ngene et al. 2017). As the elephant population grows, it will become increasingly difficult for them to avoid

conflict with (simultaneously growing) human populations. Increasing human and elephant populations further intensify HEC because they live side by side year-round. EBP's Project Leader explained the unique challenge this presents,

> You have a considerable population of wild elephants . . . living in Taita Taveta permanently. Now, that's quite different that we've got communities living right in with wild elephants. In other cases of conflict, you have elephants passing through or coming out of the park and going back in . . . but we have permanent resident people living with permanent resident elephants. [28, 6/23/17]

As human and elephant populations continue to increase, it is likely HEC will follow suit.

Elephant Malice towards Humans

Dislike of humans may also drive elephant crop-raiding. According to one farmer, "Elephants are very vicious creatures and very strong. They can destroy everything." [5, 6/6/17] Others felt similarly and offered crop trampling and other non-consumptive crop damage as evidence. For example, a farmer shared that although elephants did not eat his chilies, "They break. They step. They don't want us to benefit in anyway because if we plant crops they don't eat, they step on it." [9, 6/15/17] Some farmers felt that elephants are malevolent and consciously choose to harm farmers. For example, one farmer noted, "They have some satanic powers that when you throw stones, it [the stone] sticks near your leg and doesn't go anywhere." [11, 6/1/17] For these farmers, elephant crop-raiding is not caused by natural foraging behavior or complex community dynamics but rather by elephants' drive to terrorize farmers. Threats to personal safety and the resulting psychological impacts may be driving this view of elephants and will be discussed further in the following section. [Impacts of Crop-Raiding]

Changes in Elephant Crop-Raiding Behavior in Lower Sagalla

In addition to understanding the causes of modern-day HEC, I asked those participating in my study (farmers and Elephants and Bees Project personnel) how elephant crop-raiding has changed since Lower Sagalla was settled. In this section I examine the changes they brought up. First, I highlight changes in elephant crop-raiding behavior including increased crop-raiding frequency, larger group size, and decreased fear of humans. Then, I consider spatial changes in crop-raiding. Finally, I discuss how wildlife management and railroad construction have altered HEC.

Elephant Behavioral Changes

Both farmers and EBP's organizational leader acknowledged that elephant crop-raiding behavior has changed since it first became problematic in Lower Sagalla. Over time, crop-raiding frequency has increased. According to an elder, "They [elephants] come every time." [9, 6/15/17] Not only is crop-raiding happening more frequently but elephants are also coming in greater numbers. According to a farmer, "When elephants started coming, they come one or two or three, and you would chase them and they go . . . but of now they come so many of them, and it doesn't matter the time." [22, 6/2/17] Another farmer shared a similar experience, "Now they come in more than ten . . . in a group, and they call each other. One time they came just here more than twenty elephants." [26, 6/1/17] EBP's Project Leader has also observed large groups. She shared,

> What we have seen without question is an increase in the group size of elephants coming in. We used to get lots of singles, ones, twos, threes, but we've seen more recently groups of five and six. It went up to ten or eleven. That's new. [28, 6/23/17]

Although the cause of larger groups of crop-raiding elephants is unknown, she posited an explanation, “They’re nervous or their defense systems have got better and they come in bigger groups, or they’re more nervous about crossing the highway and the road.” [28, 6/23/17]

Regardless of the cause, larger elephant groups are more difficult to deter and cause greater damage. A farmer noted, “Before, maybe you’d hear one elephant has entered in a farm and that’s it. You can just push it because it’s one, but of today they come in big numbers.” [3, 6/16/17] Trying to deter these large groups is dangerous for famers. EBP’s Project Leader remarked, “That’s worrying for the community because that’s much more dangerous.” [28, 6/23/17] They also cause more severe crop damage. A farmer explained,

> Before if they [elephants] used to destroy, say, a quarter an acre. Nowadays, they’re destroying, if you’re not careful, everything . . . They come twenty then another one comes fifteen, another herd seven. So, there are very many. If the first herd crosses, you chase them away. They consume about one quarter. Then another herd comes when you are asleep now. Now everything. [21, 6/10/17]

Lower Sagalla’s farmers bear the brunt of larger elephant groups and more frequent crop-raiding.

Elephants are also becoming bolder and less afraid of humans. A village elder noted, “Elephants have totally changed . . . and don’t care if anyone is there.” [9, 6/15/17] A farmer remarked, “You chase some of them, but some of them are quite notorious. You try to bang . . . but then see them just waving their ears.” [20, 6/7/17] According to another farmer, “They do not even fear people. They harvest my cassavas when I am just right there.” [26, 6/1/17]. Because the elephants no longer fear people, farmers are unable to scare them away and protect their farms from crop-raiding

Other farmers interviewed in this study proposed different explanations for this change in elephant behavior. One attributed the fearlessness to the increase in the elephant population. He noted,

> The behavior is totally different . . .[Before] they [elephants] were scared of people and every time you scare them, they would run away . . . maybe because the population [of elephants] is high, so that is why they no longer fear people. [19, 7/4/17]

Another farmer believed their biology makes elephants fearless:

> If they [elephants] find food in the *shamba* [field in Swahili] they are so stubborn. They don't know what a torch is. They don't know what is a burning equipment. They don't know, and they don't listen. They don't give a damn provided there is food." [10, 5/31/17]

In this view, the drive to forage and crop-raid is so strong that it makes elephants unafraid of humans and deterrent techniques.

This newfound fearlessness is especially pronounced in sub-adult elephants. A farmer noted, "Short ones are the most terrible because they don't hear noise . . . They are most terrible, followed by the ones, which are very huge in size. But, the one who are in medium size run away very fast." [4, 5/30/17] Another farmer shared,

> The weaners, those who don't suckle their mums now, when you beat together the *mabatis* [iron sheets in Swahili] . . . They don't fear people. They just go and smell, maybe water, and they break that house, drink water, and go away. Yes, they don't fear people. [15, 5/31/17]

Their fearlessness makes it increasingly difficult and dangerous to deter marauding elephants.

Sub-adult elephants' boldness drives them to not only crop-raid but also exhibit other novel behaviors. A farmer explained what has changed,

> There must be something changed, or some problem with these elephants because they were small size, and they don't respond . . . when maybe you shout at them or whatever thing you do, they just come up to where you are. [9, 6/15/17]

Another farmer shared his personal experience with the bold sub-adults,

> When I try to lift my fire up, all the adult elephants run away, but . . . young group is left behind, and they do not fear fire . . . That group is the most dangerous because they come towards you. [26, 6/1/17]

Unlike other elephant groups, these sub-adults directly confronted humans.

In their increasing boldness, elephants have started targeting homes as an additional source of nourishment. One farmer remarked, "One time, elephants came and pulled sacks from inside the house that were having cow peas. So, they destroyed the house . . . They tear the *mabati* [iron sheet in Swahili]." [19, 7/4/17] Another shared his own experience,

> They were more than twenty. They broke my house to take eleven bags of maize. I was living in the next house, so it was like a . . . shed for me. And when I came I was almost giving up . . . because they were like twenty, and they were taking all my property. [11, 6/1/17]

When elephants eat grain stores, they endanger human life, destroy homes, and compromise farmers' food security.

Two farmers posited explanations for this behavior change. One believed this behavior originated in 2007 and that elephants target homes because they smell grain inside. He shared,

> There is . . . new behavior. Before they never used to break houses, never, but nowadays they come. They smell that there is some maize inside or some peas inside; they break. If you have some *unga* [maize in Swahili] inside for cooking *sema* [porridge in Swahili], they break. They broke my cousin's house . . . They break when you are in there, so you become terrified. [21, 6/10/17]

Another farmer suggested,

> They are even crop-raiding into the house of someone. All the crops that you've harvested. . . Maybe it's because of scarcity of food for the elephants inside the park and outside, and again, due to scarcity of rain. There's no rain, meaning there's no vegetation, meaning there's no their food . . . It just pushes them to go into someone's house to get food. [19, 7/4/17]

The same factors (e.g. land mismanagement and elephant biology) that motivate elephant crop-raiding behavior may be driving them to target human homes as a food source.

Increasing Spatial Impact of Community

The area impacted by crop-raiding has also increased. Previously, elephants foraged primarily in the bush and only crop-raided farms on Lower Sagalla's outskirts. A farmer shared,

"Long ago they wouldn't spot elephants anywhere near close to them, but they would spot them lower, near the park. They would see the footprints there. But as of today, they are coming even to step here." [9, 6/15/17] In recent years, however, elephants have begun raiding farther into the community. For example, a farmer who cultivates in the middle of the community to avoid elephants was recently crop-raided. She remarked, "I decided to come here because there is a road here. Yeah, I was fearing to stay in the bush there. So, I came to start another one [farm] here . . . They also came." [12, 6/8/17]. Some interviewees reported that elephants have even started climbing Sagalla Hill. According to a farmer,

> Since I was young, I've never heard of elephants trespassing up to the mountain, but it was just recently . . . an elephant was spotted right in the middle of that mountain. An elephant went to crop-raid cassavas and various other crops on one of the farms. [16, 6/5/17]

Another farmer summarized this change, "Every place is theirs [elephants']." [12, 6/8/17] The entire community is now susceptible to elephant crop-raiding regardless of where they farm.

Wildlife Management and the Government

Some participating farmers attributed recent changes in crop-raiding to the creation of Tsavo National Park and wildlife management strategies adopted after Kenya's independence in 1963. At that time, however, the majority of the Taita lived in Upper Sagalla and did not have claims in the lowland (Kasiki 1998). Those who lived in Lower Sagalla were adjacent to Sagalla Hill, which did not become part of Tsavo East National Park. The Taita did not settle in Lower Sagalla in large numbers until the 1980's. However, park management influences wildlife behavior, which in turn impacts Lower Sagalla residents. According to some farmers I interviewed, during colonialism the government killed elephants to manage HEC. A farmer shared,

> Formerly. . . whenever elephants came, and it crop-raided, that particular family, an elephant must die. The matriarch mostly, they [the government] shoot it to death . . . Apart from that we had some white people who came from outside . . . doing business in tusks and all that. So, every time they spotted elephants this part, they were allowed to kill, do their business, take tusks and all that. So, it was so rare for elephants to come this side of game reserve where people settled because they were either taken back or killed. [3, 6/16/17]

However, today hunting is illegal in Kenya. A farmer shared how he believes changes in wildlife management have impacted him,

> But today, it's only managed by national park, which is KWS. There are no people here managing elephants . . . 1980's elephants were just roaming everywhere. Like maybe a rule was given for them to maneuver everywhere . . . up from that time we're living now in poverty. [3, 6/16/17]

Today, Kenya Wildlife Service manages Tsavo National Park. Some farmers believe this change has allowed elephants to roam the landscape uninhibited and target farmers' fields.

The government's management of wildlife has made some feel elephant needs are prioritized over their own. A farmer remarked,

> The colonial government worked more in terms of putting elephants away . . . you wouldn't have seen an elephant . . . After then we got independence [1963]. After now you were given your freedom . . . up to now we are not able to manage our wildlife. We are suffering now. [17, 6/12/17]

He also noted,

> They should just lock them [elephants], so that we won't come into contact with elephants . . . If they say that the park is for elephants or for other animals, then they should close them [elephants] in the park and let human beings live on their side so that they can never come into confrontation . . .They [Kenya Wildlife Service] think that these elephants are starving or something of the sort and they open for them for them to go and graze. They come this side now. That's the problem." [17, 6/12/17]

One farmer bemoaned the change and lack of elephant killing. He said, "There is no one to push the elephants back or do anything, safe guard the interest of the community members. There is no business for the white people [poachers] of today . . . so the number can maybe reduce." [3,

6/16/17] These farmers felt the government has marginalized their community, so elephants can benefit.

Others were concerned the government's Standard Gauge Railway (SGR), completed in May 2017, will increase elephant crop-raiding in Lower Sagalla. The SGR has already altered elephant movement in the region. A farmer remarked,

> Because of the railway, the SGR, most of the elephants are closed within the park, but some of them do come from this side [Tsavo West] and they go and meet the railway gauge. So, they are unable to trespass and get back [to Tsavo East]. [2, 5/29/17]

Another farmer added, "They [elephants] failed to enter into Tsavo East because they were scared of the rails, so they entered into the farms." [10, 5/31/17] Elephants able unable to follow their natural migratory patterns and so are trapped on either side of the SGR.

A few farmers were concerned about the government's lack of foresight in building the SGR. According to a farmer,

> If before the SGR, if before they put the electric fence, they could push back our ellies [elephants] back to their home. Then, they could fence so the ellies could not come back to the people here. It could be so nice. But, I think, the electric fence is there already. So, those ones which are here, maybe they need to go back. They keep on living with people here. [18, 6/10/17]

Some suggest that proper fencing could have prevented this issue. However, some elephants are currently trapped in Lower Sagalla and cannot return to the protected lands of the Tsavo-Mkomazi ecosystem (e.g. Tsavo East National Park, South Kitui National Reserve) because the SGR cuts off historic elephant pathways. Participating farmers were concerned about the future ramifications SGR will have on human-elephant conflict.

Summary of Key Points

In this section, I addressed my first research question by examining the history of human-elephant farming conflict in Lower Sagalla and how it has changed since the Wasaghala began

settling in Lower Sagalla in the mid-1900s. The farmers I interviewed shared that initially the Wasaghala experienced regular conflict with wild predators, but only rarely encountered elephants.

However, over the past ten years human-elephant conflict has become more common. The farmers and local experts I interviewed proposed several drivers that may have escalated this conflict. Elephants may crop-raid because farmers' crops are nutrient dense, and therefore appealing to foraging elephants. Moreover, as farming activity rises and elephant populations grow in Lower Sagalla, the likelihood of elephant crop-raiding increases. Interviewees proposed that the conflict is further escalated by changes in national changes in wildlife management policy following Kenya's independence.

Regardless of the driver, the farmers interviewed agreed that elephant crop-raiding is more problematic than ever before. They reported that elephants now crop-raid more frequently, travel in larger groups, and impact a larger number of farms. Additionally, elephants have begun targeting food stored in homes and display less fear of humans and deterrent methods. Together, these factors have made elephant crop-raiding increasingly problematic; it was considered the second greatest challenge of farming in Lower Sagalla. In the following section I will discuss the different ways in which elephant crop-raiding negatively impacts farmers.

Impacts of Crop-Raiding on Farmers in Lower Sagalla

Human-elephant conflict (HEC) has become increasingly problematic in Lower Sagalla over the past ten years and negatively impacts local farmers. To fully understand the issue, I interviewed farmers about how they have ever been impacted by elephant crop-raiding. In this section I discuss the key themes that I found in their responses. First, I discuss crop damage and

other economic impacts. Second, I discuss how HEC threatens personal safety and the subsequent psychological impacts. Next, I examine how HEC influences community dynamics. Finally, I discuss how conflict with elephants and the lack of resolution fosters a lack of faith by farmers in the Kenya Wildlife Service.

Crop Damage & Economic Impacts

Crop damage was the most commonly reported impact of elephant crop-raiding. One hundred percent of participating farmers (n=26) reported that elephants have damaged their crops through both trampling and consumption. [Table 3] Crop damage is not only a widely experienced impact but also one participating farmers considered very serious. Seventy-four percent of interviewees (24, n=33) listed crop damages as the most severe crop-raiding impact: crop consumption (14, 42%) and crop trampling (10, 30%). [Table 4] The number of responses for crop-raiding impact severity is not uniform because some farmers I interviewed were unable to select only one primary, secondary, or tertiary impact. In this sub-section I explore the ways in which crop damage negatively impacts farmers through loss of income, food insecurity, and lack of access to alternative livelihoods.

Table 3: Farmers Experiencing Elephant Crop-Raiding Impacts (%) (n=26)

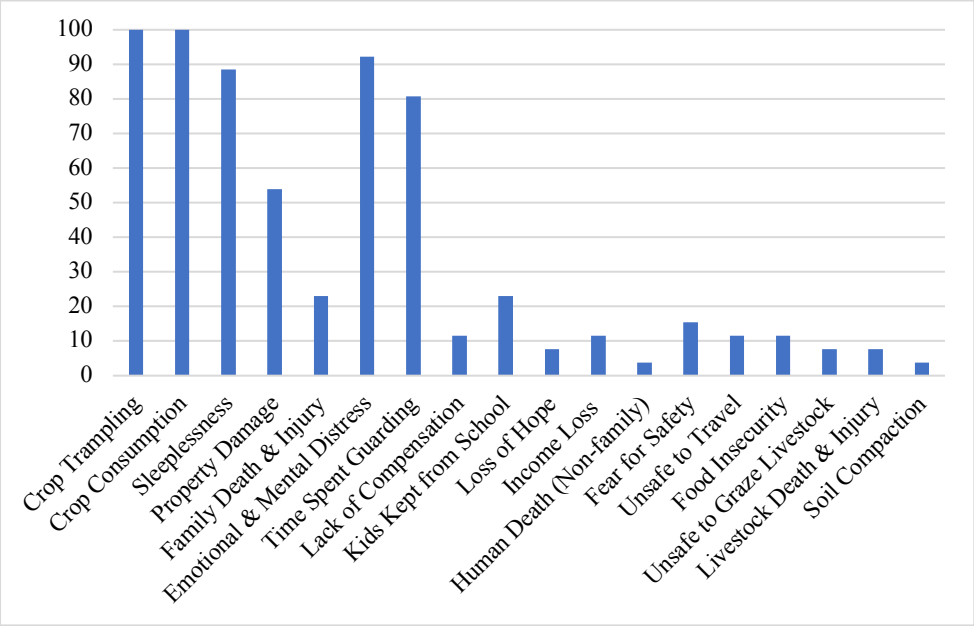
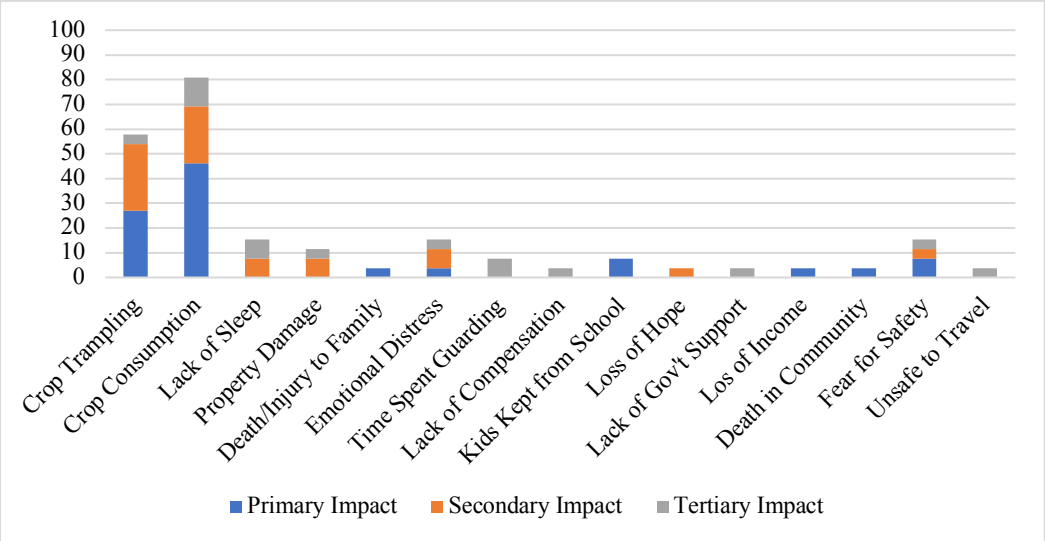


Table 4: Farmer Rankings of Elephant Crop-Raiding Impact Severity (%)



Due to elephant crop-raiding damage (i.e. elephant foraging and trampling of crops), farming is often unproductive in Lower Sagalla, but this has not always been the case. A farmer explained, "[Before] we would plant our crops, and when it was time for harvesting we would

call people . . . to come and buy our crops. I built my house through maize and took children through school." [25, 6/19/17] However, this is no longer possible. He continued,

> But of today, no children are even going to school because they are born at a much poorer level than they were before because there's nothing that's being harvested. The farms have become so much idle; they are at zero level. There's no use; they're just idle land. Whenever you plant, when it's time for harvesting, the elephants are here. They take everything, so we're not benefiting from these lands anymore. [25, 6/19/17]

Another farmer shared his experience, "Elephants are disturbing us a lot . . . I planted about six kilos of green grams; they were all eaten. One time I just fainted in the field after waking up and seeing that happen." [9, 6/15/17] According to these farmers, crop-raiding elephants can destroy an entire harvest.

When they invest in their farms and elephant crop damage prevents harvest, farmers lose money. A farmer shared,

> I planted twenty kilos of green grams. I was expecting to harvest five bags of peas. Each bag of peas can go for ten thousand shillings . . . So, you spend twenty thousand and know that you're going to get fifty thousand; so, thirty thousand on top. But they [elephants] came and they destroyed, so I got two bags . . . I got nothing. [21, 6/10/17]

When farmers continually buy seeds and harvests fail, they lose what little they had to invest.

For many in Lower Sagalla, farming is their primary or only income source. They grow crops to feed their family, and any excess is sold to buy foods they cannot grow (e.g. cooking oil) and cover other expenses (e.g. school fees). Therefore, when elephants damage crops they are unable to earn income to support their families. A farmer explained, "Without land doing well, we are thinking of no other alternative of buying food because we have no money because of poverty. There's nothing to do to have money." [8, 6/14/17] Over time, elephant crop damage and limited income opportunities have created widespread poverty in Lower Sagalla. Another farmer lamented,

> We were farmers, depending on farming crops, which was our livelihood. But now, it's taken. Now people are becoming poor. Poverty is taking everything, but then if there were not these elephants we could be someone. We could be strong. [5, 6/6/17]

Because of limited income generating opportunities, both on and off farm, farmers are unable to break this poverty.

Many participating farmers rely on their crops to earn income and to raise food crops to feed their family; they noted that elephant crop damage has made hunger ubiquitous within the community. A farmer exclaimed, "[Elephant crop-raiding] has increased too much, we are dying of hunger!" [5, 6/6/17] Another farmer shared, "These [elephant crop damages] are the most serious because they are creating hunger. They will leave the people without food. How will they survive?" [24, 6/7/17] Elephant crop damage, coupled with drought, has made hunger increasingly problematic in recent years. A farmer explained, "In 2015, the rains were not enough. It led to harvesting of nothing. 2016, the same . . . Hunger has really hit them hard. They have nothing in their houses to eat and their kids are there." [8, 6/14/17] Elephant crop damage undermines farmers' earning potential and creates widespread food insecurity.

The threat of crop damage necessitates vigilant field guarding to deter marauding elephants, especially at night, which reduces farmers' abilities to pursue off-farm income generating activities. A farmer noted, "When you find that your crops are ready and now you think an elephant might come, you won't sleep. You'll spend the night without sleeping, guarding." [24, 6/7/17] Overall, 88.5% of participating farmers (23, n=26) reported losing sleep due to night guarding. [Table 3] One farmer explained why night guarding is so important, "I will die. What will I eat? I must try to fight. Try to fight. That's why I told you I can't sleep. I can't sleep until the morning time. Just pushing." [17, 6/12/17] One farmer joked, "I can't sleep the way normal people sleep . . . I have to sleep sitting up to make my ears sharp in both

directions. That's why you see I am bald-headed." [11, 6/1/17] Although he joked, the sentiment rings true; night guarding is exhausting work.

The need for night guarding means farmers often do not have the time or energy to pursue other economic ventures. Eighty percent of participants (21, n=26) felt guarding their fields limited their time available for other activities. [Table 3] A farmer explained, "If they [elephants] are there, you have to go and look for means and ways of scaring them away, so you won't sleep. And definitely you cannot sleep during the daytime because you'll be working." [21, 6/10/17] He later elaborated, "You find that there are very many elephants and you won't sleep . . . when the herds are many, then you have to spend the whole night." [21, 6/10/17] When families spend the entire night protecting their fields from marauding elephants, they are often fatigued and must sleep during the day rather than pursuing other economic opportunities or attending school.

In addition, elephants negatively impact herdsmen's livelihoods. The presence of elephants impedes herdsmen's ability to graze their cows, sheep, and goats because it is too dangerous for humans and/or livestock to travel in the bush. A farmer explained, "Herders, sometimes they go to water their animals into far areas, also to graze, but with the increasing amount of elephants they usually herd their animals near their homesteads." [1, 6/2/17] Thus, herdsmen are forced choose between the threat of elephants and poor forage quality. Intense grazing near homes degrades the landscape and creates conflict within the community. A farmer remarked, "That causing other conflicts because you can see livestock belonging to a person going to other people's *shambas* [fields in Swahili]." [1, 6/2/17] Without access to top-quality forage, it is difficult for herdsmen to support large herds of sheep, goats, or cows.

Elephants make farming in Lower Sagalla financially unstable, and a few farmers in my study have stopped growing crops in favor of other livelihoods. One participant shared that he no longer grows crops because, "The elephants came, and they ate everything. Therefore, there was nothing to harvest . . . So, me, I decided to stop farming because of elephants and drought." [24, 6/7/17] He added, "I saw there were risks and decided to stop this business." [24, 6/7/17] Growing crops ceased to be profitable for this farmer, so he switched his efforts to running a small shop, keeping livestock, and grinding grain. Another participant shared,

> Since 2009 I have not farmed . . . It is no longer of any use. In 2011, I tried a bit of farming. All if it was crop-raided. Up to date, I have not tried it again . . . I want to still live a good life. That's why I'm interested now in pursuing livestock. [3, 6/16/17]

Rather than continuing to try and eke out a living with crops, these participants have taken a chance and pursued alternative livelihoods.

Many farmers I spoke with expressed interest in pursuing other economic activities, but few have been able to do so. The main reasons are that they lack the financial capital and resources necessary to pursue an alternative livelihood. A farmer noted, "After . . . having money, God will open my mind to see something else to do." [3, 6/16/17] For others, their access to alternative livelihoods is restricted by their physical abilities. An interviewee remarked,

> My land parcels are just idle . . . I no longer have the capability to do that . . . We are just believing in God because there's no other livelihood we're using. There is no crops. There is no animals. [5, 6/6/17]

A lack of financial capital and physical strength has made it too difficult for many to pursue alternative economic activities.

Personal Safety & Psychological Impacts

In addition, the presence of elephants within the community threatens community members' personal safety, which creates emotional and mental distress. Twenty-three percent of participating farmers (6, n=26) reported that they or their family members have ever been physically injured (e.g. hit with trunk) or killed by elephants. [Table 3] Several felt that the threat to personal safety was not worth engaging with elephants. A farmer explained, "I wouldn't risk my life because at times they [elephants] come." [26, 6/1/17] He later elaborated, "Heart is more important than food. It's not worth it to risk your life to struggle . . . If your heart is taken you cannot find another one like that, but food can always plant next season." [26, 6/1/17] For many farmers, the economic gains of farming are not worth endangering one's life.

Others knowingly place themselves in harm's way to protect their family and livelihood. A farmer shared,

> One time they came right here and they were trying to, you know, destroy this house . . . I told my wife and my kids to run away because it would not be good if I and my kids died in the same place because of an elephant. It's worth for them to go and that I die by myself. I was here fighting with them. I threw fire. Lucky enough, they responded. [23, 6/13/17]

Thankfully, he was unharmed and successfully deterred the elephants from destroying his house.

However, others have not been so fortunate. One farmer had a life-threatening encounter with an elephant while he was recovering from a vehicle accident. He described his experience,

> I was hit by elephants. I died for five months . . . I was in the bush and ran into an elephant. The elephant hit me. I had come from an operation to put metal in my head after getting in an accident . . . So, I was just grazing in the bush. The elephant hit, and the metal came out. So, I had to go again to the hospital and the metal had to be removed . . . I died for five months and came back to life. [9, 6/15/17]

Another farmer shared his dangerous encounter with elephants,

> The first time that I was attacked, or almost killed by an elephant . . . I just went to fetch water and was coming with my wheelbarrow. Though it was a bit dark, and I couldn't

> spot an elephant . . . There was a mother elephant somewhere here with a baby. And I came straight to the elephant without knowing. So, the elephant, after seeing me, at a very close distance, decided to react. It came running at a very high speed to me . . . It ran close to hitting me . . . It missed, and it hit the ground. The elephant was quite angry because after hitting the ground it started making the noise, trumpets and all that. I was quite confused and didn't understand what was happening. So, I just ran unknowingly where I was running. I ran. My mind was blocked. My eyes, I didn't see anything . . . My ears were blocked. After arriving here, I didn't even know I was in my house. [16, 6/5/17]

Although they have recovered, these farmers continue to carry physical and psychological scars from their confrontations.

Unfortunately, not everyone survives an elephant encounter. In recent years, elephants have killed several community members. A farmer explained,

> Some people have actually been killed by elephants . . . three or four cases of dead, killed by the elephants. In all those cases, I think, these guys encountered the elephants accidentally . . . on their way to home, but one of them was killed near his house . . . He was chasing this elephant . . . There was another one he didn't know about [that killed him]. [6, 6/9/17]

In 2017 elephants killed a Lower Sagalla resident. A farmer shared,

> A lady tried to chase them [elephants] but then she got stroke or heart attack, and she died right on the doorstep of her house because of elephants. She walked out trying to light fire to put them off, but to her surprise there were so many, and she decided to die because of that. [26, 6/1/17]

Although infrequent, fatal confrontations between community members and elephants do occur.

Consequently, farmers felt unsettled by elephants and reported that it negatively impacts their psychological health. Ninety-two percent of participants (24, n=26) noted that elephant crop-raiding has caused them emotional and mental distress. [Table 3] For one farmer, it was the most severe impact. [Table 4] In this section I discuss the most frequently mentioned types of emotional and mental distress: fear for personal safety, powerlessness and hopelessness, and anxiety.

Fear was the most commonly mentioned psychological impact. Two farmers considered it the most severe impact. [Table 4] I asked farmers to explain why they were afraid. A farmer remarked that when elephants are around, "You can die any time." [23, 6/13/17] Several farmers perceived elephants as antagonists that intentionally harm humans. A farmer noted, "If you make noise, at times it's like you are singing for the elephant to continue eating. And at times, it can come for you." [11, 6/1/17] He later added, "Sometimes there is nothing, but they just want to remove you." [11, 6/1/17] Even when there are not any crops, elephants still visit farms and endanger community members.

Elephants are an omnipresent threat to safety and security during the growing season. A farmer shared her experience,

> We are used to one, two elephants . . . but today you'll find twenty elephants in the *shamba* [field in Swahili]. So, everybody is scared. Like I have my group here. They feared down there . . . It's scary to live with elephants because that is somebody you cannot fight. [10, 5/31/17]

For one farmer, his fear is so great that it freezes him on the spot. He explained, "I cannot throw [a stone] when an elephant is looking at me direct. The stone cannot reach." [11, 6/1/17] Farmers feared for their personal safety and felt unable to protect their families.

Some farmers seek refuge inside their homes when elephants crop-raid. One farmer remarked, "You run to the house and sleep and save your life." [14, 6/15/17] Another farmer shared a similar view,

> For now, I'm doing nothing to put elephants away from my farm. The reason being is that the elephants have become notorious . . . There are now two hundred elephants getting my land. I don't even dare walk out and go to the loo or try chasing them. We just lock up the house and remain inside for our safety." [25, 6/19/17]

The presence of elephants in the field caused such terror that they were too afraid to go outside to perform vital human functions.

Even when inside, some farmers were afraid and worried elephants would wrench them from their homes. A farmer remarked, "When you stay in a house like this one you fear . . . You think it [an elephant] may come and collect me inside here." [12, 6/8/17] Although farmers knew their crops were being consumed and livelihood jeopardized, for some their fright was paralyzing and prevented them from trying to deter the elephants.

Some participating farmers also shared feelings of powerlessness; they felt unable to prevent crop damage due to elephants' large size and imposing presence. A farmer remarked, "It is an animal that you can't even chase . . . it goes on itself because it is a very big animal . . . I can't do anything for it." [12, 6/8/17] A farmer summed up the challenge, "If I continue fighting with the animals, trying to grow the maize and fighting with them. I won't end up anywhere." [21, 6/10/17] These participating farmers recognized the futility of farming where elephants live but felt unable to prevent elephant crop damage.

The struggle against elephants is exhausting, and several farmers felt hopeless. A farmer shared, "It's because of elephants . . . In 2015 they brought damage to me, and they broke my heart." [4, 5/30/17] This sentiment was shared by a farmer who lost his harvest to elephants, "I felt like I had better die I was so upset." [11, 6/1/17] He later added, "It's just because of old age that I have no more strength to fight." [11, 6/1/17] In the face of this struggle, several participants felt demoralized. A farmer remarked, "Whether they [elephants] go or whether they stay, that's their problem. I go in and sleep. If they refuse, what do you want me to do? Go push them out?" [5, 6/6/17] She also noted,

> You can do nothing to keep an elephant away so long as it has set its mind. Whenever it comes making those noises . . . You'll tend to light. You'll tend to make noise, but none of it works. It will come into the land and start eating. Now the problem comes whereby it's eating you've made lots of noise. You've lost voice. You bang the pots, everything, and it's not moving. Plenty of times people do shout. Shouting until the shout becomes a

> cry, and they cry again . . . They cry until there are tears, it's over. As in, you no longer have tears for crying of your food, your crops. [5, 6/6/17]

The despair caused by elephant crop-raiding is so extreme that some are unable to cope with daily life. A farmer shared how his wife responded to a serious crop-raid,

> She really cried. She was totally stressed. She was almost even killing herself because now all we have been doing and we have spent is just gone for waste. I was just talking with her and just motivating here . . . My wife just slept the whole day for several weeks without doing anything. [23, 6/13/17]

A farmer was similarly despondent, "I am living in poverty . . . They [elephants] have taken my dream, my goal." [3, 6/16/17] In the face of increasingly severe crop-damage some farmers felt they have lost everything.

Some farmers expressed acute anxiety about their future security due to elephant crop-raiding. A farmer summarized her anxiety, "How wouldn't you be stressed if they [elephants] took your food for the year or for two years?" [4, 5/30/17] Crop loss means not only reduced income but also food insecurity and an inability to meet nutritional needs. Two farmers reported lack of food security as a severe crop-raiding impact. [Table 3] One commented, "The kids at that time were coming even home and so there was no food for them." [9, 6/15/17] Another farmer shared,

> Thinking of your life in a couple of months to come. Or your kids and family whereby they won't be having anything to eat or consume and you did your best, maybe planting, but you did not harvest because of elephants. [2, 5/29/17]

This farmer and others worry their best efforts will not be enough to feed their families.

This anxiety is so great that it has motivated some farmers to consider illegal income sources. A farmer explained, "There is no livelihood for us. It's only farming, maybe asking for money from our children. Burning charcoal . . . it comes to that at times. If you're arrested burning charcoal, you're locked in." [20, 6/7/17] He was desperate for food security. Another

farmer explained, “We don’t need cars, it’s enough to have food. We don’t need so much.” [5, 6/6/17] To overcome their anxiety and despair, even a small increase in food security would be enough.

Impacts on Community Dynamics

Additionally, the fear and danger that participating farmers experience negatively impacts community-level dynamics, including childhood education, travel, and social lives. The most commonly mentioned negative impact was on childhood education. A farmer remarked, “It affects even the kids from going to school.” [20, 6/7/17] Twenty-three percent of participants (6, n=26) have experienced children being prevented from attending school due to the presence of elephants on the road. [Table 3] Two farmers considered it the most severe impact. [Table 4] A farmer explained why this occurs,

> They [elephants] prevent school kids from going to school, mostly last term [during harvest season] . . . If the elephants are maybe moving away, then you stop and wait . . . If the elephants maybe are grazing, then you have to use a different route. And when you get late to school, you are caned. [22, 6/2/17]

When the children eventually arrive at school, they have often missed classes and are disciplined for their absence.

Over time, the continued absence and tardiness caused by elephants has eroded the community’s overall education level. A farmer explained the problem,

> Now the kids are not even going to all the classes. They are stuck in one class [grade] because if it is January then the elephants come . . . The kids will not go to school during that month. Then, you can’t proceed to another class [grade] without completing your syllabus. So, the kid keeps on becoming class one forever. [25, 6/19/17]

Elephant-caused absence prevents students from progressing through school. A farmer who ranked childhood education as the most serious human-elephant conflict impact explained,

> We are long suffering of the lack of education, which has really dragged the community behind . . . Due to the elephants preventing kids from going to school maybe one or two times . . . the kid will be dragged behind in terms of education. They are already behind. If there is a way that the elephants can be put away so that the kids can study in harmony, in peace. It can be really nice. [4, 5/30/17]

Continued absences and tardiness make students fall behind.

They are unable to prevent elephants from entering Lower Sagalla, so the community has implemented strategies to address elephants' negative impacts on education. A village leader explained,

> [Elephants] have tampered the school time table . . . They [students] are supposed to report at six in the morning, but because of the frequency of the elephants . . . kids are supposed to report to school near seven. Therefore, the timetable for schools is disturbed . . . Also, they have to leave school early. [1, 6/2/17]

Although this approach reduces the danger individual students encounter traveling to and from school, it cannot prevent and may exacerbate education gaps between students in Lower Sagalla and other parts of Kenya.

Elephant crop-damage also renders many families unable to afford school fees in Lower Sagalla. Even if students are able to travel to school in relative safety, severe crop-raiding and the subsequent income loss can render a family unable to pay school fees. One farmer sold her dairy cows to pay her son's school fees. She remarked, "He is still asking to go for college . . . but I have no money to send to college." [9, 6/15/17] When families are forced to choose between food and education, school fees go unpaid and children are uneducated. A farmer explained the challenge many families face,

> We are financially poor. Most people do not have income . . . So, most people rely on these casual jobs . . . Whatever little they get, they buy food . . . And imagine maybe you have children, it's quite a headache. [6, 6/9/17]

These difficult trade-offs make Lower Sagalla' children fall even more behind academically.

Elephants also directly inhibits participating farmers' ability to travel and perform daily tasks. Three participating farmers have been unable to travel due to elephants. [Table 3] One farmer has repeatedly met elephants on the road near his home when fetching water. He shared a recent experience,

> I was going to fetch water . . . an elephant was there [the road], but I didn't spot it. So, when I came close to that elephant is when I saw the elephant also coming towards me. So, I decided to take one of the jerry cans and throw towards the elephant. And I also maneuvered myself as I moved towards the fence of Sagalla Lodge, and I ran . . . Later when I came back I found . . . the elephant had thrown the jerry cans all around. [16, 6/5/17]

Rather than risk encountering elephants, some reported they spend the night with their neighbors when they know elephants are present on the road. A farmer summarized, "Sometimes you sleep with your neighbor and you don't reach your home." [15, 5/31/17] Another farmer noted, "One time my wife slept at a friend's house because of elephants." [16, 6/5/17] The fear of encountering elephants on the road deters residents from traveling throughout the community.

The difficulty of travel also discourages socializing. Farmers noted that they do not spend much time at social meeting places when elephants are present because it is unsafe to travel after dark. According to a farmer, "Especially walking at night . . . so you have to leave for your house early, not late. If you are found late going back to your home . . . maybe, you'll meet them [elephants] at that hour." [24, 6/7/17] People have to return home early in the evening lest they encounter elephants on the road. A farmer elaborated, "They [elephants] not giving humble time for the drunkards . . . The drunkards are no longer staying for so long. At seven they have to be in their houses because the elephants are roaming around." [8, 6/14/17] The threat of elephants limits community member's opportunities to socialize with neighbors.

Lack of Faith in Kenya Wildlife Service to Resolve Human-Elephant Conflict

In addition to directly influencing life within Lower Sagalla, human-elephant farming conflict also negatively impacts perceptions of and relationships with the Kenyan government, especially Kenya Wildlife Service. A farmer noted, "The government has seen there is more benefits to this animal [elephants], more than even people." [25, 6/19/17] Several farmers believed the government has prioritized elephants over rural communities because elephants are free to damage farmers' crops and livelihoods without consequence. Moreover, they felt they have not been fairly compensated for income lost to elephant crop-raiding. A farmer bemoaned, "If people love animals so much, they should go farm for them so that they can eat and leave us alone." [11, 6/1/17] He elaborated,

> What is the love of elephants or any other wildlife creature? What is the value of it? What is the value that is making it be so much more important than anything else? Because right now I feel like elephants are more important than me, according to the government or anyone else. Because if a neighbor's cattle or cows come inside my land today, and I went reporting them to the chief or any other authority. I could be sure of payment . . . Why there no payment when it comes to wildlife? [11, 6/1/17]

Another farmer emphasized the government's seemingly preference for elephants over poor farmers because of the protection of elephants in Tsavo East National Park,

> If right now I went through here and entered the park, I would be arrested and locked in for two years. One for entering the land, the other thing for trespassing . . . Why is it so hard for the government to take action for an elephant which goes through the boundary, enters the farm, and eats his crop . . . Human beings have totally been forgotten. There is no one looking after our interest. There is no one hearing our cry. Everybody is hearing the cry of the elephant. Every is now focusing only on elephants. [3, 6/16/17]

They felt elephants belong to the government and believed the government should compensate farmers for elephants' damages.

In addition, some farmers I interviewed asserted that only the government benefits from elephants and cited safari tourism as an example. A farmer noted, "They [elephants] have to stay

around because you know some people come from Europe, they come and see and give us money. Now if you kill, that's the end of it." [21, 6/10/17] Another farmer shared, "It [elephants] is their [the government's] bank. So, if they continue shooting it, it's like they're killing their bank." [25, 6/19/17] He later added,

> Traditional methods whereby we use arrow and bow . . . It's not a sustainable method because now yes we will kill them, but what of the visitors who come from outside to only see these elephants? What of the revenue that the government is generating? [25, 6/19/17]

Farmers felt elephants' only value is as the government's financial resource.

Even community leaders interviewed in this study felt unsupported by the national government and Kenya Wildlife Service (KWS), which has fostered a negative rapport between Lower Sagalla and the Kenyan government. A community leader explained,

> Those KWS, when I call them, they are saying there is no vehicle . . . You feel negative, and there is a negative attitude that may develop . . . And even if you meet them, you see these people knowing they are civil servants and you are working together. But what are they doing, you develop a negative attitude. [21, 6/10/17]

Elephant and Bees' Project Leader echoed this sentiment; she remarked,

> They [community members] don't benefit in any way from the park. I'm not even aware of one member of the community having a job in the park. So, um, that's probably a contributor to HEC. The lack of tolerance because of a total lack of any support [from KWS]. If 30% of the youth are employed by a lodge in the park, there's a little more tolerance . . . I don't see anyone being employed from our community. There's nothing coming from the gate fees. [28, 6/23/17]

She later added,

> Often in these communities, KWS has built a school or built a well or something. The only thing that KWS did was build that huge water pan that pulled all the elephants in . . . The community asked them for boreholes and they came in and dug a big hole . . . It has created more conflict. [28, 6/23/17]

Rather than addressing community members' concerns, KWS's misguided attempt to help Lower Sagalla further escalated human-elephant conflict.

The government's lack of responsiveness has exacerbated the pain of elephant-caused mortality. The government promised compensation, but families never received recompense. A village leader explained the situation,

> The problem caused by elephants is only that they have killed people . . . It is almost ten people in some five years back to now. And we are told that they would be paid for, and we are not up to now. We just hear of them saying they'll look for the people, but it comes to happen that they are not even paid for anything . . . Every year they [elephants] come, they kill. Even last year they killed a woman . . . I don't know how we can help. [12, 6/8/17]

The lack of government support intensifies feelings of helplessness, fosters animosity towards the government, and causes feelings of abandonment. A few farmers feared the government will continue to ignore their community and felt culling elephant herds is the only solution. They feared to do so themselves because it is illegal. A farmer explained,

> They [community members] can do [kill an elephant], but they fear . . . That's why they call KWS when they hear of elephants. They [KWS] are told by people, 'If you can't make a way to send the elephants away, then we use former techniques.' And they [KWS] fear also their elephants to be shoot. So, they fear. Because if people take their own responsibility to shoot them, they can do . . . People fear only to be in prison. [12, 6/8/17]

However, others are ready to take care of matters themselves. A farmer remarked,

> It is time, an eye for an eye. I will take action because the government, every time they say, if you see an animal don't kill it . . . Then why is it killing me? It's just time, I will kill it . . . How do you expect me to be friends with animal? [11, 6/1/17]

He also noted, "KWS isn't doing anything, just waiting for their incomes, while the farmers are suffering." [11, 6/1/17] This farmer and others are desperate for government action and relief from human-elephant conflict.

Summary of Key Points

In general, the farmers I interviewed felt that elephants negatively impact their livelihoods and communities. Crop damage undermines farmers' economic and food security. Fatigue caused by vigilant field guarding and income lost to crop damage has rendered many farmers unable to engage in alternative economic pursuits. The presence of elephants also negatively impacts' community members' psychological health, childhood education access, and ability to travel and socialize. Together these stressors have made the farmers I interviewed lose faith in the government to resolve these issues and made them desperate for solutions to human-elephant farming conflict. In the following section, I examine the different strategies that Wasaghala farmers have utilized to manage elephant crop-raiding on their farms.

Human-Elephant Conflict Management

I asked the farmers I interviewed to describe which strategies, if any, they employ to reduce the negative impacts of elephant crop-raiding. They noted that deterrent method popularity has changed over time. In this section I discuss historic management of human-elephant conflict in Lower Sagalla through traditional cultural ceremonies and killing elephants. Then, I examine why the farmers I interviewed have largely discontinued these practices. Next, I report the deterrent methods used by farmers in my study. Finally, I explore how they selected their elephant deterrent strategy.

Traditional Human-Elephant Conflict Management

Historically, Wasaghala, the ethnic group who lives in Lower Sagalla, utilized several methods (e.g. clapping, homemade firecrackers, and burning dung) to deter crop-raiding

elephants. From my interviews, I found the two approaches most commonly utilized were religious ceremonies and killing elephants. In this section I describe each strategy and then explain why it is no longer widely practiced.

The Wasaghala practiced traditional religious beliefs that influenced every aspect of daily life, and several attested that traditional religious practices successfully influenced life in Lower Sagalla. For example, a participant explained how traditional religion governed the rain, "You won't imagine what they were doing, but it was working . . . We had even rainmakers then . . . So, it could not happen the way it has happened now, two seasons with no rain." [6, 6/9/17] Another participant elaborated on the rain ceremony's details,

> The old mens before they would sit down. One of them would say, 'Today, Sophia, she is the one who is going to give the goat or the sheep for celebrating our culture.' And when they come to you, you have to give that goat or sheep, whatever they ask from you without payments. Then, they go and do culture and from there we receive a lot of rain. [18, 6/10/17]

They depended on religious leaders and ceremonies for good rains and successful harvest.

Similarly, the Wasaghala relied on religious ceremonies to manage human-elephant conflict (HEC). When elephants caused problems, religious leaders collected dust from an elephant footprint and used it during a religious ceremony to prevent the elephants from returning. This traditional approach to managing HEC is referred to as the "footprint method". A farmer explained the basics, "Our forefathers would pick, you know, those footprints. They pick those footprints then they go somewhere, they burn some herbs, somewhere in the bush down there. Then, those elephants disappeared." [21, 6/10/17] Another farmer shared her family's involvement,

> My grandfather and various other people . . . they collected dust of the footprint of an elephant, and they used this small container . . . The wooden container is mostly round in shape . . . They put that dust in there, and they go up to near where the railway station is,

> near a certain mountain . . . and do traditional chants and things. Then, elephants would not be spotted again . . . and people would plant and harvest. [4, 5/30/17]

After performing the ceremony, elephants left, and the Wasaghala farmed successfully.

Although the footprint method was central part to Wasaghala culture, its details were confidential and only known by religious leaders. A farmer explained, "There's no talking of that to your wife or to no one. It's quite secret." [23, 6/13/17] Only a few leaders performed the ceremony; "the people who are allowed to do this are the most elderly, the most respected." [23, 6/13/17] A farmer explained, "Our grandfathers . . . they used to sit down and make culture methods using some medicines . . . There were special mens who were doing that." [18, 6/10/17] Therefore, few participants knew details about the footprint method. However, one community leader had observed the method and elaborated:

> They would just scoop a bit of soil as to where the elephant has stepped . . . After scooping, they put in a wooden small pot . . . After they put it, they go and maybe call the community leaders, the *wazee* [elders in Swahili]. And after calling them, they would first of all dine and maybe drink the bitter herbs, the traditional brews . . . And after drinking, they would do their things. Maybe one or two elders would pray on it [footprint soil] or spit on it . . . Just blessing this elephant away, not to come back . . . So, after they do that . . . they select two or three people again to take that container to where they need this elephant to be. Mostly they would take it to the park. So, they would go, step by step up to the park and find somewhere . . . Maybe a hole mostly . . . So, they would put it there and do their rituals a bit, maybe spit on it or something of the sort and then cover it . . . step on it, like stepping on him to stay there. And they would face back to where their homes are, to where the party was . . . so they will not face back again because it's like remembering that elephant . . . You face where the meeting was and go straight, straight to where the meeting is. So, you go and tell the *wazees* [elders in Swahili], 'We have taken that thing, that elephant, we have put him safe back to where he needs to be.' So, the *wazee* [elders in Swahili] will bless now everything . . . They would sit down and be given drinks and just celebrate and be having their own talks. [23, 6/13/17]

The Wasaghala relied heavily on the footprint method to manage HEC for decades. The method was considered effective, but it is important to note that at that time elephant and human populations were lower than today, so the potential for human-elephant farming conflict was also reduced.

Religious leaders passed down the ceremony from one generation to the next. However, the footprint method is no longer practiced, and its institutional memory on its specific mechanisms has been lost. A farmer shared,

> No one does that [footprint method] because even no one knows the roots of this tree, the leaves of this one, if you mix, you burn. No one knows . . . Those days you used to have a local god . . . It's not practiced, but now even people are talking, saying our fathers, our forefathers used to do that. Now there is no one who can tell us to do that. [21, 6/10/17]

Without this vital information, the Wasaghala are unable to implement the footprint method.

Several farmers I interviewed attributed this loss of knowledge to Christianity. The spread of Christianity in Kenya began in Mombasa in 1844, and the Wasaghala first encountered Church Missionary missionaries in 1883 (Anglican Church of Kenya 2009; Redmayne 1978). In an effort to spread their religious beliefs, missionaries undermined and vilified traditional beliefs and practices (Bell 1995). A farmer shared his view of missionary influence on the Wasaghala,

> Now they [elders] are dead so the system is not working . . . because of religion. Religion [Christianity] came here telling people, 'This is bad; this is bad. Doing this, you not go to heaven. You'll suffer after this.' So, people became scared and left the [footprint] method. Nowadays we are suffering. But nowadays, all methods are gone. No one knows how our grandfathers had been doing. No one. They went with everything. [18, 6/10/17]

Another farmer similarly remarked,

> First and foremost, what died or killed this method was religion [Christianity]. After the introduction of Christian religion, it really sweeped away most of the traditional practices and beliefs. And now their forefathers tried to talk to them of this, but they did not hear. They tried to follow more on Christian religion, believing God. But they believed in that, and after believing in that [Christianity], the old men died and passed away with the knowledge that would have been passed to them. But then they died with that knowledge and were buried with it. [4, 5/30/17]

Due to pressure from missionaries, the younger generation turned towards Christianity, and traditional religious leaders died without passing on their knowledge.

Some farmers believed that the loss of traditional knowledge was purposeful. They posited that traditional religious leaders viewed the new generation as unworthy due to

unsuitable lifestyle choices and chose not to pass on cultural knowledge and practices. According to a farmer,

> That knowledge needed people who are very strict in life. For example, there are some things that you shouldn't do. The do's and don'ts were so many. The lifestyle, the old lifestyle is not as the new one . . . For example, . . . you shouldn't drink, and these ones are always taking drinks, they're abusing, in fact. So, they cannot qualify. [6, 6/9/17]

Others noted that even with detailed instructions, the ceremony cannot work without community-wide belief. A farmer explained, "It can't work when you are only one, the other people are not believing. It's done when everyone wants to do it, and everyone is believing. That's why it's not working [today]" [9, 6/15/17] This loss of knowledge and belief has rendered contemporary Lower Sagalla unable to utilize their own culture.

A few participating farmers believed the cultural loss is responsible for the community's suffering. A farmer remarked, "We are left with no knowledge of that [footprint method], and we are suffering. It's a painful suffering, which we deserve because we did not follow our forefathers' ways." [4, 5/30/17] She later elaborated,

> "The moment when the traditional men passed away . . . was then that the method ended. So, elephants are now here . . . My mother is the one who told me stories about how my grandfather was a leader of this community and of how he practiced this thing. And my mother told me, 'You guys are going to suffer because your grandfather died and didn't pass this knowledge to any people.' Maybe because of religion, because people went to churches . . . We are really going to suffer." [4, 5/30/17]

This farmer and others believed the community would continue to suffer because they abandoned their culture.

Several farmers lamented the loss of the footprint method and cultural knowledge. According to a farmer, "That [footprint] method was good, and it was not harmful either to them or to the elephants, but the problem is that there is no one of today that I can think of practicing it." [14, 6/15/17] Even those who want to revitalize the footprint method cannot do so because

the knowledge is lost. A farmer bemoaned, "We have held a series of meetings to try and see if there is anyone who can come up or who knows of what was happening. But of now, not yet." [14, 6/15/17] Others felt that traditional practices could help heal the community. A community leader commented,

> The problem is attributed to education, which has killed that culture [footprint method]. Everyone is rushing and saying, 'We are in digital era,' whereby they don't need traditional things or traditional beliefs. But if only they needed it, or if only it was being practiced, then the nation is healed. I mean almost every problem is solved through traditional ways. [23, 6/13/17]

A few farmers believed reviving local culture can bring the community together in the face of severe HEC.

In addition, the Wasaghala historically managed HEC by killing elephants. A farmer noted, "The method that our forefathers used was to shoot, to kill them. And they would even shoot and sell ivory because it was allowed." [11, 6/1/17] Another remarked, "Before they [the ancestors] used to kill one, which was allowed by the government. Before they used to kill one in a group, and the rest would not come again." [22, 6/2/17] Killing one elephant in the group, usually the largest, scared the others into not returning. A farmer explained,

> When you kill an elephant, others won't come . . . These animals, they behave like people . . . They know this place is not safe. Why? Maybe the biggest has been killed. So, the one who is to lead others there will come and say, 'Oh somebody is dead. No! No! No! No! This place is not safe.' They just move away and fear that area. [21, 6/10/17]

The account of a recent poaching incident supported this claim. A farmer shared,

> There was a time when an elephant was killed in the bush just there . . . a poacher used an arrow . . . There were three elephants, big ones. The male one was killed, the other two ran. They had that habit of passing through and there were also others . . . Now when those two ran, they never came back again . . . The big number never came back through. [21, 6/10/17]

According to participating farmers, killing an elephant scared other elephants in the herd from crop-raiding again at the same location.

Killing elephants is no longer practiced by participating farmers. A farmer remarked, "They used arrows, but right now if you try, you are locked [up]." [5, 6/6/17] Changes in legislation made killing elephants illegal. Today, elephant poachers face serious legal ramifications. A farmer shared her family's experience,

> Using weapons, traditional weapons, *panga* [machete in Swahili], arrows, and bows . . . Myself I don't use, but my brother-in-law used to use them . . . But nowadays because of KWS [Kenya Wildlife Service], they are barred, they have thrown them away. Because when you are met with a bow and arrow, you are put in prison. [12, 6/8/17]

The fear of imprisonment deters elephant killing.

However, a few participating farmers insinuated that KWS sometimes kills elephants to manage human-elephant conflict. A farmer noted,

> KWS would be called and shoot one elephant in a group and the rest would walk away, smelling of their immortality not to return again. That method was used before, but I saw it used of late, in 2010 and 2011. Whereby an elephant was shot . . . one elephant and it was shot by KWS . . . I was one of those who benefited. I ate the meat. KWS took the tusks and told us to eat the rest of the elephant. [22, 6/2/17]

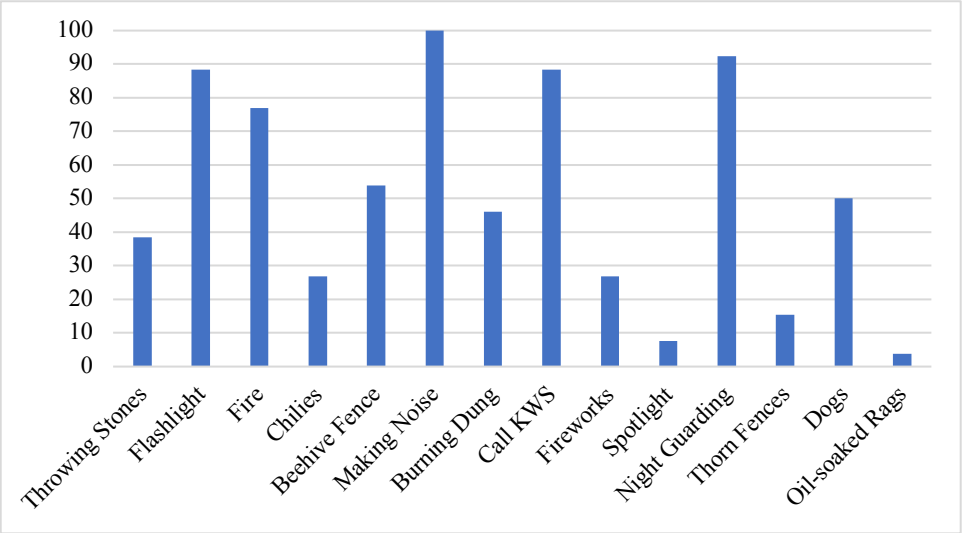
Another noted that killing elephants is not only illegal but also an unsustainable deterrent method. He remarked, "Obviously the elephants will eventually be over . . . It's not a sustainable method and should not really be used . . . Generally, it's not really a good thing." [25, 6/19/17] In addition to being illegal, killing matriarchs could decimate Kenya's elephant populations.

Modern Elephant Deterrent Strategies

To understand how the farmers I interviewed manage contemporary elephant crop-raiding, I asked them which methods they currently use to deter elephants. Rather than relying on religious ceremonies and killing elephants they now use a wide variety of methods. One hundred percent of participants (n=26) reported making noise by shouting and banging on iron sheets to scare away marauding elephants. [Table 5] As a close second, 92.3% of participating farmers

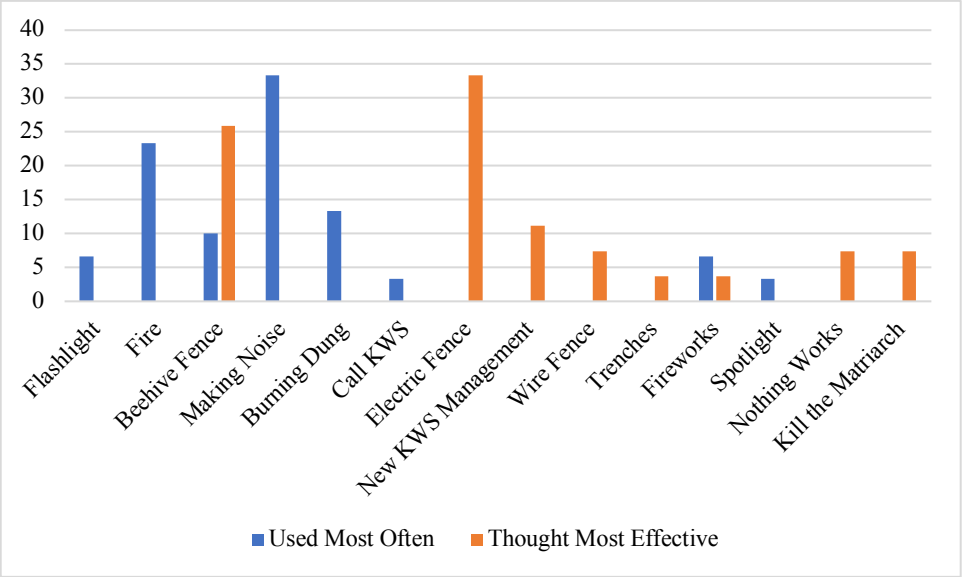
(24, n=26) utilized night guarding. Calling KWS, illuminating flashlights were tied for third most-commonly used method; each was utilized by 88.5% of participants (23, n=26). Twenty farmers (n=26, 76.9%) used fire.

Table 5: Farmer Usage of Elephant Deterrent Methods (%) (n=26)



Next, I asked which method they utilize most frequently to deter elephants and which they believe are most effective at deterring elephants. I interviewed twenty-six participating farmers, but the sample size differs for these questions because a few participants were unable to select only one method as the most frequently used or most effective. Making noise (10, n=30, 33%) and fire (7, n=30, 23%) were the most commonly used elephant deterrent techniques. [Table 6] Burning dung was the third most popular elephant deterrent technique (4, n=30, 13%). To understand why making noise, fire, and burning dung were so widely used, I asked farmers to explain how they chose their elephant deterrent strategy. In this section I discuss the most widely reported reasons: method reliability, financial accessibility, and lack of other options. I discuss perceived method effectiveness in the following sub-section.

Table 6: Farmers' Most Commonly Used Deterrent Methods (%) (n=30) and Perceived Method Effectiveness (%) (n=27)



Several participating farmers chose elephant deterrent strategies based on their own previous success. To qualify as an effective strategy, elephants leave and do not return. For example, one farmer explained why she uses flashlights to scare away marauding elephants, "When you light torch at night, then they go away very fast. I don't know why." [15, 5/31/17] Another farmer relied on light as well. He shared, "When my crops are ready, I have to leave the [flood] light on over the night . . . Elephants when they see that there is light, they don't like coming close." [24, 6/7/17] Previous success motivated farmers to continue utilizing their deterrent of choice. A farmer who relied on banging iron sheets explained that she chose

> Banging equipments, because it's the nearest. And that would scare the elephant if it is down there in the *shamba* [field in Swahili] and you hit an equipment, the elephant will get that noise, and it will, I mean, divert. If it was coming towards the house, it will divert to the other end. [10, 5/31/17]

One farmer burns dung because to him, it has proven successful at not only deterring elephants, but also other wildlife. He explained,

> [Burning dung] is reliable, works better than the others. You use it to scare some other animals, like lions. So, when you burn cow dung here, you have animals here. When the smoke goes towards the elephant, they won't get the smell of other animals. So, we use it to even scare other animals. [19, 7/4/17]

Farmers utilized methods that are familiar and previously tested.

With limited disposable income, participating farmers chose elephant deterrent strategies based on their financial accessibility. A farmer explained, "They are the ones which I feel are cheap. The methods which are cheap are the ones that are being used by the locals, I being part of them." [1, 6/2/17] Another farmer explained that he chose his deterrent methods, "Because they are the easiest, because I have no other any method." [11, 6/1/17] These farmers are unable to afford alternative elephant deterrent strategies and are forced to settle for the options that require little or no financial capital.

To understand which methods they would utilize if financial constraints were not an issue, I asked participating farmers which methods they viewed as most effective. The largest number (9, n=27, 33%) considered electric fences the most effective elephant deterrent. [Table 6] A farmer remarked,

> Electric fence, yeah, it is, even my son has used it down there. Elephants, they have been coming and going away. They have never broken those wires . . . That's the only reason, Therefore, I think that it is the best. [24, 6/7/17]

This anecdote and others of their proven success led participating farmers to deem electric fences the most effective method. Beehive fences (7, 26%) and non-electric wire fences (2, 7%) were also considered highly effective methods. [Table 6] In total, 70% of farmers (19, n=27) reported static methods (i.e. fencing) as the most effective.

While several farmers believed electric fences successfully deter elephants, none of the farmers in my (non-random sample chosen via snowball sampling) have ever utilized them. I asked farmers in my study about the barriers preventing them from installing electric fences at

their own farms. They noted that the high price of electric fences makes them inaccessible. A farmer explained, "I don't have enough funds, I have electricity, but I don't have enough funds to do that [install an electric fence]." [24, 6/7/17] They also cited a lack of financial resources as a barrier to other highly-effective methods, including trenches and beehive fences. A farmer explained,

> If you dig a big trench around the *shamba* [field in Swahili], the elephant will not want to go down there in the trench. It is scared . . . They get stuck and cannot come out . . . It is very effective, but I don't have enough money. [10, 5/31/17]

In a community where many families must divide their limited income between food, education, and farming, limited financial resources forces farmers to rely on methods they can afford, even if they perceive them as less effective.

Although participating farmers believed that static non-human labor demanding methods (e.g. electric or beehive fences) are the best elephant deterrents, EBP's Project Leader reported that human labor demanding approaches (e.g. night guarding) are the most effective. She asserted that elephants are able to make sense of fences but are unable to predict human actions. She explained,

> The most effective method is humans patrolling and shouting and hammering iron sheets and shouting with dogs and barking and fire. That's the most effective, but it's exhausting, and it takes all night. I think most project sites have shown that human patrolling is always the most effective, and then, these more static barriers like ditches and bees are kind of the back-up if you like. So, um, there are several papers on this. Human patrolling is the most effective . . . because humans are intelligent and can adapt very quickly. They can move and adapt to elephants. They can change their methods. Elephants hate spontaneity; they like something they can concentrate on. An electric fence, for them, is quite easy to work out, but a dashing human with a light and a torch and a dog; they hate that. So, that variety and that weirdness is probably why elephants are most deterred by active humans. [28, 6/23/17]

Although human patrolling may be one of the most effective ways to reduce crop-raiding it was not participating farmers' preferred method because of its high energetic and time investments required to be successful; these requirements exhaust farmers.

The farmers I interviewed shared traditional Wasaghala strategies for deterring crop-raiding elephants and explained why those methods have been largely discontinued. Additionally, they explained the methods they rely on deter elephants and how they decide which methods to use. Method selection is frequently based on methods' affordability and accessibility rather than its perceived effectiveness. This disconnect left many farmers feeling dissatisfied with their current mitigation strategies and necessitates exploration of alternative approaches to address human-elephant farming conflict. In the following section I examine the role of farming practices in human-elephant farming conflict.

Crop Selection and Palatability to Elephants

Untangling the complexities of elephant crop-raiding in Lower Sagalla requires understanding the community's agricultural context. Therefore, I asked farmers participating in my study extensive questions about their farming practices and decision-making processes. In this section I report my interview findings on the following topics: crop selection, discontinued crops, and crop location criteria.

Crop Selection Criteria

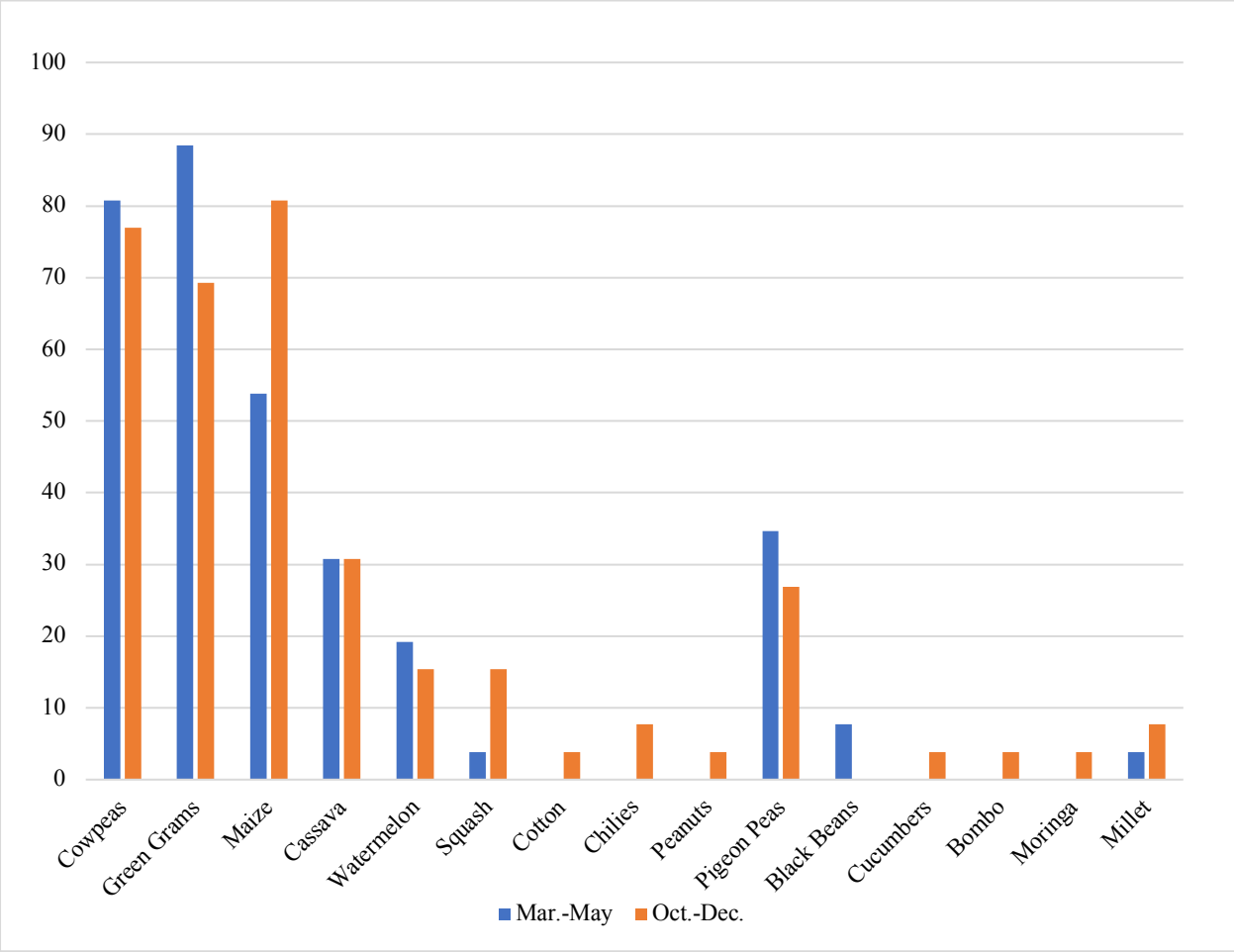
Farmers interviewed for this study considered a variety of factors when deciding which crops to plant each season. The most commonly mentioned factors included: rainfall, cultural heritage, food security, market value, and pest vulnerability. The majority of those interviewed

prioritized rainfall in determining which crops to grow each season and relied heavily on the annual rains for their subsistence farming. A farmer explained why rainfall is so important to Lower Sagalla farmers,

> When the rain is here, animals do not suffer. We ourselves do not suffer because it is the food we depend on. Water, we do not suffer from buying water. Now we buy water for a very high price, fifteen shillings per can. When the rains are here we don't suffer as when there is no rain. [12, 6/8/17]

To understand how the different rainy seasons influence farming, I asked participating farmers which crops they grew during the last growing season with typical rainfall. According to Smith and Kasiki (1999, 15), the mean annual rainfall for the Tsavo ecosystem is 550mm. Between March and May 2016, they focused on growing legumes. Eighty-eight percent of twenty-six participating farmers (n=23) grew green grams. Cowpeas (81%, n=21), pigeon peas (35%, n=9), and black beans (8%, n=2) were also widely cultivated. [Table 7] Although farmers also grew legumes between October and December 2015 they favored their staple crop, maize, and 81% of participating farmers (21, n=26) grew maize compared to only 54% (n=14) between March and May. [Table 7]

Table 7: Farmers Growing Crops in Each Growing Season (%) (n=26)



The nature of the two rainy seasons makes them well suited to growing different crops. According to one farmers,

> We plant different crops because . . . of the season. Sometimes you have that short rains [Mar.-May]. So that when you plant a crop, which would take a lot of time, it won't give anything . . . It's the season that makes the difference. In long rains [Oct.-Dec.], plant crops that take long, like maize. They take long, but there's a very big harvest in maize. [15, 5/31/17]

Another farmer shared, "Maize, *kunde* [cowpeas in Swahili], and *pojo* [green grams in Swahili] grow well during the short rains because they are fast growing crops . . . The rest do take a long time. So, they do well during the long rainy seasons." [25, 6/19/17] Another farmer shared her thought process on when to plant cassava,

> If you plant cassava during April, that time the roots will not get enough water to sustain it during the dry season. So, you have to plant it in October or September so that by, let's say, March, that's now the short rains beginning. It's catching up with enough water. By the time you reach August or July it has enough water into the cassava to sustain it to another season. [10, 5/31/17]

Farmers strategically planted crops during the season that increases the probability of a successful harvest.

Furthermore, several considered the recent drought when deciding which crops to plant. One highlighted the drought's severity; "Has it [rainfall] decreased or has it totally gone?" [14, 6/15/17] In the face of limited rainfall, some farmers adapted their farming practices to the new climatic conditions. Another shared, "I listened to the radio, and they said, 'No rain [in 2016].' So, I have to go by that." [21, 6/10/17] One farmer elaborated further,

> The climatic conditions of this place, rain is not reliable . . . The problem here is drought . . . You cannot prevent it . . . If there are some plants that you can get from the other place that are stable for this climate conditions you can introduce them here, and people can change from maize and peas. [24, 6/7/17]

A farmer noted, "If you know . . . the amount of rain is minimal, then you decide which type of crop to plant . . . If it [rainfall] is very low, you'll plant what will grow within a very short period." [21, 6/10/17] Thus, some participating farmers prioritized planting crops that can withstand drought conditions.

Several have altered their farming practices to make sure at least one crop will be harvestable, even when rainfall is limited. A farmer explained, "Nowadays, it's better to be planting something like green grams or cowpeas because it's not using very much rain and because the rain can come now small, small rain. So, there's no need of growing maize." [18, 6/10/17] Another farmer hedged his bets by planting every crop each season. He remarked, "We don't know what rain will be doing on. If rain comes a little, we get all these small ones and miss

maize. Maize needs three months rain." [17, 6/12/17] He hoped there will be enough rain for maize, but if not he knew he could harvest other crops.

In addition to rainfall, some participating farmers considered traditional farming practices when selecting crops. A farmer remarked,

> Our fathers used to plant these kinds of crops, and they do well. So, I had to follow the same because they are very good at this place, they do well. That's why I decided to plant maize, *kunde* [cowpeas in Swahili], and *pojo* [green grams in Swahili] . . . to follow according to what was being done. [24, 6/7/17]

Although cowpeas and green grams are widely grown in Lower Sagalla, maize is the staple crop today. According to a farmer, "In Taita [Wasaghala], you have to plant maize first because maize is the most important food for the community." [20, 6/7/17] An interviewee noted, "Planting maize is a habit." [15, 5/31/17] She later elaborated,

> Taitas [Wasaghala] are fond of planting maize . . . Taitas [Wasaghala] plant maize first. Even in short rains you see them planting maize . . . They are fond of planting maize because they say that you cannot prepare porridge from green grams or cowpeas. So, they like maize all the time. [15, 5/31/17]

Even when rainfall did not favor maize, they still chose to cultivate it.

For the Wasaghala maize is not only their staple food but also an integral part of their cultural identity. A farmer shared his love of maize: "I would rather plant this *pojo* [green grams in Swahili], harvest it and buy maize. Simply because I miss maize. I sell this [green grams] and get maize." [17, 6/12/17] Participating farmers grew maize for their own subsistence and to be part of the community. An agriculture expert explained,

> Traditionally, culturally, people believe in planting certain crops. 'I have to plant maize whether ten years ago, last year I didn't harvest. I still have to plant maize.' It's a cultural thing. It's not necessarily only in this particular area. My mother believes that if the neighbors pass by and find that she doesn't have maize she's perceived to be lazy. [27, 6/8/17]

Maize is prioritized over other crops because it is an important part of Wasaghala identity and continues to be cultivated even when ill-suited to the climate.

In addition, several farmers considered household food security when determining which crops to plant. Fifty percent of participating farmers (n=26) identified growing crops as their primary source of livelihood. Others who used crop cultivation as an ancillary income source, noted that it was still important to their livelihoods. Growing enough food to feed their household for the coming months is paramount because many are subsistence farmers that is, farmers whose production matches their consumption with little or no surplus. A farmer remarked that when farming, "You can harvest and store them for your future use." [12, 6/8/17] A farmer elaborated on why food self-sufficiency is important,

> One could be self-reliant. Because when you have cowpeas, you have green grams . . . When you have them in your *shamba* [field in Swahili], you know you can't go to the shop. It's like you're self-reliant, and it's cheaper to keep food in your store than going to buy. [10, 5/31/17]

This is especially important during the drought. A farmer shared,

> You also consider things to do with food later. Like right now, there is food scarcity in the entire area . . . Currently for us, we know there is food because you can dig out cassavas. So even with the drought we are doing good and eating when . . . there is not much food for now. So, you consider what happens what few months or years to come if there is no rain. So, I plant different crops for food. [13, 6/6/17]

Through thoughtful decision-making and careful planning, this farmer was hopeful his family would remain food secure despite the drought.

Some also considered the market value of different crops and prioritized crops that are high-income. A farmer explained,

> What I consider is monetary value of every crop. And comparing pojo [green grams] and maize, *pojo* [green grams in Swahili] gives good money than maize. So, my primary aim, or objective in each planting season is money. Whereby I try to have some crops that generate a high amount of money. [4, 5/30/17]

A farmer hoped that farming would shift from just producing food for home consumption to being able to sell, high-value crops. He remarked,

> What they [community members] want is the kind of plants where they can get money. They sell get money instead of relying on maize . . . When you get money, you can be able to buy rice and other things . . . People can grow, sell, get money, buy *unga* [maize flour in Swahili]. [24, 6/7/17]

Others shared this viewpoint and hoped to start planting high-value, cash or market crops. A farmer noted, "I also consider crops which have high value income, capital. Like melon, I'm planning to plant them." [11, 6/1/17] Another interviewee wants to "Plant *pilipili* [chilies in Swahili] . . . During October I will try that . . . because of money. I need money." [2, 5/29/17] If farmers successfully harvest high-value crops, they have enough income to feed their families and support their children's education.

Some also considered crop vulnerability to pests and disease. If crops are highly susceptible to these damages, harvests are destroyed, and farmers cannot profit. One farmer reported alternating crops between growing seasons to mitigate this risk. He explained,

> I am planting different crops in different seasons. One of the reasons is for pest and disease. I am really trying to control pests and disease. That is why you cannot plant one crop two seasons. If you plant maize here in October and then again in July, the disease and pest will have been maintained from the previous maize and get stronger. By planting a different crop like *kunde* [cowpeas in Swahili] and black beans, it controls disease. [16, 6/5/17]

Although this prevents farmers from growing the same high-value crops in the same field each season, it is a low-cost approach to controlling the spread of pests and disease and bolsters crop health.

Crop are also selected based on their attractiveness to the farmers' largest pest, elephants. Unfortunately for famers, their favorite crops are also loved by elephants. For example, a farmer noted, "We had planted mango trees, and some of them did very well, but when elephants came .

. . They eat, especially the mango trees. They like them. Plus the leaves they eat." [10, 5/31/17] A farmer shared another example, "Maize is very much liked by the elephants. Cassava also, when you plant cassava elephants will come there." [24, 6/7/17]

Farmers knew elephants love their staple crops, but many were unwilling to stop growing them because of the elephants. One farmer mitigated his loss to elephants by deliberately cultivating crops that mature more rapidly than maize. He explained his strategy,

> [Elephants] like green grams a lot, but green grams takes a shorter time to get ready. And also, elephants you know they normally come, they're very, very many when maize is many. Now by then you have removed your green grams. They get ready earlier than the elephants come so you can easily get harvest and remove them . . . Maize takes a longer time, three months. Green grams takes 1.5 to two months to be ready. By the time elephants come you have removed yours. [21, 6/10/17]

He used his knowledge of elephant crop-raiding behavior to his advantage. His success suggests that strategically planting some crops that mature faster than others, and hence are likely to provide yield even in the face of elephant crop-raiding can reduce elephant crop-raiding damages.

Crop Location

After discussing crop selection criteria, I asked participating farmers how they determine where to plant each crop. Some reported that they planted without much thought about each crop's location. However, others considered a variety of factors in their decision-making regarding where to locate particular crops. In this section I examine the most commonly mentioned factors: soil type and water drainage, maintaining land fertility, and crop protection from wildlife

Soil type varies throughout Lower Sagalla. From soil samples, I assessed soil texture and pH at ten farms. Soil pH ranged from 6 to 8.5, and soil texture was either sand clay loam; clay

loam, sandy; sandy clay; or sandy loam. [Appendix F] Some farmers considered these differences in soil type when determining where to plant each crop. A farmer remarked,

> I consider soil factor, whereby whenever there is soil that is a bit hard or not soft I plant there maize. Wherever there is land that is soft soil, I plant *pojo* [green grams in Swahili] and *kunde* [cowpeas in Swahili] because they do well where the soil is not so much hard. [14, 6/15/17]

Another shared, "Do you see this area? I planted *kunde* [cowpeas in Swahili] here, and this side I planted maize because the land is very fertile. So, I had a good crop here." [24, 6/7/17] Some were aware that the sand to clay ratio causes the differences in soil texture. A farmer remarked,

> There are some places where there is more clay, some places where is little clay. Where there is more clay, I prefer if there is a lot of rain I prefer beans there . . . Green grams do very well in a place where the soil texture is sandy. [21, 6/10/17]

Some farmers preferentially plant legumes on sandy soil and maize on clay soils. A farmer shared,

> On this parcel of land I plant *kunde* [cowpeas in Swahili], *pojo* [green grams in Swahili], but on that parcel of land it's maize because of soil factors . . . This soil is mixed with sand, but at that point the soil changes, and there is not much more sand that other side, it's very fertile soil. [22, 6/2/17]

They located their crops according to what they estimated was optimal soil type.

In addition, a few considered how soil type influences water retention. According to a farmer, "Water runs inside the *shamba* [field in Swahili]. Where the water stops you plant cover crops peas there, cucumbers." [19, 7/4/17] Another shared his observation,

> The soil in this parcel is different in portions. If you plant peas in this side of the land, then even when it is becoming dry, it is still green when you compare to the rest of the land because I think this side holds water more . . . Different crops grow on different soils. Some crops do well in a bit of clay soil; others do well in a bit of sand soil. An example of maize, if you grow it in a place where there is clay soil they can take long to come up because of the soil, and also it requires more rain to let the seed. The soil becomes muddy. [13, 6/6/17]

By considering which crops are best suited to each soil type, farmers can increase productivity.

A few also considered long-term soil health in determining where to plant each crop. For example, alternately planting maize and legumes can maintain soil fertility. A farmer explained,

> If there is maize here you cannot put green grams. If there was cowpeas, I cannot plant pigeon peas or whatever. I can exchange them. I rotate. I rotate because of fertilizer or what. Because, you know, once you plant maize today next time also maize the same place, now the manure will not get out from there. But if you keep on exchanging you can get a good results. [18, 6/10/17]

Alternating maize and nitrogen-fixing legumes bolsters soil fertility and contributes to long-term farming viability.

Farmers also considered how to deter crop-raiding animals when deciding where to plant different types of crops. A farmer remarked, "The only decision is to protect them [crops]. I just plant them around the house, in the [beehive] fence so I can protect them." [2, 5/29/17] A few strategically planted the crops most often targeted by wildlife next to their homes. A farmer shared, "That other parcel of land is just in the wild . . . There is no farmhouse there. Cassava needs a person being near because of the animals." [1, 6/2/17] They considered not only elephants, but also other crop raiders. A farmer noted,

> I consider wildlife, this small, small creatures like the dik-dik. They eat a lot, like the *pojo* [green grams in Swahili], and tortoise also has caused big problems. They are the worst when they get vegetables. So, I control that wildlife by putting my crops in different parcels of my land. The tortoise eats *kunde* [cowpeas in Swahili]; so I plant it at the far end, where it can get satisfied easily. I plant *pojo* [green grams in Swahili] near the house so I can monitor it easily. [22, 6/2/17]

By planting attractive crops to potential wildlife close to their homes, farmers are better able to protect their crops and increase the likelihood of a successful harvest.

Discontinued Crops

Although farmers grew a variety of crops, they have recently discontinued some due to elephant crop-raiding. In this section I discuss the three most frequently mentioned: pigeon peas, pumpkins, and millet.

Farmers reported that pigeon pea cultivation has declined in Lower Sagalla. A farmer remarked, "I've been not planting pigeon peas because of the ellies [elephants]. Pigeon peas and papay [papaya]. I've been planting them, but now I'm not planting them because elephants love those plants." [18, 6/10/17] Another farmer noted, "I tried *mbaazi* [pigeon peas in Swahili], but didn't harvest anything at all . . . The reason I am not planting is because of wildlife. Elephants raided. Elephants came when they were ready [for harvest]. They ate." [2, 5/29/17] A farmer shared his brother's experience, "He had planted pigeon peas some time back, but they got eaten by the elephant. From then, he said, 'No I won't plant these again.'" [6, 6/9/17] Widespread elephant damage discouraged pigeon pea cultivation.

Similarly, several farmers discontinued growing pumpkins because elephant crop-raiding damages became too great. A farmer remarked,

> My parents planted pumpkin. All the rest they grew, we are still growing, but the pumpkin seeds are lost. Seeds are the problem because they had not been harvested well. Elephants love pumpkins so much. They eat them and raid anytime. [20, 6/7/17]

Unfortunately, other wildlife target pumpkins as well. A farmer stopped growing pumpkins because of baboons and elephants. He explained,

> I used to plant watermelons and pumpkins for food, but today I'm not planting them. If I have planted, it's just one or two because of baboons . . . Elephants eat but it depends on the nutrition. Elephants come straight for watermelon but eat both. [16, 6/5/17]

In addition to being targeted by wildlife, climate change disincentives pumpkin cultivation. According to a farmer,

> We used to grow pumpkins, and they used to do very well. But when the elephants came, they found good food. We stopped growing and because of the climate too, because actually there is a great climate change that affects the pumpkins so much. [10, 5/31/17]

Although highly nutritious some considered pumpkin cultivation too risky.

Several farmers abandoned growing millet as well. Although millet grew well in Lower Sagalla, farmers believed elephants targeted it. A farmer had high hopes for her millet harvest until elephants came. She explained, "Millet did not do well because of elephants; it was crop-raided. I know it would do so much. I could have harvested a lot." [22, 6/2/17] Other wildlife including baboons and birds crop-raid millet as well. A farmer noted, "We grew millet, but not currently. I left it because of wildlife challenges, even birds fed on it, baboons, elephants. Elephants fed on it . . . when the crop is almost ready for harvesting." [25, 6/19/17] In addition, millet is sensitive to climatic changes, and with decreased rainfall farmers did not harvest well. A farmer shared,

> We planted millet in 2014. It didn't do well; the seeds were lost. So, we have not planted it again . . . Elephants like it; they chew . . . Millet takes seventy days to grow, to be ready to harvest. It did well I harvested and sold the seeds. There's been no consistency in rain since 2014, so I haven't tried again. [14, 6/15/17]

With successful harvests unlikely, farmers have abandoned crops like millet and pumpkins that used to be important parts of their farming practices. However, none of the farmers I interviewed elaborated on how discontinuing crops has impacted their farming and/or livelihoods.

The Lower Sagalla farmers I interviewed considered a variety of factors when deciding which crops to grow and where to plant them on their farm. Vulnerability to pests and wildlife, especially elephants, was a top criterion many farmers considered and has led them to discontinue several crops. This suggests crop palatability may drive elephant crop-raiding behavior and should be considered when designing human-elephant conflict mitigation strategies. I examine this further in the following section.

Elephant Crop-Raiding Behavior and Crop Palatability

In this section I examine crop palatability to elephants and its relationship to elephant crop-raiding behavior. I start by discussing why elephants forage selectivity. Next, I share participating farmers' knowledge about non-palatable crops. I conclude by examining barriers farmers and local NGO employees identified that make cultivating crops that are non-palatable to elephants difficult.

Several farmers noted that elephants are often selective while crop-raiding and posited explanations for this behavior. A farmer shared his observation,

> If you plant the cassava, they will become your friends until they make sure that it is finished completely because they normally come from down there. They pass all the farms to some farms up there where there are some cassavas . . . So, they just go straight to that farm. [21, 6/10/17]

Elephants love cassava much that they come right to the farms with it and stay there until they eat it all and become your "friends". A few farmers suggested that elephants selectively forage because they search for the most nutritious or delicious crops. According to a farmer,

> Elephants might not like some plants because of taste and nutrients. You know, even human beings, especially when you are sick you find you like to eat oranges . . . because it's needed in the body. So even the elephants like to come and eat the crops because they need it. [21, 6/10/17]

This opinion was echoed by another farmer who stated, "If the crops aren't nutritious to him or of any benefit to him, is why he might not eat it." [23,6/13/17] Thus, elephants only eat crops that offer them benefits (e.g. high caloric density) and bypass those that are not.

In addition to gauging participating farmers' knowledge about crops that are non-palatable to elephants, I also consulted regional experts on the topic, Elephants and Bees' (EBP) Project Leader and a regional agriculture expert. Both experts noted that elephants forage selectively and choose between crops based on palatability. The agriculture expert remarked,

"There are crop which are more attractive to the animals than others, like maize. Maize is very attractive. It's very sweet." [27, 6/8/17] Taste differences may be the result of a plant's nutritional composition. EBP's Project Leader explained,

> Plants have different nutrient contents, so that's an attractive or less attractive factor. They also have different excretions. So, some plants have toxins that they have on the outside of their skins. As we know, some crops are poisonous to humans until they're cooked, so there must be toxin there that's destroyed by boiling. [28, 6/23/17]

Plants may also be less attractive if they are too spicy to eat or too fibrous to digest. EBP's Project Leader noted, "Spicy plants are less attractive . . . Anything that in that category of spices, those plants are notoriously less attractive, and plants that have a lot of fibrous things are probably not good for elephants." [28, 6/23/17] The agriculture expert added that plant growth form might impact attraction. He remarked,

> It's easier for the animals to eat something taller than something low. For example, if someone plants maize and another one plants green grams, the one who plants maize suffers more because maize is easier to pull down and put in the mouth than green grams, particularly for big animals like elephants. [27, 6/8/17]

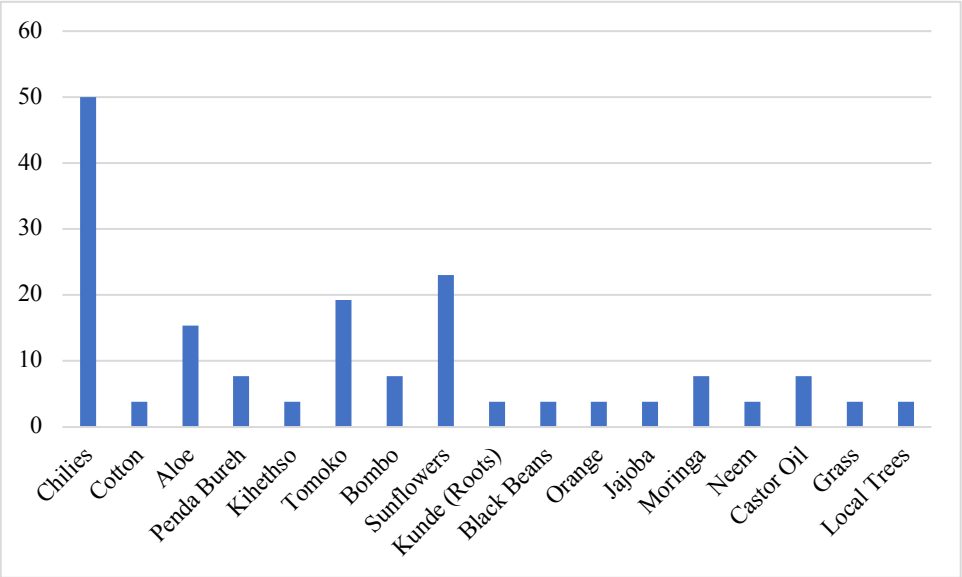
This is supported by previous research that shows elephants' preferred foraging height is above two meters (de Boer et al. 2015). By considering factors such as plant spiciness, toxicity, and sweetness it is possible to infer which crops may be less attractive to elephants. Hence, chilies, cotton, and ginger are less likely to be attractive to elephants.

Farmers can use elephants' foraging selectivity to their advantage by planting crops that are non-palatable to elephants, but beneficial to farmers. To understand non-palatable crops' potential to decrease elephant damages, I asked participating farmers about their experiences considering non-palatable criteria when making farming decisions.

First, I asked participating farmers if they knew any crops that are not typically eaten (typically) by elephants. The most frequently reported crop, chilies, was mentioned by fifty

percent of the twenty-six farmers I interviewed. [Table 8] Other crops farmers frequently reported as not eaten by elephants in their area included sunflowers (6, n=26, 23%) and aloe (4, n=26, 15%). Nineteen percent (5, n=26) of farmers I interviewed reported tomoko (*Annona reticulata*), however, as a fruit tree it is not considered a crop by the farmers I interviewed. [Table 8] Other non-palatable plants reported by this sample included castor oil, moringa, black beans, oranges, and kihethso (*Boscia coriacea*). Because of the evidence regarding the non-palatability of chilies and aloe, I probed further with the farmers in my sample about chilies and aloe. Topics I covered included personal experience, their view of causes of non-palatability to elephants, and barriers they perceived to cultivating them in their own farms.

Table 8: Frequency of Farmers' Identification of Crops Non-Palatable to Elephants (%) (n=26)



Chilies were the most commonly mentioned non-palatable crop being mentioned by half of the farmers I interviewed, and many expressed a deep understanding of their characteristics. A farmer remarked, "Chilies, they [elephants] don't like." [21, 6/10/17] One farmer successfully harvested chilies several times and believed elephants do not like them. She attested, "Nothing

can affect the chilies . . . I do intercropping between maize and chilies because the severity of damage is totally reduced." [15, 5/31/17] She later added,

> Chilies, yes it helps with the elephants not getting into the *shamba* [field in Swahili]. The chilies helps me a lot. They [elephants] come very few, yes. But the times we plant maybe maize, then you see elephants coming here. You cannot see them [elephants], when there are chilies. [15, 5/31/17]

For this farmer, cultivating chili is a way to protect her entire farm from crop-raiding elephants.

Although many believed elephants do not like chilies, few could explain why. However, one farmer postulated, "Chilies, elephants don't eat, maybe because of the bitterness. It still uproots it but does not eat." [22, 6/2/17] Chilies' spiciness may discourage elephants from targeting them while foraging. Although half the farmers I interviewed believed chilies are non-palatable to elephants, only two currently cultivate them. [Table 7]

Despite the benefits of chilies, it is difficult to cultivate them in Lower Sagalla. Participating farmers noted that chilies require large amounts of rainfall and mature slowly. According to a farmer, "Chilies need a lot of rain. Chilies also they don't grow very fast. They take time. If you plant in December, November you harvest in April" [21, 6/10/17] Furthermore, chilies are a labor-intensive crop that requires raising seedlings in a nursery before planting in the field. A farmer who had bad luck growing chilies shared his experience,

> We tried [chilies] in 2015; it did not do well. It did not do well because of rain. The rains were short. I'm planning to do them again, but then again still the problem is the rain. And chilies have a lot of work because you have to establish a nursery bed, and establishing a nursery needs a lot of water . . . It's already too late. If you start right now [June] a nursery, it won't be ready by October. [25, 6/19/17]

Their long maturation time, rainfall dependency, and high labor input made chilies an unattractive option to farmers in my sample, especially in the face of climate change and increasingly unpredictable rainfall.

Although several believed aloe is non-palatable to elephants, only a few farmers I interviewed have cultivated it. One who has not planted it explained, "We do not have enough knowledge about it [aloe], but I know it's good." [6, 6/9/17] He attested that it is good because it is non-palatable to elephants, "Aloe vera, we have seen around the water pan area. There's a gentleman who's planted aloe vera. They normally trample on them but do not eat." [6, 6/9/17] A farmer who currently grows aloe observed its non-palatability first-hand. She remarked, "Aloe vera, it's not damaged at all, at all [by elephants] . . . I tried it a little there and it's doing well." [15, 5/31/17] Another farmer who recently started growing aloe shared, "I have planted in nursery, just a few around, and it's not eaten." [4, 5/30/17] Those growing aloe were confident elephants dislike it.

Some farmers were interested in expanding their cultivation of aloe because it is non-palatable to elephants but have encountered obstacles. One farmer shared that the main challenge is "getting the seeds for the aloe." [15, 5/31/17] Another farmer currently has one aloe and would like to expand. However, aloe's lengthy maturation time makes it difficult to grow. He explained, "From that one I'll be transplanting, but the problem is that it takes years. Ten years before you harvest anything. It takes a long time, and I don't know where the market is." [20, 6/7/17] Even if they successfully grow aloe, participating farmers were unsure where to sell their harvest. An interviewee noted, "The challenge . . . you cannot consume it, it must be sold. Where are you going to sell it? That's the challenge." [6, 6/9/17] The farmers' limited exposure to aloe and its uncertain marketability made it both difficult and unattractive for them to cultivate.

Regional experts from EBP and another nearby NGO also had ideas on which crops they believed are less attractive to elephants based on their own observations and familiarity with scientific literature. They proposed crops that were not mentioned by the farmers I interviewed.

For example, EBP's Project Leader proposed, "Betel nut, ginger, turmeric, chilies, garlic that category of species. Those plants are notoriously less attractive. We believe sunflowers are less attractive. . . Cotton." [28, 6/23/17] In addition to these crops, the agriculture expert suggested that some trees might be non-palatable. He remarked, "We want to try and replace those plants [elephant attractants] with other plants, like fruit trees which are very suitable here. Plants like jojoba, baobab, moringa." [27, 6/8/17] Growing non-palatable crops has the potential to reduce elephant crop damages.

Although these crops may be non-palatable to elephants, both experts noted several barriers to widespread cultivation in Lower Sagalla. A major obstacle was the weather. The agriculture expert remarked, "The main one is the rainfall, although some of these plants are more or less rain independent. Although in some areas the rain is extremely low. That almost anything doesn't grow." [27, 6/8/17] Without reliable rainfall, farmers will be unable to harvest.

Even if the rains are good, many non-palatable crops (e.g. oranges, aloe) take several years before they are harvestable. The lag-time between planting and benefit makes cultivating them difficult. The agriculture expert explained, "The duration within which some of these plants grow is long. So, the waiting period is long and lack of awareness. People don't know. They're not well exposed here." [27, 6/8/17] Pest vulnerability further disincentives the cultivation of some non-palatable crops. EBP's Project Leader noted, "Some of them require quite a lot of pesticides. Cotton, for example, is heavily predated on by insects . . . It's a notoriously heavy pesticide user." [28, 6/23/17] Cultivating crops that are vulnerable to pests forces farmers to choose between purchasing pesticides and risking heavy insect damages.

Moreover, the cultivation of some non-palatable crops (e.g. chilies, aloe) is hindered because they do not have a strong local consumption value. They are valued by local farmers

only as cash crops and there are issues with marketing these particular crops. Lower Sagalla farmers are accustomed to subsistence cultivation and may be ill-equipped to sell their produce to large-scale buyers. EBP's Project Leader noted,

> The other main barrier is market. For those spices, for example, it would be quite hard to get our famers growing turmeric because you're simply not going to sell turmeric in Voi. Unless you find an NGO, an outside person who comes in to create that market, it would be risky encouraging farmers to grow something that is market dependent and essentially non-edible. I mean, you can eat a bit of turmeric, but it's a cash crop. [28, 6/23/17]

The agriculture expert shared a similar concern:

> People want to see a benefit from these plants. And, um some of them don't translate to benefit because there's not market. Somebody will ask, 'Now if I grow pepper, and I have heard people have pepper in the store and there's nowhere to sell. So, what is the point of growing pepper?' . . . Some people don't know there's a market, and for those who know the prices they get are extremely low. [27, 6/8/17]

Even if farmers locate markets, they rarely receive fair prices.

To successfully cultivate non-palatable crops farmers need support identifying viable markets and securing fair prices. The agriculture expert shared,

> They [community members] have not traveled a lot. They're very localized. So, they don't know where these things go. So, they need a lot of empowerment in terms of knowledge to search the market. We are willing to be that gap between the market and the community. [27, 6/8/17]

One way to improve prices farmers receive is by creating value-added products (e.g. cooking oil). The agriculture expert explained, "There's a huge challenge for us who are in the know to try and find value-adding for them, the community. They are poor, people here are very poor, but they have resources." [27, 6/8/17] With ongoing and appropriate support farmers might be able to successfully transition to growing new crops that are less palatable to elephants.

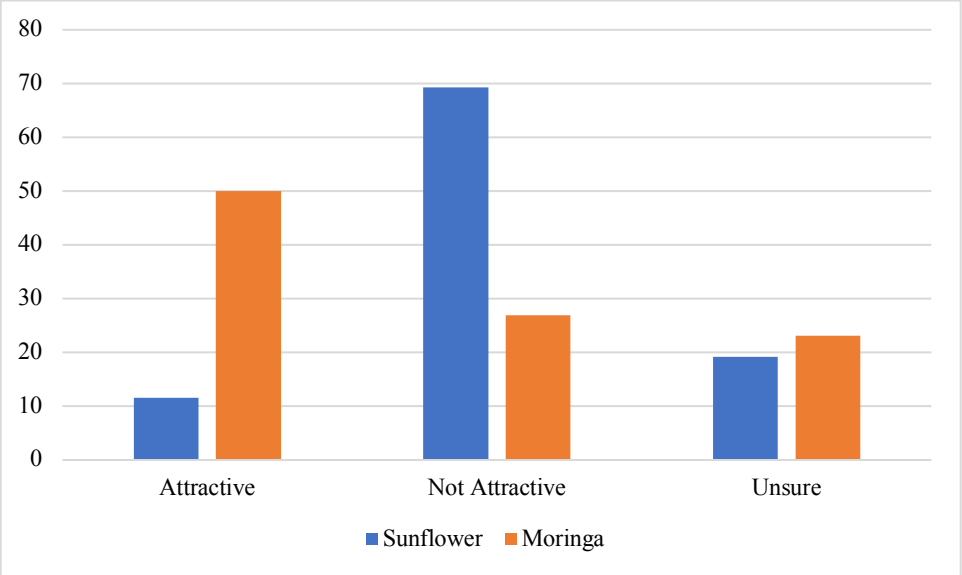
To explore the potential of non-palatable crops to reduce elephant crop-raiding behavior and benefit community members, I did additional focused research on two crops: sunflowers (*Helianthus sp.*) and moringa (*Moringa olifera*). Both crops are a climatically appropriate for

Lower Sagalla. The agriculture expert remarked, "Sunflower would grow well here." [27, 6/8/17] He later added, "Moringa does super here. They are drought tolerant." [27, 6/8/17] Furthermore, anecdotal evidence from community members suggests both crops are not attractive to elephants. As described in the methods chapter I conducted an on-farm experiment to compare the relative palatability of sunflowers and moringa to maize, a known elephant favorite. In addition, I asked farmers selected for my interview sample about their own experiences with sunflowers and moringa. In this section I report farmers' opinions regarding each crop's palatability, the benefits and challenges of cultivation, and marketability.

Sunflowers

Prior to conducting my study, anecdotal evidence in the area suggested that elephants do not like sunflowers; however, formal data had never been systematically collected. During my interviews, the majority of farmers in my sample (69% 18, n=26) reported that sunflowers were non-palatable to elephants. [Table 9] Several based this opinion on their own experiences growing sunflowers. One farmer remarked, "I have also seen of sunflower, they [elephants] do not eat sunflower. They only picked it and throw it away." [22, 6/2/17] Another farmer noted, "An elephant cannot eat sunflower." [2, 5/29/17] An EBP employee who regularly assesses elephant crop-raiding damage supported this assertion. He remarked, "I have seen several times when going tracking that sunflowers were only trampled by elephants. They did not consume it." [6, 6/9/17] However, not everyone agreed; 12% of farmers (3, n=26) thought sunflowers were attractive to elephants. According to one farmer, "Elephants consume the flower [of sunflowers]." [20, 6/7/17] The remaining 19% of participating farmers (5, n=26) were unsure about sunflowers' palatability.

Table 9: Farmers' Perceptions of Crop Attraction to Elephants (%) (n=26)



Farmers in my sample reported that sunflowers provide numerous benefits. At the top of the list was their edibility; for example, farmers can eat sunflower seeds. A farmer explained how to prepare them, "Put them [sunflower seeds] in a frying pan with salt and just cook . . . You can use as a snack." [18, 6/10/17] The seeds can also be pressed to extract oil. A farmer noted, "The seeds of sunflower makes good oil." [14, 6/15/17] Sunflower oil can be used for cooking. Another farmer added, "Sunflowers are food. Money when you sell it." [16, 6/5/17] Sunflower seeds and cooking oil can be consumed by the household or sold as an income source.

Sunflower seeds can also be used as livestock feed. A farmer explained why he plants sunflowers, "I grow them because they can be used by my chickens." [18, 6/10/17] Another farmer remarked, "The seeds you can give them to livestock. When it's used to make oil then the outer part you can give to the livestock." [2, 5/29/17] After being pressed for oil, livestock can eat the remaining seed husks.

Some farmers grew sunflowers because they benefit their bee colonies. A beehive fence farmer remarked, "Elephants don't like sunflowers, but it's attractive to bees." [26, 6/1/17] He

considered this when planting his sunflowers. He noted, “I plant them [sunflowers] just near the hives, so the bees can benefit.” [26, 6/1/17] Bees use the sunflowers as a food source. According to a farmer, “[Sunflower] helps also in the pollen grains. Sometimes the bees use it for preparing the honey.” [15, 5/31/17] Another farmer added, “[Sunflower] is attractive to bees . . . They take the pollens and make honey.” [14, 6/15/17] In addition, when farmers plant sunflowers near beehives, the hives become more attractive to bees, which may increase beehive occupation rates and honey production. Furthermore, an interviewee remarked, “They’re also very beautiful, they look like flowers and are very beautiful.” [21, 6/10/17] In addition to sunflower’s numerous material benefits, farmers also planted them because they are aesthetically pleasing.

While sunflower cultivation can be beneficial to humans and other species, growing them can be difficult for farmers. The greatest challenge participating farmers noted was unreliable rainfall. A farmer remarked, “I tried to plant sunflowers, but they didn’t do well because of drought.” [22, 6/2/17] Another farmer shared, “I planted them [sunflowers] even during this season, but then there were no rains.” [26, 6/1/17] Even when it does rain, they are not guaranteed a successful harvest. A farmer shared, “Sometimes the seeds don’t easily germinate; it takes a very long time.” [15, 5/31/17] In addition to being vulnerable to insufficient rainfall, wildlife can significantly impede a successful harvest. A farmer explained, “Rats, they eat the seeds. Birds, they eat the seeds . . . Rats and squirrels eat the ones [seeds] on the ground. Birds eat the ripe seeds.” [16, 6/5/17] Seed predation can reduce germination rates and deplete farmers’ seed banks.

The challenges of growing sunflowers extend beyond the field. Several farmers expressed interest in cultivating sunflowers but noted that they are unable to because they lack they necessary resources. A farmer shared, “I’m not planting them because of lack of finance [to buy

seeds]; though I'm hoping to plant them." [11, 6/1/17] Another farmer remarked, "Seeds are very hard to get." [2, 5/29/17] For farmers with access to seeds, sunflower cultivation presented additional challenges. Although sunflowers can be eaten, they are not a staple food like maize. A farmer explained, "The problem here when you grow sunflowers, is that sunflowers is not a [staple] food for us." [18, 6/10/17] Another farmer noted, "I plant them [sunflowers] only for the bees. I don't eat." [26, 6/1/17] While sunflower seeds are edible, a household cannot subsist on them; so, farmers must sell sunflowers to feed their families.

As essentially a cash crop, making cultivation of sunflowers a profitable activity requires an understanding of market dynamics. Among participating farmers there was a high level of disagreement regarding the local sunflower market. Some believed there was no market to sell sunflowers. When asked if there is a local market for sunflowers, a farmer responded, "I don't think so because one-time people planted, and they still have it in their homes up to now. They couldn't sell." [2, 5/29/17] However, others reported that there is a local market for selling sunflower seeds within Lower Sagalla. A farmer remarked, "There is a market, but it's just local farmers buying. I help other farmers out. I give them seeds." [26, 6/1/17] A few farmers have successfully identified a sunflower market in Voi. A farmer attested, "There is market for sunflowers. You can sell it. I sold a kilo at fifty shillings." [20, 6/7/17] With a reliable market and prices that exceed production costs, farmers could sell their sunflower harvest and use the profits to purchase maize flour and other goods.

Although local markets may exist for sunflower seeds, selling may not be viable for all Lower Sagalla farmers. Due to their small-scale production, some farmers were unable to profit from their harvest. A farmer lamented, "The market price of both crops [sunflowers and chilies] is poor. So, it's a waste of time." [11, 6/1/17] Another farmer explained the challenge; "There is

an industry in Voi. But you see, when people grow, they grow in small quantities, and the industry needs large quantities." [21, 6/10/17] The agriculture expert agreed; he remarked, "There is a market for sunflowers, but the problem is when the community sells it raw. There is exploitation. So, we would have to probably get a market and try to negotiate prices for the community or encourage people to invest in factories." [27, 6/8/17] Due to small-scale production, many Lower Sagalla farmers may be unable to sufficiently benefit from sunflower cultivation.

Moringa

I wanted to understand participating farmers' perspectives regarding moringa cultivation. In each interview we extensively discussed moringa including its attractiveness to elephants, benefits and challenges of cultivation, and market availability. Fifty percent (13, n=26) of farmers interviewed reported that moringa is attractive to elephants. [Table 9] A farmer explained,

> Yes, elephants love moringa. A close neighbor of mine has experienced that. She is crop-raided every time of her moringas. They break and consume. They have damaged about two to three of mine . . . When the elephants get in they must break those plants. I don't know why, but they love them. But I love them, the moringa. [15, 5/31/17]

Another farmer shared a similar experience, "I had one [moringa tree] in the farm, but it was growing with maize. When the elephant came it fed on both of them, even the long seed pods. He was picking them and eating them." [14, 6/15/17] A third farmer reported that elephants eat moringa roots as well. [20, 6/7/17]

However, seven farmers or 27% of the sample (n=26) disagreed and reported that moringa is not attractive to elephants. [Table 9] A farmer shared his observations, "Moringa? I think it's not attractive because there are some lands where they have grown moringa, but I've

never seen elephants destroying them or eating them, so I think they don't attract." [19, 7/4/17] Another farmer explained why elephants might not like moringa: "Once they have flowers, they release a scent, which I think is not attractive to elephants." [1, 6/2/17] The agriculture expert attested that elephants dislike moringa, "It's not [attractive to elephants]. That's something I've learned during my time here." [27, 6/8/17] Even if elephants are not attracted, they still damage the trees. A farmer shared, "I had a moringa here, one of mine. Though every time elephants went through they broke it. I suspect maybe they picked but didn't eat. All I know is moringa was every time broken." [22, 6/2/17] Similarly another farmer noted, "Moringa is not attractive [to elephants], but still ellies [elephants] used to eat it. Sometimes just destroying, breaking the trees." [18, 6/10/17] The remaining six farmers (23%, n=26) of were unsure about elephant's attraction to moringa. [Table 9] One explained his uncertainty in this way, "Moringa is a new crop, and we don't know much about it. So, I cannot tell if it is eaten or not eaten by an elephant." [2, 5/29/17] Thus there was considerable disagreement in my sample about whether or not moringa is attractive to elephants, and several hoped for additional information about moringa.

Although divided on its palatability, the majority of farmers I interviewed agreed moringa cultivation offers numerous benefits. The most commonly reported benefit was that moringa can be eaten as a vegetable. A farmer remarked, "If I plant moringa, I can use the leaves. The leaves are a vegetable." [6, 6/9/17] Another farmer explained how she used moringa, "We consume the leaves as vegetables, and the flower is used as a spice." [15, 5/31/17] Moringa can be eaten fresh or dried and stored for later; in both forms it is highly nutritious. A farmer noted, "Seed pods are good vegetable . . . The leaves, when dried and taken with porridge, are good for my health." [14, 6/15/17] The seeds can also be pressed for oil.

Another important benefit of moringa is its curative properties. A farmer remarked, "Even myself, I can use it. You see my health is not good. At times, I can even pick from a neighbor and use it. It can control my systems." [21, 6/10/17] A farmer explained a specific medicinal use, "The seeds help us a lot. It is used as medicine for those with hypertension." [15, 5/31/17] Farmers use the flowers, seeds, and leaves as medicine. [19, 7/4/17]

In addition, moringa's biological properties make it well suited for cultivation in Lower Sagalla. A farmer explained, "It is not affected mainly by the weather because it's a tuber. It stores water. It waits and grows up when rains come again." [21, 6/10/17] Therefore, it is able to withstand unreliable rainfall and extended drought when crops like maize are unlikely to survive. Moreover, moringa creates oxygen and serves as a carbon sink within the ecosystem. A farmer noted, "It's a tree so it provides . . . oxygen." [19, 7/4/17] The agriculture expert highlighted the ecological importance of moringa:

> [Moringa] are drought tolerant. I think that's one of the secrets of this place . . . Although they have no rain, the oil crops do very well here, medicinal crops that's moringa, baobab, sunflower . . . Moringa is also a legume, so it's also good for agroforestry if someone is growing other plants. It's a nitrogen-fixer. [27, 6/8/17]

Moringa can play an important role in the agro-ecological system.

Importantly participating farmers were keen to learn more about moringa and begin cultivation on their farms. A farmer remarked, "I've heard about moringa, and I think an experiment should be done on that plant within an area that has elephants." [1, 6/2/17] Moreover, EBP's Project Leader supported moringa cultivation in Lower Sagalla. She noted, "I was always very worried about us, as a project introducing cash crops because that puts a massive pressure on us providing a market. I think moringa is different because it's definitely edible, and it's part of the community." [28, 6/23/17] Tangible benefits coupled with pre-existing community interest make moringa an ideal crop to cultivate in Lower Sagalla.

Despite moringa's numerous benefits, farmers noted that moringa cultivation can be difficult. After its attraction to elephants, the second most commonly mentioned challenge was moringa's vulnerability to pests. A farmer noted, "[Moringa] is so much affected by pests, like caterpillars." [22, 6/2/17] Another farmer shared this concern; "There are pests when it's raining. Pests which usually . . . eats the flowers and also the tree itself, bringing down the flowers and also the leaves." [1, 6/2/17] Heavy pest predation decreases tree health and directly damages the most highly valued parts of the tree, the leaves and flowers.

There are further challenges with moringa cultivation. One is obtaining seeds. One farmer said, "To get the seeds is difficult." [26, 6/1/17] Another noted that, "It takes time in germinating the seeds." [15, 5/31/17] A third farmer reported that planting moringa is labor intensive. He remarked, "The only challenge is planting. It's too hard. I am old." [14, 6/15/17] They noted that moringa are also susceptible to changes in the weather. A farmer reported, "I have eight trees, but have not harvested any because of the sunlight. The sunlight is too strong." [26, 6/1/17] He later added, "Rain is a challenge, so right now I'm watering." [26, 6/1/17] When farmers cannot raise their trees to maturation, they invest a great deal of time and energy without any payoff.

Moringa cultivation was also hindered by a lack of local awareness about the plant. Although some have cultivated moringa for years, others have only heard about it recently. A farmer remarked, "I've just recently learned of moringa . . . I knew of it in 2014." [26, 6/1/17] Another farmer echoed this sentiment, "Moringa is, to us, a very new plant . . . We are being told it's a medicine, which cures a lot of sickness, but myself I don't know because I haven't used it. But now I'm planting, maybe I'll learn more." [18, 6/10/17] Despite a lack of knowledge, they were eager to learn. A farmer shared,

> You see, the issue is, the challenge is, we haven't been exposed. I was reading an article from the newspaper . . . They started growing moringa, just a small piece of land. He

> used that moringa and started exporting the leaves . . . That person now is very rich. We are not exposed to. We don't have information here. [21, 6/10/17]

Greater knowledge could make moringa a more viable option for farmers in Lower Sagalla.

To further assess the viability of moringa cultivation in Lower Sagalla, I asked whether it is a marketable crop. One farmer replied, "Everything on moringa is money. You sell the flower, money. You sell the seeds for money." [22, 6/2/17] Another agreed, "You can sell [the seed pods] and get money." [14, 6/15/17] Furthermore, several reported there are local markets for moringa. A farmer noted, "[There is market] for seeds, the flowers because people buy as vegetables. In Voi, even around here in Mwambiti." [19, 7/4/17] Some farmers provided specific information about the market price. A farmer shared, "Some people going around buying at a very good price. They are buying the seeds. One-kilogram costing two hundred shillings. In fact, that is the local price. Maybe there is a place where you can be getting a better price." [15, 5/31/17] Another farmer reported the same price point. However, one farmer suggested that a better price may be available: "The seeds are three hundred shillings per kilogram." [20, 6/7/17] These anecdotes show there is a local market, primarily for moringa seeds. Moreover, the agriculture expert noted, "People haven't gone full out to exploit the potential of moringa here, which is very huge." [27, 6/8/17]. Overall, participating farmers agreed there is great potential for moringa in Lower Sagalla.

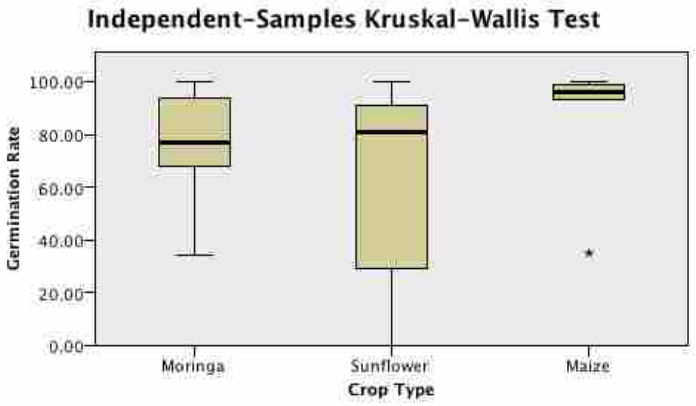
Experimental Results

In addition, to interviewing Lower Sagalla farmer and local experts to assess the relative palatability and ecological suitability, I also analyzed experimental data. In this section, I share the findings of my analysis. I start by describing observed crop-raiding events. Then, I examine

each crop's ecological suitability. Finally, I assess the relative palatability of each crop to crop-raiding elephants.

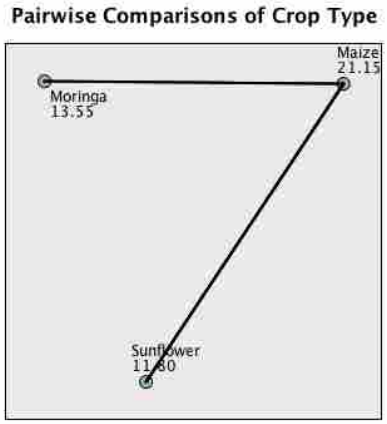
During my experimental period, elephant crop-raiding was prevalent throughout Lower Sagalla. Thirty-seven crop raiding events were recorded at nine out of ten experimental farms between December 2016 and March 2017. Each of the nine farms were crop-raided between two and eight times; the mean number of crop-raids was 4.1.

I compared the relative ecological suitability of each crop using germination rate and percent harvestable as a proxy. I compared the percentage of plants that had germinated by mid-January 2017. My Kruskal-Wallis analysis (n=30, df=2) yielded a p-value of 0.41. However, the post-hoc pairwise analysis did not show any statistically significant differences. [Figure 6] Thus, there were no significant differences in germination rate across crop types. A similar analysis conducted to compare the proportion of plants that was harvestable at the end of the growing season (March 2017) showed statistically significant differences. The Kruskal-Wallis analysis (n=30, df=2) yielded a p-value of 0.000. [Figure 7] Pairwise analysis showed significant differences between maize and sunflowers (p=0.044) and maize and moringa (p=0.000). Significantly more sunflowers and moringa were available for harvest at the end of the growing season than maize.



Total N	30
Test Statistic	6.396
Degrees of Freedom	2
Asymptotic Sig. (2-sided test)	.041

1. The test statistic is adjusted for ties.



Each node shows the sample average rank of Crop Type.

Sample1-Sample2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj.Sig.
Sunflower-Moringa	1.750	3.931	.445	.656	1.000
Sunflower-Maize	-9.350	3.931	-2.379	.017	.052
Moringa-Maize	-7.600	3.931	-1.933	.053	.160

Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same.
Asymptotic significances (2-sided tests) are displayed. The significance level is .05.
Significance values have been adjusted by the Bonferroni correction for multiple tests.

Figure 6: Germination Rate by Crop Type (January 2017) Kruskal-Wallis analysis of the proportion of seeds planted for each crop that germinated by mid-January across all experimental plots. Post-hoc pairwise comparisons show no statistically significant differences between crop types. Black lines represent non-significant relationships.

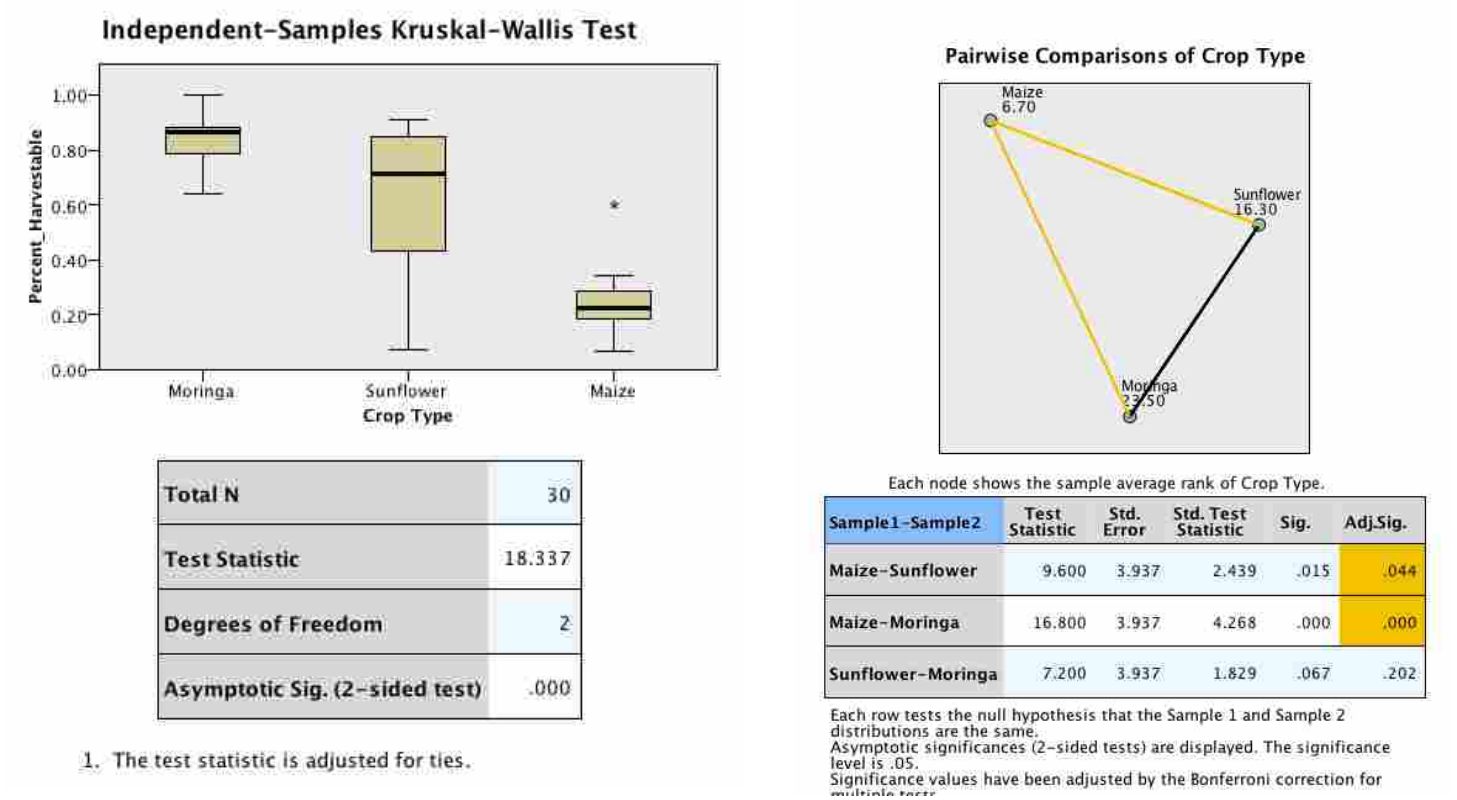


Figure 7: Proportion of Harvestable Plants by Crop Type (March 2017) Kruskal-Wallis analysis of the proportion of plants that were harvestable at the end of the growing season by crop type. Analysis show significant differences between maize and sunflowers (p=0.044) and maize and moringa (p=0.000). Yellow lines represent significant relationships; black lines represent non-significant relationships.

To assess the relative palatability of each crop, I compared rates of intentional elephant damage in January and March 2017. For both data sets, I conducted a Kruskal-Wallis analysis (n=30, df=2). In January 2017, the p-value was 0.002. [Figure 8] The pairwise comparison showed significant differences in intentional elephant damage between sunflowers and maize (p=0.001). The same analysis yielded of the March 2017 data yielded a p-value of 0.001 and pairwise comparisons showed significant differences between sunflowers and maize (p=0.002) and moringa and maize (p=0.004). [Figure 9] This strongly suggests that sunflowers and moringa are less palatable to elephants than maize.

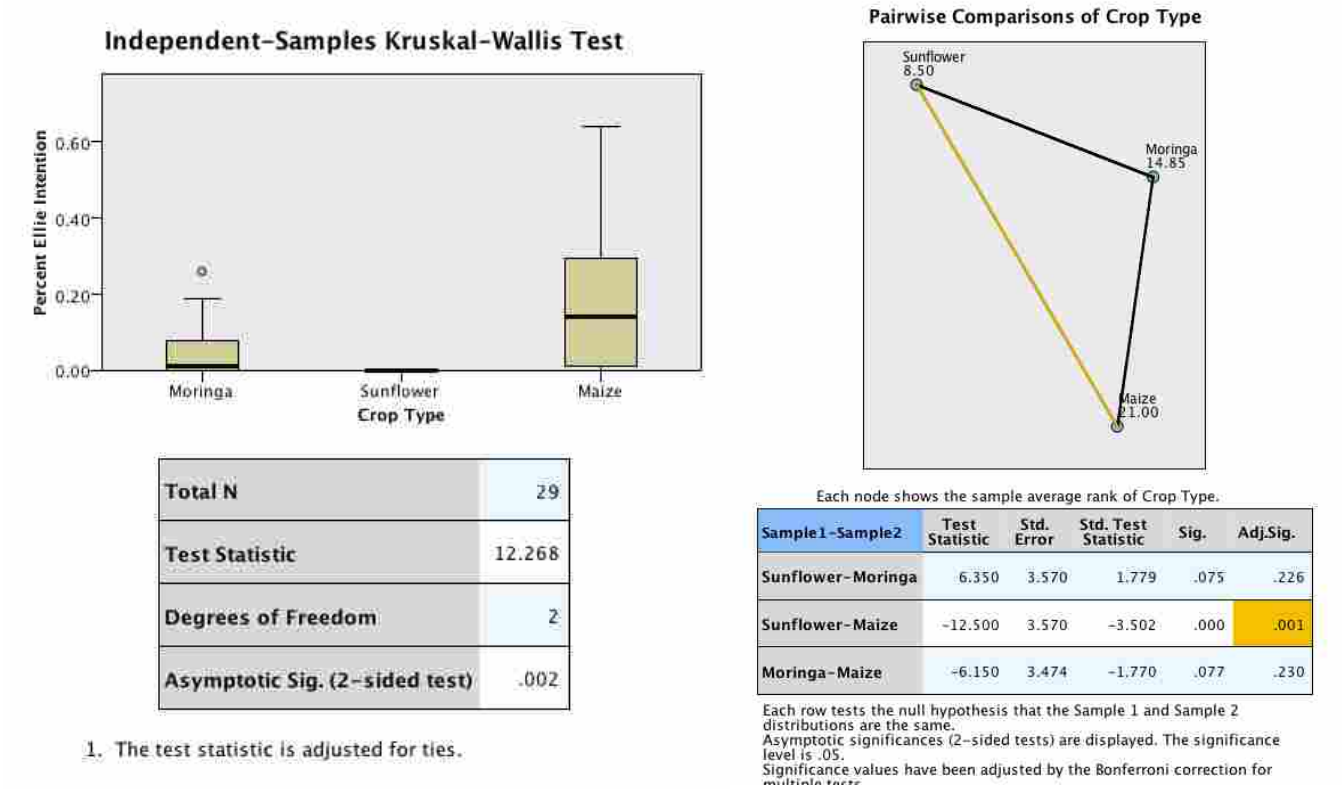


Figure 8: Proportion of Plants Intentionally Damaged by Elephants by Crop Type (January 2017) Kruskal-Wallis analysis of the proportion of each crop that was intentionally damaged by elephants via foraging and uprooting. Statistically significant differences were evident between sunflowers and maize (p=0.001). Yellow lines represent significant relationships; black lines represent non-significant relationships.

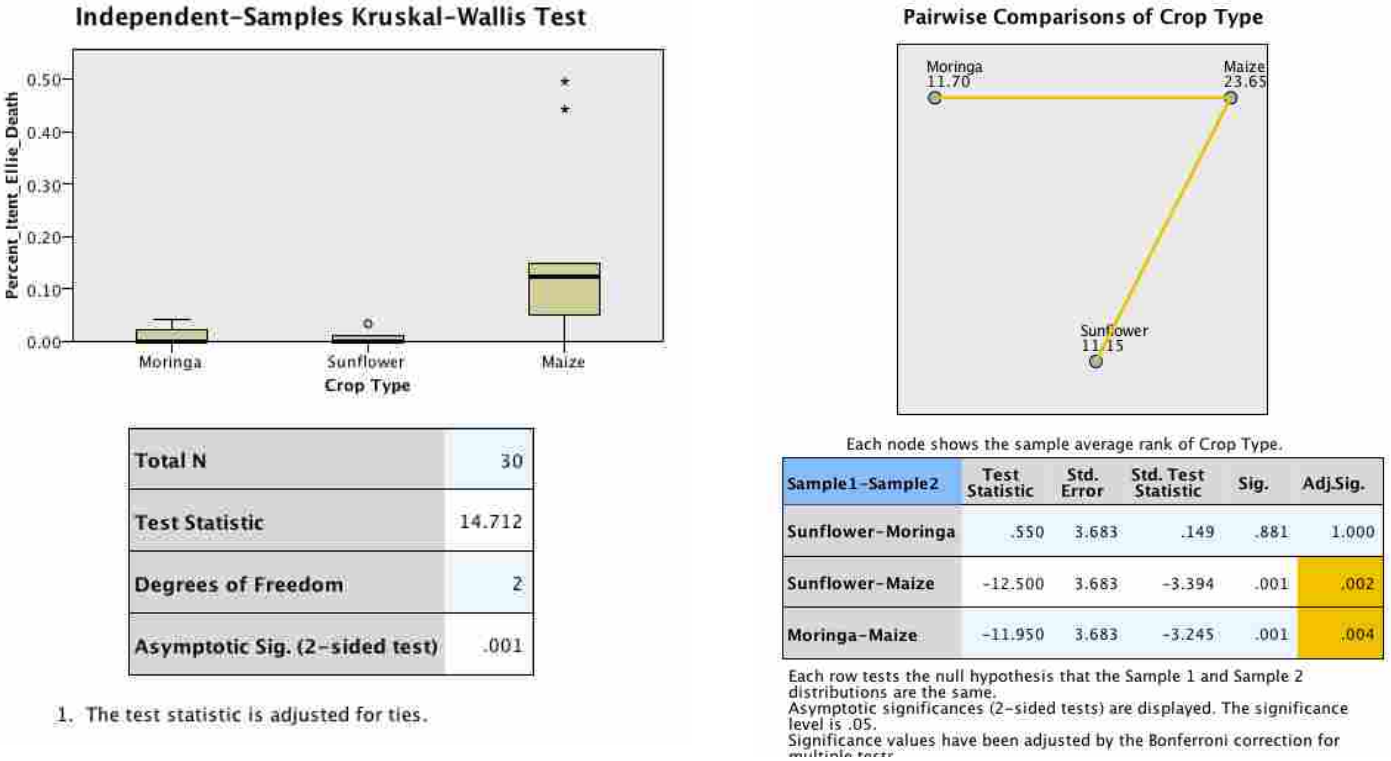


Figure 9: Proportion of Plants Intentionally Damaged by Elephants by Crop Type (March 2017)
Kruskal-Wallis analysis of the proportion of each crop that was intentionally damaged by elephants via foraging and uprooting. Statistically significant differences were evident between sunflowers and maize (p=0.002) and moringa and maize (p=0.004). Yellow lines represent significant relationships; black lines represent non-significant relationships.

Summary of Key Points

The farmers I interviewed believed that crop palatability to elephants influences elephant crop-raiding behavior. They observed that some plants appear less attractive to elephants including, chilies, aloe, and tomoko. In addition, I asked farmers about their experiences with the two potentially non-palatable crops, sunflowers and moringa. Some farmers believed both crops are non-palatable to elephants and are nutritionally and/or economically beneficial to farmers. Similarly, my experimental results show statistically significant differences across crop type; moringa and sunflowers are ecologically suited to grow well in Lower Sagalla and are less palatable to elephants than maize. Together these findings suggest both crops could be

incorporated into human-elephant farming conflict mitigation strategies. In the following section I examine farmer experiences with and perceptions of another elephant crop-raiding mitigation strategy prevalent in Lower Sagalla, beehive fences.

Beehive Fences

Beehive fences are an elephant deterrent method that was pioneered by external organization Elephants and Bees Project (EBP) and has been widely implemented. Numerous scientific publications and community member testimonials attest that it has significantly reduced elephant crop-raiding in Lower Sagalla. Planting non-palatable crops (e.g. sunflowers, moringa) in conjunction with beehive fences is among future strategies being discussed at EBP to improve beehive fences as a deterrent method.

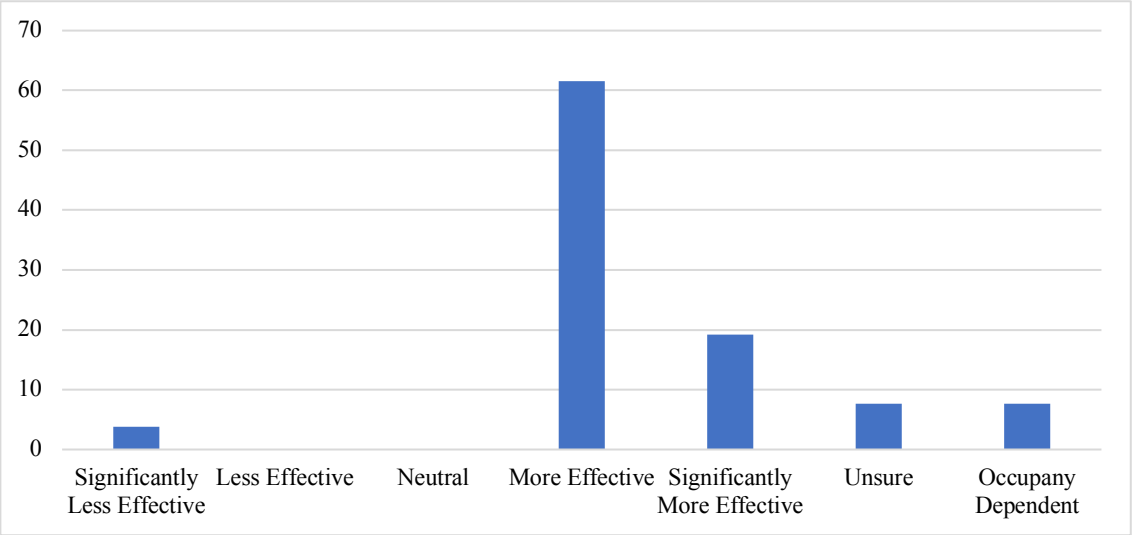
Perceptions of Beehive Fence Efficacy

During my farmer interviews, I asked them about their perceptions of and experiences with beehive fences. Fifteen farmers I interviewed had beehive fences; eleven did not. One beehive fence farmer noted, "Initially, I had no idea, but when it came into being and I saw the elephants rushing away . . . straying away from the beehives, I knew this is also a good idea". [1, 6/2/17] When asked how beehive fence efficacy compares to other elephant deterrent methods, 61% of farmers believed beehive fences are "more effective" and 19% considered them "significantly more effective" than other elephant deterrent methods. [Table 10] A beehive fence farmer explained why he believed beehive fences are "more effective",

> If you compare the hived farms with the unhived farms, the unhived ones are much more crop-raided . . . The elephants are proven to fear bees. Whenever they come they stare at the fence and then go around to find a gap, which proves they fear bees. [19, 7/4/17]

In this section I discuss what farmers with shared about the benefits and challenges of having a beehive fence on their property and their suggestions on how to improve the design. I also examine the challenges of and barriers to beehive fences shared by non-beehive fence farmers.

Table 10: Farmers' Perceptions of Beehive Fence Efficacy (%) (n=26)



Benefits of Beehive Fences

Many of the farmers lauded beehive fences and the benefits they can provide. A beehive fence farmer remarked, "We had suffered a lot. When we heard about this [beehive fences] it was just like [they were] preaching the gospel." [15, 5/31/17] The most commonly mentioned benefit was beehive fences' ability to deter elephants and protect farmers' crops. A beehive fence farmer remarked, "Elephants cannot crop-raid. They cannot consume crops where there are beehive fences. They just come and then leave hungry." [16, 6/5/17] Some farmers have observed beehive fences in action. Another shared,

> I have just seen one time one of my hives was occupied . . . [An elephant] came up to the wire, and the bees were very alert and they started coming out of the hive. And after the sound of the bees and the movement of the bees, the elephant just ran. So, that is now the impact it has on elephants. It puts them away, like chasing them. [22, 6/2/17]

Another third noted, “We have harvested, and we didn’t used to harvest before [the beehive fence].” [19, 7/4/17] By scaring away marauding elephants, beehive fences protect farmers’ crops and help ensure a successful harvest at the end of the growing season.

In addition, beehive fences eliminate the need for farmers to actively engage with crop-raiding elephants. A beehive fence farmer remarked,

> You running after elephants with drums and things is very dangerous for your life, but the beehive fence is better because it can control them. And even if the elephant went through it, then it’s just a fence and can be made, but if an elephant went through you then that’s a life taken which cannot be recovered. [7, 5/30/17]

Beehive fences protect crops even when farmers are not present. According to a beehive fence farmer,

> Beehive fences are more effective . . . Iron tapping cannot save your crops . . . The elephants may run and come back when you are asleep, whereas the beehive fence is on. You, maybe you are asleep, but the beehive fence will take care. [6, 6/9/17]

As long as the beehive fence is occupied, the crops are protected.

Farmers can also benefit from the bees themselves. Several farmers mentioned the benefit of beekeeping products, primarily honey. A beehive fence farmer noted, “Honey is food.” [16, 6/5/17] Another elaborated, “It also helps makes our foods more palatable and more nutritious by smearing on breads and other things . . . The honey has been medicinal; it has helped a lot of people in my family.” [15, 5/31/17] The honeybees provide food, medicine, and pollination services. A third beehive fence farmer remarked, “[Bees] help in pollination.” [19, 7/4/17] Another believed that her beehive fence helps support her crop production. She shared, “The sunflowers that we’ve planted around, I believe they are pollinated by the bees.” [15, 5/31/17] Bees’ pollination services can improve crop production and increase harvests.

Farmers can also sell honey as an additional income source. A beehive fence farmer remarked, “After getting honey, I sell. I get money. Last year I got plenty of money, so much

money . . . last year 13,200 shillings [~131 USD] . . . Per hive, I harvest 3,000 shillings [~30 USD].” [26, 6/1/17] Farmers use the income from their honey sales to support their families. Another exclaimed, “I will sell it [honey]. I will get money. I will buy what? Food!” [17, 6/12/17] One farmer’s honey production supports her children’s education. She noted, “[Selling honey] has improved our livelihood and we’ve used it to pay school fees.” [15, 5/31/17] Another used his honey sales to support his business. He remarked, “I have money when I sell honey . . . It is helping me so much, whereby I’m harvesting honey and the bees are deterring elephants so I’m harvesting crops. I’m selling honey and buying materials for my tailoring work.” [14, 6/15/17] With the additional income, beehive fence farmers are able to advance their families’ economic status.

Challenges of and Proposed Improvements to Beehive Fences

Despite their many benefits, beehive fences present unique challenges. Recurring maintenance was mentioned most commonly. A beehive fence farmer shared, “The challenge is post repair.” [14, 6/15/17] The ongoing repairs are especially difficult for elderly farmers who are unable to perform the maintenance themselves. A farmer remarked, “If I get money, I get somebody I ask him ‘You please, can you help me here?’ . . . The repairs every time are expensive. And I don’t have money, what can I do?” [17, 6/12/17] Another shared this sentiment,

> Plenty of repairs. All the time, the poles are drying up, and if they’re dry, they are weak and can fall and lead to the breakage. So, every time I am spending money. Because of my old age I can’t go to the forest to cut down trees. So, I’m giving money to someone to go and cut my posts. [26, 6/1/17]

These farmers must choose between paying someone and allowing their fences to fall in disrepair. To overcome this challenge, several farmers suggested using metal posts because they do not require frequent replacement.

The second most commonly mentioned challenge was damage to the hives by honey badgers. A non-beehive fence farmer remarked, "There are also some animals which go to break the beehives, the honey badgers." [12, 6/8/17] Honey badgers damage beehives and kill colonies when they steal honey. A farmer described the damage, "Honey badger comes and destroys it [beehive], tears the iron sheet." [26, 6/1/17] Another beehive fence farmer explained how honey badgers ruined her honey harvest: "One time I had full occupation, all my hives, I had struggled to maintain them, but then a honey badger destroyed all fifteen of them . . . I harvested nothing because of honey badger." [22, 6/2/17] The damage was so severe that it destroyed an entire beehive fence.

Several beehive fence farmers proposed ways to decrease beehive fences' vulnerability to honey badgers. A beehive farmer suggested, "If the hives are lifted up, so that the honey badger can stop jumping on them." [26, 6/1/17] Another developed a new method to prevent honey badger damage. He shared,

> If you tie an iron sheet around a post, there's a possibility that a honey badger can fly over the iron sheet and climb on to the hive, but if you use that flat one the possibilities are very high that it is blocked. [16, 6/5/17]

Several farmers proposed using metallic posts, which are more difficult for honey badgers to climb. A beehive fence farmer noted, "Maybe the using of metal rods that are a bit soft that the honey badger cannot climb." [19, 7/4/17] Effective honey badger deterrents would protect farmers' honey and livelihood.

Additionally, a few farmers noted that beehive fences require consistent occupancy to be effective. When occupancy is low (i.e. bees do not stick around), elephants can easily break the fence and enter the field. A farmer remarked, "It depends because maybe if the fence is not okay then the elephants will just come through if there are no bees." [16, 6/5/17] EBP's Project Leader shared a similar concern,

> [Beehive fences] would be much more effective with higher hive occupation . . . We bounce mostly between 40% and 60% [occupation] if we're lucky . . . So, what's interesting is we are roughly 80% effective and our hive occupation is about 50%, so it makes you wonder if we did have 100% occupation how effective it would be. So that's an exciting thing to look at and look at what the limits are for hives and colonies, probably the environment. So, if we had a really good rainy season one year, we might be able to boost that right up too." [28, 6/23/17]

Although low occupation rates are currently problematic, understanding the limiting factors could increase occupation and greatly reduce this challenge.

Some farmers proposed ways to increase beehive occupancy by making beehives more attractive to bees. A farmer proposed, "Plant sunflowers and pray to God that there will be bees." [26, 6/1/17] Another suggested, "Drilling a borehole, and planting some few flowers around to keep the bees excited and keep them growing in number." [11, 6/1/17] A few farmers also noted that proper beehive maintenance (e.g. installing a shade, giving bees sugar water) could improve occupancy. [19, 7/4/17]

Additionally, several farmers were concerned that gaps in beehive fences reduce their efficacy. If the fence is an "open shape" or has gaps, it is easier for elephants to enter the field. A farmer observed, "[Elephants] just check of a gap. Like this one where there is no beehive, and they will get in through there." [2, 5/29/17] Another had a similar experience: "They don't get in through the fence . . . They come around, they move around, when they see the gap here, they get in." [19, 7/4/17] This design flaw makes beehive fences vulnerable to marauding elephants and

increases the likelihood that crops will be damaged. Some farmers suggested mitigating this problem by making all fences a closed, rather than an open shape. A farmer remarked, "The problem [with beehive fences] is the spaces, if we fence everywhere and bees are there . . . then this is the effective method." [26, 6/1/17] This change would eliminate gaps where elephants enter the field to crop-raid.

Several non-beehive fence farmers believed the danger of keeping bees was not worth the protection from elephants. One non-beehive fence farmer noted that beekeeping is not allowed in his family because it is too dangerous. He shared, "For my family they [bees] are not allowed. I fear bees . . . It's so much painful when they sting you, and they kill people. I've seen them kill a goat. I've seen them kill a human being." [3, 6/16/17] Others were especially concerned for children's safety. A non-beehive fence farmer remarked, "If you have children, they can go and try and touch the beehive, and it is dangerous. It is good when the beehive is in your *shamba* [field in Swahili], to put the beehive very far away from your house." [12, 6/8/17] Another elaborated,

> [Beehive fences are] very dangerous when you have children . . . Children like playing and they like discovering. And it's in their trying to discover or their adventure they end up in problems. Yes. When maybe you're out, they've seen the hives. They will go with their stick and start playing with the bees. It's dangerous. [10, 5/31/17]

To mitigate this risk, a few proposed that beehives only be installed far away from homes and in places where there are no children. [10, 5/31/17]

Utilizing beehive fences in conjunction with non-palatable crops and other elephant deterrent techniques may reduce elephant crop-raiding and the HEC it creates. In the following chapter, I assess my results and relate my findings to pre-existing literature. Additionally, I discuss the management implications of my findings and provide recommendations for how it can be incorporated into to mitigate human-elephant conflict.

CHAPTER 5: DISCUSSION AND CONCLUSION

Although communities, governments, and NGO's have implemented numerous strategies to mitigate human-elephant farming conflict, it continues to be a serious challenge for many farmers. Intense conflict often occurs in places adjacent to protected areas because elephants leave protected areas looking for food and forage available from farmers' crops. By examining the human-elephant farming conflict in Lower Sagalla, this research provides an in-depth case study of farmers' experiences in one place regarding the sources and attempted solutions that could enable farmers and elephants to co-exist.

In this chapter I draw upon my results to discuss overarching themes and their implications. I will discuss four themes. I begin with discussing how Wasaghala farming over time has not prepared this group of farmers to adequately deal elephant crop-raiding. In recent years, the human-elephant farming conflict they experience has intensified due to drought and increasing human and elephant populations. Given these conditions, I discuss the reasons why contemporary Wasaghala living in Lower Sagalla are trapped in conflict with elephants and unable to pursue other economic options. Then, I shift focus to look at strategies they on their own and in combination with outside assistance (i.e. STE) use to mitigate human-elephant farming conflict. I explore the disconnect between externally-introduced, scientifically-tested methods and farmer interest in implementing such deterrent methods. Next, I consider crop palatability and the potential of non-palatable crops to reduce elephant crop-raiding behavior. I conclude this chapter with my recommendations and the management implications of my findings. I also identify opportunities for future research.

Local Incapacity to Manage Human-Elephant Farming Conflict

In this section I examine contributing factors that have rendered the Wasaghala farmers of Lower Sagalla unable to mitigate modern-day, large-scale human-elephant farming conflict. I start by discussing the Wasaghala's limited farming alongside elephants in Lower Sagalla and then consider traditional elephant deterrent techniques, including why they do not use them today. Finally, I examine how factors outside the Wasaghala's control have intensified the elephant crop-raiding they face.

The Wasaghala of Lower Sagalla's lack of experience farming where elephants roam limits their ability to manage increasingly problematic elephant crop-raiding. The Wasaghala traditionally lived in elephant-free Upper Sagalla and only began farming and grazing in Lower Sagalla during the mid-1900's. When they initially settled in Lower Sagalla, the Wasaghala experienced regular conflict with wild predators, but little with elephants. At that time, farming density was low; so, there was little attraction for elephants to crop-raid in Lower Sagalla.

Over thirty years, minimal elephant crop-raiding coupled with fertile farmland led to abundant harvests for the Wasaghala, which motivated others to move to Lower Sagalla during the 1980s. As greater numbers of Wasaghala relocated, human-elephant conflict remained low despite increasing farming activity. While at first surprising, the lack of conflict is explained by the size of the Tsavo elephant population at that time. When global ivory prices increased in the 1970s it caused widespread elephant poaching in the region, which combined with severe drought to decimate Tsavo's elephants (Kasiki 1998; Steinhart 1994). Thus, when the Wasaghala began settling in Lower Sagalla low elephant population numbers made crop-raiding uncommon and unlikely to significantly impact farmers' harvests.

However, as the human population grew in Lower Sagalla, conservation efforts, including a reduction in poaching, increased elephant numbers. Between 2014 and 2017 alone, elephant populations increased 14.7% in the Tsavo-Mkomazi ecosystem (Ngene et al. 2017). Together, elephant population growth and greater agricultural activity have increased the frequency of elephant crop-raiding in Lower Sagalla. The Wasaghala of Lower Sagalla have farmed under these conditions for only a few decades (i.e. 1990 to 2018), and therefore lack the experience and expertise necessary to address increasingly problematic elephant crop-raiding.

Additionally, the Wasaghala historically relied on the footprint method, a traditional religious ceremony, to manage whatever human-elephant farming conflict previously existed in Lower Sagalla. Since they originally settled in Lower Sagalla, elephant crop-raiding occurs more frequently, and elephants come in larger groups and are less afraid of humans. The footprint method was performed by religious leaders and involved gathering the soil where an elephant had stepped, reciting ceremonial prayers, and transporting the soil to elephant habitat (i.e. Tsavo National Park). Several farmers I interviewed avowed that the footprint method successfully reduced elephant crop-raiding by restricting the offending elephant and its herd to the national park. A few farmers advocated for the revival of the footprint method and believed it would reduce modern-day problems with crop-raiding elephants. Despite farmers' faith in the footprint method, its prior effectiveness likely stemmed from low elephant population density in the 1900's rather than mystical powers. The footprint method appeared to local farmers to be effective because there were not many elephants or farms at that time. Although the footprint method remains an important aspect of Wasaghala culture for many, it cannot be promoted widely as an effective tool to manage contemporary elephant crop-raiding.

However, the issue of escalating elephant crop-raiding in Lower Sagalla is more complicated than just farmer and elephant populations. The Wasaghala's other traditional elephant deterrent strategy, killing matriarchs, is no longer an option because hunting became illegal in Kenya in 1977 (Didi 2013; Steinhart 1994). Farmers are not permitted to kill elephants, even in defense of their homes and livelihoods. Additionally, Hoare's (1995) research suggested that killing elephants was not a very effective elephant deterrent technique. Thus, even if culling matriarchs was allowed, it may not reduce the frequency or severity of elephant crop-raiding.

The Wasaghala of Lower Sagalla are unable to effectively manage elephant crop-raiding because of several factors beyond their control, notably national-level infrastructure development and drought. Construction of the Standard Gauge Railroad, which separates Lower Sagalla and Tsavo East National Park, has intensified elephant crop-raiding by cutting off traditional elephant pathways. To return to the safety of Tsavo East National Park elephants must traverse a highway and railroad. Rather than risk that danger, many elephants have remained in Lower Sagalla. Thus, Wasaghala farmers must now defend their crops from not only baseline elephant crop-raiding but also from increased elephant numbers caused by the railroad. Although farmers have been able to identify the railroad as a driving force behind increasing crop-raid intensity and frequency, they are powerless to change it. Lower Sagalla's severe drought also has escalated regional human-elephant conflict. As natural foliage decreases and water holes dry up, elephants are increasingly drawn to forage in farmers' fields and drink from their water tanks (Blandy 2017). As human and elephant populations continue to grow and drought stresses both farmers' crops and natural foliage, competition between farmers and elephants over water and crops will escalate.

As elephant crop-raiding increases in severity and frequency in Lower Sagalla due to factors beyond their control, this research found the Wasaghala of Lower Sagalla to be ill-equipped to manage it. They have farmed alongside elephants for less than a century and lack the experiential knowledge and practices to deter increasing numbers of crop-raiding elephants. In addition, the Wasaghala are unable to rely on either of their traditional elephant deterrent strategies. In the following section, I expand on why they are unable to leave farming in favor of alternative livelihoods.

The Trap of Human-Elephant Farming Conflict

Many farmers I interviewed acknowledged that farming in Lower Sagalla is no longer as productive and profitable as it once was. However, few have been able to pursue alternative livelihoods. In this section I examine why Lower Sagalla farmers find themselves trapped in human-elephant farming conflict. First, I discuss how farming restricts economic opportunities. Then, I explain the role of land ownership. Next, I assess the lack of access to education and alternative livelihoods. Finally, I consider the role of limited government support.

Although farming was productive when the Wasaghala initially settled in Lower Sagalla; it is not a reliable livelihood today either for food provisioning or as a source of income. During my time in Kenya (August 2016-July 2017), severe drought and frequent elephant crop-raiding meant many farmers did not harvest anything. Over the past forty years, climate trends in Taita Taveta County have become increasingly erratic and unpredictable (MoALF 2016). Farmers invest their limited resources in hopes of a bountiful harvest but often find themselves empty-handed at the end of the season; and even in further debt. For example, Mackenzie and Ahabyona (2012) found that small-scale farmers take out loans to pay for farming supplies at the beginning of the season, and when harvests are lost to crop-raiding, farmers find themselves in

further debt. In serious instances, the farmers were imprisoned when they failed to repay their loans (Mackenzie & Ahabyona 2012). Several farmers I interviewed would like to pursue other economic activities, but challenging farming conditions make it difficult for small-scale farmers to save up enough money to do so. What little they harvest goes towards feeding the family and meeting immediate expenses (e.g. medical bills, school fees). Therefore, without reliable harvests farmers cannot accumulate enough surplus to invest in alternate livelihood activities and ultimately escape the cycle of poor harvest and food insecurity caused by elephant crop-raiding.

The demands of farming in the midst of elephant raiding further restricts farmers' access to livelihoods due to the high opportunity costs of field guarding. When farmers and their families spend hours protecting their fields, they are unable to pursue alternative economic activities. This finding is consistent with prior research by Meganze, Balakrishnan, and Belay (2017), who found that farmers considered field guarding effective at deterring wildlife, but tedious and time consuming. Additionally, farmers who spend the night defending their crops from elephants are too exhausted to do other work during the day. This forces farmers to choose between protecting their crops (a potential source of food security and income) or pursing other economic activities.

In addition, Lower Sagalla farmers cannot leverage the one resource they have in abundance which is land, to gain capital to invest in other economic activities. In Lower Sagalla, land is titled at the community rather than individual level. Instead of purchasing individual land parcels, community members pay a one-time fee authorizing them to use community land. Thus, they can claim land freely for their farming or grazing usage but cannot sell their claim to the land and use the money to purchase land elsewhere or start a business. They also cannot use it as a form of collateral to acquire loans. In Taita Taveta County as a whole, only forty percent of

farmers have title deeds (MoALF 2016). Lower Sagalla farmers are unable to profit from their farmland, so many have few options except to engage in low productivity farming where the land is free, but production unreliable and invariably limited.

Economic opportunities in Lower Sagalla are further restricted by limited access to education. Several farmers reported that children often encounter elephants on their way to school, which causes them to be tardy or miss the entire school day. In addition to being punished by teachers, habitual tardiness or absence from school, causes students to fall behind academically and repeat grades. Community leaders shortened the school day to reduce encounters between students and elephants. While successful in that regard, it also means that Lower Sagalla students spend less time in class than students in communities not impacted by elephants. Over time, this erodes the education level in the community as a whole and decreases the competitiveness of students in higher levels of education and the job market. Sitati and Ipara (2012) and Mackenzie and Ahabyona (2012) found that students living in communities that experienced wildlife crop-raiding did worse in school than those living in other communities.

Elephant crop-raiding limits access to education in Lower Sagalla through other means as well. When elephant damages decrease harvest profits, farmers are forced to choose between feeding their families and paying school fees. If school fees cannot be paid, children may stay home and work in the fields instead. Mackenzie and Ahabyona (2012) found that when children are unable to pay school fees they can be kicked out of school. In addition, children may be kept home from school to assist in guarding the fields. Reduced access to education and employment opportunities can leave children with few options besides farming in Lower Sagalla when they become adults.

Lower Sagalla farmers' economic opportunities are further restricted by the lack of government support they receive. In instances of serious crop damage, the Kenya Wildlife Service promises farmers compensation. Although every farmer I interviewed reported that they had lost crops due to elephant trampling and consumption, few had been compensated for the loss. Instead, they were met with bureaucracy and misleading information. Many depend on farming as their primary source of income. When crops are damaged, and compensation is unpaid, farmers find themselves unable to support their families. Without payouts for damage, farmers are cannot recoup their lost investment, which means they cannot put it towards another more stable economic pursuit.

Together these factors restrict farmers economic opportunities and force them to continue farming even though they know it is unreliable and not profitable. They simply do not have access to other options. In the next section, I examine the strategies that farmers utilize to mitigate elephant-farming conflict today and why their preferences differ from outside, scientific recommendations.

Elephant Deterrent Method Disconnect

Small-scale farmers, NGO's, and scientists are all working to improve human-elephant co-existence and endorse a variety of strategies to do so. However, my research revealed a disconnect between the deterrent strategies that Lower Sagalla farmers believe are the most fitting to them and their conditions with those that scientists advocate from experimental methods regarding what is most effective. In this section, I examine this disconnect. I share the views of the farmers I interviewed on elephant deterrent techniques. Then, I explain which

methods scientific researchers have deemed most effective. Finally, I explain why this disconnect persists.

Today Lower Sagalla farmers employ a variety of strategies to try and eke out a living in the face of severe elephant crop-raiding. Farmers utilize a variety of deterrent techniques; however, their options are greatly restricted by their financial constraints and ability to procure the method. Similarly, research by Hsiao et al. (2013) also found that farmers considered affordability when choosing their elephant deterrent strategy. In many instances, farmers are unable to utilize the deterrent methods they consider most effective because they are too expensive.

Many farmers perceived "set and go" methods as the most effective. These methods can be installed by the farmer and left to protect the crops. Examples include beehive, electric, and non-electric wire fences and trenches. Previous research has also revealed a similar preference by farmers for trenches and electric fences (Mackenzie & Ahabyona 2012; Noga et al. 2015). Additionally, Hsaio et al. (2013) found that after installation, farmers continued to maintain their fences, which suggested that the farmers viewed them as highly effective at deterring elephants. Farmers prefer "set and go" methods because once installed they require low levels of energetic investment and effectively deter elephants even without human presence. Additionally, Hsiao et al. (2013) showed that the elephant deterrent methods that appealed most to farmers were affordable, reduced the need for human guarding, and alerted farmers to the animal's arrival.

In contrast, scientific research suggests that human guarding is the most effective way to deter crop-raiding elephants. During my interview with Elephants and Bees Project's Project Leader she explained that elephants are deterred by field guarding because humans are erratic. Unlike static deterrent methods like fences or wind chimes, human beings are unpredictable, and

elephants have a difficult time figuring them out. Previous research on deterrent method efficacy also recommended human field guarding as a highly effective elephant deterrent (Hedges & Gunyardi 2010; Osborn & Parker 2003; Sitati, Walpole, & Leader-Williams 2005). Additionally, Harich et al. (2013) found that making noise (a form of field guarding) was the wildlife deterrent method perceived as most effective. Similarly, Gunaryadi, Sugiyo, and Hedges (2017) found that traditional guarding methods (e.g. watch towers) were highly effective when coupled with early warning systems.

Although human guarding is highly effective at deterring elephants, its efficacy requires high energetic and time investments. For Lower Sagalla farmers, who experience crop-raiding nightly during peak ripening, regular field guarding has high opportunity costs, which exhaust farmers over time. When farmers protect their crops from elephants nightly, they lose sleep and become fatigued. Therefore, farmers sleep during the day so they can protect their crops at night. Protecting fields at night and sleeping during the day, means farmers do not have the time or energy to work in their fields or pursue alternative economic opportunities during the day. In their study Mackenzie and Ahabyona (2012) noted the immense opportunity costs of field guarding including inability to pursue alternative livelihoods and children missing school.

Farmers want solutions to elephant crop-raiding that provide maximum deterrent efficacy with minimum energetic input. This would enable farmers to protect their fields and expand their economic opportunities. In the next section, I discuss how knowledge about elephant foraging preferences and relative crop-palatability can potentially benefit farmers by reducing elephant crop-raiding behavior and the necessity for field guarding.

Novel Non-Palatable Crops

Elephants are discerning foragers. They strategically choose plants that are tasty and nutritiously beneficial. In this section, I discuss my findings relating to elephant foraging selectivity in the context of previous research. Then, I examine the ecological appropriateness and relative palatability of sunflowers and moringa to elephants in Lower Sagalla.

Foraging Selectivity

The farmers and regional experts I interviewed noted that elephants forage selectively. They have observed elephants bypassing crops and farms in order to reach others that are more desirable. They attested that elephants choose between plans based on their attractive (e.g. sweetness, nutrient density) characteristics. This finding concurs with previous research on relative crop palatability. For example, Chiyo et al. (2005) found that elephants crop-raid due to a preference for cultivars over natural foliage and preferentially eat maize, bananas, and beans.

Additionally, elephants avoid foraging on crops that are less palatable. The farmers and experts I interviewed proposed that crops may be non-palatable to elephants if they are too toxic, fibrous, or spicy. This assertion is supported by previous research that examined non-palatable crops and found that chilies, peanuts, and ginger are less palatable to elephants (Webber et al. 2011). Additionally, a recent experiment by Gross, McRobb, and Gross (2015) compared elephant damages between maize and potentially non-palatable crops. They found that elephants preferentially raided maize over the plot with ginger, garlic, onion, and lemongrass. This suggests that planting crops that are non-palatable to elephants may be a strategy to reduce elephant crop-raiding damage. Furthermore, Osborn and Parker (2003) recommend planting a barrier zone of non-palatable crops around farms to decrease elephant attraction to the area.

Numerous studies have examined the use of chilies in fencing, bricks, etc. to deter crop-raiding elephants (Chang'a et al. 2016; Chelliah et al. 2010; Webber et al. 2011). However, only a few have examined other non-palatable crops (Gross et al 2015; Webber et al. 2011). This research expands upon previous findings by proposing new potentially non-palatable crops and assessing the economic, social, and ecological contexts of their cultivation.

Sunflowers

My results strongly suggest that sunflowers are a viable non-palatable crop option for Lower Sagalla farmers. They were the second most frequently mentioned non-palatable crop among the farmers I interviewed, and this assertion was supported by my experimental results. In the middle of the growing season (January 2017), elephants intentionally damaged (i.e. foraged) maize, a known elephant favorite, significantly more than sunflowers. I observed a similar pattern at the end of the growing season (March 2017); there were significant differences in rates of death caused by intentional elephant damage between sunflowers and maize. These results suggest that sunflowers are significantly less palatable to elephants than maize and may be incorporated into farms as a way to decrease intentional elephant damages.

In addition to being less palatable to elephants than maize, sunflowers also grow well in Lower Sagalla. Several farmers already grow sunflowers and reported successful harvest in recent years. Local experts also noted that sunflowers grow well in Lower Sagalla's climate. My experimental findings supported this assertion. In mid-January 2017, there were no significant differences in germination rate between sunflowers and maize. Sunflowers germinated equally as well as maize, the current staple crop. Furthermore, at the end of the growing season (March 2017), there were differences between maize and sunflowers in the percent of the crop that was

harvestable. Significantly more sunflowers survived to be harvested than maize. Sunflowers better withstood the myriad of cultivation challenges in Lower Sagalla including elephant crop-raiding, drought, and insect damage; they not only germinated well but also persisted until harvest. Similarly, MoALF (2016) reported that maize yields have diminished in the face of climate change, and they recommended the cultivation of drought-tolerant crops.

The farmers I interviewed exhibited a high degree of familiarity with sunflowers and moderate experience cultivating them, which suggests they have already been accepted by Wasaghala culture. Farmers noted numerous benefits of growing sunflowers, ranging from their use as human food and livestock fodder to bee fodder and beauty. Sunflower seeds can be used directly by the farmer or sold at locally accessible markets. Several farmers I interviewed identified a local market for sunflower seeds and have previously sold seeds there. Overall, sunflowers offer farmers a culturally and climatically appropriate alternative crop that is less palatable to elephants than maize. However, most farmers continue to plant maize because it is their staple food crop.

Moringa

Moringa's non-palatability to elephants is less clear than that of sunflowers. During my interviews, the farmers I talked to were divided on whether or not moringa was attractive or not to elephants. In my experimental plot research, as of January 2017, there were no statistical differences in intentional elephant damages between either moringa and sunflowers or moringa and maize. However, at the end of the growing season (March 2017), there was significantly less crop death attributed to intentional elephant activity in moringa than in maize. Elephants' increased attraction to maize later in the growing season may be caused by differences in crop

maturation rates. Maize reaches maturity within one growing season while it takes moringa several seasons. Prior research showed that elephants preferentially forage on maize fruits (Chiyo et al. 2005). Thus, the difference in maturity between maize and moringa in March 2017 may have caused elephants to preferentially eat maize.

Like sunflowers, moringa are well-suited to grow in Lower Sagalla. According to a regional expert, moringa trees are drought-tolerant and can persist even when rainfall is low. At the beginning of the growing season, there were no significant differences in germination rates among crops; all germinated equally well. However, by the end of the growing season (March 2017) there were statistically significant differences in the proportion of the crop that was harvestable. There were no differences between moringa and sunflowers, but there was significantly more moringa available for harvest than maize.

Only a few farmers I interviewed have cultivated moringa; however, several farmers unfamiliar with moringa expressed interest in learning more about them. Those who were familiar with moringa lauded its nutritional and medicinal benefits as well as its role as a nitrogen fixer. In addition to being directly utilized by the farmer, moringa seeds and leaves can also be sold in local markets. Some farmers noted that a local market exists for moringa and have sold seeds there.

Economic Viability of Sunflowers and Moringa

Previous research has recommended planting non-palatable crops as a strategy to reduce elephant crop-raiding (Chiyo et al. 2005). Although some Lower Sagalla farmers grow and sell sunflowers and moringa, they are predominantly doing so on a small-scale. This diversifies farm production but may not reduce the farm's attraction to elephants. Scaling up non-palatable crop

cultivation to replace maize is more complicated than simply planting different seeds. Large-scale adoption of non-palatable crops may require support from NGO's or the government because farmers lack the capital and knowledge to do so independently. Information sessions for farmers on crop cultivation and harvest would facilitate farmers' adoption of new crops by increasing their familiarity with them.

Additionally, Lower Sagalla farmers are accustomed to cultivation for home use and may be ill-prepared to cultivate and sell market-dependent non-palatable crops. This transition could be facilitated by assisting farmers in identifying markets or offering best practice trainings on secondary product production. For example, teaching farmers how to extract oil from sunflower seeds and use this oil to make soap or other value-added products with local demand. Creating secondary products increases the crop's value and shelf life. Alternatively, NGO's or the government could provide fixed price buying for small-scale farmers.

Despite the challenges of adopting moringa and sunflowers, they hold great potential as maize alternatives in Lower Sagalla. They were significantly less damaged by elephant crop-raiding than maize and are well suited to the local climate. Furthermore, both crops are already cultivated on a small-scale in Lower Sagalla, and farmers expressed interest in learning more about them. Additionally, two local NGO's expressed willingness to assist farmers in learning more about moringa and sunflowers and improve access to seeds and markets.

This research provides an in-depth look at human-elephant farming conflict in Lower Sagalla; however, the limited scale and small sample size of this experiment limit its generalizability to other communities in Kenya. Therefore, additional research on sunflowers and moringa is necessary to assess the significance of my findings and their transferability to other

communities experiencing severe elephant crop-raiding. In the next section, I share my recommendations for how non-palatable crops can be utilized to reduce elephant crop-raiding.

Conclusion

Addressing complex human-elephant farming conflict, such as found among Wasaghala farmers in Lower Sagalla, Taita Taveta County, Kenya, requires implementing multi-faceted approaches that are locally appropriate and which reduce immediate crop-damage and mitigate drivers of long-term human-elephant farming conflict. In this section, I explain my recommended approach to minimize crop loss to marauding elephants, that is, an approach entailing effective elephant deterrent methods and non-palatable crops.

For Wasaghala farmers living alongside elephants in Lower Sagalla, the most immediate concern is reducing crop damage caused by elephant crop-raiding. Therefore, these small-scale farmers need access to effective elephant deterrent techniques, and importantly, ones that mesh well with their everyday lives and resources. To maximize field protection, I recommend implementing beehive fences, a scientifically proven and economically accessible elephant deterrent method (King 2010; King et al. 2017). As a "set and go" deterrent, beehive fences satisfy famers' desire for a method that protects crops even when nobody is home and does not require constant vigilance. This would enable farmers to devote more time to pursuing alternative livelihoods and socializing within the community. Several NGO's, including Save the Elephants, are working closely with small-scale farmers across Africa and Asia to educate farmers about beehive fences and subsidize the costs of installation. Field guarding could be combined with beehive fences when elephants break through to increase farm protection. This combined approach would reduce damage to crops within the beehive fence and enable farmers to increase their access to economic opportunities.

With sufficient outside support, installing electric fences, another "set and go" method strongly preferred by farmers, could decrease crop vulnerability to elephants and increase farm productivity. Fencing small parcels with electric fences could allow farmers to intensively cultivate high-value crops without the threat of elephant crop-raiding. With fences to protect their fields, farmers would have to spend less time guarding crops and could pursue alternative livelihoods.

To further reduce crop loss to elephants, I recommend that farmers dedicate part of their farmland to cultivating non-palatable crops instead of known elephant favorites like green grams and maize. Shifting agricultural practices to cultivate crops that are non-palatable to elephants would reduce the attraction for elephants to enter that field. Growing both rapidly maturing non-palatable crops like sunflowers, chilies, and ginger as well as slow-maturing non-palatable trees including moringa would provide farmers with short-term income and long-term agro-ecological benefits (e.g. decreased soil erosion, nitrogen fixation). Non-palatable crop cultivation could be coupled with "set and go" methods to increase farm profitability. Farmers could strategically plant high-value elephant favorites (e.g. maize) inside beehive or electric fences while planting less palatable crops (e.g. sunflowers, chilies) outside the fences.

Despite the benefits and climatic suitability of growing non-palatable crops, it may be difficult for some farmers to shift farm cultivation away from maize because it is their staple crop and an important part of Wasaghala culture. According to MoALF (2016, 8), "between 61 and 80% of the County's [Taita Taveta] population is engaged in maize production mostly at a small-scale level". Additionally, most farmers currently grow crops primarily grow crops for family consumption and cultivating non-palatable crops would necessitate selling crops at local markets.

Land-use planning and the creation of non-palatable crop buffer zones around individual farms or clusters of farms may decrease human-elephant farming conflict on an even greater scale. Non-palatable crop buffer zones may mask the scent of more palatable crops, thus reducing the attraction for elephants to enter the community and crop-raid. Additionally, this could benefit the community as a whole by mitigating the indirect consequences of elephant movement and crop-raiding. For example, decreasing the number of elephants traveling in and through the community would lessen the threat to personal safety that currently restricts travel and school attendance and create widespread mental and emotional distress among people from young to old.

In addition to modifying crop cultivation, another important strategy to reducing the economic impact of human-elephant farming conflict is diversifying household livelihoods. Skills trainings should be held by the Kenyan government or local NGO's to introduce and encourage the adoption of alternative livelihoods such as poultry farming, sisal basket weaving, tailoring, and beekeeping that are not as rainfall dependent as crop cultivation. These livelihoods are already pursued on a small-scale within Lower Sagalla, and several farmers I interviewed expressed interest in these economic activities. As elephant crop-raiding and drought continue to intensify, decreasing local reliance on crop cultivation has the potential to provide greater economic stability and reduce the necessity of relying on illegal activities (e.g. charcoal burning, poaching) when crops fail. However, these changes are easier said than done and carry opportunities and costs that need to be understood. This approach could be modified as they become known.

This multi-faceted approach has the potential to address crop-raiding, the proximate cause of human-elephant farming conflict in Lower Sagalla. However, the issue is far more

complicated than subsistence farmers and elephant populations. Additional research is necessary to consider the role of larger-scale dynamics (e.g. global ivory prices, national-level wildlife policy, impacts of climate change) in the creation and resolution of this conflict. Only by addressing the underlying drivers of human-elephant farming conflict at a national and global scale can Lower Sagalla achieve human-elephant co-existence.

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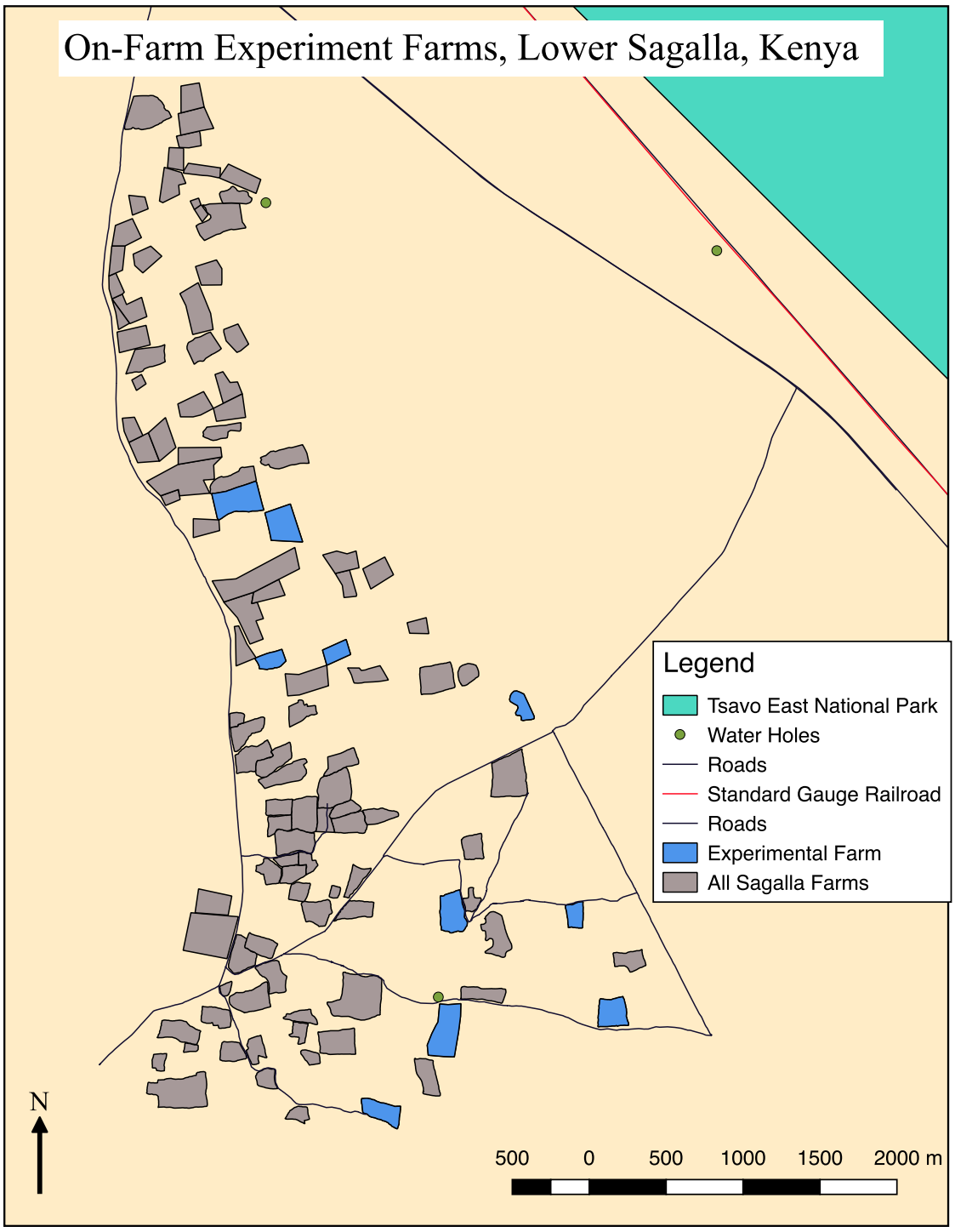
APPENDIX A: SITE MAP



APPENDIX B: INTERVIEW GUIDE

Introduction: Hi, and thank you for taking the time to do this interview with me. As you know, I am a graduate student at the University of Montana and am working with Save the Elephants for my master's thesis project. As part of my research, I want to learn about how you and others here farm and your opinions about crop-raiding elephants.

Before we begin, I want to let you know that your name and identifying information will remain confidential, and your name will not be used in any reports or presentations. If at any point you choose to no longer answer my questions, that's fine. I would like to record this conversation to ensure that I can accurately remember your views and take minimal notes. Recordings will be deleted at the end of my project. Is that alright with you? [*If yes, TURN ON RECORDER*]

While I have a list of questions I'd like to ask you, please feel free at any time to ask me a question or tell me something you think would help me understand more about your farming and how it is affected by elephants.

Personal Background/ Involvement: I'd like to start with background on your farming history in Sagalla.

1. When did you and your family start farming at this location?
2. Why did you or your family start farming at this location in Sagalla?
    a. Follow up: How did you acquire this land? [i.e. purchased, inherited]
    b. Follow up: Before farming here did your family farm somewhere else?
3. Did you and/or your family previously or do you currently farm on the top of Sagalla Hill as well? Why or why not?
    a. Follow up: Which location is your family's primary farm?
4. Follow up: Does your family farm any other parcels in lower Sagalla?
    a. Follow up: Where are your other parcels?
    b. Follow up: How large are your farm parcels?
    c. Follow up: What is the surrounding land use? [e.g. road, farm, bush]
5. Who are the farmers in your family – what does each person do?
    a. Follow up: Does anybody else help you to do farm work?
6. Who is responsible for making farming decisions? [e.g. when to plant, which crops]
7. What do you think are the three greatest challenges facing this community?

Farming in Sagalla: Great, thank you. Now, I'd like to learn more about farming in Sagalla.

1. Which crops did you and your family plant during the long rains (April-July) at this parcel last year?
2. Which crops did you and your family plant during the short rains (Oct-Dec) at this parcel last year?
    a. Follow up: Why did you plant different crops during the short and long rains?
3. In addition to crop type, what else do you think about in deciding which crops to plant?
    a. Follow up: Which factor is most important to you and your family?
    b. Follow up: Why is this the most important?
4. Did you plant something different from the year before?
    a. Follow up: If so, why?
5. Are there any crops that you and/or your family previously (or historically) grew that you no longer plant?
    a. Follow up: If so, why did you stop planting them?
    b. Follow up: Did elephants raid these crops?
        i. When?
        ii. What was the main cause of the damage? [e.g. trampling, consumption]
6. Do you plant the same or different crops at your other farm parcels in lower Sagalla?

7. How do you decide where to plant each crop? [i.e. which parcel, proximity to house/bush/ crops, attractiveness to animals, amount of care required]
    a. Follow up: Which characteristic is most important in determining the location?
8. Since you started farming in this area, has the rainfall increased, decreased, or stayed the same?

Impacts of Crop-raiding: I would like to learn more about your experiences farming in a place where there are elephants.

1. Do you think that human populations in lower Sagalla are increasing, decreasing, or staying the same?
    a. Follow up: How have these changes altered the size and number of farms in lower Sagalla?
    b. Follow up: Are there any other ways in which changes in human populations have led to changes in farming activity?
2. Do you think that elephant populations in Tsavo National Park are increasing, decreasing, or staying the same?
3. Do you think that the number of elephants that come into Sagalla is increasing, decreasing, or staying the same?
    a. Follow up: How does the current frequency of elephant crop-raiding compare to when you started farming here?
5. During which months do elephants visit your farm?
    a. Follow up: During which month do elephants visit most frequently?
6. Do elephants impact you and your family in any of the following ways? Please respond yes or no for each potential impact.

Impact	Impacted?	
Crop trampling	Yes	No
Crop consumption	Yes	No
Lack of sleep	Yes	No
Destruction of property	Yes	No
Death & injury to humans	Yes	No
Death & injury to livestock	Yes	No
Emotional & mental distress	Yes	No
Time spent guarding	Yes	No
Other:	Yes	No
Other:	Yes	No

    a. Follow up: Of the impacts you experience, which three are the most severe?
7. How does the severity of elephant crop-raiding compare to when you started farming here?

Deterrent Strategies: Since we just discussed some of the problems elephants cause to your farms, I want to discuss strategies that you may use to minimize the impacts of elephant crop-raiding.

1. Do you do anything to keep elephants out of your farms?
    a. Follow up: Why not?
2. Which methods do you use to deter elephants? Please respond yes/no for each deterrent method.

Method	Use	
Throwing stones	Yes	No
Torch (flashlight)	Yes	No
Night guarding	Yes	No
Fire	Yes	No
Fireworks	Yes	No
Dogs	Yes	No
Thorn fences	Yes	No

Chilies	Yes	No
Beehive fence	Yes	No
Shouting or banging pots & iron sheets	Yes	No
Burning dung	Yes	No
Call Kenya Wildlife Service	Yes	No
Other:	Yes	No
Other:	Yes	No

   a. Follow up: Which method do you utilize most frequently?
   b. Follow up: Why do you choose it so frequently?
3. Which method do you think is most effective?
   a. Follow up: Why do you think this is the most effective?
   b. Follow up: If it is not the method you utilize most frequently, why don't you use it more often?
4. Are there any methods that you previously utilized but not currently?
   a. Follow up: If so, why are they no longer used?
   b. Follow up: Are there any additional methods that were used by your parents or grandparents, but that you do not use?
      i. Why are they no longer used?

Beehive Fences: Now I'd like to learn more about your experiences with one elephant deterrent method, beehive fences.

1. How did you get involved with the Elephants and Bees Project? [i.e. How did you hear about it?]
2. What were your initial impressions of beehive fences? [i.e. Would they work?]
3. Currently, what impact do you think beehive fences have on elephants entering fields?
   a. Follow up: Do beehive fences impact the severity of damage caused by raiding elephants?
4. How does their effectiveness compare to other ways to deter elephants?

Significantly Less Effective	**Less Effective**	**Neutral**	**More Effective**	**Significantly More Effective**

5. Are there any benefits of having a beehive fence over other deterrent methods?
   a. Follow up: What are they?
6. What makes having a beehive fence more challenging than other deterrent methods?
7. How do you think beehive fences could be made more effective at deterring elephants?

Non-palatable Crops: Thanks for sharing. I would like to understand your views on how farming specific crops influences elephant behavior.

1. Why do you think elephants come into your field to crop-raid?
2. Do you think that the crops you plant matter to elephants?
   a. Follow up: Do elephants come the same amount no matter what you plant?
   b. Follow up: What do you think might make a plant less attractive to elephants?
3. Which crops do you think are less attractive to elephants? [i.e. palatable]
   a. Follow up: Which of these crops do you plant?
      i. Why don't you currently plant these crops?
   b. Follow up: What, if any, are barriers to planting non-palatable crops?
4. Do you think sunflowers are attractive to elephants?
   a. Follow up: What are some benefits of growing sunflowers?
   b. Follow up: What are some challenges of growing sunflowers? [e.g. money, lack of knowledge]
   c. Follow up: Do you think there is a local market for sunflowers?

5. Do you think moringa is attractive to elephants?
    a. Follow up: What are some benefits of growing moringa?
    b. Follow up: What are some challenges of growing moringa? [e.g. money, lack of knowledge]
    c. Follow up: Do you think there is a local market for moringa?

Additional Income Sources: In addition to growing crops, I'd like to know more about other income sources for you and your family.

1. Do you and your family have any forms of income in addition to growing crops?
    a. Follow up: What are they?
    b. Follow up: What is your main source of income?
2. Are there any additional income sources that you are interested in pursuing?
    a. Follow up: What, if any, are the barriers to doing so?
    b. Follow up: Why are you interested in this income source?

Wrap Up: Great, thanks, well that's about all I have on my end.

1. Is there anything else that you think is important for me to know regarding problems of elephants for you in your farm here in Sagalla?
2. Is there anyone else in Sagalla who I should talk to that may have additional information or insight on the history of elephants here, or who is doing something different to stop them from damaging farms?
3. Do you have any questions for me?

Thank you for your time! May I contact you in the future as I continue work on my research project?

ADDITIONAL QUESTIONS FOR SAVE THE ELEPHANTS EMPLOYEES:

STE Involvement: I'd like to start with your role within Save the Elephants (STE).

1. How long have you lived in the community of Sagalla?
2. What do you do for STE?
    a. Follow up: What is your job title?
    b. Follow up: Can you give me some examples of your job tasks or responsibilities?
    c. Follow up: How long have you worked for STE?
    d. Follow up: Why do you work for STE?
3. How did you first hear about STE?
4. How does your role in STE relate to human-elephant interactions in Sagalla?
    a. Follow up: Can you give me an example?
5. Do you have any other work?

ADDITIONAL QUESTIONS FOR COMMUNITY LEADERS:

Community Role/STE Involvement: I'd like to start with your role in the community.

1. How long have you lived in the community of Sagalla?
2. What is your role in the community?
    a. Follow up: What is your job title?
    b. Follow up: Can you give me some examples of your job tasks or responsibilities?
3. How does your role in the community relate to human-elephant interactions in Sagalla?
    a. Follow up: Can you give me an example?

Sagalla History: I want to learn more about the history of Sagalla.

1. When was Mwakoma/Mwambiti established?
2. Why was Mwakoma/Mwambiti first settled?
3. When it was established, how was land allocated among community members?
    a. Follow up: Who made these decisions?
4. How is land currently allocated in the community?
    a. Follow up: Who makes these decisions?
5. Are human populations in lower Sagalla are increasing, decreasing, or staying the same?
    a. Follow up: Is the population increasing mainly through birth or immigration?

APPENDIX C: DEMOGRAPHICS OF LOWER SAGALLA FARMERS INTERVIEWED

Gender	
Male	18
Female	6
Couple	2
Time Farming in Lower Sagalla	
10-20 years	9
20- 30 years	4
30-40 years	6
> 40 years	4
Not currently farming	3
Acres Farmed	
5-10 acres	12
10-20 acres	7
>20 acres	1
Not currently farming	3
Unknown	3

APPENDIX D: INSTITUTIONAL REVIEW BOARD APPROVAL

UNIVERSITY OF MONTANA

INSTITUTIONAL REVIEW BOARD
for the Protection of Human Subjects in Research
FWA 00000078
Research & Creative Scholarship
University Hall 116
University of Montana
Missoula, MT 59812
Phone 406-243-6672 | Fax 406-243-6330

Date: May 26, 2016

To: Sophia Weinmann, Society and Conservation
Dr. Jill Belsky, Society and Conservation

From: Paula A. Baker, IRB Chair and Manager

RE: IRB #118-16: "Impacts of Crop-choice on Crop-raiding and Human-elephant Conflict in Sagalla, Taita Taveta Couty, Kenya"

Your IRB proposal cited above has been **approved** under the **Exempt** category of review by the Institutional Review Board in accordance with the Code of Federal Regulations, Part 46, section 101. The specific paragraph which applies to your research is:

__X__ (b)(2) Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, **unless**: (i) Information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; **and** (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability or be damaging to the subjects' financial standing, employability, or reputation.

Under the Federal exempt category of review, obtaining written consent is not required but is optional. If you do use the written form, please use the date-stamped copy sent with this approval notice as a master from which to make copies.

University of Montana IRB policy does not require you to file an annual Continuation Report for exempt studies as there is no expiration date on the approval. However, you are required to notify the IRB of the following:

Amendments: Any changes to the originally-approved protocol must be reviewed and approved by the IRB ***before*** being made (unless extremely minor). Requests must be submitted using Form RA-110.

Unanticipated or Adverse Events: You are required to timely notify the IRB if any unanticipated or adverse events occur during the study, if you experience an increased risk to the participants, or if you have participants withdraw from the study or register complaints about the study. Use Form RA-111.

Please contact the IRB office with any questions at (406) 243-6672 or email irb@umontana.edu.

SUBJECT INFORMATION AND INFORMED CONSENT

Study Title: Impacts of Crop-choice on Crop-raiding and Human-elephant Conflict in Sagalla, Taita Taveta County, Kenya

Sponsor: U.S. Fulbright Student Program; Interdisciplinary Collaboration Network at the University of Montana; Oberlin College; Five Valleys Audubon Society

Investigator(s):

Sophia Weinmann
College of Forestry and Conservation
University of Montana
Sophia.weinmann@umontana.edu

Dr. Jill Belsky (faculty advisor)
College of Forestry and Conservation
University of Montana
Jill.belsky@umontana.edu

Special Instructions:

This consent form may contain words that are new to you. If you read any words that are not clear to you, please ask the person who gave you this form to explain them to you.

Inclusion Criteria:

- Presence of an occupied beehive fence
- Experienced elephant crop-raiding in the last year

Purpose:

This project aims to decrease elephant crop-raiding and the human-elephant conflict it creates. My objective is to use on-farm experiments to determine if sunflowers and jute are less palatable to elephants than corn and if planting less palatable crops can decrease elephant crop-raiding. I will also utilize key informant interviews to assess whether or not changing agricultural practices to include crops that are non-palatable to elephants will benefit local farmers.
You must be 18 or older to participate in this research.

Procedures:

If you agree to take part in this research study, an informal interview will be conducted. A variety of topics will be discussed including: your use of elephant deterrent techniques, economic and social impacts of crop-raiding, traditional planting strategies and harvest histories, costs and benefits of using beehive fences as an elephant deterrent, interest in planting non-palatable crops, experiences working with STE, and what resources you need to maintain the beehives over the long run. The interview will last approximately one hour.

Risks/Discomforts:

There is no anticipated discomfort for those contributing to this study, so the risk to participants is minimal.

To minimize any negative impacts, the scope of the interview will be clearly outlined before starting your interview.

Benefits:

There is no promise that you will receive any benefit from taking part in this study. The objective of this research is to examine crops that are non-palatable to elephants and of economic interest to farmers with the intention of reducing elephant crop-raiding. By reducing the severity and frequency of elephant crop-raiding, these techniques will benefit both the conservation of elephants and the socio-economic welfare of farmers.

Confidentiality:

Your records will be kept confidential and will not be released without your consent except as required by law. If the results of this study are written in a scientific journal or presented at a scientific meeting, your name will not be used. The data will be stored in password protected electronic files.

Voluntary Participation/Withdrawal:

Your decision to take part in this research is entirely voluntary and you may decide to withdraw from the research at any time with no penalty.

Questions:

If you have any questions about the research now or during the study, please contact: Sophia Weinmann (216) 924.9594

If you have any questions regarding your rights as a research subject, you may contact the UM Institutional Review Board (IRB) at (406) 243.6672.

Statement of Your Consent:

I have read the above description of this research study. I have been informed of the risks and benefits involved, and all my questions have been answered to my satisfaction. Furthermore, I have been assured that any future questions I may have will also be answered by a member of the research team. I voluntarily agree to take part in this study. I understand I will receive a copy of this consent form.

_____
Printed Name of Subject

_____ _____
Subject's Signature Date

The University of Montana IRB
Expiration Date None
Date Approved 5/26/2016
Chair/Admin

APPENDIX E: CROP STATUS ASSESSMENT FORM

Crop Status Assessment Form

FARMER NAME
GPS COORDINATES

Recorded by: _____ **Date:** _____

Raid Information:

Estimated No. of Elephants: _____

No. of Bulls: _____ **No. of Cows:** _____ **No. of Calves:** _____

Time of Raid (circle one): **Night** **Day**

Elephant Damage Assessment (check one):

Age of Crop	**Seedling**		**Condition of Crops before Raid**	**Bad**		**Severity of Elephant Damage**	**Low**	
	Intermediate			**Medium**			**Medium**	
	Mature			**Good**			**High**	

Crop Status:

Moringa **Date Planted:** _____

Hill ⇧

1-10										
11-20										
21-30										
31-40										
41-50										

General Notes on Plant Condition:

Plant Status Key:

ET	Elephant Trampling	**BF**	Baboon Foraging
EF	Elephant Foraging	**LF**	Livestock Foraging
UT	Ungulate Trampling (wild)	**LT**	Livestock Trampling
UF	Ungulate Foraging (wild)	**ID**	Insect Damage
EI	Envt Impact (e.g hail, flood)	**D**	Dead
RD	Rodent Damage	**NS**	Never Sprouted
UR	Uprooted	**RP**	Re-planted

Crop Status Assessment Form

FARMER NAME
GPS COORDINATES

Date: _____

Sunflower **Date Planted:** _____

Hill ⇧

1-10										
11-20										
21-30										
31-40										
41-50										
51-60										
61-70										
71-80										
81-90										
91-100										

General Notes on Plant Condition:

Maize **Date Planted:** _____

Hill ⇧

1-10										
11-20										
21-30										
31-40										
41-50										
51-60										
61-70										
71-80										
81-90										
91-100										

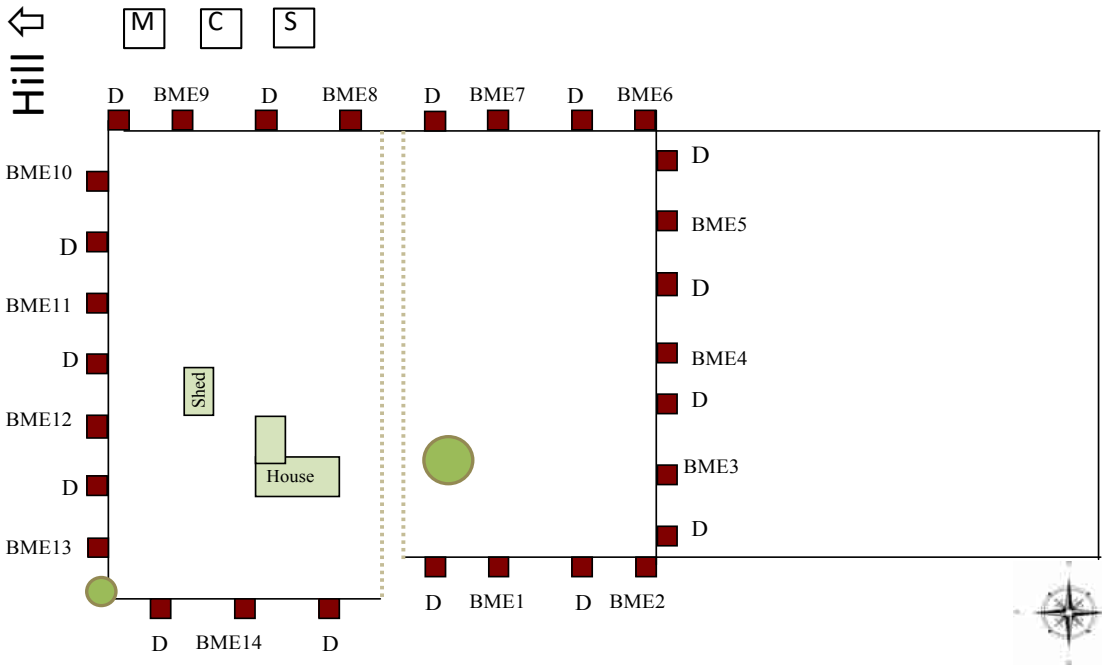
General Notes on Plant Condition:

Crop Status Assessment Form

FARMER:

Date: _____

Elephant Pathway:



Other Comments:

APPENDIX F: EXPERIMENTAL PLOT SPECIFICATIONS

Farm ID	Crop	pH	Soil Type
1	Maize	7.5	sand clay loam
	Moringa	7.5	sand clay loam
	Sunflower	8	sand clay loam
2	Maize	8.5	clay loam, sandy
	Moringa	7.5	sand clay loam
	Sunflower	8.5	clay loam, sandy
3	Maize	8	clay loam, sandy
	Moringa	7.5	clay loam, sandy
	Sunflower	7.5	sand clay loam
4	Maize	8	clay loam, sandy
	Moringa	7.5	sandy clay
	Sunflower	7.5	clay loam, sandy
5	Maize	8	sandy loam
	Moringa	7	sandy loam
	Sunflower	7.5	sandy loam
6	Maize	7	sand clay loam
	Moringa	7	sand clay loam
	Sunflower	6.5	sand clay loam
7	Maize	7	sandy loam
	Moringa	6	sandy loam
	Sunflower	6.5	sandy loam
8	Maize	8	sandy clay
	Moringa	7	sandy clay
	Sunflower	7	sandy clay
9	Maize	7	clay loam, sandy
	Moringa	7	clay loam, sandy
	Sunflower	7	clay loam, sandy
10	Maize	7.5	sandy loam
	Moringa	8	sandy clay loam
	Sunflower	8.5	sandy loam