Drivers and Consequences of Human-elephant Interactions in an Agricultural Landscape of Rural Kenya

by

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A dissertation submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Doctor of Philosophy

Auburn, Alabama
August 6th, 2022

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Abstract

Globally, interactions between people and wildlife are increasing due to habitat loss and conversion and the movement of people and wildlife into areas in which they were not previously present. Many of these interactions involve agricultural damage, which is especially problematic for resource limited communities. One species that causes extensive agricultural damage to rural farmers are African elephants (*Loxodonta africana*) which forage on cultivated crops, jeopardizing food security for humans and creating conservation concerns for elephants. While the ecological drivers of this human-elephant conflict are known, there remains a gap in our knowledge about how the farmers perceive and conceptualize the conflict that is necessary for advancing conservation. Thus, the goal of this dissertation is to develop a greater understanding of the impact of human-elephant interactions on rural farmers across social, ecological, economic, and cultural dimensions to better inform policy and decision makers in wildlife agencies mitigating these interactions. To address this goal, I developed key research questions: 1) how is the use and knowledge of deterrents by farmers and their behaviors and attitudes towards elephants related to demographic variables such as age, years farming, and exposure to deterrent information? 2) what are farmer attitudes and behaviors towards environmental threats to their livelihoods, and are there sociodemographic categories that influence farmer responses to such threats? and, 3) what are farmers' mental models of elephant conflicts, including drivers of conflict that are underrepresented or unknown in the literature and potential indicators for evaluation of mitigation programs? To address these questions and the corresponding hypotheses, I conducted social surveys and participatory modeling sessions across 6 villages in the Greater Tsavo ecosystem of southeastern Kenyan. Across the villages, ~90% of respondents had never received information on mitigating crop raiding using fencing deterrents.

The main reason for not implementing deterrents was lack of funding. Farmers were accepting of mitigation solutions for concerns such as climate change. However, 35% had never received information on solutions such as alternative crops. Likewise, ~50% of farmers would prefer to continue farming, even if alternative ways to earn income were available. Farmers positively viewed the benefits of wildlife, suggesting local community programs may be beneficial for improving attitudes. Mental models indicated several novel drivers of conflict such as road infrastructure and soil compaction and provided additional potential sociocultural indicators for evaluating mitigation programs. The models also showed that economic and environmental interactions were central variable types conserved across all villages and impacts to income levels and feeling of security were the most important variables indicated by farmers. The findings of this research provide valuable information for wildlife managers and policy makers that value stakeholder knowledge to aid in mitigating human-elephant interactions.

Acknowledgments

I am truly grateful for this extensive journey towards a PhD, especially as a first generation, non-traditional student, and for all the people who have made it possible. First, I would like to thank my husband who has been incredibly supportive of my extensive trips out of country and who has been my rock whenever I doubted myself. Next, is my friends and family who believed in me long before I did. Lastly, is the amazing set of mentors that have provided guidance since my undergraduate days. I am also appreciative of Dr. Todd Steury's statistical advice while composing this dissertation. Thanks also to those extraordinary women in STEM, proving that all of us deserve a seat at the table, and the amazing men who continue to help facilitate our inclusion. I am the scientist I am today because of the teachings and guidance of this diverse group of people who showed me that tenacity in the face of adversity or shortcomings always prevails.

I am grateful to Auburn University for the Presidential Research Fellowship that I received that allowed me to be a part of an extraordinary academic community. I am also grateful for the partner organizations and funders that helped facilitate this research: the International Elephant Foundation, the Earthwatch Institute, and the Elephant Manager's Association. In addition, several agencies assisted with travel assistance to conferences: Auburn's College of Forestry, Wildlife, and Environment, the British Ecological Society, and the Animal Behavior Society. I was also fortunate to receive awards from the Ecological Society of America, Common Purpose, and the National Socio-Environmental Synthesis Center that helped further my academic and career development.

Performing fieldwork internationally in the country of Kenya has added a beauty to my life that is nearly indescribable. A huge thanks to all the faculty and personnel at both Western

Kentucky University and Auburn University, and Wildlife Works who helped facilitate the complicated logistics. Our research team in Kenya was comprised of outstanding scholars and field biologists, and I am appreciative of for their guidance and friendship: Dr. Mwangi Githiru, Dr. Urbanus Mutwiwa, Mr. Simon Kasaine, and Mr. Benard Amakobe. Our collaboration with Wildlife Works was invaluable in not only facilitating our research goals, but providing a community of supportive colleagues and friends. To the Kivuli Camp staff, who was there to keep me supplied, supported, and feeling like I had a second home; nawakumbuka sana marafiki zangu na mtakuwa ndugu zangu daima. For the expat crew in Kenya at the office, in the field, and in the air, thanks for taking me on adventures and making me feel supported and cared about when I was far, far from home. For the community outreach team and research assistant that helped to facilitate my studies, you were vital in helping me to make connections and discoveries in the community that I will never forget.

To the rangers of Wildlife Works and those serving protected areas across the world, you are the bravest of us all and your dedication to preserving the world's most precious ecosystems is unparalleled. A special acknowledgement for the fallen rangers from Wildlife Works who have paid the ultimate sacrifice and for their grieving families. Thanks also to the rangers who were attached to me for months at a time; a girl simply couldn't have better big brothers to help watch over her (and keep her out of trouble).

If one spends years on the ground with particular groups of wildlife such as elephant herds, you will get to know individuals and their personalities. To have the honor and privilege of seeing thousands of elephants come and go and live within a few meters of them and other extraordinary wildlife is something I never thought I would experience. It has shifted my life in a way that nothing else has and I am grateful beyond words for the opportunity.

Perhaps most importantly, I want to thank the people of Kenya. From the city of Nairobi to the beaches of Mombasa, to the most rural villages and farms in Kasigau, I was always welcomed with open arms and a smile. Their wisdom, kindness, and perseverance has taught me more than any book ever could. I hope I may in some capacity serve the communities of the world who are the guardians of the most sacred knowledge of our wildlife and ecosystems. I also hope my experiences might inspire other women, non-traditional students, or underrepresented groups to pursue careers in ecology. I have been most thankful to live George Elliot's words.. ……"It is never too late to be what you might have been".

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List of Abbreviations

AICc	Akaike Information Criteria, corrected
ANOVA	Analysis of Variance
FAO	Food and Agricultural Organization of the United Nations
GLM	Generalized Linear Model
GTE	Greater Tsavo Ecosystem
KWC	Kasigau Wildlife Corridor
HEC	Human Elephant Conflicts
HEI	Human Elephant Interactions
HWC	Human Wildlife Conflicts
HWI	Human Wildlife Interactions
IPCC	Intergovernmental Panel on Climate Change
IRB	Institutional Review Board
IUCN	International Union for Conservation of Nature
PA	Protected Area
REDD+	Reducing Emissions from Deforestation and Degradation
SD	Standard Deviation
UN	United Nations
UNDP	United Nations Development Program
USAID	United States Agency for International Development
VIF	Variance Inflation Factor
WW	Wildlife Works

Chapter 1

Introduction

Protected areas have been created around the world with the goal of maintaining biodiversity, including wildlife populations (Hanski, 2005; Karanth et al. 2013; Oldekop et al. 2016). While protected areas can be beneficial for both people and animals, they can also create negative interactions. For instance, animals sometimes move outside of a protected area in search of resources (e.g., mates, food) or as part of their lifecycle (e.g., migration) Berger 2004; Avgar et al. 2013; Western et al. 2015) and encounter people and their associated infrastructures. Likewise, humans often encroach or settle near protected areas, which can provide resources that attract wild animals seeking potential food sources, causing more interactions. Thus, wildlife venturing outside of protected areas often creates dangerous situations for both people and animals (Abukari & Mwalyosi 2020).

One prevalent type of interaction between wildlife and people living near protected areas is crop raiding (or crop foraging), whereby herbivores alter their natural foraging patterns to include the crops of farmers (Songhurst & Coulson 2014; Mc Guinness 2016; Hill 2018). While crop raiding is a long-standing problem, it is especially problematic for limited-resource communities and communities experiencing severe impacts from climate change (Ali & Erenstein 2017; Salerno et al. 2021), especially near protected areas for wildlife. One species that has been causing increased challenges for farmers near protected areas of Africa is the African savanna elephant (*Loxodonta africana*). Specifically, elephants enter small shareholder farms as part of their foraging routine, consuming or trampling crops (Chiyo & Cochrane 2005; Davies et al. 2011; Gross et al. 2016). As a result, elephants create food security issues for farmers who may retaliate against them, creating a conservation concern for elephant populations (Treves et al. 2009; Guerbois et al. 2012; Raphela & Pillay 2021).

African elephants are declining at approximately 8% per year across the continent (Chase et al. 2016). In 2021, the International Union for the Conservation of Nature recognized African forest elephants (*Loxodonta cyclotis*) as a separate, critically endangered species and up-listed savanna elephants to endangered (IUCN, 2021). However, some regional populations, such as in the Tsavo Ecosystem of southern Kenya, are starting to rebound from the poaching crises of the 1980's and 1990's (Litoroh et al., 2012; Ngene et al., 2017). As elephants return to their historical ranges that are now settled by humans, the stage is set for increasing interactions. Although these rural communities have managed to coexist among elephants, they rarely have the resources to mitigate the impacts of crop-raiding (Naughton-Treves & Treves 2005; Guerbois et al. 2012).

Given the limited resources available to rural communities, a variety of strategies have been used to deter or mitigate elephant raiding. For instance, many farmers use traditional methods to scare away elephants such as chasing them, burning fires, yelling, and banging metal (Sitati & Walpole 2006; Hoare 2012). These more traditional, low-technology attempts are both time consuming and dangerous. Alternatively, modern deterrents, usually containing some type of negative and recurring stimulus, have higher efficacy rates, do not require human presence, and are regarded as more effective options to prevent or mitigate crop raiding (Graham & Ochieng 2008; Hoare 2012; Hill 2018). However, long-term effective deterrents have not been widely implemented because elephants are highly intelligent and often overcome them (CITES 2010; Mumby & Plotnik 2018). Furthermore, modern deterrents are costly, thereby limiting their use by farmers (Graham & Ochieng 2008; Dickman 2010; Noga et al. 2015). Ultimately, the practicality and affordability of modern deterrents remains a challenge for farmers (Von Hagen 2018), demonstrating that while important, they are just temporary fixes that do not address underlying factors that make households resilient to infrequent but sometimes devastating crop raids.

Farmers are also facing multiple other threats to food security. For example, climate change is increasing the length of seasonal droughts, causing flooding, and increasing temperatures (IPCC 2022). Access to new varieties of crops or techniques, poor soil quality, and invertebrate pests also can make harvests unreliable (Naughton-Treves & Treves 2005; Harvey et al. 2014; Gross et al. 2016). Given these environmental pressures, farmers may find it difficult to reliably sustain their livelihood (Armitage 2005; Twomlow et al. 2008). Understanding the socioeconomic underpinnings of farmers' ability to mitigate crop raiding and other livelihood threats as well as barriers to uptake of mitigation methods or techniques is important for devising management strategies (Graham & Ochieng 2008; Noga et al. 2015; van de Water & Matteson 2018). Thus, exploring the sociological or human dimensions of these types of conservation and livelihood issues can be informative for understanding how stakeholder perceptions, attitudes, and behaviors impact management strategies and the potentials for effective mitigation initiatives (Pătru-Stupariu et al. 2020; Pimid et al. 2022).

While the ecological drivers of human-elephant conflict are known, there remains a gap in our knowledge about how farmers perceive and conceptualize human-elephant conflict that is necessary for advancing conservation. In addition, other research questions remain fully unexplored such as which farmers are able to adopt and deploy deterrents without outside intervention and how this varies by demographics. While considerable research efforts have focused on developing various mitigation techniques to combat threats to farmer livelihoods, it remains to be seen how much of this information is actually reaching rural farming communities. Measuring the effectiveness and impact of mitigation programs is a standard practice in natural resource management, but integrating measurements that incorporate aspects of biocultural preservation is an underdeveloped area. Thus, the goal of this dissertation is to develop a greater understanding of the impact of human-elephant interactions on rural farmers across social, ecological, economic, and cultural dimensions to better inform policy and decision makers in wildlife agencies mitigating these interactions. To address this goal, I asked: 1) what is the use and knowledge of deterrents by farmers and their behaviors and attitudes towards elephants related to demographic variables such as age, years farming, and exposure to deterrent information; 2) what are farmer attitudes and behaviors towards environmental threats to their livelihoods, and are there sociodemographic categories that influence farmer responses to such threats; and, 3) what are farmers' mental models of elephant conflicts including drivers of conflict and potential indicators that are underrepresented or unknown in the literature? Addressing these questions and their associated hypotheses can contribute knowledge to inform community-based or agency actions that increase food security and sustainable livelihoods for rural farmers in Kenya, thereby improving elephant conservation by reducing negative interactions.

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Chapter 2

Socioeconomic Factors Determine Ability of Rural Farmers to Apply Deterrent Measures for Mitigating Crop Raiding by African Elephants[1]

[1] Formatted in the style of *Conservation Biology*

Abstract

Wildlife that raid crops can reduce yields, thereby negatively affecting farmer livelihoods. In the case of African elephants (*Loxodonta africana*), affordable and practical solutions to mitigate crop raiding remain elusive due to farmers' access to information and limited resources. Therefore, my goal was to examine unexplored relationships between socioeconomic factors and agricultural damage to inform conservation priorities. Based on this goal, I hypothesized that: 1) older age, higher levels of education, exposure to deterrent information, and larger farm size would be positively associated with farmers who used deterrents; 2) higher levels of education would be positively correlated with receipt of any type of deterrent or mitigation information, and particularly fencing deterrents; 3) farmers that are older, have higher levels of education, and have had exposure to deterrent information would be more likely to use traditional methods; and, 4) education levels would be positively correlated with farmers who stated they could build and implement deterrents. To test these hypotheses, I surveyed 206 farmers across six villages in the Tsavo Ecosystem of Kenya and used an information theoretic approach for analysis. Higher education levels and exposure to deterrent information were positively associated with deterrent use. Respondents with higher education levels were more likely to have been exposed to knowledge on any types of deterrents. There were no demographic factors indicative of those who used traditional vs. modern deterrents, and almost everyone adopted traditional methods. Exposure to deterrent information was indicated for farmers that believed they could adopt deterrent measures, and all farmers that were unable to adopt modern deterrents cited the lack of financial resources to do so. Overall, information about deterrents is not reaching farmers who need it most, and even when it does, socioeconomic factors may limit uptake. These insights into farmers' knowledge and use of deterrents are

important for informing mitigation strategies and programs supporting the livelihoods of local people affected by human-wildlife conflicts.

Introduction

Continued habitat loss and conversion are increasingly blurring the lines between nature and human civilization (Hanski 2005; Hill 2015). As a result, interactions between people and wildlife are escalating across the globe (Young et al. 2010; Redpath et al. 2015; König et al. 2020) as wildlife and people compete over resources, including habitable space (Madden 2004; Treves et al. 2006; Seoraj-Pillai & Pillay 2017). Negative interactions, or conflicts, are often high in regions where rural communities share boundaries with national parks, protected areas, or important wildlife features such as movement corridors (Western et al. 2015; Mc Guinness 2016; Pozo et al. 2020). One of the most common types of negative interactions involves agricultural damage in cultivated areas (Hill 2000; Naughton-Treves & Treves 2005; USDA & APHIS 2012; EIP-AGRI Focus Group 2021; McKee et al. 2021).

Wildlife may enter cultivated lands and consume or damage crops as part of their foraging strategies (Owen-Smith et al. 2010). Loss and/or damage to agricultural crops are often termed crop raiding or crop foraging and are caused by a range of species, including rodents, birds, primates, large and small herbivores, and other pests (Seoraj-Pillai & Pillay 2017; Krijger et al. 2017; Gross et al. 2018; Hill 2018). Crop raiding incidents can be damaging to human health and wellbeing as farmers may experience lost opportunity costs, fear, and stress when attempting to protect their farms and livelihoods (Barua et al. 2013). These factors make agricultural damage a major issue for farmers.

The impacts of negative wildlife interactions from agricultural damages are often borne by communities in resource-poor regions of the world (Jordan et al. 2020), threatening food security (Salerno et al. 2021; Raphela & Pillay 2021). A variety of techniques have been used to mitigate damages or losses, including fencing (Kassilly et al. 2008; Osipova et al. 2018), fear-based devices (Gilsdorf et al. 2002), and patrolling or guarding (Killion et al. 2020) as part of integrated pest management strategies. However, resources to engage with stakeholders and distribute information on deterrent methods to address human-wildlife interactions (HWI) are often facilitated by non-governmental organizations or government wildlife agencies whose funding may be limited (Folke et al. 2005; Noga et al. 2016; Galvin et al. 2018). In many areas of rural Africa, food security is low, and farmers are often dependent on resources from nature or subsist by growing their own food (Clover 2000; Baiphethi & Jacobs 2010; Wiggins 2009). For example, in Kenya, more than 1 in 3 Kenyans (36%) live in monetary poverty, which is making less than KSH 5995 per month (roughly equivalent to $60 USD). In addition, over 23.4 million Kenyans (53%) live in multi-dimensional poverty, meaning that they lack at least three basic needs, services, or rights (Kenya National Bureau of Statistics 2020). Thus, many areas of the world dealing with agricultural damage by wildlife are the least financially prepared to mitigate it.

Across their ranges in Asia and Africa, elephants are common crop raiders and compete with rural farmers for food and water resources (Desai & Riddle 2015; Hoare 2000; Shaffer et al. 2019). These negative human-elephant interactions (HEI), also referred to as human elephant conflicts (HEC), can create food security and livelihood issues for farmers. There are also conservation concerns for endangered elephant populations if farmers retaliate against what they view as oversized pests (Distefano 2005; Treves et al. 2009; Davies et al. 2011). Methods used for generations such as guarding, burning fires, or making noise are often employed to frighten elephants away, but may have limited success as elephants can habituate to sounds or the presence of humans (Hoare 2012; Mumby & Plotnik 2018; Gross 2019). In addition to rudimentary fences made of wood, acacia branches, or barbed wire, these more traditional types of efforts to deter wildlife often require human presence or use of materials that are easily available. More modern methods such as electric fences, first used in the 1930's (Mcatee 1939; Kioko et al. 2006), and methods specifically designed to deter elephants starting in the 1990's such as chili (Osborn 2002; Parker & Osborn 2006; Hedges & Gunaryadi 2010; Chang 'a et al. 2016), beehive (King 2010), solar light (Adams et al. 2020), or metal fences (Von Hagen et al. 2021) may have higher efficacy, as these types of fences use some component of recurring negative stimulus. Modern methods are intended to require no human presence (since traditional methods can be dangerous for farmers) and use specific methodologies and standardized materials. However, modern deterrents may be harder to implement because of limited resources to purchase materials or local availability of materials. Therefore, successful deterrents need to be affordable, practical, and effective. To do so, new deterrent designs must consider elephant physiology, behavior, and cognition (Mumby & Plotnik 2018) and the socioeconomic limitations of farmers to create mitigation techniques that are also resistant to elephant habituation (Osborn & Parker 2003; Naughton-Treves & Treves 2005; Dickman 2010; Von Hagen 2018).

Mitigating negative human-elephant interactions through deterrent use can reduce tensions and improve livelihoods, but only if farmers have the means to implement deterrents. Knowing which socioeconomic factors inhibit deterrent use can allow for targeted outreach by practitioners to farmers. Attitudes of farmers towards the uptake and use of elephant deterrents have been examined in several regions of Africa (Graham & Ochieng 2008; Noga et al. 2015). However, the socioeconomic factors that may inform whether or not farmers can implement elephant deterrents without agency or practitioner assistance has not been fully examined.

Farmer decision making on other related issues has demonstrated the importance of socioeconomic background. Aging tends to make people more risk averse. However, decision making is often impacted by local culture and can be highly variable (Rieger & Mata 2015). While older farmers may be hesitant to try new techniques or crop types, some farmers often accumulate local knowledge of elephant movement and their behaviors (Buchholtz et al. 2020). Therefore, specialized local knowledge and information from local peers could accumulate across time and positively impact adoption of deterrents. Older farmers may also be more likely to use or know which deterrent methods have been effective in the past and had more opportunities for communication with neighboring farmers. In addition, education levels are highly variable amongst rural farmers (Noga et al. 2015), and level of education is known to positively affect farmer productivity and adoption of new farming techniques (Oduro-Ofori 2014). Therefore, education and exposure to deterrent information, either from outside agencies or accumulated over time, may positively influence the use of deterrents. Farm size can also be an indicator of higher income, as farmers who grow more than their family consumes may sell the excess for profit. Owning larger farms may also indicate having accumulated experience with farming techniques necessary to maintain larger plots. However, larger farms are more prone to food insecurity when crop losses occur (Raphela & Pillay 2021). Ultimately, understanding the socioeconomic factors that are related to farming decisions generally, and reducing human-elephant conflict specifically, is an important aspect of improving conservation and managing efforts.

Given the gaps in knowledge about farmers, the pressing need to conserve endangered African elephants, and the threats to livelihoods of rural farmers in Kenya, my overall goal was to examine the relationships between socioeconomic factors and agricultural damage to inform conservation priorities. To address this goal, I hypothesized that: 1) age, education, exposure to deterrent information, and farm size would be positively associated with farmers who used any types of deterrents; 2) most rural farming households had not received or been exposed to any type of information on mitigating the impacts of human-elephant interactions, but amongst those that had, education would be positively correlated with receipt of any type of deterrent or mitigation information, and particularly fencing deterrents (Oduro-Ofori 2014); 3) farmers that are older, have higher levels of education, and have had exposure to deterrent information would be more likely to use traditional methods; and, 4) most farmers who are unable to implement deterrents would be constrained by economic resources and that only education levels would be positively correlated with farmers who stated they could build and implement deterrents. Evaluating these hypotheses can provide necessary information for improving conservation planning strategies and efforts to improve food security while simultaneously preserving wildlife.

Methods

African savannah elephants (*Loxodonta africana*) are frequent crop raiders in the Greater Tsavo Ecosystem (GTE) of Kenya and a source of conflict between community members and corresponding wildlife officials (Kagwa 2011; Litoroh et al. 2012; Githiru et al. 2017; Kamau 2017). The Kasigau Wildlife Corridor (KWC) of Kenya contains 14 community ranches and lies between Tsavo East and West National Parks in Southeastern Kenya (Fig. 2.1). The region is home to the country's largest elephant population of ca. 15,000 individuals (Waweru et al. 2021), and many elephants use the corridor to move between the two parks (Ngene et al., 2017; Omondi et al., 2008). Rukinga Wildlife Sanctuary, one of the ranches in the corridor, is operated by Wildlife Works, as part of the Kasigau Corridor REDD+ Project. Sanctuary management allows no human settlements or livestock grazing within the ranch, making it favorable habitat for elephants. The REDD+ project area contains a subset of the larger elephant population numbering around 2,000 with 3-500 residents around the sanctuary, shifting seasonally (Githiru, M. pers. comm). The other ranches also contain some refugia for wildlife, but the presence of villages and livestock nearby creates higher levels of interactions. Rural villagers in these areas are mostly subsistence farmers with limited incomes and access to resources. The region's poverty level is around 1500 KSH per month (approximately $15 USD), and in years with lower crop yields, 39% of the population drops below this level (Kasaine & Githiru 2016). These circumstances make wildlife crop raiding events economically damaging and a challenge to food security (Githiru et al. 2017).

I selected six villages surrounding Rukinga Wildlife Sanctuary to test the hypotheses. The prerequisites for selecting these locations were that: 1) a community had to share a boundary with the sanctuary and be within one-hour drive of the centralized base on the ranch for logistical feasibility; 2) the community must be comprised of a majority of farming households and have experienced frequent and recent negative elephant interactions; and 3) local decisionmakers had to be in favor of allowing research to be conducted in their respective villages. I selected and engaged with members of the villages of Itinyi & Kombomboro (combined due to small population size and close proximity, hereafter referred to as Itinyi), Bungule, Miasenyi, Kisimenyi, Buguta, and Mwakwasinyi (Fig. 2.1).

I developed a questionnaire (Appendix A) based on previous research conducted with farmers experiencing crop raiding (Hoffmeier-Karimi & Schulte 2015), and knowledge of encounters with elephant incidents and the villagers of this area. The survey contained 64 questions, 19 of which are the basis of this chapter. The questions focused on the knowledge of and use of deterrent methods, attitudes and behaviors towards elephants, and demographic variables (Table 2.1). The survey was reviewed and approved by Auburn University's IRB panel (Protocol no. 20-440 EX 2009) in the U.S. and Strathmore University's Institutional Ethics Review Committee (Approval no. SU-IERC0877/20) in Kenya. The research was conducted under the umbrella of Wildlife Works' PIC/MAT agreement with Kenya Wildlife Service and with approval from NACOSTI (Kenya's science agency, License No. NACOSTI/P/20/2292).

Because of the COVID-19 pandemic, international field work was not possible in 2020 and a local facilitator was hired to administer the surveys following strict pandemic protocols. I requested the assistance of Chiefs, sub-chiefs, and elders from each village to select 30-35 farmers from their respective villages. Chiefs are elected officials of Locations (the smallest administrative unit recognized by Kenya's Ministry of the Interior). They also oversee sub-chiefs who monitor sub-locations, several of which can exist within one Location. Within each sub-location there are several villages each overseen by an elder elected by the Chiefs and villagers. I requested that Chiefs select farmers who experienced the highest amounts of crop raiding. To avoid gender bias, I asked that the selected number of participants be approximately half male and half female. Only one farmer per household was allowed to participate in the study to maintain sample independence. Following these guidelines, the sample population was 206 participants across the six villages (Supplemental Table S.2.1). These individuals were invited to participate in a meeting occurring over 4-5 hours, each on one day in their respective village. At the meeting/workshop, the research assistant administered a paper survey and was available to resolve any confusion over questions and aid those who might be illiterate (White et al. 2005), which was approximately 15% of the participants (n = 31 across all villages). These participants had surveys administered orally with the facilitator aiding in recording responses on the paper survey. To assure construct validity, the facilitator clearly defined the concepts of 1) crop raiding: the act of any animal entering a farm and consuming or trampling crops, and 2) deterrents: any method used to prevent entry or frighten animals away from farms, which could involve just human presence or action (such as yelling, waving a torch (flashlight), or patrolling) or passive objects such as any type of fencing. For participating farmers, the survey had many open-ended questions so that all ideas could be equally represented. All hardcopy surveys were entered into a database using the open-source software mWater (www.mwater.com, 2022), which is designed to be used off-line in rural locations with limited connectivity, and then transferred to Microsoft Excel (V 16.55).

I edited data to correct spelling and grammatical mistakes and created various groupings for survey questions to make the data more suitable for analysis. For education level responses, I grouped college, university, or any type of technical certificates into the term “upper.” Likewise, I grouped questions 4 (What type of information on methods to prevent crop raiding did you receive?) and 6 (what types of deterrent(s) fences information did you receive?) into general deterrents and fencing deterrent categories, respectively. For question 2, the types of deterrents used were grouped into the categories of rudimentary fencing, making noise, torch, burning fire, guarding, solar along fencing, cloths and oil, planting peppers, and Kasaine metal fences. Any type of deterrent that had ≤ 3 answers (with the exception of Kasaine metal strip fences, a modern method developed and introduced locally) was grouped into a miscellaneous category as some farmers used completely novel methods. For question 6, I also grouped the deterrents into either traditional or modern categories, with traditional methods being burning fire, guarding, making noise, chasing elephants, using scarecrows, waving a torch (flashlight), soaking rags with oil, or erecting rudimentary fencing made of wood, trees, or barbed wire. Modern deterrents were considered any type of solar or electric lighting, electric fencing, beehive fences or beekeeping, Kasaine metal strip fences, or intercropping with chili peppers (alternative crops). While other modern methods exist (see intro.), no others were mentioned by respondents. Question 7's 4 Likert-scale responses were lumped into a yes (Definitely and Possibly) and no (I am unsure and (Definitely not) categories. There was a follow up question not used in this manuscript that inquired of those responding "yes" to question 10 (Have you ever actively chased elephants from your farm?) on what tools were used. Perhaps misunderstanding the question, 24 respondents provided a tool they chased elephants with, even though they said no to the initial question 10. Therefore, these 24 answers were changed to yes.

For each of the four hypotheses I developed *a priori* models (Table 2.2). Any respondents with missing answers to relevant questions were excluded from model analyses so that model comparisons would have equal sample sizes, resulting in different degrees of freedom for each hypothesis (see respective tables). For the deterrent user hypothesis (H1), the yes/no answer from Q1 was used as the dependent variable (n = 189) and models 1-23. In the deterrent exposure hypothesis (H2), on villagers that received information on any type of deterrents (H2A) and more specifically on deterrent fencing (H2B), the yes/no answers to Q5 (n = 189) were used as the dependent variable and assessed both with the null model (M1), education level (M3), and model 24 (M24) which combined each of the remaining variables but excluded exposure (the dependent variable). Questions 4 (n = 46) and 6 (n = 24) were asked to determine what types of deterrent information were disseminated. The deterrent-type hypothesis (H3) used Q2 on types of deterrents used, and responses were categorized as traditional or modern, as the dependent variable and then analyzed using models 1-10, 12, 15, and 19-23. However, the category of none, under education level, had no modern deterrent users (for H3), so I modified the variables of education level to eliminate the category of none for this analysis. The village category, specifically Buguta, also had prohibitively small sample sizes. Thus, results for H3 do not include comparisons for the categories of none in education level and the village of Buguta resulting in a final sample size of 82. The economic barriers hypothesis (H4) used Q7 as the dependent variable and was analyzed with models 1-9, 12, 13, 15, and 17-23, again, representing single variable models and all models including any combination with education level as a variable (n = 98). Because the upper education category had a low sample size, it was also excluded in testing H4. Question 8 was open ended, but all answers fell into the same category of financial impediments. Questions 9-13 focused on attitudes and behaviors regarding elephants, and Q14-Q19 were demographic in nature.

I evaluated each variable of interest (age, education level, years farming, gender, exposure, farm size, and village of origin) for collinearity with a robust variance inflation factor (VIF). All VIFs were ~1.0, signifying no collinearity between variables. All models were analyzed using a generalized linear model (GLM) which accounted for the non-normal nature of the data. A binomial function was used, making the models logistic regression models. Model results were compared using Akaike information criteria corrected for sample size (AICc) as a measure of fit. I also report pseudo r^2 values according to Zhang, 2017. Models having $\leq \Delta 2$ AICc (Burnham & Anderson 2002) were considered in conjunction with the explanatory values of model weights and adjusted, pseudo R^2 values. Top models are reported but are not an indicator of support of hypotheses as each is independently evaluated from respective model metrics and sociological meaning. All analyses were conducted in the statistical program R (v. 4.0.2., 2020).

Results

Of the 206 villagers that completed the survey, the number that participated by village ranged between 29 and 37. The ratio of female and male participants was similar (53:47), though this varied by village (Supplemental Table S.2.1). Respondents ranged in age from 18 to 85 years old with a mean age of 46 (± 13.63 SD) and household size ranging from 2 to 34 with a mean of 8 (± 3.95 SD). The majority of respondents came from the Taita ethic community (59%), followed by Kamba (15%), Duruma (9%), and Mijikenda (5%), with the remaining 12% comprised of 12 different tribal affiliations. Most participants (64%) had a primary level education, while 22% had a secondary level, 7% had upper education, and the remaining 7% had no formal education. The main source of income for 92% of respondents was farming.

For the questions associated with attitudes, behaviors, and local context, 54% of farmers used one or more forms of deterrents to prevent crop raiding by elephants. Of farmers in the survey, 22% had received information on any type of deterrent methods and 10% of villagers had received information specifically on deterrent fences. Elephants were cited as the main reason behind crop losses of 84% of farmers (Q9), followed by drought (10%), other wildlife (4%), and pests (2%). Elephants had been actively chased from 74% of farms (Q10). In response to Q4, the types of deterrent methods about which villagers had received information were primarily rudimentary fencing methods (Table 2.3). Most individuals (87%) that used deterrents used traditional types (Supplemental Table S.2.2). Few farmers (94%) had attempted to harm elephants (Q11), though 4% said they attempted to harm them all the time or regularly and 1% said they only attempted to harm elephants once. When asked how much they fear elephants (Q12) 55% said they were very afraid, 29% were somewhat or a little bit afraid, 15% were not afraid at all, and 7% were unsure. Farmers receiving information on how to safely live with elephants (Q13) was 16%. Only 40% of respondents believed they could definitely invest in deterrents, and 100% of those that said they could not cited economic restraints as the reason.

For the deterrent-use hypothesis (H1), model 12, education level + exposure to deterrent methods best described which farmers used deterrents (Table 2.4). Education level (M3), was the best fitting model for the first part of the deterrent exposure hypotheses (H2A), on farmers who had received information on general crop raiding deterrents, and for specifically fencing deterrents (H2B) the null model (M1) was the best fit (Table 2.5). For the deterrent-type hypothesis (H3), the null model (M1) was again the top model (Table 2.6). The final economic barriers hypothesis (H4), was associated with the model of the exposure to deterrent methods (M6) as the best fitting model.

Discussion

Over half of the participants in this study used some type of elephant deterrent(s) on their farms. The deterrent use hypothesis (H1) had a top model of education level + exposure, and the second and third-best models included the variable of exposure to deterrents, suggesting exposure as an important variable. However, upon examining other metrics, not much of the variation in the data was explained by the variables. In regard to the deterrent exposure hypothesis (H2), the hypothesis was supported in that higher education levels (M3) were related to general deterrent information received by respondents (H2A), but not for specific information received on deterrent fencing (H2B) where the null was the best fitting model (M1). Likewise, there was no support for the deterrent use-type hypothesis (H3) that a combination of age, education level, and exposure to deterrents was related to those who used traditional deterrents. Rather, the null model (M1) was the best fit. Finally, the economic barriers hypothesis (H4) was not supported with education levels, but rather greater exposure to deterrent information (M6) was positively correlated with farmers who could build and implement deterrents. The prevalence of exposure across several models suggests the importance influence of farmers receiving this type of information which can impact their usage and uptake behaviors.

The vast majority of farmers live in fear of elephants, which can impact health and wellbeing, and cause lost opportunity costs for farmers (McShane et al. 2011; Jadhav & Barua 2012; Barua et al. 2013; Mmbaga et al. 2017; Nyumba et al. 2020; Thondhlana et al. 2020). Another factor perhaps leading farmers to fear elephants was that most had never received any outside information on how to live safely near or interact with elephants. In addition, the vast majority of villagers blamed elephants for their crop losses, despite significant drought, presence of other pests, and rudimentary farming practices present in the area (Karimi 2009; Kasaine & Githiru 2016; Githiru et al. 2017). These frustrations from crop losses can lead farmers to lash out at elephants, (Hill 2004; Naughton-Treves & Treves 2005; Treves & Santiago-Ávila 2020) though only a small percentage admitted to attempting to harm elephants. However, if the few participants who tried to harm elephants were extrapolated to a larger population, this could result in a substantial threat to individuals of the local elephant population. Most respondents, admitted to actively chasing elephants from their farms, a common way to deter elephants (Fernando 2015; Mariki et al. 2015; Montero-Botey et al. 2021), but a dangerous undertaking for both elephants and farmers. The number of farmers indicating they tried to harm elephants is likely an underestimate as participants may have been reluctant to admit to these behaviors for fear of being reprimanded (though it was stated responses to this question would not be shared with authorities and participants were anonymized). From these multiple insights, one can see that negative interactions with elephants in this area present a threat to human health and livelihoods and pose serious concerns for elephant conservation. These insights into attitudes and behaviors towards elephants can be used to inform curriculum for programs that bring information to remote villages on elephant behavior and address farmer concerns.

Most farmers had never received information on ways to prevent crop raiding, and nearly all had never received information specifically about different fencing types (usually more modern methods). Education level was a demographic factor impacting those who received any type of deterrent information but not for those receiving more specific information on fencing deterrent types. Most of the information received by farmers was on traditional mitigation measures, such as using a torch (flashlight) to chase elephants or erecting rudimentary fences. So not only is information rarely reaching villagers, but when it does, it is based on potentially less effective and more time consuming (though more practical) traditional methods. While modern deterrents are more often effective as long-term strategies, the lack of access to materials and knowledge can impede the use of newly developed mitigation methods, and the effort needed to be present in farms to protect them can create additional hardships and danger (Hoare 2012; Gunaryadi et al. 2017). Only a small number of farmers used modern methods such as solar lights deployed along fencing, planting chili peppers (an unpalatable crop; Osborn & Parker 2003) or Kasaine metal strip fences (Von Hagen et al. 2021). This low uptake rate of modern deterrents demonstrates the need for outreach efforts that provide information on such deterrents and programs that can help fund their construction

Overall, my findings mirror other human-wildlife conflict studies that found deterrent methods can be too labor intensive, require too many resources, or lack community cooperation may fail even if successful in other areas (Osborn & Parker 2003; Sitati & Walpole 2006; Graham & Ochieng 2008). However, exposure to deterrent information was a common correlate in several of my hypotheses suggesting that receiving information on new or different types of deterrents is an important factor for farmer deterrent adoption. All of the respondents who indicated they could not implement deterrents, cited a lack of finances as the reason, which is consistent with other conflict mitigation research (Vedeld et al. 2012; Seoraj-Pillai & Pillay 2017).

With the exception of exposure to deterrent methods, most demographic variables explained little in the models. Demographic factors may not have been important because of low sample sizes after binning the yes or no answers to detect substantial differences (as in H2A where a very small proportion of respondents had received information on deterrent fencing) and that the sample famer population was essentially homogenous in their views and behaviors regarding these issues related to deterrents. Homogeneity of views on issues surrounding deterrent usage can actually be beneficial for wildlife managers as they develop mitigation strategies in conjunction with farmers. Thus, programs can be developed which encapsulate these farmer viewpoints with little need for multiple or diverse approaches. Several questions in the survey may have been considered controversial to farmers and it is possible some may have responded in a manner to express what I expected to find (i.e. positively). This could have created social desirability bias if a large component of respondents answered in the same way (Chung and Monroe, 2003). There were several respondents who did not fully answer questions and some two-part questions seemed to have contradictory answers, indicating that some may not have fully understood specific questions. Those not answering questions resulted in a reduction in the sample sizes for models, though answers to most questions were robust. Many of the survey questions and answers from this study were context specific for farmers in this region. Thus, other areas experiencing conflict may have different environmental pressures or more heterogenous opinions on deterrent methods and their usage. However, while many of the findings may be specific to this region, other areas with similar circumstances may find them applicable and useful for the respective agencies managing human-elephant interactions.

These findings demonstrated that vital information for reducing elephant crop raiding is not reaching stakeholders that are willing to implement deterrents, and that multiple barriers exist for use of deterrents. These overall findings contain pertinent information for managers and policymakers who may be designing and implementing programs to mitigate conflicts, and suggest several key management recommendations. First, there is a need for increasing outreach efforts to farmers to share knowledge on deterrent approaches, especially in remote areas and using more effective, modern deterrent types. Second, after receiving information and/or training about construction of deterrents, programs are needed that provide financial resources to support the purchase of mitigation supplies. Third, provide information for farmers on how to live safely near elephants, including the dangers of attempting to chase or harm elephants, so as to decrease farmers' fear of elephants. A combination of these efforts could increase farmers' tolerance of elephants and increase food security. Without these additional educational and financial resources being provided for rural farmers the likelihood of elephants raiding crops is unlikely to change.

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Table 2.1. Questions administered to farmers from 6 villages in the Kasigau Wildlife Corridor of Kenya related to African elephant crop raiding.

Question	Relevant Survey Questions
1	Do you use methods to prevent crop raiding by wildlife on your farm? Yes/no
2	If yes, what type of methods do you use? Open-ended
3	Have you ever received information on methods to prevent crop raiding? Yes/no
4	If yes, what type of information on methods to prevent crop raiding?
5	Have you ever received instructions on how to build deterrent fences? Yes/no
6	If yes, what types of deterrent(s)? Open-ended
7	If you were given information about ways to prevent crop raiding how likely is it you would be able to invest in and build deterrent methods? Definitely, possibly, I am unsure, definitely not
8	If no, please tell us why you would not be able to purchase or construct deterrent methods? Open-ended
9	What do you feel is the main reason for your crop losses? Open-ended
10	Have you ever actively chased elephants from your farm? Yes/no
11	Have you ever harmed or attempted to harm elephants when they came to your farm? (These answers will NOT be shared with authorities)? All the time, never, once, Regularly, Several Times
12	How much do you fear elephants? Very Afraid, Somewhat Afraid, Not at All, Unsure, a little bit
13	Have you ever received information on how to safely live with elephants? Yes/no
14	How many acres do you currently use for crop farming? Open-ended

Table 2.1. Continued

15	How many years have you been farming? Open-ended
16	What year were you born? Open-ended
17	Village of Origin? Open-ended (This was verified on each survey)
18	Gender? (Male, female)
19	What is the highest level of education that you have achieved? Open-ended

Table 2.2. A *priori* models used to test hypothesis. Hypotheses were related to the use of deterrents to prevent crop raiding by elephants in villages proximate to Rukinga Wildlife Sanctuary.

Model	Description	Hypotheses
1	Null	All
2	constant + age	H1, H3, H4
3	constant + education level	H1,H2, H3, H4
4	constant + years farming	H1, H3, H4
5	constant + gender	H1, H3, H4
6	constant + exposure	H1, H3, H4
7	constant + farm size^2	H1, H3, H4
8	constant + village	H1, H3, H4
9	constant + age + education level	H1, H3, H4
10	constant + age + exposure	H1, H3
11	constant + age + farm size^2	H1
12	constant + education level + exposure	H1, H3, H4
13	constant + education level + farm size^2	H1,H4
14	constant + exposure + farm size^2	H1
15	constant + age + education level + exposure	H1, H3, H4
16	constant + age + exposure + farm size^2	H1
17	constant + education level + exposure + farm size^2	H1, H4
18	constant + age + education level + exposure + farm size^2	H1, H4
19	constant + age + education level + years farming	H1, H3, H4

Table 2.2. Continued

20	constant + age + education level + years farming + gender	H1, H3, H4
21	constant + age + education level + years farming + gender + exposure	H1, H3, H4
22	constant + age + education level + years farming + gender + exposure + farm $size^2$	H1, H3, H4
23	constant + age + education level + years farming + gender + exposure + farm $size^2$ + village	H1, H2, H3, H4
24	constant + age + education level + years farming + gender + farm $size^2$ + village	H2

Table 2.3. Deterrent type information received by farmers. Categorized responses from questions 4 and 6 (see Table 2.1), inquiring about the type of deterrent method information received in the survey submitted to 206 villagers in the Kasigau Wildlife Corridor of Kenya.

Question	Type of Deterrent Method	No. of Villagers
Q4. General Deterrents (n = 42)	Barbed Wire Fence	3
	Beekeeping	6
	Chasing Elephants	2
	Digging Trenches	1
	Electric Fences	2
	Fencing (basic, non-specific)	8
	Guarding Overnight	3
	Help from Kenya Wildlife Service (KWS)	2
	Planting Chili Peppers	4
	Making Noise	4
	Planting Hedges or Trees	3
	Pouring Gas Around Farm	1
	Using Torch (Flashlight)	3
Q6. Fencing Deterrents (n = 22)	Barbed Wire	6
	Beehive	1
	Electric	6
	Solar or Lights	3
	Thorny Branches	5
	Tree	1

Table 2.4. Results of binomial generalized linear models for H1, evaluating which farmers were currently deterrent users based on demographic variables, df=188. Model descriptions are presented in Table 2.2, Adj R^2 = adjusted, pseudo r^2 value, w_i = weight assigned to each model LL = Log Likelihood, k = the number of variables in each model.

Model	Intercept	AICc	ΔAICc	Adj R^2	w_i	LL	k
12	-0.93	253.71	0.00	0.07	0.36	-121.69	5
15	-1.54	255.05	1.33	0.07	0.19	-121.29	6
6	-0.04	255.55	1.84	0.04	0.14	-125.74	2
17	-1.09	256.30	2.59	0.07	0.10	-120.84	7
10	-0.05	257.61	3.90	0.03	0.05	-125.74	3
18	-1.55	257.97	4.26	0.06	0.04	-120.58	8
14	-0.18	258.07	4.36	0.04	0.04	-124.93	4
21	-1.22	258.59	4.87	0.06	0.03	-120.89	8
16	-0.11	260.17	6.45	0.03	0.01	-124.92	5
22	-1.29	261.94	8.23	0.05	0.01	-120.35	10
3	-0.69	262.19	8.47	0.02	0.01	-130.03	4
1	0.18	262.50	8.79	0	0.00	-130.24	1
9	-1.36	263.28	9.56	0.02	0.00	-126.47	5
5	0.35	263.44	9.72	<0.00	0.00	-129.69	2
4	0.32	264.13	10.41	<0.00	0.00	-130.03	2
2	0.07	264.50	10.78	-0.01	0.00	-130.22	2
19	-1.21	264.85	11.13	0.01	0.00	-126.19	6
13	-0.73	265.85	11.92	0.01	0.00	-126.59	6

Table 2.4. Continued

7	0.16	265.69	11.98	-0.01	0.00	-129.78	3
20	-1.04	266.61	12.89	0.01	0.00	-126.00	7
11	0.11	267.77	14.05	-0.01	0.00	-129.77	4
8	0.24	269.22	15.51	-0.01	0.00	-128.38	6
23	-1.47	261.28	17.56	0.04	0.00	-119.25	15

Table 2.5. Results of binomial generalized linear models for H2, a two-part hypothesis, evaluating which farmers had been exposed to any deterrent information (H2A) and specifically fencing deterrents (H2B) based on demographic variables, df = 188. Model descriptions and terms are presented in Table 2.2.

Hypothesis 2A-Any deterrents

Model	Intercept	AICc	ΔAICc	Adj R^2	w_i	LL	k
3	-1.61	182.90	0.00	0.08	0.97	-87.34	4
24	-0.89	189.59	6.69	0.10	0.03	-80.75	13
1	-1.32	197.12	14.22	0.00	0.00	-97.55	1

Hypothesis 2B-Specific fencing deterrents

Model	Intercept	AICc	ΔAICc	Adj R^2	w_i	LL	k
1	-2.13	129.67	0.00	0.00	0.95	-63.82	1
3	-2.40	135.52	5.86	-0.01	0.05	-63.65	4
24	-4.29	148.42	18.75	-0.04	0.00	-60.17	13

Table 2.6. Results of binomial generalized linear models for H3, evaluating which demographic factors determined the use of traditional deterrents. The education level of none and the village of Buguta were not included in this analysis due to low or no presence of traditional deterrent users in these categories, df = 80. Model descriptions and terms are presented in Table 2.2.

Model	Intercept	AICc	ΔAICc	Adj R^2	w_i	LL	k
1	1.65	73.41	0.00	0.00	0.27	-35.68	1
5	1.95	74.77	1.36	<-0.00	0.14	-35.31	2
4	1.37	75.13	1.72	-0.01	0.11	-35.49	2
2	2.19	75.25	1.84	-0.01	0.11	-35.55	2
6	1.63	75.49	2.08	-0.01	0.09	-35.67	2
3	1.63	75.50	2.09	-0.01	0.09	-35.67	2
10	2.19	77.35	3.95	-0.02	0.04	-35.52	3
9	2.19	77.40	3.99	-0.02	0.04	-35.55	3
12	1.58	77.62	4.21	-0.03	0.03	-35.65	3
7	1.50	77.63	4.22	-0.03	0.03	-35.66	3
8	1.95	77.85	4.44	0.01	0.03	-33.53	5
15	2.16	79.56	6.15	-0.04	0.01	-35.52	4
20	2.02	80.92	7.51	-0.04	0.01	-35.06	5
21	1.96	83.17	9.76	-0.05	0.00	-35.02	6
19	1.98	84.10	10.69	-0.06	0.00	-35.48	6
22	1.69	87.75	14.34	-0.07	0.00	-34.88	8
23	2.28	93.48	20.07	-0.06	0.00	-32.45	12

Table 2.7. Results of binomial generalized linear models for H4, evaluating demographic factors of villagers who said they definitely could erect deterrents. The education level of upper was not evaluated in this model due to low sample sizes, df = 97. Model descriptions and terms are presented in Table 2.2.

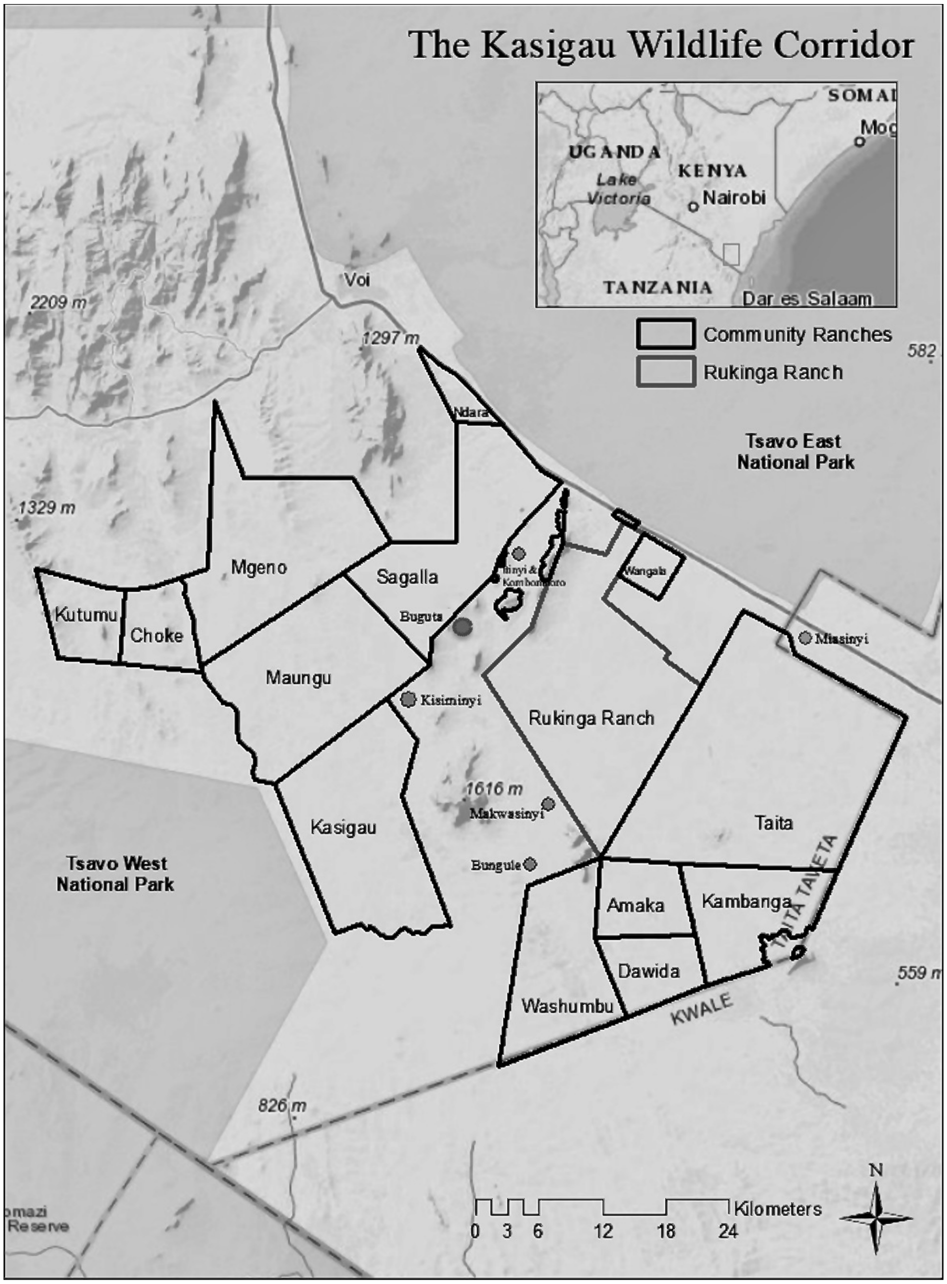
Model	Intercept	AICc	ΔAICc	Adj R^2	w_i	LL	k
6	1.12	119.24	0.00	0.03	0.39	-57.56	2
1	0.87	121.09	1.85	0.00	0.16	-59.52	1
12	2.12	122.29	3.05	0.02	0.09	-56.93	4
4	1.13	122.62	3.38	<-0.00	0.07	-59.25	2
2	1.20	122.98	3.75	-0.01	0.06	-59.43	2
5	0.84	123.15	3.91	-0.01	0.06	-59.51	2
3	1.95	123.82	4.59	-0.01	0.04	-58.78	3
15	2.83	124.05	4.82	0.01	0.04	-56.70	5
7	0.41	124.17	4.93	-0.01	0.03	-58.96	3
9	2.65	125.52	6.28	-0.01	0.02	-58.54	4
8	1.10	126.09	6.86	0.01	0.01	-56.58	6
17	1.87	126.43	7.19	<0.00	0.01	-56.75	6
13	1.52	127.12	7.89	-0.02	0.01	-58.23	5
19	2.89	127.25	8.01	-0.02	0.01	-58.30	5
21	3.13	127.87	8.64	<-0.00	0.01	-56.31	7

Table 2.7. Continued

18	2.64	128.18	8.94	-0.01	0.00	-56.47	7
20	2.89	129.46	10.23	-0.03	0.00	-58.27	6
22	2.94	132.44	13.20	-0.02	0.00	-56.20	9
23	3.91	137.50	18.26	0.01	0.00	-52.22	14

Figure Legends

Figure 2.1. The Kasigau Wildlife Corridor of Kenya, shown with its 14 community ranches and the location of the six participating villages in this study.



The Kasigau Wildlife Corridor
SOMAL
Mog
UGANDA
KENYA
Lake Victoria
Nairobi
TANZANIA
Dar es Salaam
Community Ranches
Rukinga Ranch
Voi
2209 m
1297 m
582
Tsavo East National Park
Ndara
1329 m
Mgeno
Sagalla
Wangala
Kutumu
Choke
Buguta
Mwasinyi
Maungu
Kisiminyi
Rukinga Ranch
1616 m
Makwasinyi
Kasigau
Taita
Tsavo West National Park
Bungule
TAITA TAVETA
Amaka
Kambanga
Dawida
559 m
Washumbu
KWALE
826 m
Reserve
Kilometers
0 3 6 12 18 24
N

Supplementary Information, Chapter 2

Table S.2.1. Farmer demographics. A breakdown of the gender and number of survey respondents in each of the participating villages in surveys distributed to farmers in rural villages in the Kasigau Wildlife Corridor, Kenya.

Village	Men	Women	Total per village
Buguta	15	14	29
Bungule	18	17	35
Itinyi	12	25	37
Kisimenyi	17	17	34
Makwasenyi	21	14	35
Miasenyi	13	23	36
Totals	96	110	206

Table S.2.2. Types of deterrents used by farmers. Answers with 3 or less (with the exception of Kasaine fences, a local modern deterrent) were grouped into a miscellaneous category, all of which were traditional deterrent types (n = 114).

Type of deterrent	Quantity
Fencing (rudimentary)	29
Making noise	15
Torch (flashlight)	14
Burning fire	12
Guarding	12
Solar on fencing	8
Cloths and oil	6
Planting peppers	4
Kasaine metal strip fences	3
Miscellaneous	11

Chapter 3

Kenyan farmers' attitudes towards changing resources and livelihood threats in the Kasigau Wildlife Corridor, Kenya[1]

[1] Formatted in the style of *Biological Conservation*

Abstract

Farmers in resource-poor areas of the world are facing multiple threats to their livelihoods, including climate change, poor soil quality, insect pests, and crop raiding herbivores. How environmental, economic, and social factors impact farmers' attitudes and responses to livelihood threats remains fully unexplored. With the goal of informing policy and management priorities for agencies attempting to mitigate these threats, I developed a set of *a priori* hypotheses related to farmers and their belief in the negative impacts of climate change, their interest in cultivating alternative crops, and whether they wished to continue farming despite alternative means of income. To assess my hypotheses, I surveyed farmers across 6 villages in the Greater Tsavo Ecosystem of Kenya and evaluated responses with generalized linear models in comparison to sociodemographic variables. Most farmers believed that climate change had negatively affected their lives, but no demographic variables were explanatory of those more likely to have these beliefs. A third of the farmers had never heard of alternative crop types, and again no demographic variables explained this variation. Half of the farmers preferred to continue to farm despite other means of income, potentially indicating a strong sense of place. Additional survey questions revealed other disparities such as 55% of farmers had no farm training, and men and those with higher education were more likely to have visited the national parks. An above average belief in the benefits of wildlife was also notable across the villages. These findings can be used to inform programs that bring vital information to local farmers and to create specific management priorities for agencies that assist farmers in building resilience in the face of threatened natural resources.

Introduction

Rural subsistence farmers around the world face environmental and ecological threats to food security that can affect their livelihoods (Ali and Erenstein, 2017; Harvey et al., 2014; Salerno et al., 2021; Zellera et al., 1998). Climate change influences weather patterns and what crops can be grown (Howden et al., 2007; IPCC, 2022; Kurukulasuriya et al., 2006; Vermeulen et al., 2012) and nutrient poor soils and limited water supplies can impede crop growth (Gautam, 2006; Griggs, 2013; Lasco et al., 2011; Wheeler and von Braun, 2013) and prevent irrigation (Angelakis et al., 2020). Furthermore, a variety of pest species may limit crop success (Hill, 2018; Pozo et al., 2020; Seoraj-Pillai and Pillay, 2017). These threats present a formidable set of challenges for farmers and their families.

The impacts of climate change may make some areas unsustainable for agriculture using current practices and crop variants (Below et al., 2012; Howden et al., 2007; IPCC, 2022). Migration or relocation for some communities may be necessary as irregular weather patterns are contributing to failing crops including prolonged drought, higher temperatures, and bouts of flooding (Arnell and Lloyd-Hughes, 2014; Diggs, 1991; Howden et al., 2007). More intense and prolonged droughts and the necessary adaption mechanisms continue to challenge farmers' natural and financial capital and resilience to adverse events (Bailey et al., 2019; Shiferaw et al., 2014). Climate change impacts are especially severe in equatorial and semi-arid communities where temperatures are highest (Brondizio and Moran, 2008; Yengoh and Ardö, 2020), threatening agricultural production.

Compounding the impacts of climate change are the availability of nutrient rich and productive soils, poor agricultural practices, and equitable access to water. Subsistence farmers in semi-arid savanna drylands have soils that are typically nutrient poor (Scholes, 1990), which can limit the types of usable crop varieties. Furthermore, monocultures, lack of soil amendments and poor farming methods can strip the nutrients from soil, reducing crop yields or viability (Diaz S et al., 2019; Eitzinger A et al., 2022; Jacques and Jacques, 2012; Menaleshoa, 2016; Perez et al., 2015). In addition, many rural farmers lack access to farm training or information on improved seeds or alternative types of crops (Balmford et al., 2012; Harich et al., 2013; Hussain et al., 1994; Westengen et al., 2019). The increasing spread of crop-damaging pests such as arthropods, emerging crop diseases, or large herbivores, can also reduce or eliminate crop yields for farmers (FAO, 2022; Gross et al., 2018; Kansky and Knight, 2014; Lobell and Gourdji, 2012; Mainka and Howard, 2010). Finally, rainfall can be highly variable, especially in semi-arid environments, and access to water for irrigation can impede productivity (Angelakis et al., 2020). These existing issues are likely to be further exacerbated by increasing global temperatures and weather events as part of climate change (IPCC, 2022; Jägermeyr et al., 2021). Thus, these challenges to agricultural production can result in reduced crop yields, compromising food security.

Access to information on how to mitigate some of these threats such as wildlife interactions can be limited, and financial resources may be allotted to other pressing concerns (Chapter 2; Thondhlana et al., 2020; Zimmermann et al., 2021). Committing time and resources to deterring wildlife can often limit other opportunities for rural people as they struggle to provide the necessities for their families (Barua et al., 2013). In addition, farmers may blame wildlife for crop losses when other issues are equally problematic such as drought (Gautam, 2006; Hoffmeier-Karimi and Schulte, 2015; Von Hagen, 2018; White and Ward, 2010). Coping with these negative interactions, especially in low-resource communities, remains a major challenge in conservation. Even if farmers are educated on the various types of threats to their food security and the corresponding mitigation types, they may be limited in their ability to effectively respond due to financial or social constraints.

Financial resources, education on best farming practices, access to new information, and the availability of technology are social and economic challenges that compound the impacts of environmental and ecological threats to farmers' food security. For example, lack of access to technology or knowledge about methods that can improve crop yields may not be reaching rural farming communities (Balmford et al., 2012; Harvey et al., 2014). In addition, some farming communities lack collective adaptive capacity, or strategies to respond to adverse events, because of limited resources (Bailey et al., 2019; Bebbington, 1999; Cobbinah et al., 2015; Eitzinger et al., 2022; Olsson et al., 2004). Many of the drivers of these hardships are well known, but farmer attitudes and perceptions surrounding them are diverse and can vary depending on local context and within demographic categories (Christie et al., 2020; Hill, 2004; Jin et al., 2020; Marshall et al., 2007; Mc Guinness, 2016; Roco et al., 2015; Sofoluwe et al., 2011; van Hulst et al., 2020).

Local and individual variation exists in the uptake and accessibility of new farming methods, alternative livelihoods to agricultural production, and access to viable markets. These additional challenges make it difficult to mitigate the more immediate threats to food security for farmers. Some rural farmers may be resistant to using new farming methods, or may not have access to different types of crops that are drought, pest, or wildlife resistant (Gross et al., 2016; Lasco et al., 2011). Lack of access to sustainable alternative livelihoods to farming, especially in remote areas (Banchirigah and Hilson, 2010; Belay, 2016; Roe et al., 2015; Wright et al., 2016), can also compromise food security. Many farmers in Africa, Asia, and South America, are subsistence or smallholder farmers, cultivating farms under 2 ha, and producing 30-40% of the world's food (Ricciardi et al., 2018). Access to markets to sell products (including livestock, farm outputs, or handcrafts) is another limitation for farmers which can compromise livelihood viability (Bebbington, 1999; Zellera et al., 1998; Zulu and Richardson, 2013). As food security and livelihoods become increasingly threatened, it may become essential for initiatives that offer alternatives to traditional subsistence farming so as to maintain humane living standards and promote health and well-being in accordance with the United Nation's Sustainable Development Goals (UNDP, 2015).

In many African countries, farmers are open to climate change and alternative livelihood initiatives, and adoptive farming practices, but how this varies across demographic, social, and economic scales has not been fully explored (Arku, 2013; Asante et al., 2021; Douglas et al., 2008; Kemausuor et al., 2011; Sofoluwe et al., 2011; Yengoh and Ardö, 2020). For example, higher education levels impact whether farmers adopt new farming techniques (Oduro-Ofori, 2014), yet older people tend to be more risk averse, and decision-making varies and is impacted by local culture (Rieger and Mata, 2015). Thus, clarifying how demographic factors affect attitudes, perceptions, and adoption behaviors is important when examining environmental issues surrounding farmers. Data on how much information finds its way to the hands of rural farmers in need of adaptive techniques is also limited. Understanding these variations in rural farming communities may help to inform policy decisions and conservation initiatives that build community resilience to a variety of environmental and social challenges.

To understand the demographic variation in farmer attitudes and responses to livelihood threats, my goal was to explore the influencing environmental, economic, and social factors. The purpose of this goal was to better inform policy and management priorities for agencies attempting to mitigate these threats using a rural landscape of Kenya. Based on this goal I hypothesized that farmers: 1) who believed that climate change had negatively affected their lives would be positively correlated with age, education, and years farming (H1) (Kurukulasuriya, 2006; Debesai, 2020); 2) with interest in cultivating other crops from those traditionally grown, especially maize, would be positively correlated with age, education, years of farming experience, exposure to information on new farming techniques and methods, and those receiving farming education (H2) (Oduro-Ofori, 2014; Shikuku et al., 2017); and, 3) who wished to continue farming despite having alternative means of income would be positively correlated with age and years farming, and negatively correlated with those who had learned about alternative livelihoods (H3) (Rieger and Mata, 2015; Wicander and Code, 2015). I also assessed questions surrounding other topics of interest by demographic categories such as the use of national parks, how farmers felt about benefits from wildlife, access to alternative livelihoods and new farming techniques, and market access. Having a greater understanding of the complex factors that may impact farmer awareness of and reaction to environmental challenges can help to inform programs which build resilience in communities facing these escalating challenges.

Methods

Study Area

The Kasigau Wildlife Corridor (KWC) of Kenya contains 14 community ranches and lies between Tsavo East and West National Parks in southeastern Kenya (Figure 3.1). This geographic area experiences high instances of human wildlife interactions (Kaitopok, 2015; Kamau, 2017; Kioko et al., 2006; Smith and Kasiki, 2000; Von Hagen, 2021) as wildlife uses the corridor to move between the two parks (Githiru et al., 2017; Ngene et al., 2017; Omondi et al., 2008). The region is home to the country's largest elephant population of ca.15,000 individuals

(Waweru et al., 2021) and crop raiding is common in the area. The region is also being impacted by climatic changes such as prolonged droughts (USAID, 2022), and contains many subsistence farming households (Kasaine and Githiru, 2016). Rukinga Wildlife Sanctuary, one of the community ranches in the corridor, is operated by Wildlife Works as part of the Kasigau Corridor REDD+ Project (Githiru and Njambuya, 2019) which employees community members, disburses funds for village improvement projects, and has interactive outreach and education programs. Management allows no human settlements or livestock grazing within the sanctuary, making it favorable habitat for wildlife.

Approximately 36% of the Kenyan population lives in monetary poverty, which is less than 5995KSH per month (~$60 USD). In addition, over 23.4 million Kenyans (53%) live in multi-dimensional poverty; lacking at least three basic needs, services, or rights such as access to water, nutrition, education, housing, or sanitation (Kenya National Bureau of Statistics, 2020). Most rural villagers in the KWC (and participants in our study) experience these same poverty levels. Villagers living under these conditions find it difficult to build personal or community resilience against events such negative wildlife interactions, droughts, or urgent health needs (Githiru et al., 2017; Kasaine and Githiru, 2016). The majority of Kenya experiences a bimodal rainfall pattern comprised of the long rains between March and June and the short rains from October and December (Bryan et al., 2013).

Study Design

For this study, I selected six communities surrounding Rukinga Wildlife Sanctuary in the KWC to test my hypotheses. The prerequisites for selecting these locations were as follows: 1) a community had to share a boundary with the sanctuary and be within one-hour drive of the centralized base on the ranch for logistical feasibility; 2) the community had to be comprised of a majority of farming households experiencing crop raiding by wildlife (Chapter 2); and 3) local decision-makers had to be in favor of allowing research to be conducted in their respective villages. Based on these criteria I selected and engaged with members of Itinyi & Kombomboro (combined due to small population size and close proximities, hereafter referred to as Itinyi), Bungule, Miasenyi, Kisimenyi, Buguta, and Mwakwasinyi villages (Figure 3.1).

I developed a questionnaire (Appendix A) based on previous research conducted with farmers experiencing crop raiding and other challenges to household and livelihood security (Hoffmeier-Karimi and Schulte, 2015; Kasaine and Githiru, 2016). The survey contained 64 questions, 21 of which focused on farming and its associated challenges, alternative livelihood opportunities, the relationships to wildlife and the National Parks, and demographic variables (Table 3.1), and was administered in Swahili. Prior to administration, the survey was reviewed and approved by Auburn University's IRB committee (Protocol no. 20-440 EX 2009) in the U.S. and Strathmore University's Institutional Ethics Review Committee (Approval no. SUIERC0877/20) in Kenya. The research was conducted under the umbrella of Wildlife Works with Kenya Wildlife Service's PIC/MAT agreement and with approval from NACOSTI (Kenya's science agency, License No. NACOSTI/P/20/2292).

Because of the COVID-19 pandemic, international field work was not permitted in 2020 and a local facilitator was hired to administer the surveys following strict pandemic protocols in conjunction with village administration. Chiefs are elected officials of Locations (the smallest administrative unit recognized by Kenya's Ministry of the Interior). They also oversee Assistant Chiefs who monitor sub-locations, several of which can exist within one Location. Within each sub-location there are several villages each overseen by a village elder, elected by the Chiefs and villagers. I requested that these local representatives from each village collaborate to select 30-35 farmers from their respective village. To avoid gender bias, an approximate equal sex ratio of participants was selected. To maintain sample independence, only one farmer per household participated in the study. Following these guidelines the sample population was 206 participants across the six villages (Supplemental Table S.3.1). These individuals were invited to participate in a meeting occurring over 4-5 hours, each on one day in their respective villages. At the meeting, the research assistant administered a paper survey and was available to resolve any confusion over questions and aid those who might be illiterate (White et al., 2005), which was approximately 15% of the participants (n = 31 across all villages). These participants had surveys administered orally with the assistant aiding in recording responses on the paper survey. To assure construct validity, the facilitator clearly defined the concepts of 1) climate change (changes in the environment such as prolonged drought, hotter days, increased flooding, or any other type of differentiation from normal patterns), 2) alternative livelihoods (any (legal) ways of earning extra money other than farming) and 3) irrigation (adding water to by any means to crops). For participating farmers, the survey had many question types including open-ended questions so that all ideas could be equally represented. All hardcopy surveys were translated by the facilitator and entered into a database using the open-source software mWater (www.mwater.com, 2022), designed to be used in areas with limited connectivity, and then transferred to Microsoft Excel (V 16.55).

Data Analysis

I edited data to correct spelling and grammatical mistakes and made specific modifications to questions including groupings as follows. For education level responses, I grouped college, university, or any type of technical certificates into the term upper. For Q10, regarding belief that wildlife benefited their household, I eliminated 6 responses as they were contradictory to a follow up question (not used in this manuscript) on *how* they believed it benefitted their household. For Q15, regarding market access, only one person answered unsure, so it was eliminated from analysis.

I evaluated each demographic variable of interest (age, education level, years farming, gender, farm size, and village of origin) for collinearity with a robust variance inflation factor (VIF). All VIFs were <1.5, signifying no collinearity between variables. For each of the three hypotheses I developed *a priori* models that evaluated each hypothesis in relation to the variables of interest and relevant combinations (Table 3.2). All models were analyzed using a generalized linear model (GLM) which accounted for the non-normal nature of the data. A binomial function was used, making the models logistic regression models. Model results were compared using Akaike information criteria corrected for sample size (AICc) as a measure of fit. Adjusted, pseudo R^2 values according to Zhang, 2017 are also reported. Models having $\leq \Delta 2$ AICc (Burnham & Anderson 2002) were considered in conjunction with the explanatory values of model weights and R^2 values. Top models are reported but are not an indicator of support of hypotheses as each is independently evaluated from respective model metrics and sociological meaning. All analyses were conducted in the statistical program R (v. 4.0.2., 2020).

I established dependent and independent variables for each hypothesis as follows. For the climate change hypothesis (H1), I used Q9, do you believe that climate change has negatively affected your life? as the dependent variable. The answers of *very much* and *somewhat* as an overall effect of some impact of climate change on farmers were combined, and 2 answers of *I don't know* were eliminated. For model comparisons, I eliminated any respondents who did not answer relevant questions, giving a final sample size of n = 185. Each question was then tested against each demographic variable (Models 1-7) and all potential combinations of the variables of age, education level, and years farming (Models 8-9, 12, and 18) according to my hypothesis.

For the alternative livelihoods hypothesis (H2), any participant surveys without all questions answered were eliminated for model comparison, reducing the sample size to n = 178. The dependent variable was Q3, Are you interested in planting different types of crops than what you normally plant? Compared against each demographic variable (Models 1-7) and all potential combinations of the variables of interest (education level, age, years farming, exposure to new techniques (Q14) and those receiving farming education (Q1)) (Models 8-35). For Q14, Have you ever received information about new agricultural techniques that could increase your crop yields?, 7 answers of *I don't know* were eliminated for analysis.

For H3, the alternative livelihoods hypothesis, Q8, If you had other ways to earn money, would you still continue to farm? was used as the dependent variable. The answers of *definitely* and *possibly* were combined into a positive category and *maybe not* and *definitely not* as the negative category in order to use a binomial GLM. No participants responded with the option *I don't know*. Any participant who did not answer all of the questions was eliminated, reducing the sample size to n = 171. These answers were then compared against each demographic variable (Models 1-7) and combinations of the variables of age, years farming, and exposure to livelihood alternatives (Models 12, 35-37).

For questions 10-15, responses were evaluated whether they differed based on the demographics of age, education level, gender and village with a Pearson's chi-square tests (χ^2) for education level, gender, and village, and ANOVA for age. Significant χ^2 results were analyzed with a Bonferroni post-hoc test to identify the significant variables. Variables were considered significant using an alpha of ≤0.05. All analyses were conducted in the statistical program R (v. 4.0.2., 2020)

Results

The village sessions represented a wide diversity of participants from the population. Of the 206 villagers that completed the survey, the number that participated by village ranged between 29 and 37. The ratio of female and male participants was similar (53:47), though this varied by village (Supplementary Table 3.1). Respondents ranged in age from 18 to 85 years old with a mean age of 46 (± 13.63 SD) and household size ranging from 2 to 34 with a mean of 8 people (± 3.95 SD). The majority of respondents came from the Taita ethnic community (59%), followed by Kamba (15%), Duruma (9%), and Mijikenda (5%), with the remaining 12% comprised of 12 different tribal affiliations. Most participants (64%) had a primary level education, while 22% had a secondary level, 7% had upper education, and the remaining 7% had no formal education. The main source of income for 92% of respondents was farming.

The climate change hypothesis (H1) was evaluated using the survey question on the level at which farmers believed that climate change had negatively affected their lives (Q9, n = 204). Most farmers indicated climate change negatively affected their lives (42% very much and 39% somewhat), with only 17% indicating it did not affect them at all or that they did not know (1%). Farmers indicated numerous ways they believed climate change had affected them (Q16, n = 206), with less rains and more drought (33%), wildlife come crop raiding more often (27%), and temperatures being hotter (27%) being the top responses. The best fitting model for H1 was the null model (M1; Table 3.3).

Related to the alternative crops hypothesis (H2), 55% of the respondents had received no additional training for farming outside of their family (Q1). Farmers planted 22 different types of crops (Q2); 18 (9%) grew only maize, while 188 (91%) grew two or more types of crops with a maximum number of 8 crops grown. The predominant crop was maize (grown by 99% of respondents), followed by cow peas (76%), green grams (lentils) (75%), and sorghum (32%). The vast majority of famers (82%) were interested in growing other types of crops (Q3), with 18% showing no interest or were unsure. The majority of farmers were aware of new agricultural techniques (61%), but over a third (35%) had never heard about other methods, and 4% did not know (Q14). The null (M1) was the top model for H2 (Table 3.4).

For the alternative livelihoods hypothesis (H3), farmers were asked if there were other way to earn money if they would still continue with farming (Q8, n = 205). Approximately half (51%) of the farmers indicated they were open to other approaches, while the rest (48%) were unreceptive or did not know (1%). Over two thirds (66%) of the farmers had learned about other ways to earn money than farming (Q13, n = 201), with the remaining farmers having not learned (31%) or did not know (3%). The best fitting model for H3 was village (M7), specifically the village of Kisimenyi (Table 3.5).

The majority of farmers (79%) stated that drought sometimes affected their harvests each season (Q7) and the vast majority (91%) did not use any form of irrigation (Q6). The predominant reason farmers blamed for the loss of their crop (Q4) was elephants. Farmers quantified their total crop losses (n = 205) at 320.03 hectares per season (Q5). The majority of farmers (62%) had a way to bring products to market (Q15). Many famers believed that their household benefited from the preservation of wildlife to some degree (68%, Q10). Those responding to the specific benefits they received from wildlife (Q17), indicated that wildlife brought jobs to the community (55%), followed by the understanding that wildlife tourism is important for the economy of Kenya (20%), and those that believed there were no benefits to them (18%). For Q11 and Q12, I found that most farmers had neither been to any National Park nor the Tsavo Parks (full results for multiple questions in Table 3.6).

For examining the sociodemographic differences of questions 10-15 only Q11 and Q12, regarding National Park visits, differed based on demographic factors (Table 3.7). Specifically, more men and those with more education were more likely to visit any National Park. For the Tsavo National Park visit question (Q12), village of origin was significant with the village of Buguta less likely to have visited the park.

Discussion

The climate change hypothesis (H1) and the alternative crops hypothesis (H2) were not supported, with the null models (M1) being the best fit. The alternative livelihoods hypothesis (H3) was also not supported, and village, specifically the village of Kisimenyi was the best fitting model. However, most variables were weak in terms of explaining any variation in the data when examining the other metrics of fit. This suggests two possibilities: 1) some responses to questions did not have adequate sample sizes to detect substantial differences (as in H1, where the vast majority of respondents believed in negative impacts of climate change) and/or, 2) there are homogenous views and behaviors by farmers regarding these issues. A homogeneity of views on issues surrounding livelihood threats and with farmer attitudes can be beneficial for practitioners as they develop livelihood or resilience strategies in conjunction with farmers. Thus, programs can be developed which encapsulate these farmer viewpoints with little need for multiple or diverse approaches. Lack of strong indicators of variation also adds to the body of literature suggesting the need for greater sociological understanding of factors that contribute to attitudes towards alternative livelihoods and acceptance of adaptations to climate change (Haden et al., 2012; Ricart et al., 2019; Shikuku et al., 2017).

The vast majority of respondents believed that climate change had negatively impacted them. This elevated awareness of climate change impacts may be due to personal experiences or proximity to conservation groups (Berkes and Turner, 2006; Gómez-Baggethun et al., 2013; Vinyeta and Lynn, 2013) and perceptions of climate change are highly contextual (Fierros-González and López-Feldman, 2021). There were slightly more women that believed in the negative impacts of climate change vs. men. This is logical as women in the study area are largely responsible for farming duties, and other research shows how perceptions of climate change often differ in males and females (Demetriades and Esplen, 2010). The disparities in the vulnerability of women and girls from climate change are well known (Glazebrook et al., 2020; UN WomenWatch, 2009) and climate change is expected to continue to exacerbate food insecurity in this region, which will increase pressure on female farmers. Therefore initiatives that target mitigation of climate change impacts are imperative for these communities.

Though models could not detect any variation amongst demographic categories, most farmers were interested in growing alternative crops, including those who had never heard of new techniques. This openness to new techniques, is *despite* many never being exposed to information. Overall, approximately half of farmers did not want to stop farming, even if other means of earning a living were available, which poses a challenge for their future livelihoods. This finding could also be indicative of a strong sense of place and cultural attachment to a farming lifestyle (Kudryavtsev et al., 2012). Hesitation by farmers to adopt other career paths may become problematic if as predicted climate change continues to make producing viable crops more challenging and relocation may be necessary in some areas.

Threats to farmers' food security are often further complicated by a lack of alternative livelihoods in remote farming communities (Adhikari, 2011; Ngugi and Nyariki, 2005). While most respondents had heard something about alternative livelihoods, this figure could be skewed by the successful women's basket weaving program that exists in the region. However, a third of respondents still had not received information on potentially different career pathways. This gap in dissemination of information is an additional justification for increased livelihood initiatives that can focus on assuring there are supportive resources for transitioning away from subsistence-based agriculture if needed.

Over half of farmers had no formal farming training outside of what was passed down from family members, which could be improved and potentially make farmers more accepting of new methods. Most of the crop losses were attributed to elephant crop raiding, not drought, even though drought was a major factor in crop losses and failure in recent years (Von Hagen, 2018). Contradictory information on the reasons behind crop losses may be demonstrative of farmers over-attributing losses to elephants, not recognizing the equal or greater detriment of other factors (Hoffmeier-Karimi and Schulte, 2015), or cultural beliefs (Salite, 2019). The vast majority of farmers also did not use any means of irrigation. Like other semi-arid areas, vulnerability to drought for farmers is further complicated by the inability to irrigate crops due to access to adequate water resources or the financial means to implement irrigation methods (Angelakis et al., 2020). Thus, making agricultural training available for farmers, including ways to acquire drought-tolerant seed varieties is one approach for improving crop yields and thereby food security.

Despite understandable frustration with crop raiding by elephants and other wildlife, farmers showed a complex understanding of the benefits of wildlife, likely due to Wildlife Works and other local wildlife agencies' outreach efforts. Notably, a larger proportion of the farmers viewed wildlife in a positive light relative to other communities (Granados and Weladji, 2012; Kansky et al., 2014; Mogomotsi et al., 2020; Ochieng et al., 2021). This positive view of wildlife is despite that living in close proximity to the parks, most villagers (especially women and those with lower levels of education) had never visited the parks. Higher rates of belief in the benefits of wildlife are evidence for how outreach and community engagement may have positively influenced attitudes towards wildlife, even in an area of high conflict. Belief in the benefits of wildlife also contributes to the call for understanding how locally specific interventions impact communities (Salerno et al., 2016).

Farmers were eager to participate in the study and share their vast ecological knowledge of the area. As with many social survey studies, this research had several caveats that are important to acknowledge. First, several questions in the survey may have been considered controversial to farmers and it is possible some may have responded in a manner to express what I expected to find (i.e. positively). This response could have created social desirability bias if a large component of respondents answered in the same way (Chung and Monroe, 2003). Second, there were several respondents who did not fully answer questions and some two-part questions seemed to have contradictory answers, indicating that some may not have fully understood specific questions. Those not answering questions resulted in a reduction in the sample sizes for the three models, though answers to most questions were robust.

Collectively, the farmers' views and experiences elaborated on the challenges for finding solutions to their food security and livelihoods. Almost every farmer surveyed planted maize, which is highly favored by elephants (Chiyo and Cochrane, 2005; Weinmann, 2018) and an introduced staple, but is expected to decrease markedly as a viable crop by 2030 due to climate change (Jägermeyr et al., 2021). One potential solution is using new climate-resilient maize which could increase yields by 5-25% (Cairns and Prasanna, 2018). Most farmers grew several different types of crops and were open to growing other additional types. Thus, introducing alternative types of crops, perhaps those less favored by elephants, or drought resistant could increase crop diversity, and reduce losses from drought and elephants or other wildlife (Gross et al., 2016; Vermeulen et al., 2012). However, a barrier to introducing new crop varieties and other potential crop yield increasers such as climate smart agriculture (Harvey et al., 2014; Partey et al., 2018) is awareness by farmers of these available products and techniques (Westengen et al., 2019). Moreover, a large barrier to change is funding as the low incomes and lack of financial support makes changing methods and crops quite difficult.

These findings are focused on a sample population from the KWC, having management implications specific to the local context (Christie et al., 2020). However, recommendations can also be applied broadly to conservation, management, and policy decision makers outside of this area. First, community-based farming programs that will holistically address ways to increase food security, reduce wildlife conflicts, create sustainable livelihoods, and increase overall health and wellbeing for farmers are needed. An important lesson from the work here is that challenges can be very specific to each village or community. Thus, programs should be tailored to first comprehend the range of these complexities. Second, developing and implementing programs that offer training or alternatives to farming or providing aid to those who are unable to find alternatives, as farming may be increasingly difficult as the climate continues to change.

Working with rural farmers to create sustainable interventions is essential for building resilience in local communities facing multiple livelihood challenges.

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Table 3.1. Social survey questions administered to farmers in six villages in the Kasigau Wildlife Corridor of Kenya related to farming practices, livelihoods, and climate change.

Survey Questions
1. Have you had any formal farming educational training (other than family)? Yes/No
2. What types of crops do you plant? Multiple Choice: Maize (Mahindi), Green Grams (Pojo), Cow Peas Kunde), Ground Nuts (Njugu), Sorghum (Mtama), Other (Please specify)
3. Are you interested in planting different types of crops that what you normally plant? Yes/No
4. What do you feel is the main reason for your crop losses? Multiple choice: Bad seeds, drought, elephants, other wildlife, pests, disease, other (please specify)
5. How many acres do you believe are lost? Open-ended
6. Do you irrigate your crops in some way? Yes/No
7. How often does drought affect your harvest per season? Select one: Every season, I don't know, never, sometimes
8. If you had other ways to earn money, would you still continue to farm? Multiple choice: Definitely, possibly so, I don't know, maybe not, definitely not
9. Do you believe that climate change has negatively affected your life? Multiple choice: Very much, somewhat, I don't know, not at all

Table 3.1. Continued

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10. Do you believe your household benefits from the preservation of wildlife? Multiple choice: Yes-a lot, somewhat, not sure, no-not at all

11. Have you ever visited a National Park? Yes/No

12. Have you ever visited Tsavo East or Tsavo West National Park? Yes/No

13. Have you ever learned about other ways to earn money than farming? Please check one: I have heard a lot about other ways, I have heard a little bit about other ways, I have never heard about other ways, I do not know

14. Have you ever received information about new agricultural techniques that could increase your crop yields? Please check one: I have never heard about new techniques, I have heard a little bit about new techniques, I do not know, I have heard a lot about new techniques

15. Do you have a way to bring products that you want to sell to a market? Yes/No

16. How do you believe climate change has affected you? Check all that apply: Animals come more often to raid, I don't believe climate change has affected me, I don't know, The crops are unpredictable, The temperatures are hotter, There are less rains/more drought, There are more pests, There is more flooding, Other (open-ended)

17. How do you believe your household benefits from wildlife? Check all that apply: I understand that healthy wildlife is important to the ecosystem, I understand that preserving wildlife is important for tourism for the Kenyan economy, I enjoy watching or seeing wildlife, Wildlife brings jobs to the community, I don't believe my household benefits from wildlife, I don't know

Table 3.1. Continued

18. How many acres do you currently use for crop farming? Open-ended
19. How many years have you been farming? Open-ended
20. What year were you born? Open-ended
21. Village of Origin? Open-ended (This was verified for each survey)
22. Gender? (Male, Female)
23. What is the highest level of education that you have achieved? Open-ended

Table 3.2. *A priori* models used to test hypotheses related to climate change, interest in alternative crops, and alternative livelihoods in villages in the Kasigau Wildlife Corridor of Kenya.

Model	Description	Hypotheses
1	Null	All
2	Constant + age	All
3	Constant + education level	All
4	Constant + years farming	All
5	Constant + gender	All
6	Constant + farm size^2	All
7	Constant + village	All
8	Constant + ed level + age	H1, H2
9	Constant + ed level + years farming	H1, H2
10	Constant + ed level + exposure	H2
11	Constant + ed level + farm education	H2
12	Constant + age + years farming	ALL
13	Constant + age + exposure	H2
14	Constant + age + farming education	H2
15	Constant + years farming + exposure	H2
16	Constant + years farming + farming education	H2
17	Constant + exposure + farming education	H2
18	Constant + ed level + age + years farming	H1, H2
19	Constant + ed level + age + exposure	H2

Table 3.2. Continued

20	Constant + ed level + age + farming education	H2
21	Constant + ed level + years farming + exposure	H2
22	Constant + ed level + years farming + farming education	H2
23	Constant + ed level + exposure + farming education	H2
24	Constant + age + years farming + exposure	H2
25	Constant + age + years farming + farming education	H2
26	Constant + age + exposure + farming education	H2
27	Constant + years farming + exposure + farming education	H2
28	Constant + ed level + age + years farming + exposure	H2
29	Constant + ed level + age + years farming + farming education	H2
30	Constant + ed level + age + exposure + farming education	H2
31	Constant +ed level + years farming + exposure + farming education	H2
32	Constant + age years farming + exposure + farming education	H2
33	Constant + ed level + age + years farming + exposure + farming education	H2
34	Constant + ed level + age + years farming + exposure + farming education + farm size + village	H2
35	Constant + exposure alt. livelihood	H2, H3
36	Constant + age + exposure alt. livelihood	H3
37	Constant + years farming + exposure alt. livelihood	H3

Table 3.3. Results of binomial generalized linear models testing the climate change hypothesis (H1) of farmers in the Kasigau Wildlife Corridor of, Kenya, df = 184. Adj. R^2 = Adjusted, pseudo R^2, w_i = weight assigned to each model LL = Log Likelihood, k = the number of variables in each model. Model descriptions are presented in Table 3.2.

Model	Intercept	AICc	ΔAICc	Adj. R^2	w_i	LL	k
1	1.53	175.52	0.00	0	0.26	-86.75	1
4	1.92	175.81	0.29	0.01	0.23	-85.87	2
5	1.73	176.38	0.85	0.00	0.17	-86.16	2
2	1.48	177.56	2.04	-0.01	0.10	-88.75	2
12	1.90	177.88	2.35	0.00	0.08	-85.72	3
6	2.11	178.16	2.64	-0.00	0.07	-86.01	3
7	1.15	178.76	3.23	0.01	0.05	-83.14	6
3	1.50	181.54	6.02	-0.02	0.01	-88.66	4
9	1.83	181.87	6.35	-0.01	0.01	-85.77	5
8	1.49	183.66	8.13	-0.02	0.00	-86.66	5
18	1.85	184.01	8.48	-0.02	0.00	-85.77	6

Table 3.4. Results of binomial generalized linear models testing the alternative crops hypothesis (H2) of farmers in the Kasigau Wildlife Corridor of Kenya, df = 177. Model descriptions are presented in Table 3.2.

Model	Intercept	AICc	ΔAICc	Adj. R^2	w_i	LL	k
1	1.44	175.64	0.00	0.00	0.25	-86.81	1
5	1.55	177.34	1.70	<-0.00	0.11	-86.64	2
7	0.58	177.35	1.71	0.02	0.11	-82.43	6
4	1.34	177.55	1.91	<-0.00	0.10	-86.74	2
2	1.47	177.68	2.04	-0.01	0.09	-86.81	2
6	1.77	178.92	3.30	-0.01	0.05	-86.40	3
3	0.10	179.56	3.92	<-0.00	0.04	-85.67	4
16	1.35	179.61	3.97	-0.01	0.03	-86.74	3
12	1.36	179.61	3.98	-0.01	0.03	-86.74	3
14	1.47	179.75	4.11	-0.01	0.03	-86.81	3
15	1.52	181.01	5.37	-0.02	0.02	-86.39	4
13	1.67	181.13	5.49	-0.13	0.02	-86.45	4
17	1.65	181.13	5.49	-0.01	0.02	-86.45	4
8	0.67	181.55	5.91	-0.01	0.01	-85.60	5
9	0.91	181.59	5.96	-0.01	0.01	-85.62	5
11	0.98	181.68	6.04	-0.01	0.01	-85.67	5
25	1.37	181.70	6.06	-0.01	0.01	-86.74	4
10	1.27	182.99	7.35	-0.01	0.01	-85.25	6
27	1.54	183.11	7.47	-0.02	0.01	-86.38	5

Table 3.4. Continued

24	1.56	183.12	7.48	-0.02	0.01	-86.39	5
26	1.68	183.24	7.60	-0.02	0.01	-86.45	5
18	0.60	183.61	7.97	-0.01	0.00	-85.56	6
20	0.66	183.68	8.04	-0.16	0.00	-85.60	6
22	0.90	183.73	8.09	-0.01	0.00	-85.62	6
19	1.00	185.07	9.43	-0.17	0.00	-85.21	7
21	1.19	185.09	9.45	-0.16	0.00	-85.21	7
23	1.27	185.15	9.51	-0.02	0.00	-85.25	7
32	1.57	185.25	9.61	-0.02	0.00	-86.38	6
29	0.60	185.77	10.13	-0.02	0.00	-85.55	7
28	0.93	187.19	11.56	-0.02	0.00	-85.17	8
30	1.00	187.25	11.61	-0.02	0.00	-85.20	8
31	1.20	187.27	11.63	-0.02	0.00	-85.21	8
33	0.92	189.39	13.76	-0.03	0.00	-85.16	9
34	0.19	194.77	19.13	-0.02	0.00	-80.90	15

Table 3.5. Results of binomial generalized linear models testing the alternative livelihoods hypothesis (H3) of farmers in the Kasigau Wildlife Corridor of Kenya, df = 171. Model descriptions are presented in Table 3.2.

Model	Intercept	AICc	ΔAICc	Adj. R^2	w_i	LL	k
7	0.63	230.40	0.00	0.07.	0.82	-108.95	6
2	-1.03	235.10	4.70	0.02	0.08	-115.52	2
12	-1.12	237.03	6.63	0.02	0.03	-115.45	3
36	-0.95	237.05	6.65	0.02	0.03	-115.45	3
1	0.15	238.09	7.69	0	0.02	-118.03	1
35	0.22	240.04	9.64	-0.01	0.01	-117.98	2
4	0.09	240.05	9.65	-0.01	0.01	-117.99	2
5	0.17	240.11	9.71	-0.01	0.01	-118.02	2
6	0.13	250.16	9.75	0.00	0.01	-117.01	3
3	$-1.82e^{-01}$	241.88	11.48	-0.00	0.00	-116.82	4
37	0.16	242.06	11.66	-0.01	0.00	-117.96	3

Table 3.6. Summary statistics for questions from a survey with farmers in the Kasigau Wildlife Corridor of Kenya.

Question	n	Respondent Answers				
Q4- What do you feel is the main reason for your crop losses?	206	Elephants (83%)	Drought (10%)	Other Wildlife (4%)	Pests (2%)	Bad Seeds (1%)
Q6- Do you irrigate your crops in some way?	206	Yes (91%)	No (9%)			
Q7- How often does drought affect your harvest per season?	206	Sometimes (79%)	Every Season (17%)	Never (4%)		
Q10. Do you believe your household benefits from the preservation of wildlife?	200	Somewhat (35%)	Yes, a lot (33%)	No, not at all (23%)	Unsure (10%)	
Q11. Have you ever visited a National Park?	206	No (80%)	Yes (20%)			
Q12. Have you ever visited Tsavo East or Tsavo West National Park?	206	No (79%)	Yes (81%)			
Q15. Do you have a way to bring products that you want to sell to a market?	206	Yes (62%)	No (35%)	Does not apply (3%)		
Q16. How do you believe climate change has affected you?	206 (451 total responses)	There are less rains/more drought (33%)	Animals come more often to raid (27%)	The temperatures are hotter (18%)	The crops are unpredictable (8%)	There are more pests (5%)
	There is more flooding (4%)	I don't believe climate change has affected me (3%)	I don't know (1%)	Other (.50%) Cutting trees affects the weather. Animals lack water so raid crops.	Other (.25%) Hunger and poverty.	Other (.25%) Lack of money and water.
Q17. How do you believe your household benefits from wildlife?	206 (359 total responses)	Wildlife brings jobs to the community (55%)	I understand that preserving wildlife is	I don't believe my household benefits from wildlife (18%)	I enjoy watching or	I don't know (3%)

Table 3.6. Continued

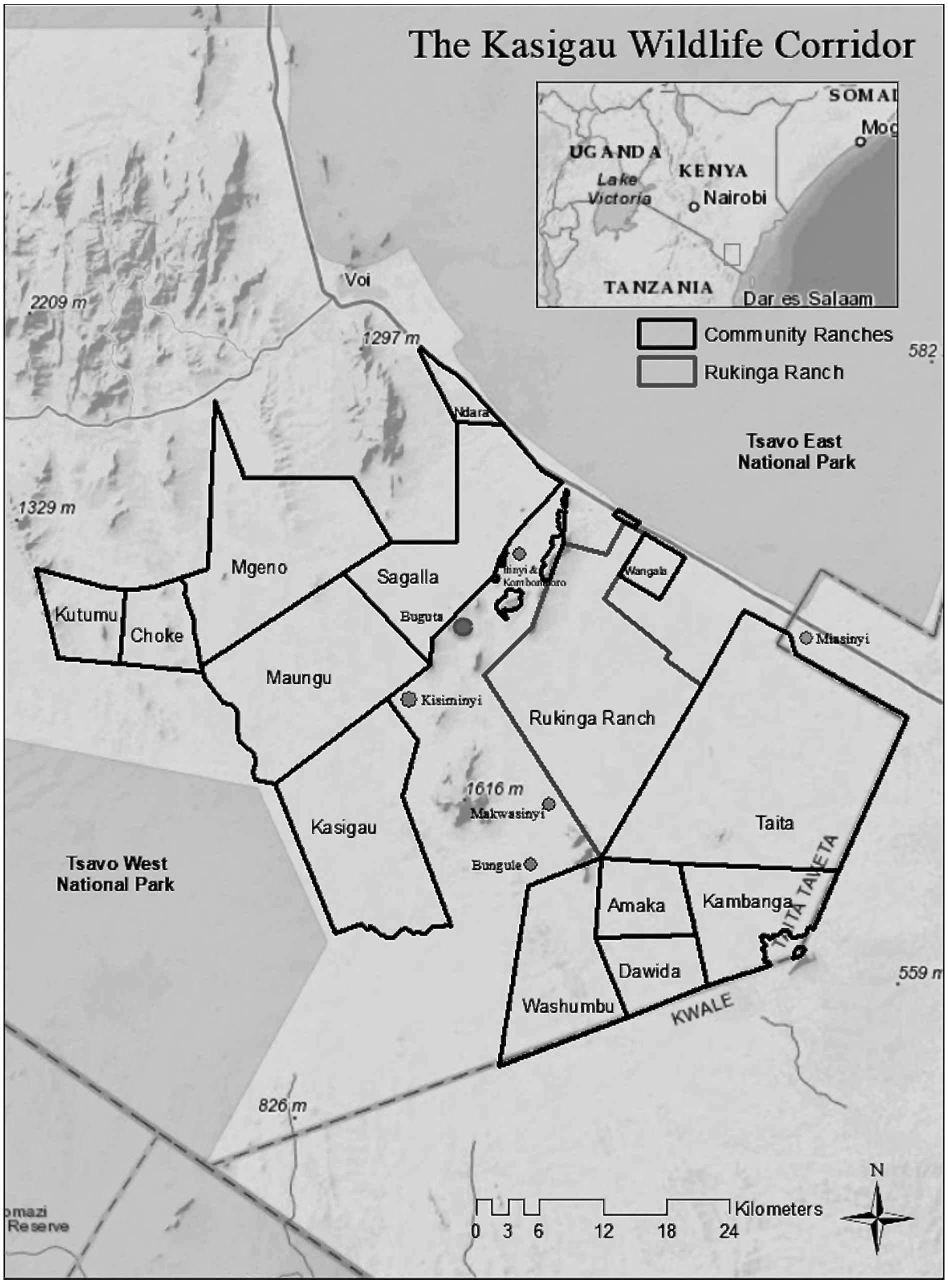
	important for tourism for the Kenyan economy (20%)	seeing wildlife (4%)

Table 3.7. Results of sociodemographic survey question analyses from farmers in the Kasigau Wildlife Corridor of Kenya. Full survey questions are shown in Table 3.1. Statistic column contains F statistic from ANOVA tests for the factor of age and the remainder of statistics are Pearson's chi-square test. Significant values are in bold.

Question Subject	Factor	Statistic	df	p-value
10. Wildlife Benefits	Education	13.11	9	0.16
	Gender	1.01	3	0.80
	Village	13.27	15	0.58
	Age	1.84	3, 187	0.14
11. National Park Visit	Education	49.81	3	**<0.01**
	Gender	4.96	1	**0.02**
	Village	10.01	5	0.08
	Age	0.05	1,189	0.82
12. Tsavo Park Visit	Education	2.57	3	0.46
	Gender	1.76	1	0.18
	Village	16.59	5	**<0.01**
	Age	0.41	1,188	0.52
13. Alternative Livelihoods	Education	7.27	9	0.61
	Gender	1.61	3	0.66
	Village	19.28	15	0.20
	Age	0.74	3,186	0.53
14. New Farm Techniques	Education	10.89	6	0.09
	Gender	0.73	2	0.69
	Village	10.38	10	0.41
	Age	1.42	2,181	0.25
15. Market Access	Education	4.93	3	0.18
	Gender	0.29	1	0.59
	Village	2.41	5	0.79
	Age	0.69	1,188	0.41

Figure Legends

Figure 3.1. The Kasigau Wildlife Corridor of Kenya, shown with its 14 community ranches and the location of the six participating villages in this study.


The Kasigau Wildlife Corridor
UGANDA
KENYA
Lake Victoria
Nairobi
TANZANIA
Dar es Salaam
Community Ranches
Rukinga Ranch
Tsavo East National Park
Tsavo West National Park
Voi
2209 m
1297 m
1329 m
1616 m
826 m
559 m
Ndara
Mgeno
Sagalla
Kutumu
Choke
Maungu
Buguta
Wangala
Kisiminyi
Rukinga Ranch
Makwasinyi
Bungule
Kasigau
Taita
Amaka
Kambanga
Dawida
Washumbu
KWALE
TAITA TAVETA
Kilometers
0 3 6 12 18 24
N

Supplemental Information, Chapter 3

Table S.3.1. Summary statistics of the gender and number of survey respondents in each of the participating villages in surveys distributed to farmers in rural villages in the Kasigau Wildlife Corridor, Kenya.

Village	Men	Women	Total per village
Buguta	15	14	29
Bungule	18	17	35
Itinyi	12	25	37
Kisimenyi	17	17	34
Makwasenyi	21	14	35
Miasenyi	13	23	36
Totals	96	110	206

Chapter 4

Participatory modeling across Kenyan villages facilitates greater understanding of the complexity of human-elephant interactions[1]

Abstract

Negative human-wildlife interactions are a growing problem, particularly near protected areas and wildlife refuges. In Kenya, African elephants (*Loxodonta africana*) threaten food security for subsistence farmers by crop raiding, and conservation priorities are jeopardized as farmers may retaliate against elephants. With the goal of developing a systems view of human-elephant interactions amongst stakeholders to inform policy and management, I had two objectives: 1) to evaluate stakeholder mental models of human-elephant interactions, and 2) to use a biocultural approach to determine indicators for assessing the success of mitigation programs. To address these objectives, I conducted participatory modeling sessions in six villages in rural Kenya using Fuzzy Cognitive Mapping. Each village co-created visual models with variables that relate to negative interactions with elephants. A total of 14 variables were common across all models, with the two highest centrality scores belonging to income and feelings of security, suggesting the importance of elephant conflicts as both economic and contributing to human health and well-being. The majority of variables across all villages fell into two categories: environmental interactions and policy and management. Multiple consequences of negative interactions were seen that had not been previously identified in human-elephant conflicts such as soil compaction and child labor and sociocultural indicators were noted such as feelings of security and family separation. The participatory methodology used was a valuable tool for gaining additional insights into the drivers and consequences of interactions with elephants which could also be used for other complex conservation issues. The indicators found represent a means of incorporating social and cultural dimensions into measurements of success for mitigation programs. This more holistic view of the impacts of

human-elephant interactions can lead to sustainable co-developed programs that benefit both farmer livelihoods and elephant conservation.

Introduction

Negative human-wildlife interactions are increasing around the world as people and wildlife increasingly share spaces and compete for resources (Atkins et al., 2017; Nyhus, 2016; Richardson et al., 2020; White and Ward, 2010). These negative interactions include vehicle collisions (Lepczyk et al., 2019; Schell et al., 2021), attacks on livestock (Patterson et al., 2004), agricultural damage (Hill, 2018), and species invasions (Richardson et al., 2020), all of which can affect human health and livelihoods (Barua et al., 2013; Salerno et al., 2020; Treves and Santiago-Ávila, 2020). Notably, rural communities and those bordering protected areas and wildlife refuges may be more susceptible to interactions (Adams et al., 2016; König et al., 2020; Western et al., 2015). As a result, rural communities, particularly those that have minimal resources, bear the brunt of negative interactions (Armitage, 2005; Chen et al., 2013; Jordan et al., 2020; Mcleod et al., 2015). Mitigating negative human-wildlife interactions are particularly challenging in these communities because stakeholders and wildlife officials often disagree over management approaches (Hill, 2015; Madden and McQuinn, 2014; Marshall et al., 2007; Redpath et al., 2015). These disagreements can be fueled by social or economic marginalization of stakeholders (Dickman, 2010; Madden and McQuinn, 2014), especially in areas where local or Indigenous people have been displaced or colonialist policies still persist (Cernea and Schmidt-Soltau, 2006; Kamau and Sluyter, 2018; Nyumba et al., 2021). As a result, rural communities may lose enthusiasm for conservation programs and harm wildlife if they feel their livelihoods or safety are in jeopardy (Kolinski and Milich, 2021; Mogomotsi et al., 2020).

One type of negative wildlife interaction that is especially problematic for stakeholders across Asia and Africa are human-elephant interactions (HEI; Desai and Riddle, 2015; Hoare, 2000; Shaffer et al., 2019). Living near elephants is challenging due to their need for large amounts of food and water, and space to roam and migrate (Kangwana, 1996; Loarie et al., 2009; Sach et al., 2019; Sukumar, 1990). Though positive elephant interactions drive tourism in many countries, negative HEI, or human-elephant conflicts are one of the greatest threats to the species after poaching and habitat loss (Boult et al., 2019; Goswami et al., 2014; LaDue et al., 2021; Nyirenda et al., 2018). Crop raiding is the main type of negative interaction, whereby elephants alter their natural foraging routines to include cultivated crops (Davies et al., 2011; Hill, 2018; Osborn, 2004). Elephants may also raid food or water stores, especially in times of drought (Hoare, 2000; Kagwa, 2011; Karidozo et al., 2016). The act of crop raiding can also result in livestock encounters, the destruction of property, and injury or death of people and/or elephants (Kassilly et al., 2008; Schlossberg et al., 2020; Zarestky and Ruyle, 2016).

While efforts to mitigate human-elephant interactions are a primary focus for many agencies, socioeconomic disparities hinder implementation efforts (Jordan et al., 2020; Nyirenda et al., 2018; Raphela and Pillay, 2021; Virtanen et al., 2020). For instance, farmers seeking to mitigate detrimental interactions with elephants can be constrained by knowledge of deterrent methods (Chapter 2) or access to financial or material resources to do so (Chelliah et al., 2010; O'Connell-Rodwell et al., 2000; Osborn and Parker, 2003). Notably, while numerous sustainable solutions to the negative impacts of elephants have been evaluated, such as fencing deterrents or compensation programs, none have emerged as ubiquitous solutions (Blackwell et al., 2016; Mumby and Plotnik, 2018; van de Water and Matteson, 2018). African savannah elephants (*Loxodonta africana*) are frequent crop raiders in many countries such as Kenya where farmers are already facing multiple threats to their food security (Chapter 3). Negative interactions with elephants continue to compromise the livelihoods of farmers in areas such as the Greater Tsavo Ecosystem of southeastern Kenya, and are a source of conflict between community members and corresponding wildlife officials (Githiru et al., 2017; Kagwa, 2011; Kamau, 2017; Litoroh et al., 2012). Managing human-elephant interactions continues to be a major conservation challenge for wildlife agencies.

One reason that organizations managing human-elephant conflicts are challenged is that they may not fully understand how the local communities conceptualize the problem or how the problem varies dependent on local context (Waylen et al., 2010). This lack of understanding when engaging with stakeholders, local, or Indigenous partners is relatively common within human-wildlife conflicts specifically and natural resources conflict generally (Redpath et al., 2013; Wheeler and Root-Bernstein, 2020). To solve this challenge, practitioners are increasingly using participatory processes with stakeholders, such as participatory modeling that can provide unique insights and local ecological knowledge when offered with free, prior, informed consent (Buchholtz et al., 2020; Jessen et al., 2022; United Nations, 2007). These processes can ultimately be used to create beneficial and sustainable solutions for people and wildlife (Ochieng et al., 2021; Verma et al., 2016; Wheeler and Root-Bernstein, 2020; White et al., 2005).

Biocultural approaches to conservation start by incorporating more cultural perspectives from local people and recognizing how ecological and human health are interconnected (Gavin et al., 2015; Sterling et al., 2017). Evaluating program effectiveness is an important part of creating long-term effective solutions and a biocultural approach can help to identify locally relevant and qualitative indicators that may not be typically used by practitioners (DeRoy et al., 2019; Dacks et al., 2019). In the case of human-elephant conflict, understanding how farmers conceptualize the connections, interactions, and causes of the conflict is a critical gap in our knowledge (Bridgewater and Rotherham, 2019; Gavin et al., 2015) as there is little information on the complex social and economic factors that make crop raiding so impactful to stakeholders and the cascading, interactive, consequences for farmers and their families.

Incorporating community views on the causes and consequences of negative human-elephant interactions is needed for advancing current management strategies. Given this need, my overarching goal was to develop a systems view of human elephant interactions amongst rural communities to inform policy and management. To address this goal, my objectives were to: 1) evaluate stakeholder mental models of human elephant interactions to understand how farmers conceptualize human-elephant interactions and determine if novel system components were present and, 2) use a biocultural approach to determine if indicators are present that would be useful in assessing the success of mitigation program efforts. I expected that previously unknown drivers would emerge from the mental models based on stakeholder expertise and complex local understanding of human-elephant interactions.

Methods

Study Area

The Kasigau Wildlife Corridor of Kenya lies between Tsavo East and West National Parks in Southeastern Kenya in the Greater Tsavo Ecosystem and contains 14 community-owned ranches. The region is also home to the country's largest and growing elephant population of 15,000 + elephants (Waweru et al., 2021). Many animals use the wildlife corridor to transit between the safety of the two parks (Ngene et al., 2017; Omondi et al., 2008). Rukinga Wildlife Sanctuary, operated by Wildlife Works, is part of one of the world's largest REDD+, UN-backed, carbon offset projects. There are approximately 2,000 elephants in the corridor and 300-500 resident elephants near the sanctuary (Githiru, M. pers. comm.) as well as villages, farms, and livestock, creating many opportunities for wildlife interactions. Local people benefit from the presence of Wildlife Works through job and educational opportunities and community outreach has been prevalent in this area, which made it ideal for additional efforts in participatory engagement with villagers.

After conducting preliminary interviews with Chiefs and select community members in 2019, six communities surrounding the ranch were selected as the focus of the study. The prerequisites for selecting these locations were: 1) a community had to be adjacent to and within one-hour drive of the research base in the sanctuary 2) the community had to be comprised of a majority of farming households and have experienced high rates of negative HEI, and 3) local Chiefs and elders (See Chapter 3 for local political structure) had to be in favor of allowing participatory research to be conducted in their respective villages. Members of six villages were selected in: Itinyi and Kombomboro (combined due to small population size and close geographic proximity, hereafter referred to as Itinyi), Bungule, Miasenyi, Kisimenyi, Buguta, and Makwasinyi (Figure 4.1).

Participatory Sessions

One participatory approach that aids in creating a shared knowledge space about conservation issues is mental modeling (Biggs et al., 2011; Gray et al., 2012; Moon et al., 2019). Mental models are the individual cognitive constructs of how someone views the world or a specific issue (Johnson-Laird, 1986; Jones et al., 2011). The use of mental models has demonstrated marked differences between stakeholders and wildlife managers (LaMere et al., 2020; Moon et al., 2019) but has rarely been utilized to evaluate human-wildlife interactions (but see: Mosimane et al., 2014; Nyaki 2015). This type of modeling can be used with stakeholders to obtain knowledge on unforeseen drivers of an issue and examine the spatial, social, and economic relationships therein (Bardenhagen et al., 2020; Kontogianni et al., 2012; Vasslides and Jensen, 2016).

Participatory modeling workshops were created in conjunction with social surveys to be administered in the six villages (chapters 2 and 3). Due to COVID-19 pandemic restrictions, a local facilitator was hired to conduct the participatory sessions with strict pandemic protocols to protect villagers. Chiefs and elders selected 30-35 farmers from each village (approximately half male and half female, as women are equally or more responsible for farming duties) for the survey sessions. Chiefs helped to reduce this number to 12-15 for the modeling sessions to the most impacted and thus knowledgeable farmers in each village, an optimal number for a participatory setting (Nyaki et al., 2015; Phillips and Phillips, 1993). To maintain sample independence, only one person per household was invited to participate in the sessions. These parameters resulted in a total sample size of 77 villagers (39 male, 38 female; Supplemental Table S.4.1). One village per session was conducted on a Friday or Saturday in each village and participants signed consent agreements.

On the day of the workshop, the bi-lingual facilitator initiated the participatory session (conducted in Swahili) by first introducing the concepts of the research and model building and clarifying the terms that would be used (such as crop raiding and deterrents) in order to assure construct validity. People in the study area mostly refer to interactions with elephants as conflicts. Thus, using colored markers and large sheets of paper the central issue of human-elephant conflict was listed in the center of the paper and participants were asked to list variables, one by one, that related to the conflict. Each variable had to be related to a corresponding variable (i.e. capable of increasing or decreasing it) such that no variables could exist in isolation. To illustrate these relationships, lines were drawn to connect corresponding variables. Participants were then asked if the variable they had suggested had an increasing or decreasing effect on the variable (initially human-elephant conflict), which was denoted on the chart in different colors, red for increasing, blue for decreasing, and using plus or minus signs. The model building continued with branches off of other variables until no further variables were identified.

For the fuzzy portion of the model construction, the last step was to inquire on a scale of 1 (least impact) to 10 (highest impact) how the two variables related to each other. Negative influences were indicated with – and positive with +. Normally this process is done on a valence scale of -1 to +1 with decimal intervals (Özesmi and Özesmi, 2004), but for simplicity we used -10 to +10. For each step, consensus was agreed upon amongst the individuals in a given village and every voice allowed to speak. Anyone not providing input was asked throughout the sessions to make sure their voice was equally and accurately represented. Repeating the process as each variable was added assured that the complexity of the drivers for each variable were represented, and some variables included reciprocal relationships. We chose not to construct shared group mental models directly in a computer with the stakeholders as has been done in similar studies (e.g., Nyaki et al. 2015); in this remote area, most participants were unfamiliar with such technology. The survey and study design were reviewed and approved by Auburn University's IRB panel (Protocol no. 20-440 EX 2009) in the US and Strathmore University's Institutional Ethics Review Committee (Approval no. SU-IERC0877/20) in Kenya. This project operated under the Kenya Wildlife Service's PIC/MAT agreement with Wildlife Works and with approval from NACOSTI, Kenya's science agency (License No. NACOSTI/P/20/2292).

Data Analysis

Once field data were collected, I used the Mental Modeler Software (1.0; Gray et al., 2013, 2017) to convert the hand drawn models and construct Fuzzy Cognitive Maps for each village (Figure 4.2. and Supplemental Figures S.4.1.-S.4.5.). To examine and compare each village's models the software determined the number of concepts (i.e., variables, a measure of the components of the model) in each model including, the number of connections (indicates the degrees of interactions; Özesmi and Özesmi, 2004), transmitters (the drivers that affect other variables but are not impacted by them), receivers (items that only receive and do not impact other components), and ordinary components (variables that are both receivers and transmitters; Eden, 1992). I calculated the centrality (to demonstrate the influence of a concept upon the system; Kosko, 1986) of individual concepts, complexity (to determine the complex systems thinking according to some previous studies; Eden, 1992; Özesmi and Özesmi, 2004), and the density (to compare the number of connections in a particular model to all possible connections; Özesmi and Özesmi, 2004). In two of the six models a single element was not weighted by the participants and the facilitator added the weight based on knowledge of system. This single weighting did not markedly change the model's metrics.

During model construction I noted that some models were more complex than practically usable and the complexity of the models seemed to increase with each successive village session. To assess if changes occurred over time, I plotted the number of variables, connections, drivers, ordinary components, and density over time and tested these with a linear regression (Figures 4.3.a & 4.3.b). The positive correlation coefficient values for variables ($p = 0.002$), connections ($p = <0.001$), drivers ($p = 0.006$), and ordinary components ($p = 0.007$) ranged from 0.93 to 0.98 and the density had a negative correlation coefficient of -0.98 ($p = < 0.001$). These correlations suggest that the facilitator improved their skills over time resulting in the models becoming more complex.

To address this facilitator adaptation and potential bias, I created a qualitative aggregation method across villages (Figure 4.4; see Misthos et al., 2017; Vasslides and Jensen, 2016) using four locally relevant categories that each variable from each villages' model would be grouped under: economic, environmental interactions, social, and policy or management. The economic category contained variables that impacted farmers' financial stability such as *income levels* or *farming costs*. Environmental interactions were variables that pertained to the physical environment such as *drought* or farmers' *proximity to ranches*. Social variables involved community interactions or feelings of the community related to crop raiding such as *feelings of security* or *farming spirit*. Policy and management included interactions with, or programs created by wildlife agencies such as *HEC compensation* or *education on elephants.* Creating categories for each variable and assigning each category a different color resulted in a cognitive color spectrum (see Cholewicki et al., 2019) (Supplementary Figure S.4.6.). I then calculated the percentage of variables within each category for each village and compared the means of each category with ANOVA and a Tukey's post hoc HSD test for multiple comparison. This organization of the variables from each village aggregated into the four categories also indicates which types of variables are predominant in the system.

As a second approach to reduce bias and provide a useful management tool, I developed a single co-created model of human-elephant conflict based on the six village models and a review of current literature I incorporated my own experiences from witnessing the aftermath of crop raiding events in the area and interviewing affected villagers, all incorporating local context (Figure 4.5). I also added variables that were not always mentioned in village models that were significant concerns identified by local agencies. Using a systems view to evaluate the village models, I also looked for variables in all models that were novel within the corresponding scientific literature. All statistical analyses were conducted in the program R (v. 4.0.2., 2020) with a $p \leq 0.05$ considered significant.

Results

The Mental Modeler program was a useful tool for visualizing how farmers conceptualize human-elephant conflict as well as uncovering new potential indicators. The village of Bungule (Figure 4.2) had the highest complexity score and the village of Miasenyi (the last session conducted) had the highest number of variables, connections, driver variables, and ordinary variables and also the lowest density (Table 4.1). The last session having some of the highest amounts of components illustrated the bias introduced from increasing facilitator adaptation, but all results were adjusted to account for facilitator bias through the aforementioned statistical adjustments. In the qualitative aggregation for the four categories of variables (economic, environmental interactions, social, and policy/management), environmental interactions emerged as the leading source of variables, followed by policy/management in every village (Figure 4.4). These four variables differed significantly ($F_{3,20} = 23.86$, $p < 0.001$) with and post hoc analysis revealed significant category differences between environmental-economic ($p < 0.001$, 95% C.I. = [9.31, 23.03]), environmental-policy/management ($p < 0.001$, 95% C.I. = [-16.86,-3.14]), environmental-social ($p < 0.001$, 95% C.I. = [-26.03, -12.31]), and social-policy/management ($p < 0.01$, 95% C.I. = [-16.03, -2.31]).

A total of 14 variables were consistent across all models, aside from the key variable of HEC. The most important variables based on centrality (conveying importance within the model) were income levels and feelings of security with elephant population being the lowest (Table 4.2). The co-created model shared many of the same variables as the individual village models (Figure 4.5) but featured several drivers that were not prevalent in the village models. The co-created model variables along with literature references and quotes from local people used to inform the models are found in Supplementary Table S.4.2. Several variables emerged from the models representative of novel or under-represented drivers and consequences of elephant conflicts from the villages including infrastructure (specifically road conditions), fire-setting, the rearing culture of elephants, and a potential sociocultural indicator, protection from God. Likewise, consequences that were novel or under-represented in the literature of conflict with elephants were soil compaction, immoral behavior, child labor, early marriages and pregnancies, motherhood deliveries, and separation of families. A variable that could be adapted as a biocultural indicator was farming spirit (willingness to farm), and variables directly related to the drivers of alternative livelihoods were resident mobility and commercial businesses.

Discussion

In evaluating farmers' models, the majority of village mental models shared high-level views and it was only in smaller nuances that villages differed. Broad understanding of the drivers of conflict shows that views of conflict may vary across smaller scales but many of the major drivers are commonly understood across all villages. Income level was the variable most important to farmers, holding the highest centrality score, suggesting that economic impacts from crop raiding are a key driver of conflict. In particular, when income levels are negatively affected, individuals have less resources available to address such challenges as drought or medical emergencies (Karimi et al., 2019; Mcleod et al., 2015; Twomlow et al., 2008). Feelings of security was also an important variable and coincides with the surveys that showed the vast majority of villagers live in fear of elephants (Chapter 2). However, this variable also alludes to economic security and overall human health and wellbeing, as the impacts of crop raiding are not only economic (Barua et al., 2013; McShane et al., 2011; Mmbaga et al., 2017). These findings collectively point to HEC as a multidimensional issue jeopardizing the ability of farmers to thrive across multiple, nested levels.

Overall, environmental interactions were the dominant category in the models across all villages which suggests the interconnectedness of farming life with ecosystem processes in a highly interactive social-ecological system. The prevalence of environmental interactions also demonstrates multiple other layers of concern for villagers, not just surrounding elephant conflicts but concerns such as drought. The policy and management category was the second most prevalent type of variable in the models indicating that participants were concerned with the way that wildlife and the resulting interactions are managed (Marshall et al., 2007; Mcleod et al., 2015; Pooley et al., 2020).

For the co-created model, most of the variables were similar to village models, but several issues that are prominent in this system were not highlighted in village models. One that was specifically related to economic impacts from crop raiding was the payment of school fees. When crop raiding reduces household income, payment of school fees becomes difficult and sometimes children have to withdraw from school till fees are paid. School fee payment and other intermittent events such as illness in the household can also drive the increase in illegal activities such as charcoal production and bushmeat poaching. Illegal grazing also did not emerge in the village models as some farmers believe they should be allowed to graze anywhere within the ranches, against the wishes and policies of local management. Other indirect connections to elephant conflicts were also noted in the co-model such as carnivore conflicts and poor agricultural practices which can exacerbate economic losses. Overall, the co-created model had more reciprocal relationships and included more specificity when it came to agency concerns.

A variety of novel drivers of interest emerged from the mental models that are not prevalent in the literature. First, *infrastructure* was identified across all the villages as many remote roads become impassable after heavy rains, and wildlife officers cannot reach stakeholders when called to assist with elephant presence. Thus, investing in road repairs for areas that have high instances of crop raiding could improve accessibility by wildlife officers and benefit community members' mobility. Second, was *fire setting*, a technique used by farmers to remove dead vegetation after drought seasons. Farmers usually coordinate this activity so only one farm burns its litter at a time, so as not to alarm their neighbors. However, fires can confuse or alarm elephants, causing some elephants to retreat but others to go further into the farm areas. Burning fires is not environmentally friendly and can be risky during times of drought. Reducing, eliminating, or at minimum coordinating these activities with wildlife agencies could prevent elephants from becoming confused and traversing deeper into farms. Third, was the *rearing culture of elephants*. Villagers believed that conservation agencies that rescue, rehabilitate, and release elephants into Tsavo are making them less wild, causing them to come into farming areas with little fear of humans. This claim has not been validated, but communication with the respective agencies on this concern is important and could be evidence of a communication gap between agencies and stakeholders. Fourth, was the *protection from God* which is indicative of a strong religious and sociocultural belief in that the more one gives to God (in the form of devotion, time, or money), the more they will be protected from crop raiding. Thus, piety is rewarded by fewer instances of elephant incursions on one's property. These novel drivers illustrate important aspects for practitioners to consider in developing management options. For example, local agencies such as the Kenya Wildlife Service, Wildlife Works, or the Sheldrick Wildlife Trust could work to improve infrastructure, train farmers on best practices for farm management, and continue to hold community meetings to address issues of concern from villagers. Moreover, many of these aforementioned drivers are not normally addressed with stakeholders and can inform future strategies by local agencies.

Additional variables appeared in the village models that are less well known such as *Soil compaction* which creates an economic challenge. Farmers believe that when elephants frequent the same areas of their land, they compress the soil with their weight, making the soil too hard to till, resulting in the added cost of renting equipment to plow their fields. Soil compaction from livestock or heavy machinery does prevent water and air filtration and can cause crop stress and reduced yields (Chyba et al., 2014), though there are also many benefits to large grazers in ecosystems (Knapp et al., 1999). One study evaluating African elephants' presence found positive benefits in moderate elephant presence but found that soil moisture, infiltration rates, nitrogen mineralization, and nitrification all decreased with increased elephant presence (Maponga et al., 2022). Thus, negative effects of heavy elephant presence appear to be an issue known by some farmers, but only now receiving attention from researchers.

Cultural and social consequences emerged in several villages which were novel in relation to crop raiding impacts. The *Immoral behaviors* variable reflected some villagers' beliefs that when income levels were low (often due to elephant crop raiding) then drug and alcohol abuse, pre-marital relations, theft, and crime all increase because people become idle or depressed. There is literature to suggest these types of human behaviors can result from food insecurity and poverty (Abrahams et al., 2018; Murali and Oyebode, 2004), and health impacts are a documented concern due to stress, fear, and lost opportunity costs from repeated elephant interactions (Barua et al., 2013). However, the parallels have yet to be highlighted between these social behaviors and the negative impacts of human-elephant interactions. *Child labor* results when the family has little money because of crop raiding and must have their children take jobs to earn income or stay home to help support the family. When children enter the workforce it can interfere with their education, causing them to fall behind in their studies. Another type of disruption in education is that some children must miss school when elephants are nearby because of fear of injury when walking to school (Mackenzie and Ahabyona, 2012; Weinmann, 2018). These social impacts (or belief in them) are demonstrative of filter-down effects that can ultimately be traced back to crop raiding.

Novel variables related to crop raiding also emerged that had negative consequences for farming families and could also be sociocultural indicators. *Early marriages and pregnancies* and *motherhood deliveries* were considered positive variables when harvests and incomes are good but can be negative variables if crop raiding impacts finances and delays these social norms. Thus, some villagers believe that elephants raiding too often and causing crop losses can prevent people from starting their families, another indicator of happiness and wellbeing, though with an economic dimension. The *farming spirit* variable was the willingness of farmers to keep persevering and enjoying their farming lifestyle which may decrease with frequent crop raiding. This variable could be adapted as a biocultural indicator as it relates to sense of place, cultural identity, and is sensitive to impacts (DeRoy et al., 2019). *Separation of families* was also noted as a consequence as when crop yields are low, male members of the household may have to leave home to find work. Having fewer men present in the household also increases the burden on women who would then be in charge of farming and child-rearing.

The *Standard Gauge Railway* emerged in some models as a unique local variable. Construction of the railway, beginning in 2014, has been controversial because of its reduction in pathways for wildlife to cross one of the main highways bisecting Tsavo East NP (Okita-Ouma et al., 2016). The railway has been particularly difficult for the village of Miasenyi (evident in their model) because one of the wildlife crossing is close to their village, funneling the elephants in their direction more often, which they believed had increased crop raiding in their community. Using this participatory methodology was especially pertinent in uncovering these types of layers of local context.

Two drivers of alternative livelihoods of interest were *resident mobility* and *commercial businesses*. Most villagers in this area do not own vehicles and either must call for transportation via motorbike or walk. Thus, finding work outside the village that can supplement incomes is difficult without transportation negatively impacts opportunities for alternative livelihoods. *Resident mobility* is also related to infrastructure as residents have difficulty moving about after roads are washed out from floods. Small commercial businesses are commonplace, selling a variety of wares, supplies, or produce. The business variable positively affected livelihoods as when there are good yields villagers can open businesses. One positive benefit for the village of Miasenyi, was able to open more small business as the railway had a stop nearby, even though they were negatively affected by increased elephant presence. Some additional variables were indirectly related to mitigating elephant presence, such as improving soil quality or climate adaptation, which can increase crop yields and therefore improve livelihoods. However, positive improvements to crop yields can potentially increase elephant presence due to more forage availability.

Despite the novel and informative insights revealed by farmers there were some limitations to this study. First was the facilitator adaptation noted as the sessions progressed as in-person training was impossible due to pandemic restrictions. To avoid such issues and reduce bias for future project managers I recommend the following: 1) creating training and practice sessions with facilitators so they can become familiar with creating the models and speaking with stakeholders; 2) following a standard script in model creation and, 3) providing detailed information on the issue of interest so the moderator is fully informed before conducting the sessions. Using facilitators familiar with participatory modeling in rural communities is ideal, but they are rarely available and extensive training may be necessary. Thus, my experiences can assist others with preparing new facilitators to use this or similar methodologies. The second limitation is some variables will be unique to this study system and many not be applicable in every community experiencing elephant conflict. However, many issues will be broadly applicable in African communities living alongside elephants. And finally, though all participants were encouraged to share their opinions, larger personalities or social intimidation by some farmers may have caused others to refrain from fully expressing themselves.

This study provided several management implications for agencies working with farmers to mitigate the impacts of negative interactions with elephants. The first is with multi-dimensional indicators to measure program success. For example, if mitigation programs were instituted, assessing a stakeholders' *feelings of security* in their community would be a sociocultural indicator to track to see if villagers or farmers felt more comfortable or secure prior to implementation, during, or after mitigation programs. Feelings of fear or security could also be a metric that is inversely proportionate to fewer elephant injuries. If farmers do not feel threatened, they could be less like to retaliate against elephants. Other potential more socially based indicators include *family separation* or *child labor*. Findings from the models suggest implementation of programs that provide educational information for farmers, assistance with mitigation efforts, and that will initiate additional research to assess the true impact of some of the social variables mentioned by farmers. One way to reduce illegal activities such as bushmeat poaching is to supplement incomes or having micro-loan programs for needed expenses when income is lean (Roe et al., 2015; Tanzania Wildlife Research Institute, 2019; Wicander and Coad, 2015). Thus, implementing community-based programs that work to increase community resilience in the face of challenges such as crop raiding positively benefits farmers and wildlife conservation.

Overall, mental models provided important insights related to human-elephant conflict that can aid future conservation, management, and policy efforts. Several of the variables found in the models can be considered as indicators that capture both the ecological and social-cultural impacts of elephant interactions on farmers (Sterling et al., 2017). Furthermore, some novel drivers discovered can be used by practitioners seeking to incorporate systems thinking as a way of holistically addressing conservation issues in management plans. Working with stakeholders to gain insights into complex conservation issues such as human-elephant conflict is an important first step for creating customized mitigation programs that prioritize the livelihoods of people while simultaneously preserving ecosystem health.

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Table 4.1. Summary metrics of mental model components related to human-elephant conflict in six villages in the Kasigau Wildlife Corridor of Kenya.

Order	Villages	Variables	Connections	Drivers	Ordinary	Density	Complexity Score
V1	Makwasinyi	18	28	6	10	0.09	0.33
V2	Kisimenyi	24	46	4	17	0.08	0.75
V3	Bungule	28	57	7	18	0.08	0.43
V4	Buguta	30	59	9	18	0.07	0.33
V5	Itinyi	43	84	14	24	0.05	0.36
V6	Miasenyi	52	103	15	31	0.04	0.33
--	Co-model	21	73	2	17	0.17	0.00

Table 4.2. Mental model variable centrality scores. Ranking of the common variables from six villages in the Kasigau Wildlife Corridor of Kenya surrounding drivers and consequences of human-elephant conflict.

Variable	Centrality Scores						Totals	Rank
	Buguta	Bungule	Itinyi	Kisimenyi	Makwasinyi	Miasenyi		
HEC	11.40	11.20	13.80	9.90	2.38	17.45	66.13	1
Income Levels	6.20	6.40	8.30	6.20	1.80	8.90	37.80	2
Feelings of Security	5.10	4.70	4.40	4.60	3.30	6.90	29.00	3
Deterrent Fencing	3.20	4.00	5.70	3.40	3.80	5.50	25.60	4
Crop Yields	4.30	5.40	3.90	4.20	3.70	4.00	25.50	5
Officer Response Time	4.00	4.60	2.70	3.00	3.00	3.40	20.70	6
Relationship w/ Wildlife Officers	2.40	2.90	4.20	3.70	2.30	3.60	19.10	7
Drought	2.60	3.40	3.00	2.20	2.70	4.50	18.40	8
Government Resources	3.40	3.30	0.58	2.50	2.38	3.40	15.56	9
Proximity to Ranches/Boundary Issues	2.50	2.20	1.10	3.40	2.70	2.10	14.00	10
Infrastructure	2.90	2.30	1.28	1.50	1.98	2.20	12.16	11
Alternative Livelihoods	1.50	2.10	2.70	1.50	1.50	1.10	10.40	12
Resident Mobility	1.70	2.10	1.10	1.50	1.30	2.30	10.00	13
Elephant Population	1.70	1.10	1.50	0.70	0.80	1.70	7.50	14
Totals	52.90	55.70	54.26	48.30	33.64	67.05		

Figure Legends

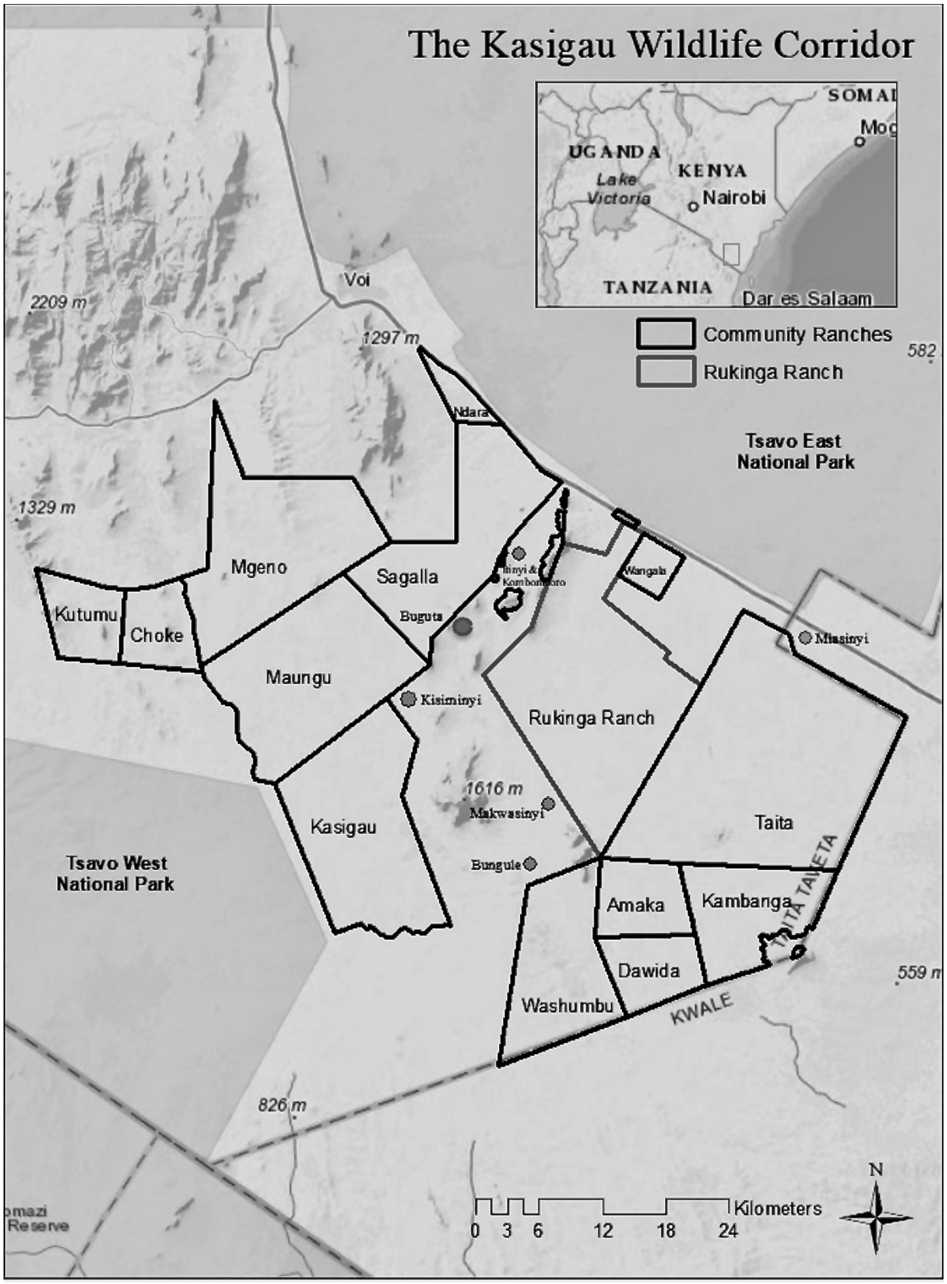
Figure 4.1. The Kasigau Wildlife Corridor of Kenya, shown with its 14 community ranches and the location of the six participating villages in this study.

Figure 4.2. A mental model and Fuzzy Cognitive Map created with Mental Modeler software from a participatory session in the village of Bungule in the Kasigau Wildlife Corridor of Kenya concerning human-elephant conflict. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. A + sign denotes a positive influence by a variable in the direction of the arrow, while a – sign denotes a negative influence by a variable in the direction of the arrow.

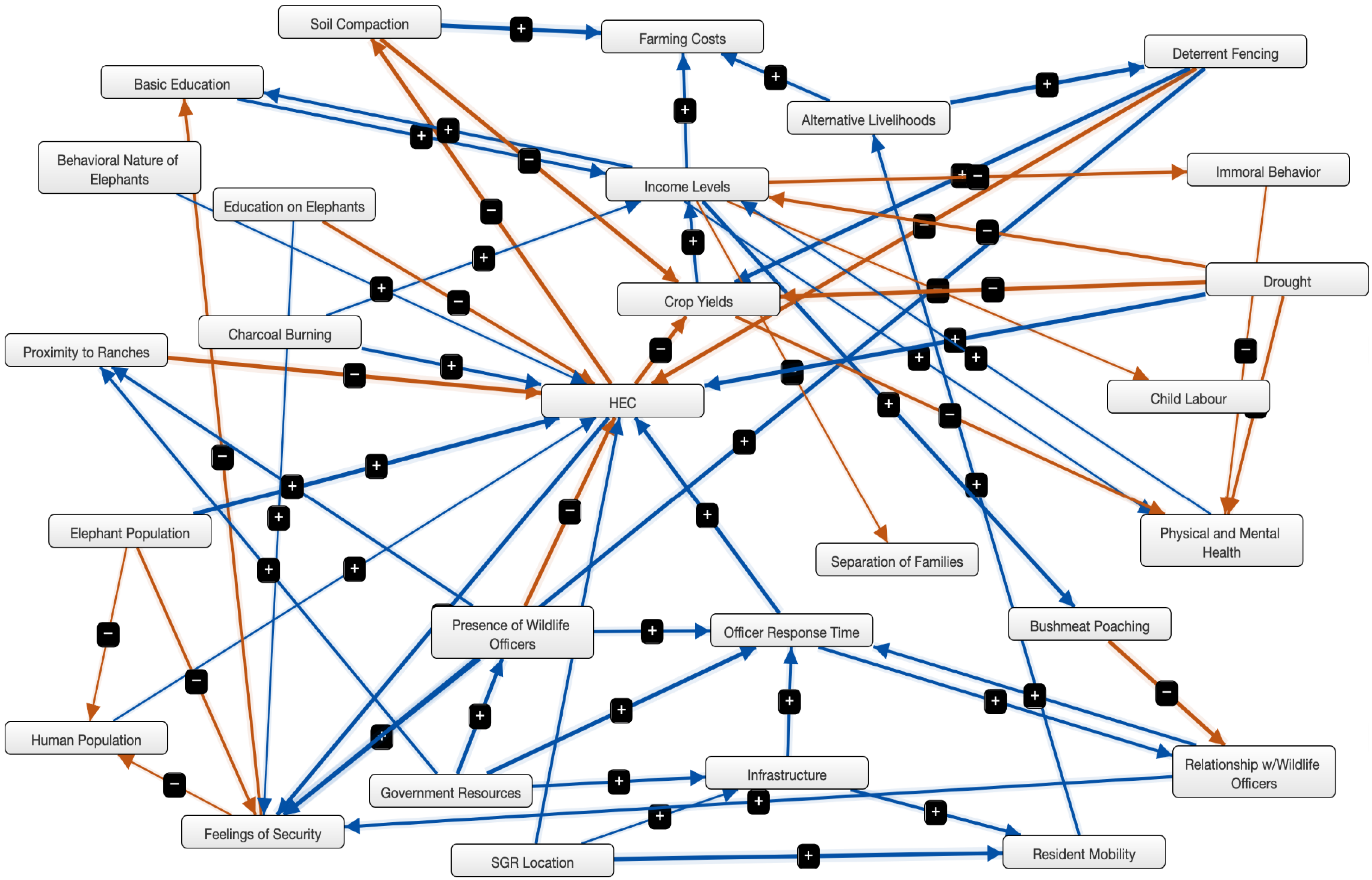
Figure 4.3. A graphical representation of the increases in key mental model metrics demonstrating facilitator adaption after each session over time for the number of variables, connections, drivers, and ordinary components (3a) and the decrease in density (3b). Error bars are standard deviation.

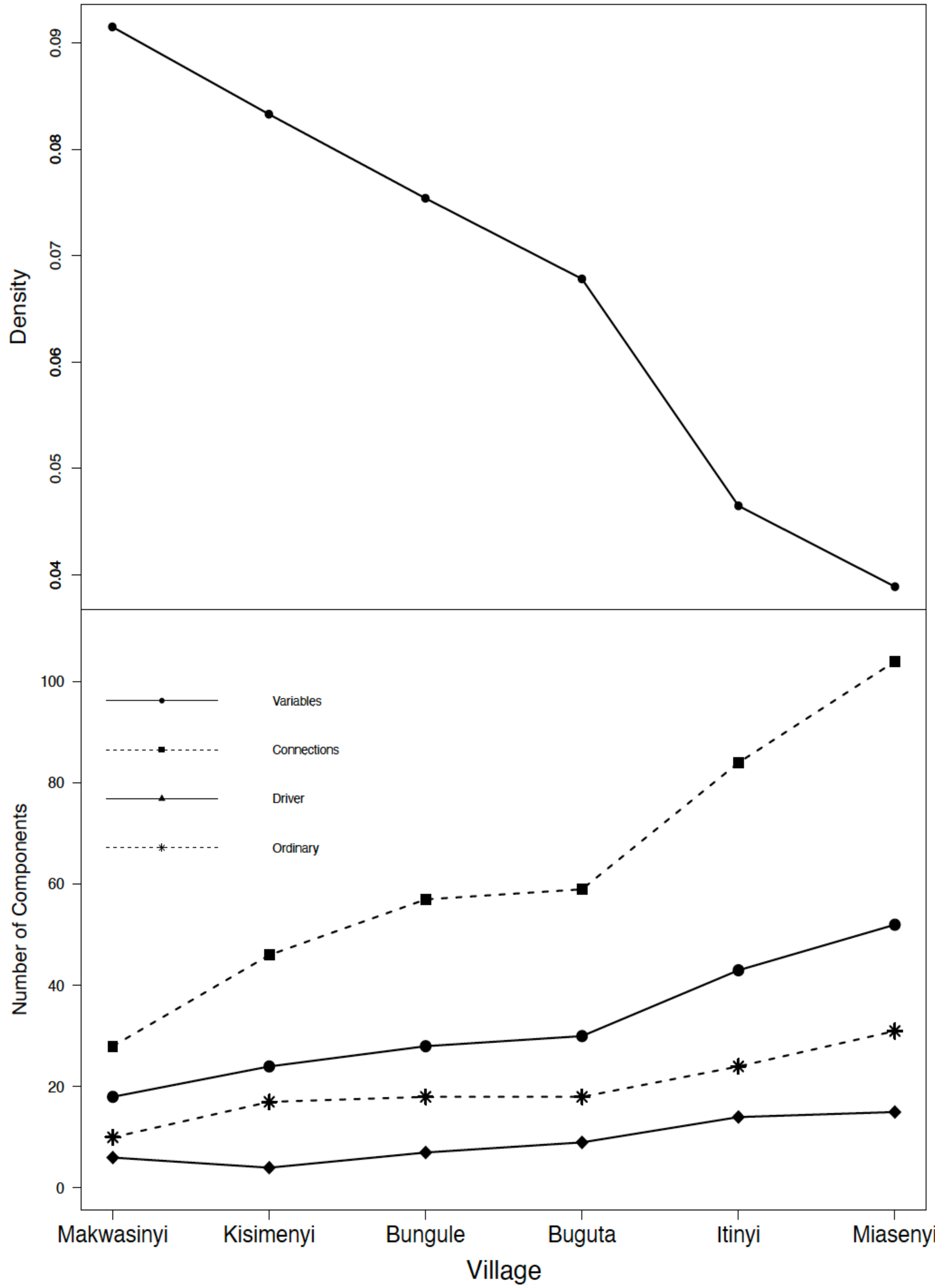
Figure 4.4. A qualitative aggregation of model variables attributed to four categories from participatory mental model sessions with six villages in the Kasigau Wildlife corridor of Kenya surrounding the issue of human-elephant conflict.

Figure 4.5. A co-created mental model based on knowledge of the local context and literature by the author combined with expertise on issues surrounding human-elephant conflict from local villagers in the Kasigau Wildlife Corridor of Kenya.

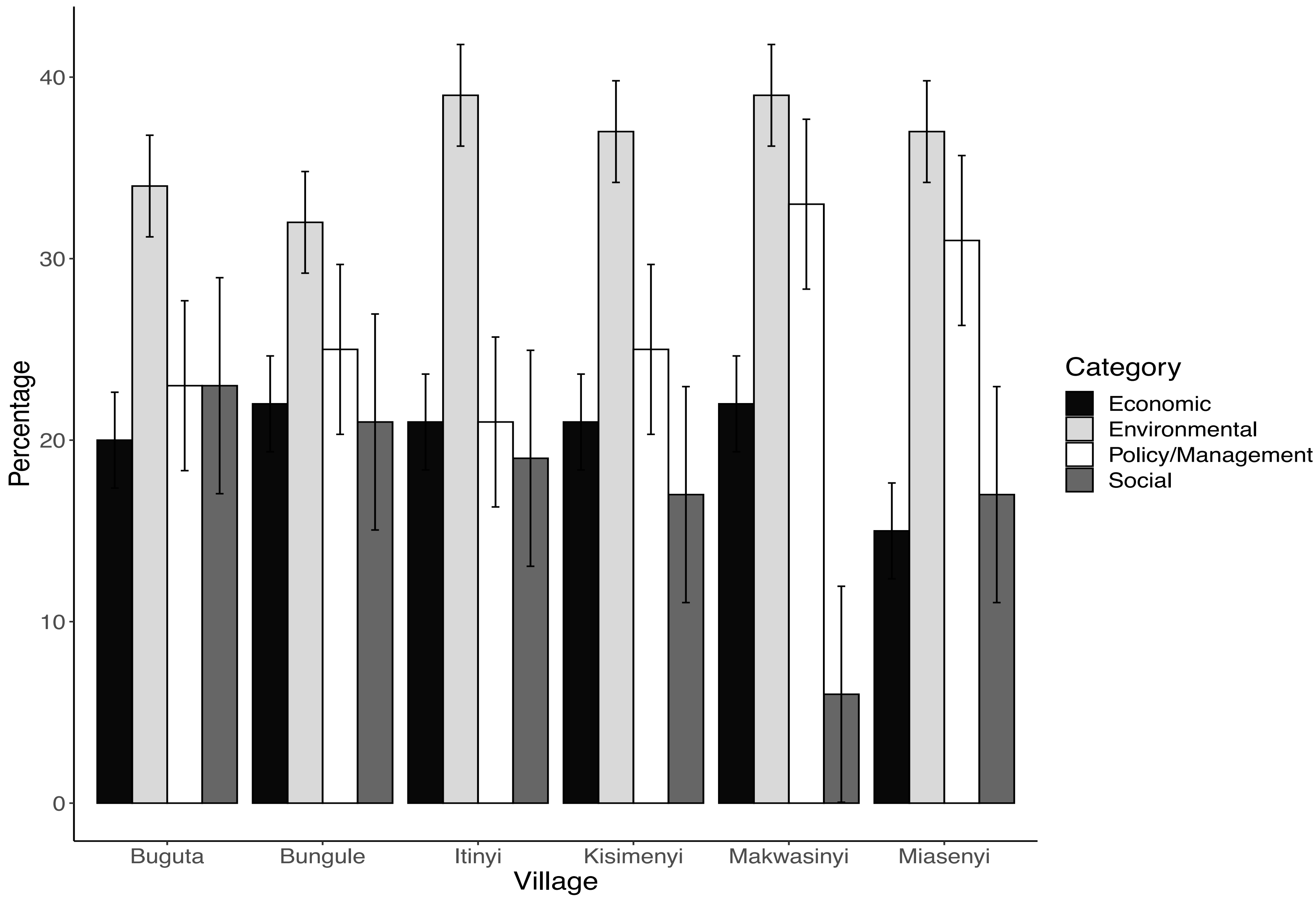


The Kasigau Wildlife Corridor
SOMAL
Mog
UGANDA
KENYA
Lake Victoria
Nairobi
TANZANIA
Dar es Salaam
Community Ranches
Rukinga Ranch
582
Tsavo East National Park
Voi
2209 m
1297 m
1329 m
Ndara
Mgeno
Sagalla
Wangala
Kutumu
Choke
Buguta
Maungu
Kisiminyi
Rukinga Ranch
Taita
1616 m
Makwasinyi
Kasigau
Tsavo West National Park
Bungule
Amaka
Kambanga
TAITA TAVETA
Dawida
559 m
Washumbu
KWALE
826 m
Kilometers
0 3 6 12 18 24
N

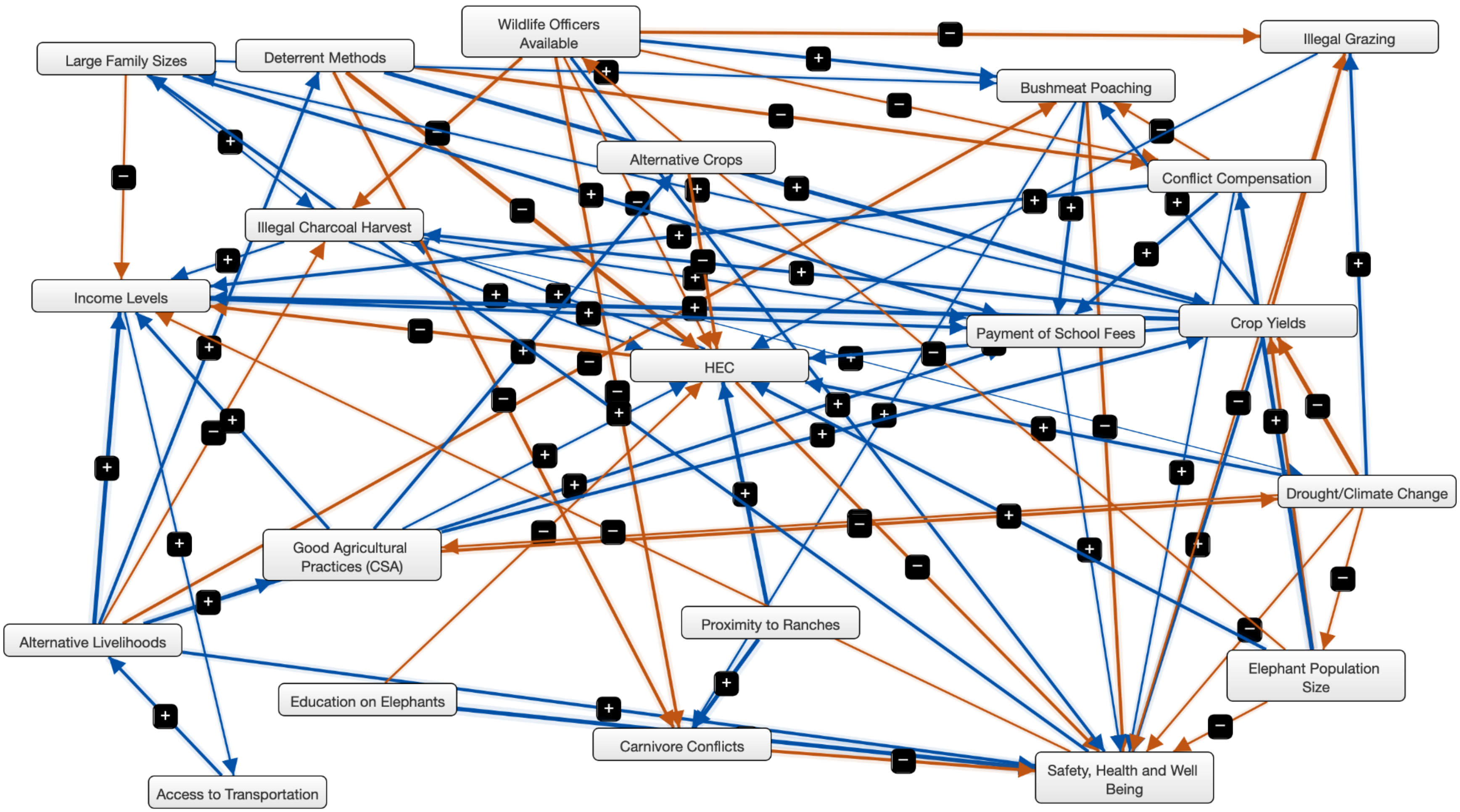

Soil Compaction
Farming Costs
Deterrent Fencing
Basic Education
Alternative Livelihoods
Behavioral Nature of Elephants
Income Levels
Immoral Behavior
Education on Elephants
Crop Yields
Drought
Charcoal Burning
Proximity to Ranches
HEC
Child Labour
Elephant Population
Separation of Families
Physical and Mental Health
Presence of Wildlife Officers
Officer Response Time
Bushmeat Poaching
Human Population
Government Resources
Infrastructure
Relationship w/Wildlife Officers
Feelings of Security
SGR Location
Resident Mobility



Density
0.09
0.08
0.07
0.06
0.05
0.04
Number of Components
100
80
60
40
20
0
Variables
Connections
Driver
Ordinary
Makwasinyi
Kisimenyi
Bungule
Buguta
Itinyi
Miasenyi
Village



Percentage
40
30
20
10
0
Buguta
Bungule
Itinyi
Kisimenyi
Makwasinyi
Miasenyi
Village
Category
Economic
Environmental
Policy/Management
Social


Wildlife Officers Available
Illegal Grazing
Large Family Sizes
Deterrent Methods
Bushmeat Poaching
Alternative Crops
Conflict Compensation
Illegal Charcoal Harvest
Income Levels
Payment of School Fees
Crop Yields
HEC
Drought/Climate Change
Good Agricultural Practices (CSA)
Proximity to Ranches
Alternative Livelihoods
Elephant Population Size
Education on Elephants
Carnivore Conflicts
Safety, Health and Well Being
Access to Transportation

Supplemental Information, Chapter 4

Table S.4.1. Farmer demographics. The list of participants and their gender from participatory sessions in the Kasigau Wildlife Corridor of Kenya.

Village	Total Participants	Male/Female
Buguta	13	7/6
Bungule	12	6/6
Itinyi	12	6/6
Kisimenyi	12	6/6
Makwasinyi	13	7/6
Miasenyi	15	7/8
Total	77	39/38

Table S.4.2 Local and literature references for variables in the co-created model including quotes from participants which helped to inform the model (see Figure 4.5.).

Variable	Literature Reference	Local References (Quotes from Participants)
Access to Transportation	(Karidozo et al., 2016; Virtanen et al., 2020)	"During the rains, our roads are dangerous to use, also when livestock farmers wake up in the early hours to go milk their cows, sometimes they use motorbikes, if they meet elephants on the way it can cause a fatal accident"
Alternative Crops	(Gross et al., 2016; Hill, 2018; Mmbaga et al., 2017)	"Having alternative crops that are not so pleasing to the elephant would reduce human-elephant conflict at a large percentage, but, we do not have market, expertise, good weather conditions for other crops other than what we are already used to."
Alternative Livelihoods	(Nyirenda et al., 2018; Roe et al., 2015; Salerno et al., 2020)	"We have been farmers all our life, …..we have minimal alternatives to do other than farm."
Bushmeat Poaching	(Larson et al., 2016; Mijele et al., 2013; Nyaki et al., 2014)	"I only depend on bushmeat for my family. It's the only way we get to at least consume a better meal. This places us at crossroads with wildlife officers, but, until they solve our issues of elephant conflict then we will continue consuming the bushmeat. As long as its harmless to our health."
Carnivore Conflicts	(Di Minin et al., 2021; Gray et al., 2020; Patterson et al., 2004)	"We have had lions crossing our roads late at night and Hyenas scaring our school going children and this is never addressed by the wildlife services."
Conflict Compensation	(Jackson et al., 2008; Mackenzie and Ahabyona, 2012; Ravenelle and Nyhus, 2017; Salerno et al., 2020)	"Compensation forms that are to be filled by the farmers experiencing destruction of crops and property by elephants are always available but the funds are rarely processed."
Crop Yields	(Chiyo et al., 2005; Davies et al., 2011; Gross et al., 2018; Lobell and Gourdji, 2012)	"Pests or drought affects the quantity of crop yields, we may have a small range of the harvest but when elephants raid your farm, you are assured of zero percent of the produce."

Table S.4.2. Continued

Deterrent Methods	(Adams et al., 2020; Chang 'a et al., 2016; Dublin and Hoare, 2004; Graham and Ochieng, 2008; Killion et al., 2020; King et al., 2011; Von Hagen et al., 2021)	"We have tried a few techniques as use of fire, guarding the farms with torches, making noise out of iron sheets, putting up thorny branches around the farms among others. The elephants get used to most of the techniques and thereafter, they no longer react to any of them. We need better and more effective ways."
Drought/Climate Change	(Kurukulasuriya et al., 2006; Lobell and Gourdji, 2012; Salite, 2019; Shiferaw et al., 2014)	"Drought reduces our crop yields, and at the same time when this happens in our farms it also happens in the parks which prompts the elephants in moving towards the residential and farming lands in search of plantations."
Education on Elephants	(EHRA Peace Project, 2020; Makecha and Ghosal, 2017; Odweyo, 2016; Von Hagen et al., 2021; Zarestky and Ruyle, 2016)	"We are unaware of the effective ways of peacefully living with elephants. If we could've been a bit knowledgeable, then HEC would be reduced by now."
Diverse Agricultural Practices/ CSA	(Asante et al., 2021; Bryan et al., 2013; Nyamwamu et al., 2015; Nyumba et al., 2019; Partey et al., 2018)	"Our county leadership does not effectively support the farmers at least in providing for fertilizers, seeds and irrigation measures in the wildlife corridor; leaving farmers in this side of Taita poor in agriculture and also in our general being."
Illegal Charcoal Harvest	(Asante et al., 2021; Haro et al., 2005; Milupi et al., 2019; Zulu and Richardson, 2013)	"Charcoal harvest is one of the reasons that we as a community contribute to HEC by cutting of trees in the wildlife parks such that the elephants do not have enough plantings in the parks."~ Contributed by local Chief
Illegal Grazing	(Kamau and Sluyter, 2018; Mackenzie and Ahabyona, 2012; Okita-Ouma et al., 2021)	"Untouchable political leaders, who are allowed to graze their cattle in the parks especially during drought period enhance HEC as the elephants now have to move towards the residential and farming area in Kasigau"
Income Levels	(Guerbois et al., 2012; Mackenzie and Ahabyona, 2012; Naughton-Treves et al., 2006)	"When elephants attack and raid our farms then it reduces our crop yields which is always meant for sale, thus reducing our income levels and leaving farmers poor."

Table S.4.2. Continued

Large Family Sizes	(Kideghesho et al., 2007; Nyumba et al., 2020)	"Large family sizes come with poverty and early marriages that happen due to low-income levels brought about by lack of crop yields (majorly destroyed by elephants) to sell to generate income."
Payment of School Fees	(McCabe and Woodhouse, 2022.; Distefano, 2005; Glazebrook et al., 2020; Kamau, 2017)	"Low-income levels due to low crop yields, means that community members sustain themselves with minimum economic means, thus a struggle in paying school fees for their school going children. Students sometimes have to dropout due to these reasons."
Proximity to Ranches	(Galanti et al., 2006; Harris et al., 2008; Monney et al., 2010; von Gerhardt et al., 2014)	"Our close proximity to the ranches enables the elephants to easily pave their way to residential and farming lands and that is why the metal strip fences would be much effective in our area."
Wildlife Officers Available	(Adams et al., 2017; CITES, 2010; Smith and Kasiki, 2000; Western et al., 2015)	"Wildlife officers are not located next to our residential areas, so even apart from their response being slow, they cannot make it into the villages when called upon during destruction by elephants."

Supplementary Information, Chapter 4, Figure Legends

Figure S.4.1. A mental model and Fuzzy Cognitive Map created with Mental Modeler software from a participatory session in the village of Makwasinyi in the Kasigau Wildlife Corridor of Kenya concerning human-elephant conflict. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. A + sign denotes a positive influence by a variable in the direction of the arrow, while a – sign denotes a negative influence by a variable in the direction of the arrow.

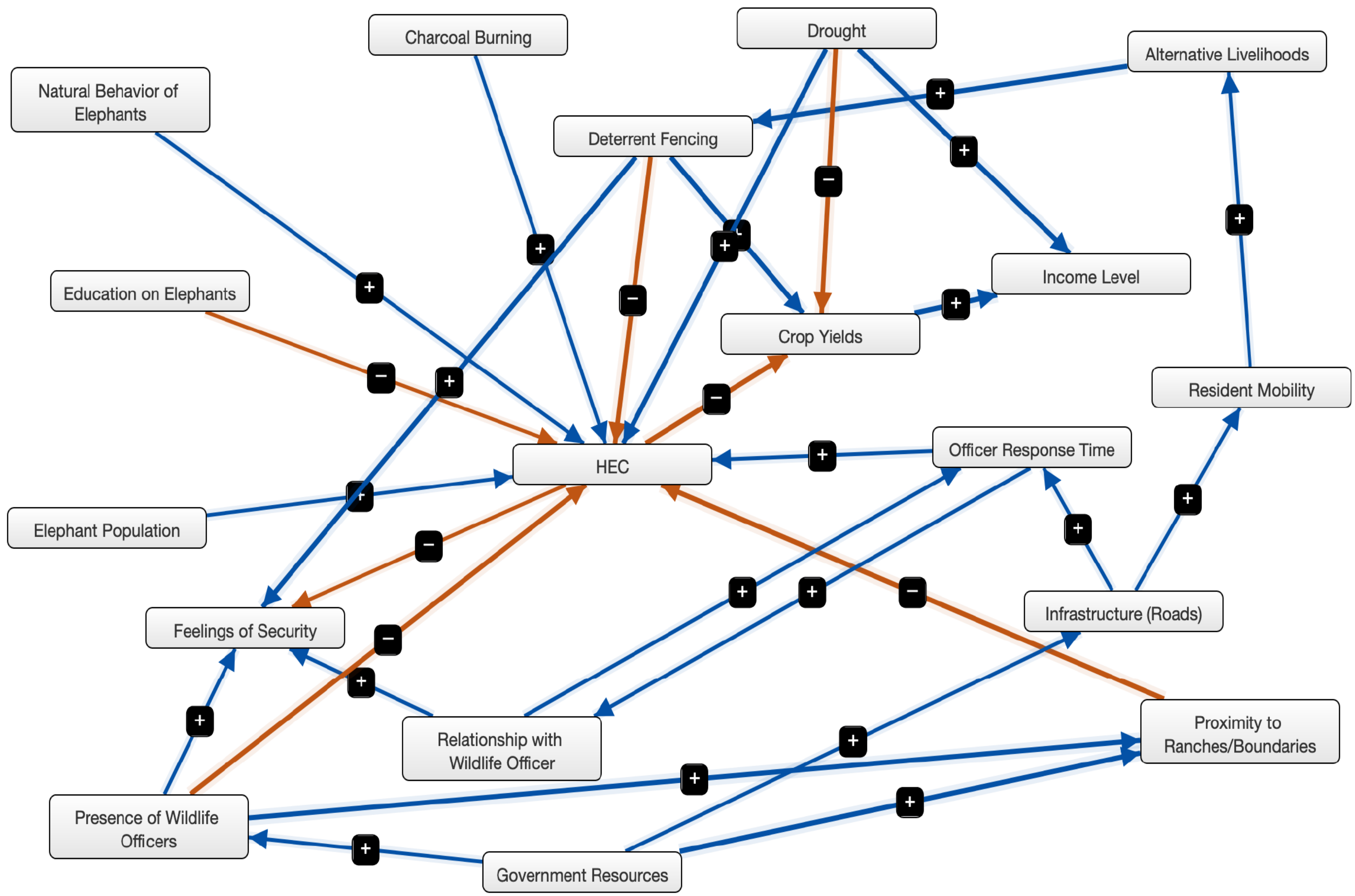
Figure S.4.2. A mental model and Fuzzy Cognitive Map created with Mental Modeler software from a participatory session in the village of Kisimenyi in the Kasigau Wildlife Corridor of Kenya concerning human-elephant conflict. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. A + sign denotes a positive influence by a variable in the direction of the arrow, while a – sign denotes a negative influence by a variable in the direction of the arrow.

Figure S.4.3 A mental model and Fuzzy Cognitive Map created with Mental Modeler software from a participatory session in the village of Buguta in the Kasigau Wildlife Corridor of Kenya concerning human-elephant conflict. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. A + sign denotes a positive influence by a variable in the direction of the arrow, while a – sign denotes a negative influence by a variable in the direction of the arrow.

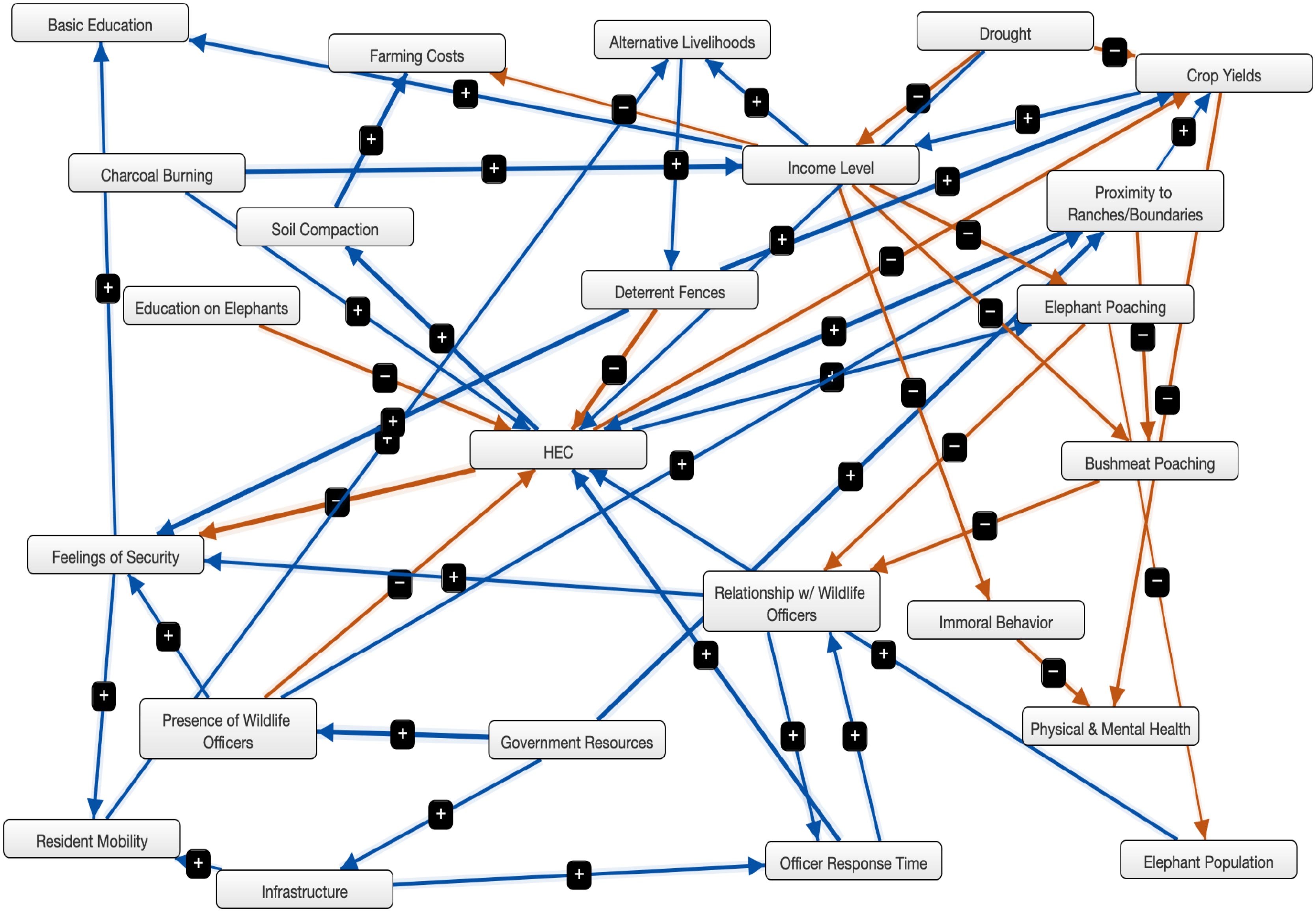
Figure S.4.4. A mental model and Fuzzy Cognitive Map created with Mental Modeler software from a participatory session in the village of Itinyi in the Kasigau Wildlife Corridor of Kenya concerning human-elephant conflict. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. A + sign denotes a positive influence by a variable in the direction of the arrow, while a – sign denotes a negative influence by a variable in the direction of the arrow.

Figure S.4.5. A mental model and Fuzzy Cognitive Map created with Mental Modeler software from a participatory session in the village of Miasenyi in the Kasigau Wildlife Corridor of Kenya concerning human-elephant conflict. Variables are linked together through connecting lines (edges) with the strength of association represented by the thickness of the lines. A + sign denotes a positive influence by a variable in the direction of the arrow, while a – sign denotes a negative influence by a variable in the direction of the arrow.

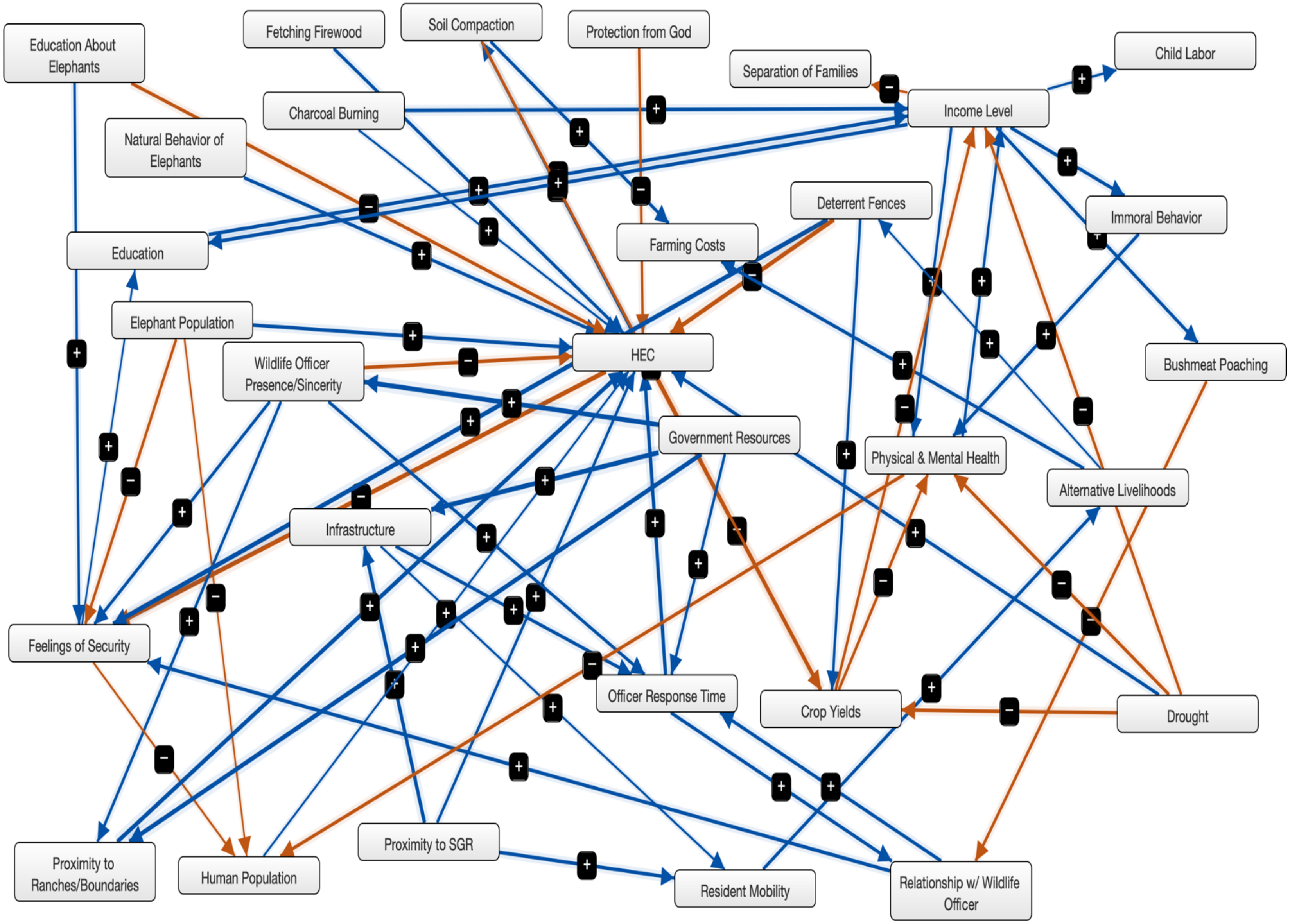
Figure S.4.6. A qualitative color aggregation of the four categories of variables from participatory sessions and mental model creation with six villages in the Kasigau Wildlife Corridor of Kenya

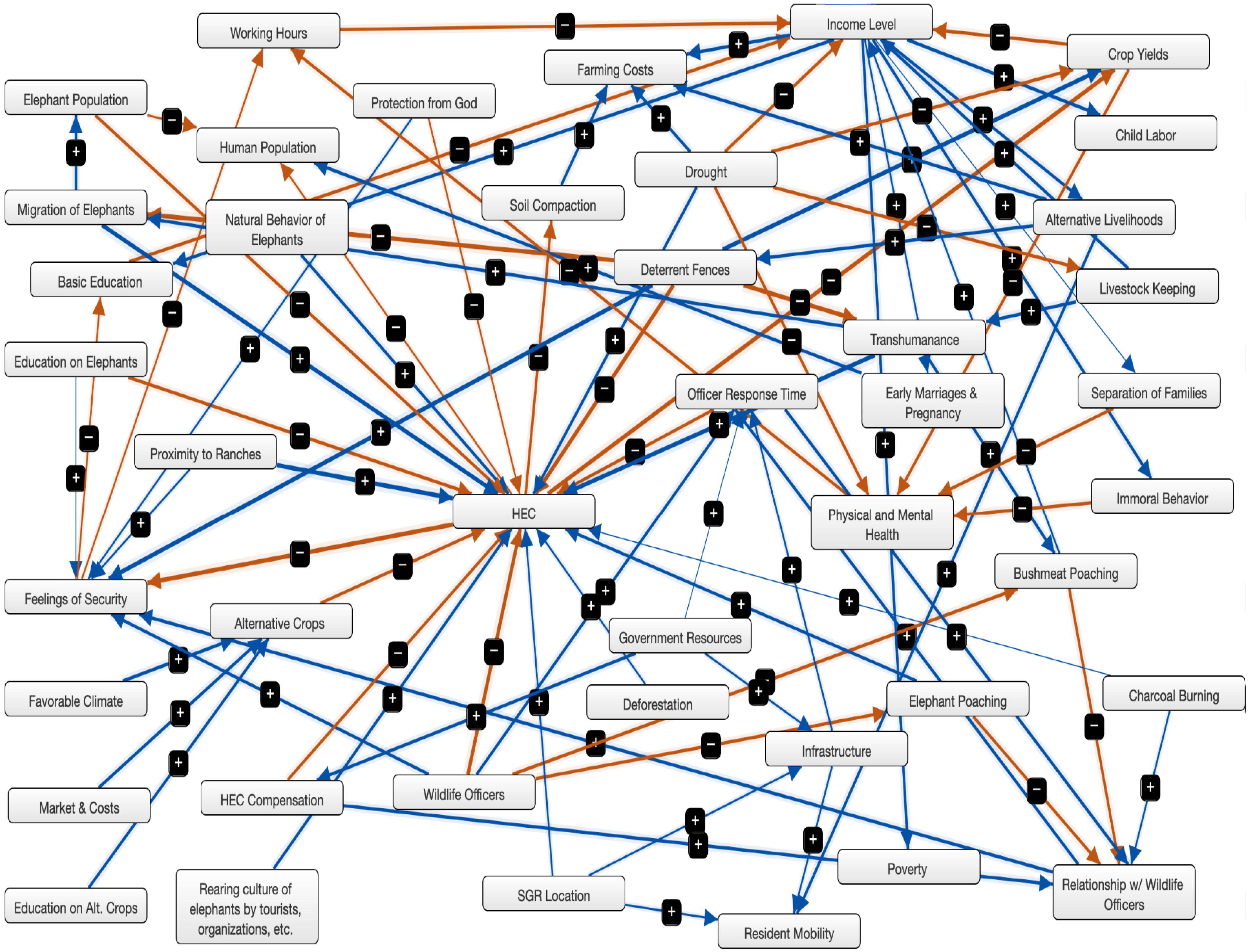


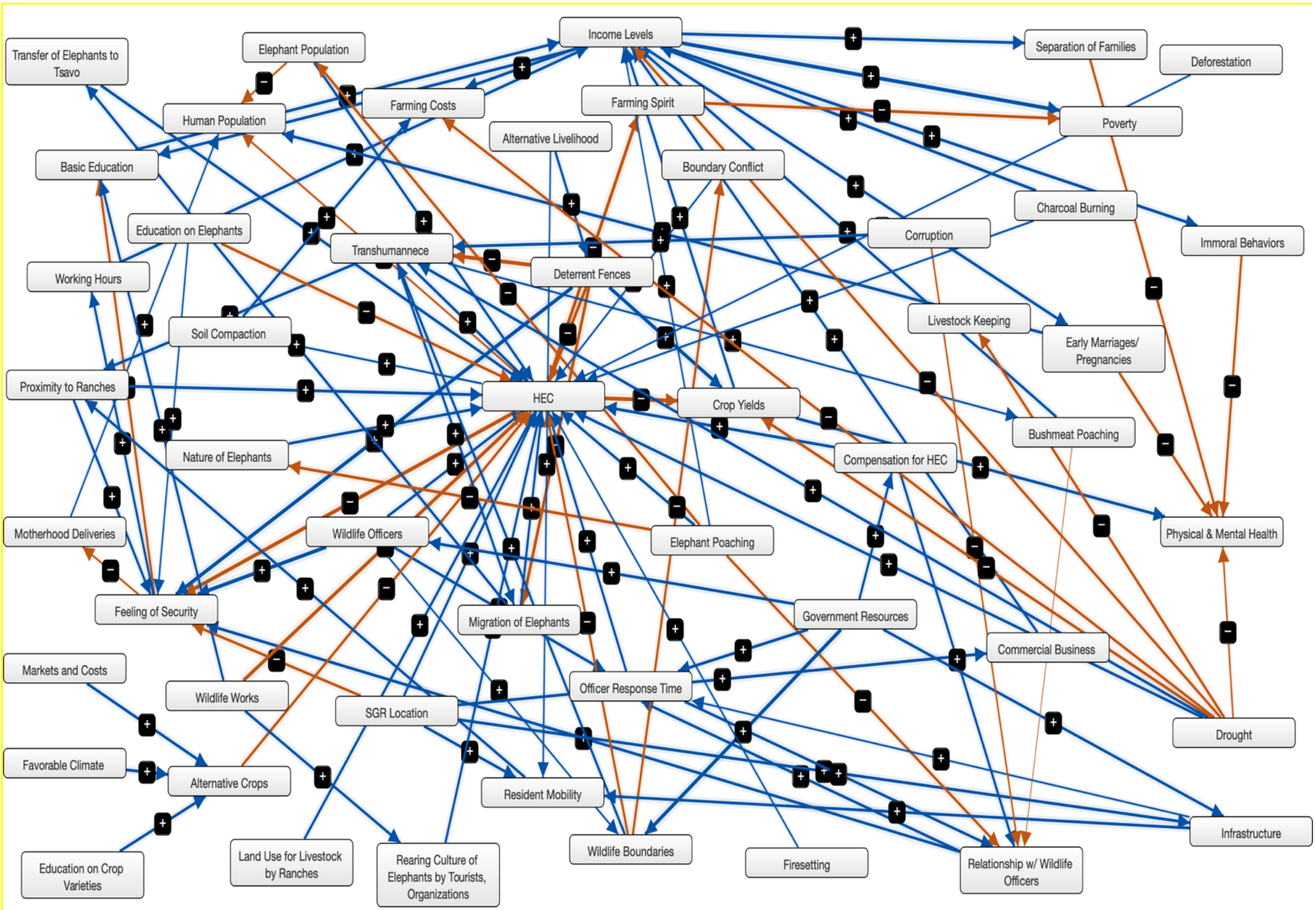
Charcoal Burning
Drought
Alternative Livelihoods
Natural Behavior of Elephants
Deterrent Fencing
Income Level
Education on Elephants
Crop Yields
Resident Mobility
Officer Response Time
HEC
Elephant Population
Infrastructure (Roads)
Feelings of Security
Relationship with Wildlife Officer
Proximity to Ranches/Boundaries
Presence of Wildlife Officers
Government Resources



Basic Education
Farming Costs
Alternative Livelihoods
Drought
Crop Yields
Charcoal Burning
Income Level
Soil Compaction
Proximity to Ranches/Boundaries
Deterrent Fences
Education on Elephants
Elephant Poaching
HEC
Bushmeat Poaching
Feelings of Security
Relationship w/ Wildlife Officers
Immoral Behavior
Presence of Wildlife Officers
Government Resources
Physical & Mental Health
Resident Mobility
Infrastructure
Officer Response Time
Elephant Population


Education About Elephants
Fetching Firewood
Soil Compaction
Protection from God
Separation of Families
Child Labor
Charcoal Burning
Income Level
Natural Behavior of Elephants
Deterrent Fences
Immoral Behavior
Education
Farming Costs
Elephant Population
Wildlife Officer Presence/Sincerity
HEC
Bushmeat Poaching
Government Resources
Physical & Mental Health
Alternative Livelihoods
Infrastructure
Feelings of Security
Officer Response Time
Crop Yields
Drought
Proximity to Ranches/Boundaries
Human Population
Proximity to SGR
Resident Mobility
Relationship w/ Wildlife Officer


Working Hours
Income Level
Farming Costs
Crop Yields
Elephant Population
Protection from God
Child Labor
Human Population
Drought
Migration of Elephants
Natural Behavior of Elephants
Soil Compaction
Alternative Livelihoods
Basic Education
Deterrent Fences
Livestock Keeping
Transhumanance
Education on Elephants
Officer Response Time
Early Marriages & Pregnancy
Separation of Families
Proximity to Ranches
HEC
Physical and Mental Health
Immoral Behavior
Bushmeat Poaching
Feelings of Security
Alternative Crops
Government Resources
Charcoal Burning
Favorable Climate
Deforestation
Elephant Poaching
Infrastructure
Market & Costs
HEC Compensation
Wildlife Officers
Poverty
Relationship w/ Wildlife Officers
Education on Alt. Crops
Rearing culture of elephants by tourists, organizations, etc.
SGR Location
Resident Mobility


Transfer of Elephants to Tsavo
Elephant Population
Income Levels
Separation of Families
Deforestation
Human Population
Farming Costs
Farming Spirit
Poverty
Alternative Livelihood
Basic Education
Boundary Conflict
Charcoal Burning
Education on Elephants
Corruption
Immoral Behaviors
Transhumannece
Deterrent Fences
Working Hours
Soil Compaction
Livestock Keeping
Early Marriages/ Pregnancies
Proximity to Ranches
HEC
Crop Yields
Bushmeat Poaching
Nature of Elephants
Compensation for HEC
Motherhood Deliveries
Wildlife Officers
Elephant Poaching
Physical & Mental Health
Feeling of Security
Migration of Elephants
Government Resources
Commercial Business
Markets and Costs
Wildlife Works
Officer Response Time
SGR Location
Drought
Favorable Climate
Alternative Crops
Resident Mobility
Infrastructure
Education on Crop Varieties
Land Use for Livestock by Ranches
Rearing Culture of Elephants by Tourists, Organizations
Wildlife Boundaries
Firesetting
Relationship w/ Wildlife Officers

Buguta West	Bungule	Itinyi	Kisimenyi	Makwasinyi	Miasenyi
Alternative Livelihoods	Alternative Livelihoods	Alternative Crops	Alternative Livelihoods	Alternative Livelihoods	Alternative Crops
Basic Education	Basic Education	Alternative Livelihoods	Basic Education	Charcoal Burning	Alternative Livelihood
Bushmeat Poaching	Behavioral Nature of Elephants	Basic Education	Bushmeat Poaching	Crop Yields	Basic Education
Charcoal Burning	Bushmeat Poaching	Bushmeat Poaching	Charcoal Burning	Deterrent Fencing	Boundary Conflict
Child Labor	Charcoal Burning	Charcoal Burning	Crop Yields	Drought	Bushmeat Poaching
Crop Yields	Child Labor	Child Labor	Deterrent Fences	Education on Elephants	Commercial Business
Deterrent Fences	Crop Yields	Crop Yields	Drought	Elephant Population	Charcoal Burning
Drought	Deterrent Fencing	Deforestation	Education on Elephants	Feelings of Security	Child Labor
Education About Elephants	Drought	Deterrent Fences	Elephant Poaching	Government Resources	Compensation for HEC
Elephant Population	Education on Elephants	Drought	Elephant Population	HEC	Corruption
Farming Costs	Elephant Population	Early Marriages & Pregnancy	Farming Costs	Income Level	Crop Yields
Feelings of Security	Farming Costs	Education on Alt. Crops	Feelings of Security	Infrastructure	Deforestation
Fetching Firewood	Feelings of Security	Education on Elephants	Government Resources	Natural Behavior of Elephants	Deterrent Fences
Government Resources	Government Resources	Elephant Poaching	HEC	Officer Response Time	Drought
HEC	HEC	Elephant Population	Income Level	Presence of Wildlife Officers	Early Marriages/ Pregnancies
Human Population	Human Population	Farming Carts	Immoral Behavior	Proximity to Ranches/Boundaries	Education on Crop Varieties
Immoral Behavior	Immoral Behavior	Favorable Climate	Infrastructure	Relationship with Wildlife Officer	Education on Elephants
Income Level	Income Levels	Feelings of Security	Officer Response Time	Resident Mobility	Elephant Poaching
Infrastructure	Infrastructure	Government Resources	Physical & Mental Health		Elephant Population
Natural Behavior of Elephants	Officer Response Time	HEC	Presence of Wildlife Officers		Farming Costs
Officer Response Time	Physical and Mental Health	HEC Compensation	Proximity to Ranches/Boundaries		Farming Spirit
Physical & Mental Health	Presence of Wildlife Officers	Human Population	Relationship w/ Wildlife Officers		Favorable Climate
Protection from God	Proximity to Ranches	Immoral Behavior	Resident Mobility		Feeling of Security

Figure S.4.6. Continued

Proximity to Ranches/Boundaries	Relationship w/Wildlife Officers	Income Level	Soil compaction	Fire setting
Proximity to SGR	Resident Mobility	Infrastructure		Government Resources
Relationship w/ Wildlife Officer	Separation of Families	Livestock Keeping		HEC
Resident Mobility	SGR Location	Market & Costs		Human Population
Separation of Families	Soil Compaction	Migration of Elephants		Immoral Behaviors
Soil Compaction		Natural Behavior of Elephants		Income Levels
Wildlife Officer Presence/Sincerity		Officer Response Time		Infrastructure
		Physical and Mental Health		Land Use for Livestock by Ranches
		Poverty		Livestock Keeping
		Protection from God		Markets and Costs
		Proximity to Ranches		Migration of Elephants
		Rearing culture of elephants.		Motherhood Deliveries
		Relationship w/ Wildlife Officers		Nature of Elephants
		Resident Mobility		Officer Response Time
		Separation of Families		Physical & Mental Health
		SGR Location		Poverty
		Soil Compaction		Proximity to Ranches
		Transhumance		Rearing Culture of Elephants
		Wildlife Officers		Relationship w/ Wildlife Officers
		Working Hours		Resident Mobility
				Separation of Families

Figure S.4.6. Continued

SGR Location
Soil Compaction
Transfer of Elephants to Tsavo
Transhumance
Wildlife Boundaries
Wildlife Officers
Wildlife Works
Working Hours

Chapter 5

Conclusions

Human-elephant conflict has been primarily addressed by attempts to understand or quantify crop raiding behavior or with interventions such as deterrents or mitigation programs. Relatively little attention has focused on how farmers conceptualize these interactions, if they are getting needed information to mitigate crop raiding and other livelihood threats, and the social and cultural dimensions of this complex conservation issues. Local farmers were upset and concerned over the impact of crop raiding, eager to share their attitudes and experiences, and hopeful for assistance that would help mitigate crop-raiding. The majority of farmers had never received information about mitigation techniques (exposure), indicating that those in need of information may not be receiving it. Just over half of farmers used some type of deterrent but most also used traditional, more ineffectual techniques. Economic disparities were prevalent in the study as well, and 100% of people who wanted to but couldn't build deterrents to protect their farms cited economic constraints I was able to clearly illustrate the inconsistencies involved for local farmers regarding those with less exposure to deterrents, and those who were resource poor. In chapter 3, income level was the variable that was the most relevant across the models with farmers, again demonstrating the importance of negative HEI as an economic issue. Most participants lived in some level of fear of elephants, which can cause various health impacts, and decrease tolerance for wildlife and general conservation effort support. This fear also was expressed in the mental models related to feelings of security. While human wildlife conflicts are often treated as a wildlife issue, this study illustrated the importance of using systems thinking to consider the needs of farmers or stakeholders and their ability to respond to wildlife presence as a key part of this complex conservation issue.

Farmers had an intricate understanding of the social and ecological changes that were occurring in the system they lived in as well as awareness of their inability to respond to it. Furthermore, even if given an opportunity to earn money if they left Tsavo, half of participants indicated that they did not want to move away from the farming lifestyle potentially indicating a cultural attachment to place. Thus, while climatic change is threatening farming livelihoods, farmers either do not wish to change or may not have the means to do so. Most farmers already participated in mono-cropping and had no means to irrigate their crops, exacerbating the impacts of climate change. These combined factors can create a humanitarian concern if climate change continues to reduce crop yields and farmers are unable to or will not relocate or find new sources of livelihood. Farmers were also aware of the benefits of wildlife preservation, much more so than in other studies, but still remained limited in their ability to respond to negative wildlife impacts.

Frustration with wildlife officers and their ability to respond to wildlife conflicts was a major source of contention for farmers. Farmers noted infrastructure as a key variable in mental models, as impassable roads compromise officers' ability to respond to crop raiding calls. These ongoing tensions are evidenced in comments from farmers who believe that wildlife lives are valued above their own. If farmers feel discouraged in this manor, they are less likely to invest in preserving wildlife and habitats and will continue to be frustrated with authorities. These insights into the attitudes and behavior of farmers are valuable as they can be used to create community-based initiatives that help to mitigate elephant crop-raiding.

Several other potential variables were found that were novel to or underrepresented in the literature. Sociocultural indicators such as increased feeling of security, or reduced family separation can be used to measure the impact on farmers' satisfaction with conservation initiatives and as a gauge for mitigation program success. The need for systems thinking in approaching elephant conflicts was also evident just from the number of different variables present in the mental models of farmers. The co-created model was context specific to this ecosystem and represented the views of farmers and wildlife agencies and was informed by prior literature.

This study had some expected and unexpected limitations, as is normal during research. First, the COVID-19 pandemic limited the ability to be present in Kenya for data collection and the timeline and objectives of the original research plan had to be modified. Not being able to be present during the surveys and modeling sessions, limited my ability to oversee operations which could have introduced error. During execution of the participatory sessions, bias was unintentionally introduced into the construction of mental models with each progressive session. While I sought to address this bias by categorizing data and building a unified single mental model, I could not make village to village model comparisons. Second, the results from this study are contextual and specific to the Kasigau Wildlife Corridor and certain aspects may not apply to some communities living near African elephants. There are however many commonalities in HEI that can be broadly applicable for other areas of the country or continent. Third, most of the hypotheses tested were unsupported and models showed that demographics were not explanatory factors as model weights and other metrics did not adequately explain the variation in the data. Fourthly, participants may not have understood questions fully as several went unanswered or had to be discarded as they did not make sense with prior answers. There may have also been social desirability bias introduced as farmers hoped to please those conducting the surveys and modeling. Lastly, some groupings from questions such as those who used modern deterrents or had upper education levels were so small that models likely could not discern any variation in these demographic categories. Despite these limitations, the work provided unique and interesting data related to farmers' ability to be resilient against multiple environmentally based challenges.

While this study has revealed multiple insights, it also has revealed other questions and potential next steps for advancing this area of research. First, additional research with different communities facing human-elephant conflict would help validate if my findings are unique or more generally representative of the issue. Second, how community outreach or aid programs can impact farmer attitudes and behavior towards elephants and general tolerance towards wildlife is important to understand. For example, if farmers feel their economic situation is stable, will they remain angry with elephants when crop raiding occurs? Thirdly, if farmers receive information on how to live safely around elephants (as indicated in farmer mental models) will that shift attitudes towards elephants and reduce levels of fear in the community? And fourthly, what are best practices and avenues for agencies with limited funding to reach rural farmers to deliver the various sources of information farmers are lacking to stabilize their livelihoods? Addressing these additional gaps in our knowledge will help inform policy and management strategies for mitigation initiatives and help create pathways to coexistence for people and elephants.

Appendix A

Community Survey

Farming

How many acres do you currently use for crop farming?

Have you had any formal farming educational training (other than family)?

- ◯ Yes
- ◯ No

If yes, what type of training?

How many years have you been farming?

What types of crops do you plant? (Check all that apply)

- ☐ Maize (Mahindi
- ☐ Green Grams (Pojo)
- ☐ Cow Peas (Kunde)
- ☐ Ground Nuts (Njugu)
- ☐ Sorghum (Mtama)
- ☐ Other (please specify)
- ☐ Other (please specify)

Are you interested in planting different types of crops that what you normally plant?

◯ Yes
◯ No
◯ Unsure

If yes, what types of plants are you interested in planting?

What do you feel is the main reason for your crop losses? (Please choose one)

◯ Drought
◯ Elephants
◯ Other wildlife
◯ Pests (wadudu)
◯ Disease
◯ Bad seeds
◯ Other (please specific)

How many acres do you believe are lost?

Do you irrigate your crops in some way?

◯ Yes
◯ No

If yes, what type of irrigation do you use?

How often does drought affect your harvest per season? (Select one)

☐ Never
☐ Sometimes
☐ Every Season
☐ I Don't Know

If you had other ways to earn money, would you still continue to farm? (Select One)

- ☐ Definitely Not
- ☐ Maybe Not
- ☐ I Don't Know
- ☐ Possibly So
- ☐ Definitely

Would you be interested in planting rough lemon as a way to earn income?

- ◯ Yes
- ◯ No
- ◯ Unsure

Crop Raiding

Do animals crop raid your farm(s)? (Check One)

- ☐ Often
- ☐ Sometimes
- ☐ Never
- ☐ I don't know
- ☐

If yes, please list the animal(s) that come to your farm

Which animal do you believe comes to your farm the most often?

How many acres of your crops do you believe elephants normally damage in a typical season?

During a good harvest season (crops are present), how many times per week do elephants visit your farm?

Do elephants visit your farm during the day?

- ◯ Yes
- ◯ No
- ◯ Sometimes

Have you ever actively chased elephants from your farm?

- ◯ Yes
- ◯ No

If you have actively chased elephants, did you use any tools? For example, were you waving a torch or making noise or something else?

If yes, how many times per week do you chase elephants away during the height of the crop raiding season?

Have you ever harmed or attempted to harm elephants when they came to your farm? (These answers will NOT be shared with authorities)

- ◯ Never
- ◯ Once
- ◯ Several Times
- ◯ Regularly
- ◯ All the Time

Do you use methods to prevent crop raiding by wildlife on your farm?

◯ Yes
◯ No

If yes, what type methods do you use?

Have you ever received information on methods to prevent crop raiding?

◯ Yes
◯ No

If yes, what type of information on methods to prevent crop raiding?

Have you ever received instructions on how to build deterrent fences?

◯ Yes
◯ No

If yes, what types of deterrent(s)?

If you were given information about ways to prevent crop raiding how likely is it you would be able to invest in and build deterrent methods?

☐ I would definitely be able build deterrent methods
☐ I would possibly be able to build deterrent methods
☐ I am unsure if I would be able to build deterrent methods
☐ I would definitely not build deterrent methods

If no, please tell us why would you not be able to purchase or construct deterrent methods?

Have you ever tried to contact authorities about elephants or other wildlife on your farm?

- ◯ Once
- ◯ 1-2 times
- ◯ 3+ times
- ◯ No

If yes, who did you attempt to contact? (List All)

If you had enough income to support your family would you still feel angry at elephants when they crop raid?

- ◯ I would not feel angry anymore
- ◯ I Don't know
- ◯ I would still feel a little angry
- ◯ I would still be very angry

Is there anything else you would like to share concerning your feelings about elephants and crop raiding?

Elephants

How much do you fear elephants?

- ◯ Not at all
- ◯ A little bit
- ◯ Unsure
- ◯ Somewhat afraid
- ◯ Very afraid

Have you ever been injured by an elephant?

- ◯ Yes
- ◯ No

Have you ever received information on how to safely live with elephants?

◯ Yes
◯ No

If yes, what type of information did you receive and from whom?

Have you ever received information about the role of elephants in the environment?

◯ Yes
◯ No

If yes, what type of information did you receive and from whom?

Environment, Wildlife and Climate Change

Do you believe that climate change has negatively affected your life?

◯ Not at all
◯ Somewhat
◯ I don't know
◯ Very much

How do you believe climate change has affected you? (Check all that apply)

- ☐ I don't believe climate change has affected me
- ☐ The temperatures are hotter
- ☐ There are less rains/more drought
- ☐ The crops are unpredictable
- ☐ There is more flooding
- ☐ There are more pests
- ☐ Animals come more often to crop raid
- ☐ I don't know
- ☐ Other (please specify)

Do you believe your household benefits from the preservation of wildlife? (Choose One)

- ◯ Yes, a lot
- ◯ Somewhat
- ◯ No, not atall
- ◯ Not sure

How do you believe your household benefits from wildlife? (Check all that apply)

- ☐ I don't believe my household benefits from wildlife
- ☐ Wildlife brings jobs to the community
- ☐ I enjoy watching or seeing wildlife
- ☐ I understand that healthy wildlife is important to the ecosystem
- ☐ I understand that preserving wildlife is important for tourism for the Kenyan economy
- ☐ I don't know
- ☐ Other (please specify)

How do you feel about wildlife authorities and your relationship with them? (Check One)

- ☐ I am not happy with the authorities
- ☐ I am slightly unhappy with authorities
- ☐ I do not know
- ☐ I am slightly pleased with authorities
- ☐ I am very happy with authorities
- ☐ I do not have a relationship with wildlife authorities

Which authorities have you had a relationship with concerning wildlife? (Check all that apply)

- ☐ Kenya Wildlife Service
- ☐ Wildlife Works
- ☐ Kenyan Police
- ☐ Other
- ☐ I have never contacted wildlife authorities

Have you ever visited a National Park?

- ◯ Yes
- ◯ No

Would you be willing to introduce new techniques that improve crop yields on your farm (s)?

- ◯ Yes
- ◯ No
- ◯ Unsure

Do you have a way to bring products that you want to sell to a market?

- ◯ Yes
- ◯ No
- ◯ Doesn't apply tome

What is your main means of income?

If you have other means of income, please describe here.

Have you ever visited Tsavo East or Tsavo West National Parks?

- ◯ Yes
- ◯ No

Livelihood

Have you ever learned about other ways to earn money than farming? (Please check one)

- ◯ I have never heard about other ways
- ◯ I have heard a little bit about other ways
- ◯ I do notknow
- ◯ I have heard a lot about other ways

Have you ever received information about new agricultural techniques that could increase your crop yields? (Please Check One)

- ◯ I have never heard about new techniques
- ◯ I have heard a little bit about new techniques
- ◯ I do notknow
- ◯ I have heard a lot about new techniques

Personal & Household Information

NAME

If you would like to be contacted for future surveys, please list your phone number

What year were you born?

Village of origin

Gender

◯ Male
◯ Female

Which ethnic community are you from?

How many people in your household?

What is the highest level of education you have received?