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Assessing the Vulnerability of the Human and Natural Systems and Prioritizing Alternatives to Reduce Vulnerability at Mt. Kasigau, Kenya.

Njoroge Ikonye Gathongo
University of Tennessee, ngathong@vols.utk.edu

To the Graduate Council:

I am submitting herewith a dissertation written by Njoroge Ikonye Gathongo entitled "Assessing the Vulnerability of the Human and Natural Systems and Prioritizing Alternatives to Reduce Vulnerability at Mt. Kasigau, Kenya.." I have examined the final electronic copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geography.

Liem Tran, Major Professor

We have read this dissertation and recommend its acceptance:

Micheline van Riemsdijk, Nicholas Nagle, Robert E. Jones

Accepted for the Council:

Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

Assessing the Vulnerability of the Human and Natural Systems and Prioritizing Alternatives to Reduce Vulnerability at Mt. Kasigau, Kenya.

A Dissertation Presented for the

Doctor of Philosophy

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DEDICATION

I dedicate my work to Dad, my late Mom, Waithera, Leone, Leshan, Wacera, Mwangi, Waruguru, Njoki, and Ciku.

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ABSTRACT

The goal of this research was to examine the vulnerability of the human and natural systems to anthropogenic threats and environmental changes at five villages (Kiteghe, Makwasinyi, Jora, Bungule, and Rukanga) in Mt. Kasigau, Kenya. To accomplish this goal, three research objectives were pursued: (1) to assess the vulnerability of the human system, (2) to assess the vulnerability of the natural system, and (3) to assist the community in identifying, evaluating, and prioritizing ways for reducing vulnerability. These three objectives linked together and are structured in three manuscripts in this dissertation.

This study adapted a vulnerability framework that conceptualized vulnerability as a function of '*exposure'*, '*sensitivity'*, and '*adaptive capacity'*. The Analytical Hierarchy Process (AHP), which is a multi-criteria decision-making tool is used to structure vulnerability into a hierarchical format and to build a vulnerability assessment and reduction model based upon the benefits, costs, opportunities, and risks criteria in order to evaluate each alternative.

Results from this study illustrated that adaptive capacity and exposure played a critical role in determining the social and environmental vulnerability among the five villages. Therefore, measures to reduce vulnerability should emphasize these two components of vulnerability, especially for the most vulnerable village. Additionally, the vulnerability reduction model that was used by the community identified environmental conservation as the most preferred alternative for reducing vulnerability. The information derived from this research can help local policymakers, non-governmental organization, and other practitioners who are interested in developing policies that promote sustainable development.

Lastly, this place-based dissertation research contributes to the discipline of geography by emphasizing how vulnerabilities vary across space and time. It also advances the body of knowledge in vulnerability and sustainability studies through bridging the gap between socio-ecological and biophysical dimension of vulnerability. The need to understand the issue of vulnerability was essential if we are to realize sustainable development. Hence, this study advances sustainability literature by identifying the economic, social, and environmental factors of vulnerability that create barriers to sustainable development at the community level (e.g., village). In this regard, this study could play a vital role in creating a platform for scholars who are interested in vulnerability and sustainability studies.

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CHAPTER I
INTRODUCTION

Although humans have always depended on nature, this reliance is increasingly at risk because various ecosystem services that are critical to human well-being are being degraded. Human activities and environmental changes have increased human and environmental vulnerability. To minimize future losses, a clear understanding of what makes people and places vulnerable is needed. In this context, the major goal of this chapter is to provide a theoretical-conceptual background and framework utilized in my studies. I begin the chapter by providing information about coupled human and natural systems. Next, I provide an overview of the relevant literature related to the field of sustainable development and vulnerability. Following, I explore and assess different conceptual frameworks and models which have been used to assess vulnerability. This is followed by brief discussion of the model that was selected for this study. Next, I explain the rationale and objectives of this research. Finally, an overview of the research significance of the study is provided.

1.1 Coupled Human and Natural Systems

Coupled human and natural systems are complex and integrated systems where human and nature interact with each other reciprocally across diverse organizational levels (Carter et al., 2014; Liu et al., 2007). Even though this kind of interaction can be traced back to the beginning of human history, the scope and intensity of interaction has increased dramatically since the onset of the Industrial Revolution (Liu et al., 2007). Coupled human and natural systems exhibit several emergent properties such as feedback loops, resilience, heterogeneity, non-linearity, surprises, and time lags (An, 2012; Liu et al., 2007; Pickett et al., 2005). These emergent properties are formed as a result of interactions between human and natural environment and are not necessarily unique properties that separately belong to the human or natural system (Liu et al., 2007). Such systems are affected by human activities, resulting in various environmental disasters that may in turn affect future human behavior and decisions (An, 2012).

Many aspects of nature on which humans depend are currently threatened or have disappeared as a result of human activities (Gascon et al., 2015; Liu et al., 2007; Turner et al. 2007). On the other hand, natural processes such as floods, drought, and landslides can devastate human systems (Liu et al., 2007). For example, in rural areas, humans depend on agricultural lands and forests to meet their basic needs. However, quite often humans overuse agricultural land without replenishing the nutrients lost from poor soil management practices or convert old growth forest into farmland without planting trees. This results in damage of soil, water, and

biodiversity, which leads to reduced crop yields, biodiversity loss, and degradation of ecosystem services (Liu et al., 2007). Eventually, this form of ecological exchange makes the whole system vulnerable to human activities. Thus, researching and understanding the root causes of what makes people, and the biophysical environment vulnerable is important because it may assist in reducing losses or lead to better adaption strategies in the long run.

1.2 Theoretical Background

Sustainability and vulnerability are intrinsically intertwined concepts (Harrington, 2005). On one hand, vulnerability is related to the ability of a society or community absorb to risks or shocks (Janssen et al., 2006). On the other hand, sustainability focuses on conditions that promote the stability of a system (Khagram et al., 2003; Harrington, 2005). In the context of coupled human–environment systems, sustainability involves enhancing resilience and reducing vulnerability (Wu, 2013). Sustainable development has emerged as a framework to achieve sustainability. To achieve sustainable development, it is important to reduce the vulnerability of societies and communities to human and natural disasters, enhance their adaptive capacity, and strengthen their resilience (Le Blanc, 2015). Sustainable development, like vulnerability reduction, not only depends on structural and engineered solutions, but has important social, economic, environmental, political, and cultural dimensions (Uitto and Shaw,2016). To develop measures, which can contribute to sustainable development, it is important to examine factors that may create vulnerability (Eriksen et al., 2011: 11). In the context of this dissertation, vulnerability is seen as an obstacle to sustainable development. Hence, this study draws on theories and literature from sustainable development and vulnerability studies. Before I begin the journey of reviewing this literature, I briefly explore the current state of the planet highlighting various issues that make the world vulnerable and unsustainable. Next, I highlight theories that have been used to interpret sustainable development in the context of human- environment interaction. Lastly, I illustrate how this study contributes to the sustainable development literature.

Today, human population is growing at an alarming rate, and there are not enough resources to produce or support the necessities of life for the world's population (Flint, 2012). Moreover, the quality of life for humans is challenged by competition for dwindling natural resources and habitable space. This shrinking of resources accelerates the problems of economic disparities between developed and developing countries (ibid). Additionally, ecological problems

currently plaguing the planet includes unequal distribution and access to resources, climate change, extinction of species, acid rain, deforestation, pollution, desertification, soil erosion famine, and floods among others (Foster, 1999). The main causes of the environmental challenges we are currently facing are not the product of individual human choices or biological constructed (De, 1992; Foster, 1999) but are "socially and historically rooted in the technological imperatives, productive relations, and historically conditioned demographic trends that characterize the dominant social system" (Foster, 1999: 12). While some of these problems may occur on a local scale, they transcend to regional and global scales and may result in catastrophic events that can significantly decrease the ability of human beings to sustain their livelihoods and threaten environmental sustainability (Hart, 1997).

Throughout the world, population growth and the pursuit of economic development have spurred rapid and immense social, economic, and ecological changes that affect virtually "all the development priorities that are on top of regional, national, and global agendas" (Albrectsen, 2013). At present, many development trends not only leave poor people vulnerable but also degrade the environment (ibid). This has led many commentators to argue that the established development patterns are unjust and unstainable (Grainger, 2004). However, dynamics in population, "not only affect critical development objectives; they are themselves affected by the social, economic, environmental", institutional, and cultural changes (Albrectsen, 2013: 1) Over the last 50 years, it is economic development rather than population rise per se, that has fundamentally influenced the rate of changes of the earth's life support system (Lee, 2003). These changes have reached a scale that they are presently threatening many environmental systems, and for the first time in human history, economic activities are so extensive that they are producing environmental changes at the global level (Flint, 2012). On one hand, environmentalists defend the idea of preserving natural resources and decreasing the level of contamination (Martin et al., 2016). On the other hand, economists support the idea that development and economic growth are crucial for poor countries to achieve the basic standards of living (Mitcham, 1995; Keeble, 1988). Thus, the challenge that the planet is currently facing is the "problem of meeting the increasing needs and expectation of a growing population while at the same time trying to modify the current consumption and production patterns" (Albrectsen, 2013). In order to meet these needs, there is a need for a paradigm shift that will develop ways to balance the needs for economic development and environmental conservation. Some of the

major ideas and strategies about how to balance these needs are found within the literature and among supporters, groups, and institutions of "sustainable development".

1.2.1 Sustainable Development

Sustainable development is an idea that emerged around the end of the 20th century to address the global ecological crisis driven by overpopulation, resource degradation, social inequalities, and poverty (Duran et al., 2015; Moldan et al., 2012; Blewitt, 2012; Mitcham, 1995). The idea of sustainability appeared first in the German forestry sector in the 17th century as a strategy of "never harvesting more trees than what the forests would yield in new growth" (i.e., sustainable harvest) (Kuhlman and Farrington, 2010: 3437). However, it was not until the mid-1980s that the concept became popular (Duran et al., 2015). This was after the Brundtland Commission published its report, "Our Common Future", with the goal of linking issues of environmental stability and economic development (WCED, 1987). The Brundtland report defined sustainable development as the ''development that meets the needs of current generations without compromising the ability of future generations to meet their needs and aspirations'' (ibid). The ultimate aim of this definition is to ensure a better quality of humans, "both for the present and future generations, by promoting the concept of reconciling economic and social progress without endangering the earth's life support systems" (Duran et al., 2015: 814). In other words, sustainable development represents a vision and commitment to create fair and effective socio-economic strategies in order to adapt to ecological realities (Jones, 2019). Overall, sustainable development is about creating healthy, adaptive, resilient, and equitable conditions on the earth and among its biophysical and social systems and its inhabitants so they can persist over time and for future generations (ibid).

Today, sustainable development is viewed as "a holistic concept that combines aspects of natural, social and economic being involved in two big problems of mankind: the ability to create and to maintain" (Duran et al., 2015: 814). In the three decades since the term was coined, sustainable development still remains a contested idea, and there are a variety of theories and policies that have been used to formulate and implement its basic goals (Kuhlman and Farrington, 2010). The concept has become widely used in academia, private sectors, and public institutions. In 2015, the United Nations (UN) General Assembly further broadened and deepened it by launching the Global 2030 Agenda for sustainable development covering 17 goals and 169 targets that were adapted by all United Nations Members States (Dlouha and

Pospisilova, 2018; UN, 2015). The UN resolution on sustainable development goals called on all countries whether poor, middle income or rich to promote prosperity while protecting the environment (UN, 2015). At the heart of the resolution was the recognition that ending poverty must be accompanied with approaches that address a wide range of social needs such as education, health, economic growth, equity, and equality among others (Lee et al., 2016, UN, 2015).

Today, sustainable development is "presented as the intersection between environment, society, and economy, which are conceived of as separate although connected entities" (Giddings et al., 2002: 187). On one hand, an economically sustainable system should constantly produce various goods and services as well as "maintain manageable levels of government and external debt, and to avoid extreme sectoral imbalances which damage agricultural or industrial production" (Harris, 2003: 1). On the other hand, an environmentally sustainable system should avoid over-exploitation of resources and maintain a stable base of renewable and non-renewable resources (Harris, 2003; Harris and Roach, 2017). Finally, social equity must be achieved in a socially sustainable system (Sundar, 2014). This includes fairness in provision of job opportunities, access to education and health, gender equity and equality, and public participation among others (Harris and Roach, 2017). Arguably, the synthesis of these three dimensions (environment, society, and economy) introduce many potential problems for the original definition of the concept.

The idea of sustainable development first emerged as a useful concept when the topics of pollution, ozone depletion, and "environment degradation were at the forefront of political debate" (Duran et al., 2015: 813). However, today's reality is that the environment and society are dominated by the economy (ibid). Therefore, scholarly communities in different research traditions mainly use economic theories to interpret the meaning of sustainable development (Mulder et al., 2001). For example, environmental economists explain environmental impacts in terms of damage caused by the businesses (e.g., damage to biodiversity, pollution, and loss of attractiveness to a given landscape) (Clayton and Radcliffe, 2015).

A variety of theories have been associated with sustainable development. Three of the major ones are ecological economics, environmental economics, and social cultural theories (Laurent, 2015). All three theories regard development as a long-term path, but each takes a

different approach to integrate the social, economic, and environmental aspects of development (Grainger, 2004; Munasinghe, 1993).

Ecological economic theory aims at remedying the traditional neglect of the environment by the economy (Grainger, 2004). It portrays human economy as a subsystem of the global ecological system (Daly, 2008; Grainger, 2004) and views the flow of income and materials within the economy as part of the "wider transfer of energy and materials within" this system of planetary biosphere (Grainger, 2004: 16). The central idea of ecological economics is that sustainability ought to be approached both quantitatively and qualitatively, and particular attention should be paid to spatial scales (i.e. from local to regional level) and biophysical indicators (ibid).

Unlike the ecological economic, the environmental economic theory includes and distinguishes between the three aspects (social, environmental, and economics) of sustainable development (ibid). In this theory, development is depicted as the accumulation of capital (both human and man-made) at the expense of reducing the natural capital (ibid). Thus, it assumes that flow of income can be created as long as we maintain the stock of assets (or capital) that yields these benefits (Beder, 2011; Grainger, 2004). The basic idea of the environmental economic theory is to study economy-environmental interaction "based on the view that both economic development and environmental change should be seen as evolutionary processes" (Mulder et al., 2001: 118). This is because the "economic system is not isolated from the physical environment but is subject to a physical flow of material and energy" (ibid: 119).

Ironically, the standard environmental economic theory generally views sustainable development as being identical to sustainable growth, which is measured by monetary indicators (Grainger, 2004). Thus, the ideal condition for sustainable development based on this theory is the scale where human economic activities do not exceed the carrying capacity of the planet (Grainger, 2004). According to this theory, any development path is compatible with this condition as long as it does not breach this upper limit (i.e., carrying capacity of the planet) (Grainger, 2004). Therefore, the long-term viability of human activities depends upon how well they comply with the rules governing the biosphere.

Lastly, the social cultural theory of sustainable development focuses on maintaining the stability of cultural and social systems by reducing hunger, poverty, diseases, conflicts, and maintaining both intra-generational and inter-generational equities (Woods, 2002; Laurent, 2015;

Steurer et al., 2005; Munasinghe, 1993). In this theory, the preservation of cultural diversity, and the use of knowledge regarding sustainable practices embedded in non-dominant cultures are paramount (Munasinghe, 1993). In addition, it highlights the significance of grassroots communities participating in decision-making processes for socially sustainable development (ibid).

These theories are important for addressing various issues associated with sustainable development. For example, in the context of natural resource management, researchers have employed environmental economics theories for a better understanding of the complex relationships between human and natural systems (Grainger, 2004). Additionally, researchers use the understanding from environmental economics theory to develop policies that "can lead to a world which is ecologically sustainable, has a fair distribution of resources" (both social and natural), "and efficiently allocates scarce resources including natural and social capital" (Costanza, 2003: 1). Therefore, the current research aligns with this theory in its assumption that sustainability of the coupled human and natural systems requires reducing inequalities, eradicating human deprivation, staying within environmental carrying capacity, and maintaining innovation (Flint, 2012). In the context of this dissertation, this entailed the identification and reduction of vulnerability that inhibits sustainable development.

In theoretical discourses, there are two significant challenges in theorizing sustainable development. First, deciding how to integrate the three dimensions of sustainable development and second, ensuring that any theory has practical relevance (Grainger, 2004). These tasks are complicated by the need to achieve an internal consistency within a given theory and to treat development as a long-term phenomenon (ibid). Sustainable development theory ultimately should serve the practical purpose of designing sustainable systems and futures. The major systems included in conceptual frameworks, theories, and models of sustainable development include social equity, environmental protection, and economic growth as well as understanding how these systems are interconnected. In this research, the economic and environmental systems were of particular concern. Inasmuch as social equity, which has to do with fairness in opportunities, rights, access to all forms of biophysical and social resources, services and capital

(Jones, 2009), was left out, due to the historical injustices[1] of the people in the study area that left them deprived of developmental opportunities.

In the context of this dissertation, part of this effort was to identify and evaluate local, regional, national, and global conditions that might serve as bridges or barriers to sustainable development. One potential barrier, and major topic examined in this research is the vulnerability of the human and natural systems to significant degradation, disruption of communities, disasters, loss of resources and function, or the overall well-being and integrity of the systems. The need to understand the issue of vulnerability is essential if we are to realize sustainable development. As Pratt et al. (2014) highlights, the increasing focus on global sustainability demands that we obtain a better understanding of how vulnerability affects the different pillars of sustainable development. Therefore, this study examined how the human and natural systems are vulnerable in the five targeted villages to the multiple environmental and human changes by identifying the economic, social, and environmental factors that create barriers to sustainable development.

1.2.2 Geographers' Views on Vulnerability and Sustainability

Geographers have a long-standing interest in sustainability and vulnerability research (Paul, 2013). In vulnerability and sustainability studies, geographers are not only interested in systems but also concerned about the interaction between systems and how systems processes shape a community or region. In the past, geographers who were interested in vulnerability studies focused on understanding physical processes that create vulnerability, the spatial distribution and patterns of vulnerability, and to some extent the impacts of hazardous events (Montz and Tobin, 2011). However, in the past, little attention was paid to socially constructed vulnerability because of the difficulty of quantifying the causes of social vulnerability. Instead,

[1] According to the oral story, the community was forcibly evicted from the region to Malindi in 1912 (approximately 200 km away) and their livestock and properties confiscated. Later in 1917, they were transferred to Mwatate (approximately 70 km away) and the villagers were not granted permission by the British colonial government to return to Mt. Kasigau until 1936. This forced displacement and resettlement as suggested by the community set behind development initiatives at Mt. Kasigau, especially from missionaries, in relation to other regions in the country.

considerable attention was paid to the built environment; and social vulnerability was often described only in terms of "individual characteristics of people (e.g. age, race, health, income, type of dwelling unit, employment)" (Cutter et al., 2003: 243). More recently, geographers working in the area of vulnerability studies have started paying considerable attention to social processes by which certain environmental conditions become socially defined as a problem (Day, 2017). These geographers include sustainability factors such as social equity, economic, environmental, political, and cultural values to analyze the dynamics of social and ecological systems that make certain communities and places vulnerable to global environmental changes and anthropogenic risk. Indeed, geographers have played an important role in uncovering sustainability factors that make the coupled human and natural systems less vulnerable or more resilient to the multitude of forces (Hogan and Marandola, 2005).

This geographic research makes significant contributions both theoretically and practically to the body of knowledge in vulnerability and sustainability studies in various ways. First, this study advances the theory of vulnerability within the context of a developing nation, where lack of accurate such as socioeconomic and climate is a major limitation to vulnerability studies. Second, this study integrates the social and environmental vulnerability of the farming communities at Mt. Kasigau. Thus, the results of this study could serve as a valuable resource to students, researchers, and educators who are interested in vulnerability studies, sustainability studies, interdisciplinary studies, and human-environment interactions. In this regard, this study could play a major role in bridging the gap between socio-ecological and biophysical dimensions of vulnerability. Finally, this place-based vulnerability assessment answers the call for action from global and regional organizations such as IPCC[2] and ISDR[3] that requires the integration of local, technical, and scientific knowledge to improve the assessment and identification of vulnerabilities.

1.2.3 The Concept of Vulnerability

The concept of vulnerability can be traced back to studies on poverty and natural hazards (Fussel, 2007; Gallopin, 2006; Janssen et al., 2006). Subsequently, it has been used in a variety

[2] Intergovernmental Panel on Climate Change
[3] International Strategy for Disaster Reduction in Africa

of studies in economics, engineering, psychology, sociology, natural resource management, and anthropology (Adger, 2006; Gallopin, 2006). Scholarly communities across these disciplines use the concept of vulnerability to imply different meanings, making it difficult to clearly determine and identify its major features (Adger, 2006; Fussel, 2007; Janssen et al., 2006). In most disciplines, vulnerability has been used to portray a negative connotation (Fussel, 2007). Broadly speaking, vulnerability is defined as "the state of susceptibility to harm from exposure to stresses associated with environmental or social change and from the absence of capacity to adapt" (Adger, 2006: 268). Vulnerability also encompasses a combination of other factors that determine the degree to which humans or the natural systems are placed at risk (Adger, 2006; Eakin and Luers, 2006; Janssen et al., 2006). Thus, the concept of vulnerability is a "powerful analytical tool" used to "describe the state of exposure to harm, powerlessness, and marginality" of both physical and social systems (ibid: 268).

As it pertains to global environmental change, vulnerability has been conceptualized as a "function of exposure, sensitivity and adaptive capacity regarding a specific risk" (Adger, 2006; Birkmann, 2006; Janssen et al., 2006; Turner et al., 2003; Turner et al., 2007). Exposure is the nature or the degree to which a system(s) or elements of a system experience stress emanating from humans or the natural environment, including "frequency, magnitude, duration" of occurrence of a disaster, and "the areal extent" of the disaster (Adger, 2006: 270). Consequently, if the system components are exposed to stresses – which can be chronic or periodic, they can become vulnerable (McCarthy et al., 2001). Sensitivity refers to the degree to which humans or natural systems are affected or modified by perturbation (Gallopin, 2006). Finally, "adaptive capacity is the ability of a system" to change or "evolve in order to accommodate" societal or environmental changes so that the system can maintain or even expand its "range of variability with which it can be able to cope" (Adger, 2006: 270). In the context of humans, adaptive capacity is also the ability of people to address, plan for, or adapt to exposure (Ford and Smit, 2004).

However, it needs to be acknowledged that the body of literature on vulnerability is growing rapidly, reflecting strong development across a multitude of disciplines. At this stage, however, the literature is to some extent inconsistent. The majority of the studies in global environmental change often refer to the abovementioned definition of vulnerability, but define it

more simply "as a function of exposure, sensitivity, and adaptive capacity" (Birkmann, 2006: 42). Thus, from this point onward, this simpler definition will be used in this dissertation.

1.2.4 Aspects of Vulnerability

Literature on vulnerability highlights two major aspects: social and biophysical (Birkmann, 2006; Ford and Smit, 2004). From the biophysical standpoint, vulnerability is determined by the nature of a physical event, the frequency or likelihood of it occurring, the extent of human exposure, and the sensitivity of human to the impacts of that event (Brooks, 2003; Ford and Smit, 2004). Within the biophysical aspect, the role of humans to influence or modify these events is neglected, and focus is instead given to the event itself, its spatial distribution, frequency, magnitude, and the likelihood of the event occurring (ibid). Thus, the biophysical perspective of vulnerability treats "vulnerability as a pre-existing condition" and people are vulnerable because of their presence in a particular location that is regarded as hazardous (Cutter, 2003; Ford and Smit, 2004; Blaikie et al., 1994). The social aspect of vulnerability is primarily viewed as the product of social, cultural, political, institutional, and economic conditions that make people susceptible to harm and govern "their ability to respond" (Cutter, 2003: 243). Given this perspective, disasters or hazards are recognized not only as a result of the physical event itself, but also as a product of the economic, political, cultural, and social conditions surrounding the event (Adger and Kelly, 1999; Ford and Smit, 2004). Consequently, social vulnerability has been the primary focus in vulnerability studies that are concerned with mapping places and people who are vulnerable, and for examining variations in vulnerability among different places that might experience similar hazards or disasters (Brooks, 2003; Downing, 2003).

1.2.5 Vulnerability Assessment

What makes people vulnerable to environmental and human changes? What can we do to reduce vulnerability? How can resilient communities be built? These are some of the questions that vulnerability and risk assessment researchers ask themselves. On one hand, the answers are straightforward; e.g. poverty, diseases, resource depletion, and marginalization make people vulnerable. On the other hand, answers to some of these questions are complex because of the diversity of risks that are generated by the interplay between local and global processes (Bankoff et al., 2004). The saddest part, perhaps, is that for many people in different parts of the world, the nature and intensity of their vulnerability changes, while their ability to cope with these changes

diminishes. Hence, answering these questions requires the identification and understanding of the social, historical, cultural, economic, and environmental dimensions and drivers of vulnerability.

Vulnerability assessment is defined as the practice of identifying and ranking of vulnerability factors in a system (Li et al., 2011). Vulnerability assessment focuses on determining the factors or characteristics that are likely to cause harm, loss, or injury to people or natural systems as well as the capacity of both to resist or recover from these negative impacts, and even the ability of both to adjust (Birkmann,2006). Thus, the goal of vulnerability assessment is to prioritize needs and inform decision makers about options for adapting (Schroter et al., 2004). The process involves identifying people and places that are susceptible to natural or human-induced disasters (Nitschke and Innes, 2008) and ways to help reduce their vulnerability to disasters and minimize the impacts of disaster (Li et al., 2011). However, before vulnerability can be measured, it is necessary to identify who and what is vulnerable, and why they are vulnerable (Turner et al., 2003; Huynh and Stringer, 2018). The answers to these questions often require building a conceptual framework or model that can identify and map complex relationships among humans and their environment (Turner et al., 2003; Huynh and Stringer, 2018; Fraser et al., 2011).

1.3 Vulnerability Assessment Frameworks/Models

One major aspect of sustainability studies is to investigate the major barriers of sustainable development including not only vulnerability, but also lack of willingness to implement change, lack of understanding of the behavior of complex systems, and inadequate capacity to perform necessary actions and changes among others (Jones, 2019). This dissertation investigates just one of these barriers (i.e. vulnerability of the coupled human and natural systems at five villages in Mt. Kasigau, Kenya), taking into account the social, environmental, and economic dimensions of sustainable development because these aspects are interconnected and are an integral part of the ecological system (ibid). For example, hunger, poverty, and deforestation are linked together as are environmental, economic, and social problems. In that context, the following section examines the major features of selected conceptual frameworks and models that have been used in vulnerability research. Overall, the frameworks/models presented here provide an insight into how vulnerability and its components are conceptualized and assessed.

Within vulnerability studies, various conceptual models have been proposed to represent vulnerability and ways to decrease it (Adger, 2006; Fussel, 2007; Cutter, 2000; Cutter et al., 2008; Turner et al., 2003). These conceptual models and frameworks are diverse but have some elements that are common such as "the significance of place-based studies, assessing vulnerability from a social-ecological perception" (Letsie, 2015: 13), and the conceptualization of vulnerability as a matter of social equity (Fussel, 2005; Sarewitz et al., 2003; Cutter et al., 2000; O'Brien et al., 2004; Brooks, 2003; Cutter et al., 2008). Since "vulnerability manifests itself spatially", a geographical point of view that incorporates the particularities of a certain place is important (Letsie, 2015: 13). Thus, the different definitions and views of vulnerability have led to the development of a variety of theoretical frameworks and conceptual models. Some of the major frameworks and models are reviewed in the following section.

1.3.1 The Double Structure of Vulnerability Framework

The double structure framework of vulnerability views vulnerability from the internal and external side (Birkmann, 2006) (Figure 1). The external side of vulnerability involves exposures to environmental stress (Matthew et al., 2010) and is influenced by political economic approaches[4], human ecology perspectives[5], and the entitlement theory[6] (Bohle, 2001; Ciurean et al., 2013). Most of these factors are largely beyond the control of a particular community (Matthew et al., 2010).

[4] The political economy approach deals with issues of social inequalities and injustices that makes people struggles as well as conflicts between different social classes.
[5] The human ecology perspective deals with the dynamics in population as well as the capacity of people to manage their biophysical environment.
[6] The entitlement theory argues that people who are unable to obtain or manage their assets via legitimate economic ways have higher chances of becoming vulnerable.

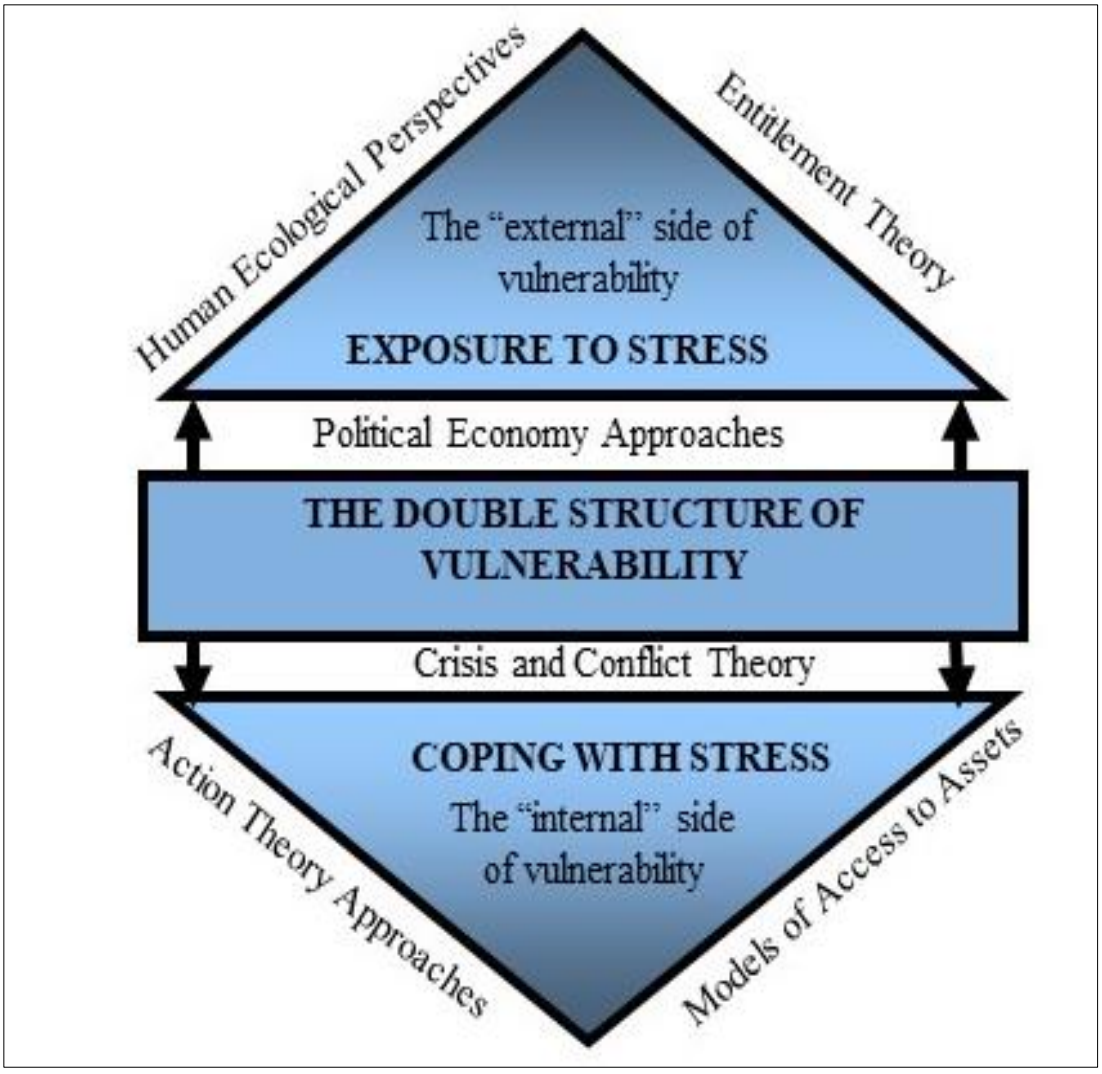

Figure 1: The Double Structure of Vulnerability Framework adapted from Bohle (2001).

The internal side, also known as coping, has been described as "the capacity of a system to cope with, anticipate, resist and recover from the impact of a disaster" (Birkmann, 2006: 42). This side is influenced by the "crisis and conflict theory[7]", "action theory approaches[8]", and "models of access to assets[9]" (Bohle, 2001; Ciurean et al., 2013: 8). In this sense, groups of individuals who control key assets cope more effectively with disasters, making them less vulnerable. Therefore, the "internal side focuses on the inner working" of a community and "community members' ability to respond to stress associated with the external side of vulnerability" (Matthew et al., 2010: 38).

Exposure to stress from the external side and the capacity to cope from the internal side together determine how communities are vulnerable (Birkmann, 2006). For instance, a "community with a high level of adaptive capacity can withstand and recovers from exposure to a relatively severe event" (Matthew et al., 2010: 38). Equally, "for a community that is already in a vulnerable state and with a limited coping capacity, exposure to a relatively modest" environmental stress may make them more vulnerable to environmental changes (ibid: 38). This conceptual framework of vulnerability thus provides explanation of vulnerability as well as its key causes (Birkmann, 2006). However, a major drawback of the double structure framework of vulnerability is that it "focuses on stressors that are largely beyond the control of a particular community" (Matthew et al., 2010: 38).

1.3.2 The Risk-Hazard (RH) Model

The RH model considers "the impact of a hazard as a function of exposure to the hazard and the dose-response (i.e., sensitivity)" (Figure 2) (Turner et al., 2003: 8075). This model portrays vulnerability as "not only registered by the exposure to stresses but also resides in the sensitivity and resilience of the system experiencing stress" (ibid.: 8075). Therefore, the sensitivity of a system is determined by human-environmental conditions such as biophysical and social "capital that influences the existing coping mechanisms" in response to a certain

[7] How control and management of "resources and assets through crisis situations can influence vulnerabilities" (Joakim, 2008: 23).
[8] How people act or react due to economical, societal, or governmental constraints.
[9] Reducing vulnerability through accessing assets.

threat, hazard, or disaster (ibid.: 8077). The RH model has mainly been used in studies that examine the effects of food insecurity and/or natural hazards on the natural environment (Eakin and Luers, 2006). Also, it has been used by engineers and economists to assess risks to certain valued elements, so-called "exposure units" (Fussel, 2007). The major aspect of the RH model is the distinction between the factors that determine the risk of a system (i.e., 'hazard' and 'vulnerability') (Fussel, 2007). Hazard is "a potentially damaging physical event, phenomenon or human activity and is characterized by its location, intensity, frequency, and probability" (ibid.: 160) whereas vulnerability denotes the "relationship between the severity of hazard and the degree of damage caused" (ibid.: 160). A major disadvantage of this model is that it does not show how the underlying conditions of the system under study "amplify or attenuate the impacts" of the threat as well as the role institutions and social structure play in shaping "differential exposure and consequences" (Turner et al., 2003: 8074). Additionally, it is always difficult to apply this model to people whose exposure depends mainly on their behaviors (Fussel, 2007).

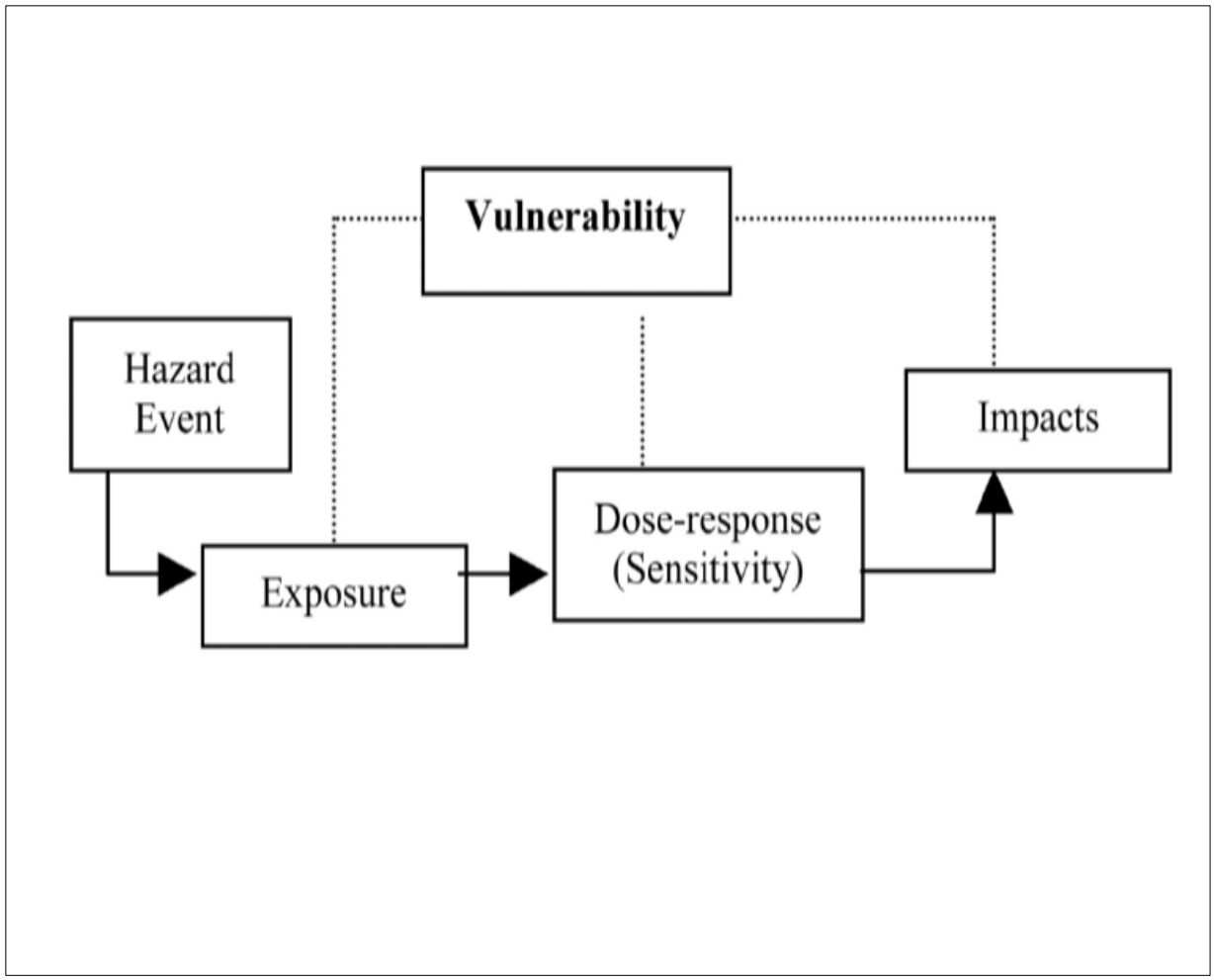

Figure 2: The Risk-Hazard Model adapted from Turner et al. (2003).

1.3.3 The Pressure and Release (PAR) Model

The Pressure and Release model was proposed by Blaikie et al. (1994) and developed further by Wisner et al. (2004). It portrays vulnerability as the "interaction between physical exposure to natural hazards" and the processes that create vulnerability in different levels within a given society (Letsie, 2015: 14-15). This model presumes that vulnerability is nested between two major processes: pressure and release (Figure 3). The pressure aspect focuses on the root causes of vulnerability (Birkmann, 2006; Tapsell et al., 2010). The release aspect focuses on relieving the pressure so as to reduce vulnerability (Birkmann, 2006; Tapsell et al., 2010). This "model takes its starting point from the risk-hazard" model and defines risk as being a product of hazard and vulnerability (Fussel, 2007; Kasperson et al., 2003). Next, it presents an explanatory model of vulnerability that involves "root causes", "dynamic pressures", and "unsafe conditions" (Letsie, 2015: 15). Thus, this model does not explicitly define the term "vulnerability", but identifies some of the root causes of vulnerability that create or increase it (e.g. demographics, economic, and political factors among others), dynamic pressures (i.e. the features of a society such as population growth), and unsafe conditions (e.g., group of people who live in areas that are marginalized) (Birkmann, 2006; Joakim, 2008; Letsie, 2015; Roberts et al., 2009; Wisner et al., 2004). Thus, a unique aspect of the PAR model is that it provides a useful method for conceptualizing the progression of vulnerability through space and time (Kuruppu and Willie, 2015). The major benefit of this model is how it highlights vulnerability "by taking into account both physical and social components" (Letsie, 2015: 15). For example, from a social perspective, the PAR model would focus "on how population growth" and unequal "access to resources increase vulnerability" of a given community (ibid: 15). The major drawback of this model is that "it does not address the coupled human-environment" systems when considering the overall vulnerability of the biophysical system (ibid: 15). Another limitation of the PAR model is that it focuses too much "on the 'pressures', or vulnerabilities, with little emphasis on the 'releases' that could increase resiliencies and overall coping capacity" (Joakim, 2008: 26).

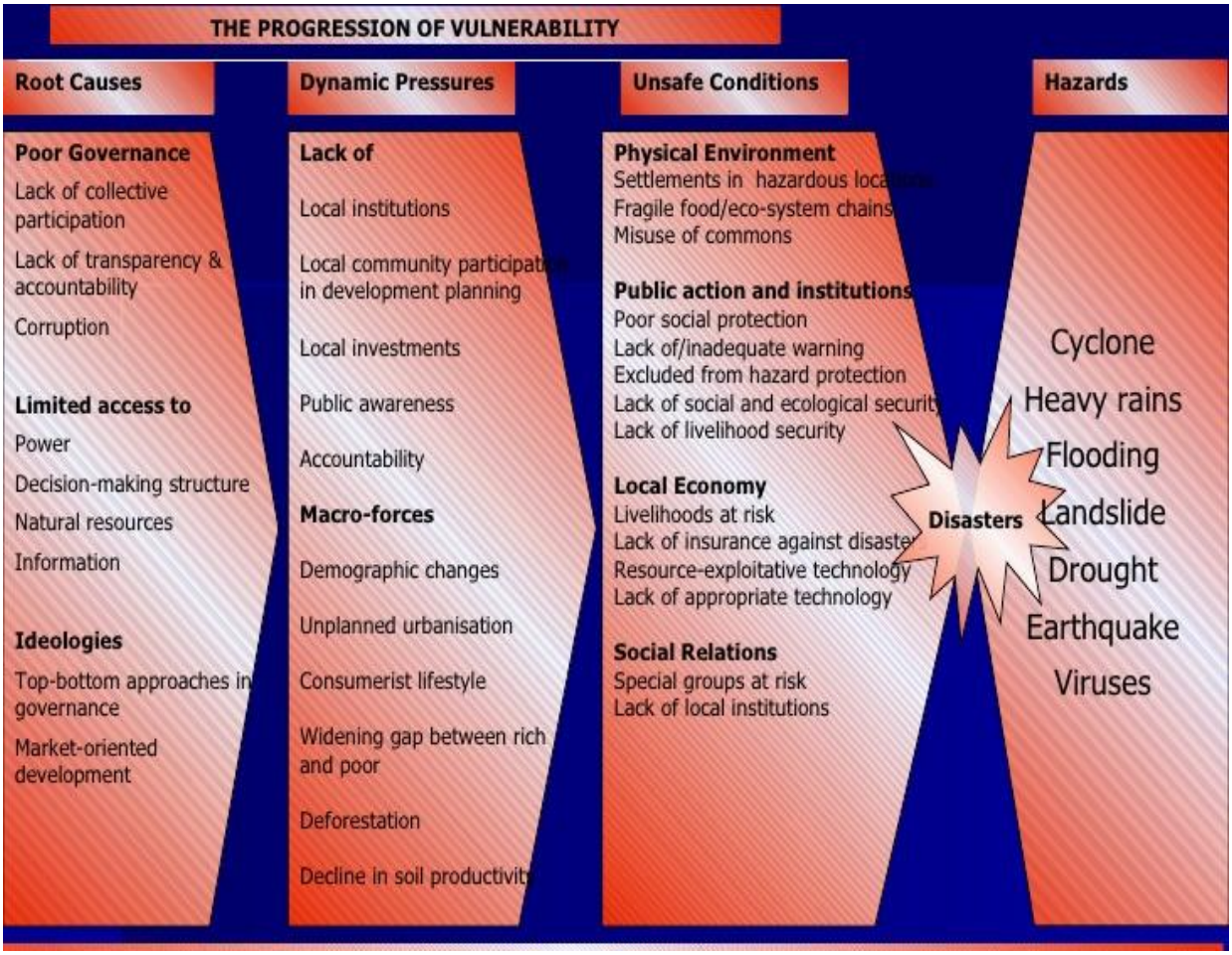

Figure 3: Pressure and Release model adapted from Wisner et al. 2004.

1.3.4 The Hazard of Place Model (HoP)

The hazard of place model was introduced by Cutter (1996). It combines the "biophysical and social components into a place-specific assessment of vulnerability" (Letsie, 2015: 15). The biophysical aspect of vulnerability deals with environmental processes that generate "hazardous conditions and suggest that vulnerability is a pre-existing condition" (Joakim, 2008: 57). The main mechanism for quantifying biophysical vulnerability is "through proximity to the hazard itself" (ibid.: 57). From the social point of view, "patterns of vulnerability" are influenced by factors such as political power, social relations, and economic development, as well as indicators such as age, race, gender, and income (ibid: 57). The integration of the biophysical and social components, therefore, creates an understanding of vulnerability that depends on the biophysical features that are specific in a certain location and the political, economic, and social processes that occur in that area (Joakim, 2008).

1.3.5 The Coupled Vulnerability Framework

This framework was developed by Turner et al. (2003) arguing for a broader conceptualization of vulnerability that considers the totality of the system. This framework directs attention to the coupling of human and environmental systems since vulnerability and sustainability of a system are based on the interaction between the human and biophysical subsystems (ibid). While developing the framework, Turner et al. (2003) noted that any vulnerability analysis, especially for studies aimed at advancing sustainability, should include the following elements: the exposure of the system "beyond the presence of a perturbation and stress"; "the sensitivity of the coupled system to the exposures"; "the system's adaptive capacity"; "the multiple interacting perturbations and stresses as well as the sequencing of them"; "the system's restructuring after the responses taken (i.e., adjustments or adaptations)"; and "the nested scales and scalar dynamics of hazards, coupled systems, and their responses" (8075). Thus, this framework is based on the notion that the vulnerability of a system resides in the conditions and processes that operate in a coupled human-environmental system, including exposure, sensitivity to the exposures, and the adaptive capacity of a system. Additionally, the coupled vulnerability approach links vulnerability across geographic dimensions from place, to region, to the globe (ibid).

1.4 Evaluation of the Model

The discussion of different conceptual frameworks and models in the preceding section has revealed that different research fields have developed a variety of theoretical frameworks and conceptual models to assess vulnerability. Hence, this section provides a summary of the frameworks/models and a theoretical rationale for the model selected for this research. Such frameworks/models are important because they represent the conceptual and theoretical ideas on how to frame problems and how to characterize vulnerability. Given the large number of theoretical frameworks and conceptual models, it is important to acknowledge that each framework/model characterizes vulnerability very differently as summarized in Table 1. For example, the coupled vulnerability framework by Turner et al. (2003) emphasizes the idea of human-environmental systems. The PAR highlights the significance of root causes, dynamic pressures, and unsafe conditions (i.e. the progression of vulnerability). The double structure of vulnerability developed by Bohle (2001) has strong linkages to different theories and also shows the points of entry for these theories. Finally, the hazard of place model is “inherently more geographically centered" (Joakim, 2008: 34).

Table 1: Models of Vulnerability

Model	Characteristics	Strengths	Weaknesses
The Double Structure of Vulnerability	• Vulnerability has an external (and internal side.	• Takes into account coping and response capacity of a system.	• Focuses on the environmental factors that are sometimes beyond the control of a given community
The (RH) Model	• Considers vulnerability as a function of a system exposure and its sensitivity to the exposures.	• Gives a clear distinction between elements that determine the risk of system.	• Hard to apply to communities or people whose exposure to various type of hazards is mainly depended on their behavior. • Does not clearly differential between exposure and sensitivity.
The PAR Model	• Tracks progression of vulnerability.	• Provides a suitable method for conceptualizing the progression of vulnerability across space and time.	• Doesn't factor the coupled human-environment system. • Places most of it emphasis on national and global levels, but some unsafe conditions are caused by local processes.
Hazards-of place Model	• Regards vulnerability as place-based and context-based.	• It combines social and biophysical components of vulnerability into place-based assessment.	• Does not account for the root causes of social vulnerability.
The Coupled Vulnerability Framework	• It places the human-environmental system at the center analysis.	• It factors for adaptation, which is seen as an aspect that increase resiliency.	• No clear differentiation between the impacts to a system and its adaptive capacity.

1.5 Choice of the Model

Since the aim of this research was to assess the vulnerability of the social-ecological systems at five villages in Mt. Kasigau, Kenya, I was interested in a model that would combine social and biophysical components of vulnerability. This means that the framework/model had to clearly identify the social-ecological system as a unit of analysis as well as identify and define the major components of vulnerability. It was critical to define those components of vulnerability in the vulnerability framework/model due to the diverse definition of vulnerability (Wu et al., 2002). Since vulnerability of any given system is a product of multiple perturbations and stresses that arise from social and natural systems (Damm, 2010), I needed to select a model/framework that considers multiple perturbations, because both "internal and external stresses can put pressure" on a social-ecological system (ibid: 35). Social-ecological systems "are subject to influences that operate" and interact temporally and "spatially across a range of nested scales and levels" (ibid: 35). Therefore, it would not have been sufficient to adapt a model that centers on a single place of analysis, but to select a model that can examine the factors and drivers of vulnerability beyond the place of analysis.

For those reasons the coupled vulnerability framework developed by Turner et al. (2003) was adapted for this study because it meets the needs mentioned above. First, this model directs its attention to the interacting parts of the coupled human environmental system and helps in identifying gaps and information that are relevant for reducing vulnerability in the system as a whole (ibid). Second, this framework clearly defines the main components of vulnerability (i.e. exposure, sensitivity, and adaptive capacity) in the coupled human and environmental system. Third, this framework illuminates the nested scales of vulnerability while also providing an understanding of the vulnerability of a particular place. Fourth, this "framework places the coupled human-environmental system at the center of the vulnerability analysis" (Birkmann, 2006: 41). Fifth, the "framework takes into account the interaction of multiple perturbations and stressors" (ibid: 49). Finally, unlike other models/frameworks, the coupled vulnerability framework "accounts for adaptation, which is viewed as an element that increases resilience" (ibid: 49).

1.6 Justification of the Study

Mt. Kasigau is a region within the Eastern Arc Ecoregion, which is a chain of isolated mountainous forests that runs from Northeast Tanzania to Southeast Kenya (Kalibo and Medley,

2007; Medley and Kalibo, 2005). The region is recognized as a biodiversity hotspot by the International Union for Conservation of Nature (IUCN) and the World Wildlife for Nature (WWF) due to its high number of endemic species, high species richness, and high degree of fragmentation (Burgess et al., 2007; Myers et al., 2000; Newmark, 2002). As a biodiversity hotspot, the region is designated for priority conservation because it harbors greater concentration of biodiversity than other regions of the world (Myers et al., 2000).

The productivity and sustainability of the region depend on how resources are managed and used over time. As an area inhabited by a farming community, the region is under constant threat (Gathongo, 2012). The residents' inability to rely entirely on their farms has forced some of the community members to resort to other modes of survival such as sand harvesting, charcoal burning, expanding farmland towards the dryland forest, gemstone mining, illegal hunting, all of which threaten the natural environment (Gathongo, 2012). Specifically, the expansion of farmlands and settlements within the community trust lands and along the corridor that links Tsavo West and East National Park threatens the dryland flora and fauna, especially the endangered and vulnerable wildlife such as the African hunting dog, the African elephant, lion, Colobus monkeys, cheetah, and the Grevy's zebra (Mulwa et al., 2007). Thus, a vulnerability assessment of the human and natural systems in this area is an important process for identifying the causes and consequences of vulnerability, discerning which village is more vulnerable, and devising ways of reducing vulnerability.

1.7 Description of the Study Area/Villages

Mt. Kasigau is located in Taita-Taveta County at the Coastal Province of Kenya. According to the Government of Kenya's (2009) National Bureau of Statistics, the population of the area was approximately 9,721 people in 1,803 households. The five villages that surround the mountain are Makwasinyi, Kiteghe, Bungule, Jora, and Rukanga (Figure 4). These villages fall under two administrative sub-locations (i.e., Rukanga and Makwasinyi). Makwasinyi sub-location has an area of 415.2 km^2 and includes Makwasinyi, Kiteghe, and Kisimenyi (not included in the study) villages (Government of Kenya, 2009). The Rukanga sub-location includes Jora, Rukanga, and Bungule villages and has an area of 1,106.5km^2 (ibid).

There are two rainy seasons in the region. A short rainy season that begins in October and lasts to December and a long rainy season that begins in March and lasts to late June. However, at higher elevations, rain is a common occurrence due to the 'cloud forest' located at the peak of

the mountain (Kalibo and Medley, 2007). Thus, water trapped from the cloud forest, feed the rivers that flows down to these villages, sustaining the villagers who would otherwise be deprived of water for the most of the year. In all five villages, with the exception of Jora village, water from the cloud forest is trapped behind large dams that drain into big water tanks and later on is sold to the community from water kiosks.

The residents of the five villages share similar cultural virtues, values, and beliefs in addition of being from the same tribe. However, there are other tribes in these villages due to pastoral activities (i.e. Kamba and Somali tribes). Politically, these villages are governed by one member of parliament and one member of the County Assembly[10] (MCA), although, within each village, they have their own village elders who don't wield 'real' power.

Economically, the people of Kasigau are primarily farmers who grow crops in both communal and private lands. Crops grown include beans, cassava, maize, pigeon peas, and lentils. They also raise livestock such as goats and cows in community ranches. There are basket weaving associations in each village formed by women groups. The women's groups sell these baskets to tourists to supplement their income. As mainly a subsistence farming community, where all share similar economic, cultural, historical, and social backgrounds residents' livelihoods are vulnerable to environmental and societal changes.

[10] The Member of County Assembly is an elected leader whose role is legislation, representation and oversight of the County government. The MCA present people's views, opinions, and proposals before the county assembly.

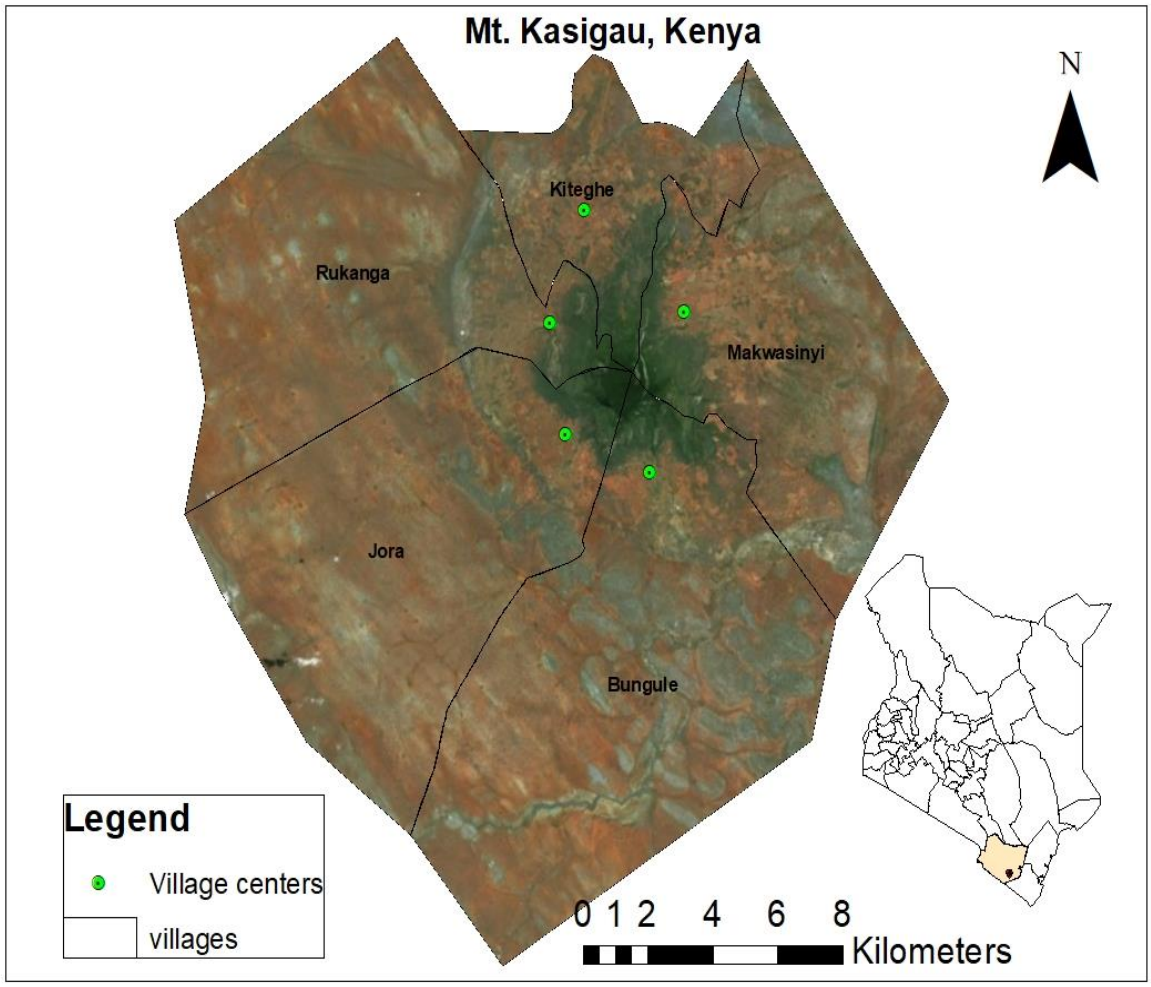

Figure 4: Location of the Study Villages

1.8 Research Objectives

The overall goal of this research was to examine the vulnerability of human and natural systems at five villages in Mt. Kasigau, Kenya. Specifically, I examined the vulnerability of Kiteghe, Makwasinyi, Jora, Bungule, and Rukanga villages, by emphasizing how human-environment interactions are continuously shaping and changing the vulnerability of people and the natural environment. These five villages are the only villages in the region directly adjacent to the mountain. Additionally, because of my earlier work in two of the study villages (Jora and Makwasinyi), I was able to gain an entry into the other three villages.

To address this goal, I used decision-making science, specifically the Analytical Hierarchy Process (AHP) to develop a model for assessing the vulnerability of the human and natural systems. I adapted Turner et al. (2003) vulnerability conceptual framework, which conceptualizes vulnerability into three major components: *exposure*, *sensitivity*, and *adaptive capacity*. I utilized GIS, remote sensing, and spatial landscape analysis to collect data for examining the vulnerability of the natural system. I used semi-structured interviews, focus group discussions, observation, and impact tree diagrams to collect data for assessing the vulnerability of the social or human systems. Finally, I developed a model using the AHP for the residents of these villages to evaluate and prioritize alternatives for reducing their own vulnerability. Thus, the specific objectives of this research are:

1. To assess the vulnerability of the human system,
2. To assess the vulnerability of the natural system, and
3. To assist the community in, evaluating and prioritizing different options for reducing vulnerability.

1.9 Significance of Research

The assessment of vulnerability of the human and environmental systems requires analyzing and documenting threats that systems are exposed to, their sensitivity, and adaptive options that are employed by the systems to address these threats. This research assessed the vulnerability of human and environmental systems and assisted the community at Mt. Kasigau, Kenya evaluate different options for reducing vulnerability. This was significant to understand how and why the residents and their environment were vulnerable, and which place was most vulnerable. Results obtained from the vulnerability assessment of the villages in this study can be

used to identify villages that should be given the highest priority in terms of allocating resources for reducing vulnerability.

This study integrated knowledge from the community and examined their preferences. By integrating traditional and local knowledge of the community members, this study promoted collaborative learning between the researcher and the researched (i.e. community). The researcher gained knowledge through various ethnographic techniques such as semi-structured interviews, focus group discussion, and participant observations. On the other hand, the community learned various mechanism of using decision-making science to examine their preferences, and they were empowered to solve their own problems. Simply put, when community members work together sharing experiences or exchanging ideas they engage in collaborative learning. In this study, during the focus group discussions, residents worked together searching for the causes of social vulnerability and options for reducing vulnerability as well as making decisions using the AHP model. By doing so, they were able to learn from their peers and broaden their knowledge. This form of collaborative learning was important because the active exchange of ideas and opinions within the focus groups not only increased their interest, but also promoted their critical thinking skills on analyzing complex issues. In light of this and from my own personal opinion, the best way to tell if collaborative learning occurred during these discussions was to listen and observe the participants as they generated a dynamic interchange of thoughts through shared inquiry. For example, when different people were responding to the same material, their questions and comments contributed to deeper learning.

Finally, in this study, two different frameworks for assessing vulnerability and one model for assisting residents to make decisions for reducing their vulnerability were developed. These frameworks and model were simple, understandable and have real-world application since they can be transferred to other villages, used by the local policymakers, non-governmental organizations, or communities themselves to examine vulnerability and plan various mitigation measures. In conclusion, by developing an integrated method of examining vulnerability and using it to study the vulnerability of human and natural systems, this research contributes to the field of human-nature interaction and vulnerability science.

1.10 Organization of Dissertation

This dissertation is divided into six chapters. In Chapter 1, I provide a general background and impetus for this study. Chapter 2 provides a comprehensive explanation of the

research methods that were used in this research. Given the three article format that has been adapted in this dissertation, Chapter 2 paints a clear picture of the field research methods that were used in this dissertation. Therefore, Chapter 2 provides me an opportunity to be specific about the literature of each method. Due to the word limits in publishable articles, the literature review on the research methods in Chapter 3,4, and 5 has been condensed. Therefore, the first publishable paper is Chapter 3. Accordingly, Chapter 3 assesses the social vulnerability of the five villages in Mt. Kasigau, Kenya using the analytical hierarchy process. In this article, I utilized observation, focus group discussions, and semi-structured interviews to assess how the residents of the five villages are vulnerable to societal and environmental changes. Chapter 4 examines the vulnerability of natural systems using the analytical hierarchy process. This chapter uses GIS, remote sensing, and spatial landscape analysis to examine the vulnerability of the natural systems. In Chapter 5, I focus on developing a framework to help the residents at Mt. Kasigau evaluate different options for reducing vulnerability. Lastly, Chapter 6 provides a summary of the findings of Chapter 3 to 5, highlights the policy implication and limitations of the study, explains how this research contributes to the field of geography and discusses the major contributions of this dissertation and future research direction.

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CHAPTER II
RESEARCH METHODS

2.1 Introduction

The research for this dissertation is based on fieldwork which was conducted in two phases (mid-June to mid-July 2015 and mid-June to mid- July 2018). The first phase was to assess the vulnerability of the human systems and collect supplementary information on the vulnerability of the natural systems. The purpose of the second phase was to help the community to evaluate and prioritize different options for reducing vulnerability and aid them in the decision-making process. In both phases, I lived with the community in order to gain first-hand and comprehensive understanding of the human system's vulnerability. The objectives and methods/strategies used during the two phases of this research are listed in Table 2.

Due to the nature of this study, I selected qualitative methods over quantitative methods, because social issues and people's views or perceptions are not easily quantifiable (Philip, 1998; Rich and Ginsburg, 1999; Ritchie et al., 2013). Furthermore, as Qu and Dumay (2011) explicitly state, qualitative methods are useful in providing a rich description of a phenomenon as well as enhancing our understanding of the context of a particular social process. Because of this, human geographers are more likely than physical geographers to be "concerned with elucidating human environments and human experiences within a variety of conceptual frameworks" (Winchester and Rofe, 2010: 5). By using qualitative methods to study social structures, social scientists are able to answer questions about human experience, meaning, and perspectives, most often from the standpoint of the participants (Hammarberg et al., 2016).

Human geographers and other social scientists use qualitative methods to study how a multitude of factors such as culture, human experiences, and beliefs interact to form people's perspectives and guide social processes (Rich and Ginsburg, 1999; Berkwits and Inui, 1998). These methods have been utilized to reach in-depth understandings of particular groups or phenomena under investigation (Philips, 1998). As Winchester and Rofe (2010) argue, qualitative methods are used "to verify, analyze, interpret, and understand human behavior of all types" (21). For that reason, in this particular research, I used qualitative methods to explore *how* and *why* the communities at the study villages were vulnerable and how they could reduce their own vulnerability. Specifically, I employed observation, focus-group discussions, and semi-structured interviews. By utilizing this multi-method approach it was possible to address the gaps and weakness of any one of these methods by itself (Humphrey and Lee, 2004; McHendrick, 1999).

Table 2: Objectives of the fieldwork and the methods used to realize each objective.

Objectives	**Method/strategies**
Phase 1	
• To gain access to informants. • To learn about some of the major causes of vulnerability in each village.	Informal conversation
• To discover and document evidence of vulnerability in each village.	Observation
• To determine the major threats that faced each of these villages. • To identify the direct and indirect causes of these threats. • To connect the direct and indirect causes of these threats by drawing an impact tree diagram for each village.	Focus group discussions
• To assess the impact tree diagrams and determine if there were some threats or direct and indirect causes of them that had not been identified during the focus group discussions.	Semi-structured interviews
Phase 2	
• To identify different options for reducing vulnerability based on the threats that were identified during phase 1. • To facilitate the decision making process (i.e., pairwise comparisons of different elements that were contained in the Analytical Hierarchy Process).	Focus group discussions

I begin by providing a brief background on how each of the qualitative research methods was used and connected to the objectives of this study. Finally, I will explain how data acquired by these methods were analyzed and how I ensured rigor in this research. At the end of this chapter, I will highlight how the data used in assessing the vulnerability of the natural system was processed.

2.2 Methods

2.2.1 Informal Conversation

I began my fieldwork by contacting a local field assistant who lives in Jora village. The local field assistant knows a lot people in these villages and had assisted me during my master's fieldwork. During the two phases of this research, the local field assistant accompanied me and served as the point of contact before, during, and after the fieldwork. After a brief conversation with the local field assistant explaining the purpose of my research, I embarked on a familiarization tour and held several informal conversations with the *gatekeepers* of the community. According to Lawton (2014) "gatekeepers are those who have the power" to grant or withhold access to people required for the purposes of research (252). To obtain access to informants, I visited the chief of the location, sub-chiefs, local elders, and other government and non-governmental officials and informed them about my research and the need to engage the residents of the five villages in the research. Because of the informal nature of these conversations, it was impossible to tape record them, but I jotted some notes that were useful in the next stage of the process. For instance, local elders informed me about problems facing the residents of their villages (e.g., lack of jobs); non-governmental officials briefed me on issues they were tackling (e.g., improving educational standards); and sub-chiefs provided insights on social problems existing in their communities (e.g., alcoholism). This information was useful during the observation process because I was able to see how the residents of each village were vulnerable.

2.2.2 Observation

Observation involves "the systematic noting and recording of events, behaviors, and artifacts (objects) in the social setting chosen for study" (Marshall and Rossman, 2006: 98). In this research, I used unstructured observation to study the context of social vulnerability at each village. This is a form of observation where a researcher enters the field having some ideas on what might is salient, but no preconception of what might be observed (Given, 2008; Mulhall,

2003). The advantage of using unstructured observation is that it "is not controlled in the sense of being restricted to" what a researcher should observe (Kearns, 2010: 243). Additionally, in unstructured observation, a researcher may have "some ideas as to what to observe, but these may change over time as they gather data and gain experience in the particular setting" (Mulhall, 2003: 307). Although observation refers literally to that which is seen, it may also involve more than just seeing (Kearns, 2010). It may also include "listening, smelling, touching, as well as interviewing which is a critical aspect that has been utilized by human geographers" (Kearns, 2010: 241). In light of this, the observational process used in this study involved seeing *what* is vulnerable, and *how* the community was vulnerable as well as listening on *why* the community is vulnerable.

In this research, observation was used for contextual understanding of vulnerability and to complement other qualitative methods. As Kearns (2010) suggests, to achieve this contextual understanding, a researcher should insert themselves to the "socio-temporal context of interest and use first-hand observation as the prime source of data" (242). For that purpose, I traversed the five villages visiting farms, homesteads, grazing areas, mining ground, and community centers to get a visual experience of how the community was vulnerable. In each village, I spent a maximum of five hours walking and talking to the residents. Using this strategy, I saw and recorded evidence of social vulnerability such as poor living conditions, poor sanitation facilities, poor road infrastructure, under-equipped schools, women walking long distance to fetch firewood, and dilapidated houses, among others. This information helped me to design questions during the focus group sessions. Additionally, observation was used to collect supplementary evidence that would add value to other methods (Humphrey and Lee, 2004; Kearns, 2010). Arguably, through observation, I was able to develop a more comprehensive understanding of the social vulnerability in these villages.

Selection of Participants

Participant selection is the process of selecting individuals to be included in the study (Etikan et al., 2016). Generally speaking, informants are selected on the basis of their expertise on the subject matter (Cameron, 2010). As Bradshaw and Stratford (2010) suggest, participants that are to be included in a qualitative research must be selected with care and discernment, and their inclusions must be relevant to the research question. In this research, a total of 78 participants (Table 3) were selected using purposeful, snowball, and criterion sampling

techniques. On one hand, Baxter (2010) describes purposeful sampling as a strategy of finding participants who are rich in information related to the phenomenon of interest, whereas the criteria sampling technique consists of selecting participants who meet some predetermined criteria (e.g. age, income level etc.) (Baxter, 2010; Palinkas et al., 2015). On the other hand, snowball sampling is a technique whereby one person refers the researcher to others for recruitment (Suri, 2011). Using these strategies, I recruited only participants who were elders, born and raised in the area, and had ample knowledge of their respective villages. These participants were recruited because they had rich historical information about the human society and natural environment in these villages. This set of conditions ensured that the information collected from the participants was credible and insightful. I also employed snowball sampling techniques to recruit other participants particularly for the semi-structured interviews. Thus, the initial informants identified in each village with the assistance of the field resource person were used to recruit other participants.

Table 3: List of participants involved in the focus group and semi structured interviews.

Village	**Number of informants who participated in the focus group**			**Number of informants who participated in the semi-structured interviews**		
	Male	Female	Total	Male	Female	Total
Jora	9	2	11	0	4	4
Makwasinyi	9	0	9	1	4	5
Bungule	8	4	12	0	3	3
Kiteghe	10	3	13	2	3	5
Rukanga	9	4	13	1	2	3
Total	35	13	58	4	16	20

2.2.3 Focus Group Discussion Sessions

Focus groups are a form of group interviews that is interactive and "provides an opportunity for participants to explore different point of view" of a certain issue. (Kitzinger, 1994: 113). Focus group discussions involve a small group of people discussing an issue that the researcher has defined (Cameron, 2010). The interactive aspect of focus groups is that it provides an opportunity for participants to explore, formulate, as well as reconsider their own ideas and understanding about a certain issue together (Cameron, 2010; Kitzinger, 1994). Indeed, human geographers use focus groups because data generated in these groups are usually deeper and richer compared to data obtained on a one-on-one situation (Lederman, 1990). Also, focus group are important because they probe not only what participants "think but also how they think and why they think it" (Kitzinger, 1994). This was important because this research was exploring how and why these villages were vulnerable and the causes of social vulnerability. Given this research goal, the following objectives were pursued in the focus group discussions during first phase of this research: to determine (1) what the residents of each village saw as the major threats to their villages, and (2) what they viewed as the direct and indirect causes of these threats. During the second phase, the objectives that were pursued involved: (1) Asking participants to identify different options for reducing vulnerability, and (2) engaging them in the decision-making process.

The composition and size of a focus group is important because both can impact the quality of data (Cameron, 2010). Too few participants can limit the discussion, while too many participants can restrict the time allocated for each individual, and larger groups are harder to facilitate (ibid). Despite the widespread use of focus groups, there is no "correct" size for any group (Morgan, 1995). However, according to Guest et al. (2017) the ideal group size is four to twelve participants. When deciding the size, researchers should consider other factors such as the purpose of the research, the sensitivity of the topic, the complexity of the topic, the skills of the facilitator, and the needs and expectation of the group members (Tang and Davis, 1995). In order to fully harness the power of focus groups, as suggested by Gill et al. (2008) "it is better to slightly over-recruit for a focus group and potentially manage a slightly larger group, than under-recruit and risk having to cancel the session or having an unsatisfactory discussion" (293). As Fern (1982) highlights in research meant to examine the effect of moderating focus group discussions involving four and eight members respectively, an eight-member focus group

generated significantly more ideas than a four-member group. Thus, I used that logic to set the lower and upper threshold on the number of people in each focus group with the belief that more ideas would be generated by seven to fifteen participants. Therefore, the decision on the number of participants was based upon prior studies and research exploring specifically the question of ideal numbers of participants (Morgan, 1995).

In this research, my plans were to engage the participants into an in-depth discussion exploring how and why the community was vulnerable as well as develop impact tree diagrams that visualized the direct and indirect causes of social vulnerability (phase 1). For that purpose, I recruited 20 participants in each village, but approximately seven to fifteen participants per village showed up for the discussions. In my personal opinion, that size was appropriate for the study because having with fewer participants might have limited the interactive aspects of the focus groups, resulting in less information being collected.

In the first phase of this research, five focus group discussions (one per village) were conducted during the 3rd and 4th week of June 2015. A similar number of focus group discussions were organized in the 4th and 1st weeks of June and July 2018 in the second phase. Only participants who got involved in the first phase were invited for the second phase although some of the informants were unavailable. The focus group discussions were conducted in two phases for the following reasons: (1) to examine how and why the villages were vulnerable and (2) to engage the participants in identifying various alternatives that would reduce their vulnerability as well as involve them in the decision-making process (i.e. conducting pairwise comparisons of different elements in the AHP model that was developed by the researcher).

There were nine men and two women who participated in the first focus group session. All of the women identified themselves as housewives, three of the men were traders, five were farmers, and one was a primary school teacher. In the second focus group session, nine men participated. Six were farmers and one was an agricultural extension officer, while the other two identified themselves as a businessman and a barber respectively. During the third focus group discussion session, only eight men and four women participated. Two of the women were farmers, and the rest a hairdresser and housewife respectively. Out of the eight men, six were farmers and the other two a miner and a motorbike operator respectively. In the fourth focus group discussion, ten men and three women attended the sessions. The three women were a housewife, teacher, and farmer. Out of the ten men, eight were farmers and the rest businessmen.

Lastly, I gathered nine men and four women participants in the fifth session. Five of the men were farmers, two were businessmen, one a driver, and the remaining a night guard. All the four women recognized themselves as farmers. In recruiting the participants, the aim was to have a mixed gender group; however, due to the patriarchy social system within the community and country at large, few women participated in the focus group.

During the fieldwork, I relied on the use of Kiswahili, the national language of the Republic of Kenya and a language that I speak and write fluently. Moreover, all the participants were conversant with it. However, in some instances, conversations were translated from Kitaita to Kiswahili and vice-versa by the field assistant or the participants themselves. The translations involved Kiswahili words that some participants were unable to understand or Kitaita words used by the participants. Kitaita is a native language that is widely spoken in the region, and all the participants were conversant in the language. Hence, some participants felt conformable conveying information in Kitaita even though they knew how to speak Swahili. A major drawback of using translators in the field, especially in research that involves face-to-face interaction, is that the translator can be faced with an astounding array of possible word combinations that they could use to convey the nuances of particular expressions (Temple and Edwards, 2002). Thus, the translator may fail to capture the precise feelings and values that were intended by the participant. Another major drawback of using translators is that no translator has the time to "think through a completely accurate translation of the informant's words and, at the same time, maintain a natural, free-flowing interview" (Phillips, 1959: 188). As a fluent speaker of the Swahili language this researcher avoided such limitation. Each group discussion lasted approximately 3-4 hours and took place in different public venues (i.e., schools and community centers). The venues were identified by the group members of each village as neutral environments and centrally located. As Cameron (2010: 161) highlights, "focus groups are best held in an informal setting that is easily accessible to all participants", and the best locations are local community centers, schools, churches and libraries.

Conducting the Focus Group

At the start of each discussion, I introduced myself, explained the purpose of the research, and stipulated the expectations from the participants. Next, I asked for consent from the participants and stressed that their participation was voluntary any member could leave at any time, and any information they shared would never identify their village or them as individuals.

Fortunately, all the participants in each focus group discussion sessions consented. Next, I asked their permission to audio record the conversation. As Cameron (2010) highlights, recording is important since the presentation of results obtained via focus groups includes direct quotes that are used to illustrate key points. Additionally, focus groups involve plenty of discussions, and without a recording, it would be impossible to recall every detail of discussion. In light of this, I used a high quality android app known as "sound recorder" to record the conversation, while my local field assistant acted as a note-taker of the key points that were being discussed by the participants.

Being the facilitator of the sessions, I opened up the discussions by asking open ended questions. These questions were based on what I had observed in each village, in addition to the information that I had been provided during the informal conversation. Some of the questions that opened discussion during the first phase included

1. *Can you give me an example of threat that is facing this village?* – highlighting different threats.
2. *Thinking of this threat, does anyone have an idea on what causes it?* – follow up question to identify direct and indirect causes of social vulnerability.

During the second phase, some of the questions that opened the discussions included

1. *There are various problems in this villages, such as poverty, hunger, deforestations, human-wildlife conflicts etc. Does anyone have an idea on how they can be solved?* – to propose different options for reducing vulnerability.
2. *In your own opinion, between these two elements with respect to the above element, which element is important and by how much*? – when conducting pairwise comparisons using a scale of 1 to 9.

Before opening the floor to the participants, I clarified the type of information I was interested in by giving an example of some threats that I had observed in each village (e.g., lack of sanitation facilities, poverty, lack of access to clean water, and poor road infrastructure). From this point onwards, participants engaged in an in-depth conversation, responding to the questions, asking each other questions, and agreeing and disagreeing with each other. As the moderator of the sessions, I allowed participants to say as much as they wanted as I maintained a neutral position at all times. Throughout these discussions, I asked follow-up questions to elaborate and clarify issues. Moreover, I kept the discussion on track and encouraged quiet

participants to contribute to the discussions. To encourage a quiet person, as suggested by Cameron (2010), I would directly ask the person if they had something to contribute to the discussion or nod to them when they were speaking. As Cameron (2010) highlights, human geographers can use non-verbal signs such as nodding or pointing to a person who is ready to contribute in order to curb talkative participants. Using this strategy, I was able to curb talkative participants and giving others a chance to air their views. Additionally, I ensured that each member would contribute to the discussions by pointing at them or asking them a question whenever I felt someone had not spoken or had been quiet for too long.

Taking into account that I conducted this research in two phases, I facilitated the participants in developing impact tree diagrams that visualized the spatial context of social vulnerability across scale in the first phase as highlighted in Figure 5. The impact tree diagrams were used as a way to visually represent the different causes of threats in a hierarchical structure from direct to indirect causes.

As the facilitator of these sessions, I used felt pens and large pieces of manila papers to list all the types of threats that were identified by the participants (Figure 6). Each threat listed was further broken down into two or more branches depending on the causes of the threat. This process was repeated until all the possible direct and indirect causes of the threats had been identified (from the village to the national level). This resulted in an impact tree diagram, as discussed in section 2.2.4. In the second phase of this research, focus groups were used to obtain an in-depth understanding of the participants' opinions regarding options for reducing vulnerability as well as to involve them in the decision making process (i.e. making pairwise comparisons of the AHP model). Thus, in the second phase, I conducted the focus group discussions sessions while using my laptop which contained the AHP model that I had constructed using the *Superdecision* software to incorporate all the vulnerability reductions options that were identified by the residents of each village into the AHP model. Further explanation on the pairwise comparisons can be found in Chapter 4 of this dissertation.

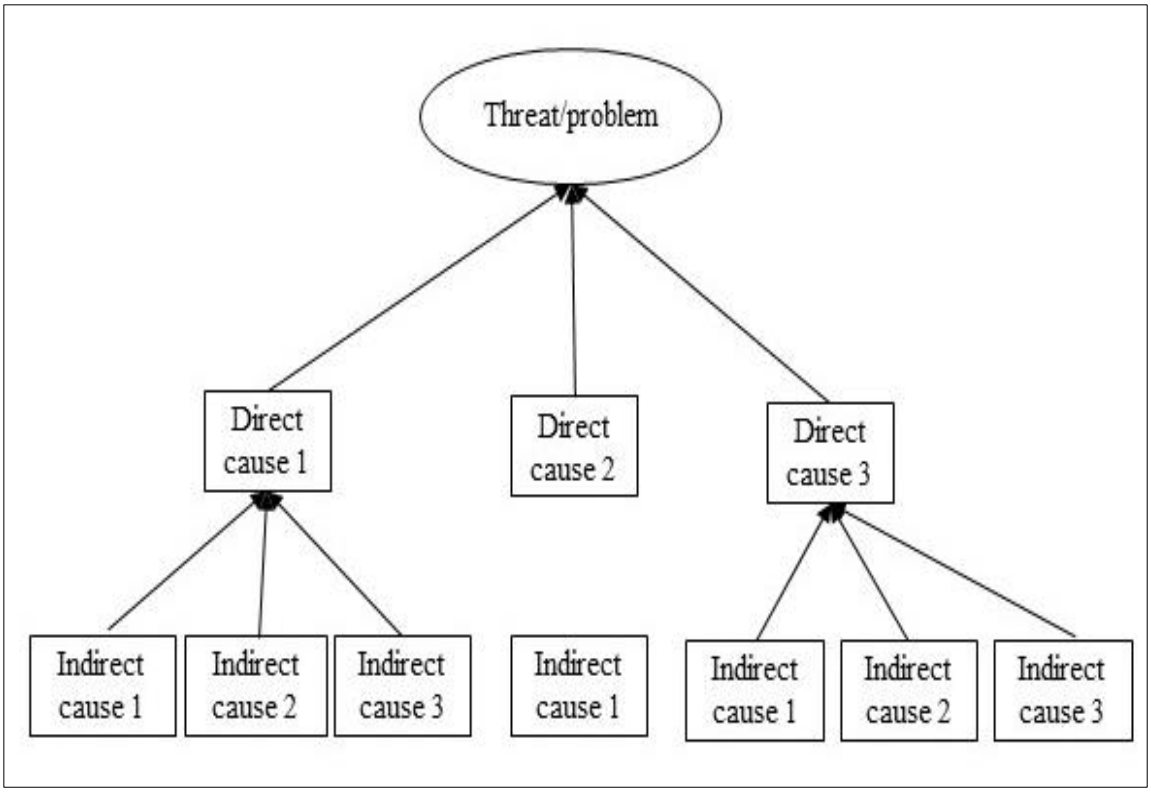

Figure 5: An example of an Impact Tree Diagram that highlights one single threat, the direct and indirect causes of that threat.

Figure 6: Researcher drawing the impact tree diagram during one of the focus group discussion sessions.

2.2.4 The Impact Tree Diagram

An impact tree diagram is a tool that can be used to identify, record, and visually represent all the possible causes of a problem hierarchically from direct and indirect causes to potential impacts (Williams, 2009; Knutson et al., 1998). In this study, the impact tree diagrams were products developed by the participants during the focus group discussions in each village (see appendix 1). During these sessions as explained in the preceding section, participants identified various types of threats as well as the direct and indirect causes of these threats. Again, I acted as a facilitator and drew the impact tree diagrams in each session. For each possible threat that was identified, I followed up by posing the question, what were the causes of that threat? Once the participants identified the causes, I posed another question, what were the causes of the previously identified cause? Thus, each cause identified was turned into a subject and further broken down into indirect causes. This process was repeated several times until the participants had exhausted all the potential causes (direct and indirect) of various types threats they had identified. For example, if the residents had identified hunger as a threat, I followed up by asking them what directly caused hunger in their village. The answers they gave became the direct causes of this threat. If they said poor farming methods and inadequate rainfall, I would again ask them what the causes of low precipitation and poor farming techniques were. Their answers became the indirect causes of these threats. At the end of the exercise, impact tree diagrams that contained multiple branches of direct and indirect causes were produced in each village visualizing the spatial context of social vulnerability across scale (from village to national level). These impact tree diagrams became the foundation for the analysis.

2.2.5 Semi Structured Interviews

Interviews are the most common qualitative methods used by human geographers because they are "an excellent method of gaining access to information about events, opinions, and experience" (Dunn, 2010: 102). Interviewing allows researchers to produce information that is rich and varied in an informal setting (Kitchin and Tate, 2000). As Longhurst (2010) acknowledges, semi-structured interviews are important in eliciting the views of people and their description of a phenomenon. They also have the benefit of uncovering issues that might not have been anticipated by a researcher. Human geographers and other social scientists recognizes the legitimacy of many different interviewing techniques, such as structured interviews, semi-structured interviews, and structured interviews (Kitchin and Tate, 2000). In this research, the

technique used was the semi-structured interviews. The strength of semi-structured interviews is that "it allows depth to be achieved by providing the opportunity on the part of the interviewer to probe and expand the interviewee's responses" (Rubin and Rubin, 2011: 88). Additionally, this style of interviewing allows a researcher to ask questions not anticipated before the interview (Kitzinger, 1994).

As Dunn (2010) highlights, semi-structured interviews can be used to 1) "to fill a gap in knowledge" that other method are unable to bridge efficaciously and 2) "to collect a diversity of meaning, opinion, and experience" (102). For this study, interviews were conducted to fill gaps that were left by other methods, specifically, the focus group discussions, and to collect a diversity of opinions from marginalized members of the community (women and youth) without fear of being rebuked by their peers (Dunn, 2010; Humphrey and Lee, 2004). Hence, by combining semi-structured interviews with other methods, I was able to overcome potential weaknesses or biases of the other qualitative methods that were used in this research (Dunn, 2010).

The Interview Guide

For this study, I developed a list of topics that I wanted to cover during the semi-structured interviews (see appendix 2). I developed the interview guide after intensely reviewing the impact tree diagrams that were produced by the participants of the focus group discussions in each village. I reviewed the impact tree diagrams to check if there were some pertinent issues (i.e. threats, and direct and indirect causes of vulnerability) that had been left out during the group discussions. Purposely, I wanted to check if the participants had identified threats that were more common in other regions of the country (e.g. gender violence, equity, corruption, poor leadership, female genital mutilation etc.). Some of these threats (e.g., female genital mutilation, equity, and gender violence) are specific to certain regions of the country that are inhabited by members of certain tribes, while other (e.g., corruption) are widespread. Thus, semi-structured interviews were useful in investigating whether these place-specific issues were common in these villages. Due to the open and semi-structured nature of these interviews, it seemed to make more sense to let the interviewees answer the questions in an unconstrained manner, mentioning whatever they thought was a threat to community. Many interviewees brought up themes that had already been covered during the focus groups. However, some interviewees revealed different types of threats and causes of vulnerability that had not emerged

during the focus groups (e.g. gender-based violence and harmful cultural and traditional practices). Thus, the interview guide was used solely to probe the interviewees on themes previously covered and to check gaps left by the focus groups.

Conducting the Interviews

I conducted twenty interviews in the 2nd and 3rd week of July 2015 with 4 men and 16 women as highlighted in Table 2. The interviews were conducted using Swahili language, at the interviewees' homes and lasted between 45 minutes to 1 hour. The respondents were selected using snowballing sampling techniques, with the first contact being the chairlady of one of the basket weavers' associations in the area. It was through her that I was able to interview the other informants. A major disadvantage of this technique is that the first contact usually nominates a person they know very well; hence, representativeness of the population is not guaranteed, which can lead to bias because the sample obtained might share the same characteristics and traits (Etikan et al., 2016). To overcome the inherent bias, in the snowballing sampling technique I asked the first contact person to recommend two or three people whom I would interview. Next, I randomly selected one participant from the list and, after interviewing the informant, I again asked the interviewee to recommend two or three people. This process was repeated until the last informant was interviewed.

To begin the interview process, I introduced myself and asked each informant to sign a consent form, authorizing me to record the conversation and to use the information conducted during the interviewing process. Next, I informed the interviewees of the premise of my research, followed by a question based on the interview guide I had developed. In the first village, I conducted four interviews with a group of women who were members of a basket weavers' association. I was referred to these women in part due their availability, but also because of their strong influence in promoting the activities of the association. In the second village, I interviewed four women who identified themselves as farmers and housewives as well as one male informant who worked as a volunteer. In the third village, the three women whom I interviewed were members of a "table banking" association as well as farmers. In the fourth village, I interviewed two women who identified themselves as farmer and a teacher as well as one male informant who had just completed his undergraduate studies. In the fifth village, I conducted a total of five interviews. Two of the interviewees were male; a teacher and a farmer. The three women identified themselves as a farmer, social worker, and a public health officer.

The three women were also members of a women basket weaving association in this village. Ultimately, the few additional insights gained from the semi-structured interviews were incorporated into the impact tree diagrams produced in each village.

Closing the Interviews and Semi-Structured Interviews

At the conclusion of the semi structured interviews as well as the focus group discussions, I provided each participant who attended the sessions a monetary compensation (300 Kenya shilling ≃ $3 per person) for the time spent. This monetary compensation was not really a 'payment' but a token of appreciation. As Masadeh (2012) highlights, participants can be recruited by offering incentives because the researchers' work runs on participants' own time, as opposed to their paid working hours. Therefore, it is important to offer some form of incentives to the participants. On the flip side, offering incentives to participants can have some ethical implications. For example, Head (2009) notes that offering incentives can lead to recruitment of participants that "would assume characteristics falsely in order to fit the eligibility criteria for a study" (342). Moreover, McKeganey (2001) noted that if we provide incentives, some informants might tell "us what we want to know" rather than their "authentic account" of their experiences (1237). However, the reality is that the majority of qualitative research projects require participants to engage and dedicate their time, and for most, incentives can be a significant engagement tool. For this study, I did not incentivize the participants when recruiting them, and so it is doubtful that they were seeking monetary gain but based on my knowledge of the culture, participants expect to be compensated whenever they give the gift of their time.

2.3 Conducting the Analysis

After completing the fieldwork and returning to the US, I transcribed the raw data so as to analyze it. I began by transcribing the focus group discussions and interviews as well as typing my field notes, which was tedious exercise and took several days. I transcribed all the recorded conversation myself because I was best placed to reconstruct the interchange (Dunn, 2010). After transcribing the conversations, I was ready for the analysis.

For this study, I used content analysis to identify themes that emerged during the discussions. This form of analysis can be done by a computer or hand but either way, it involves identifying terms, phrases, and themes that appears in document or recording and then counting how many times they appear and in what context (Cope, 2010). For this study, the impact tree diagrams played a critical role in the analysis. To start the analysis process, I hand coded the

impact tree diagrams and the printed field notes as well as the transcribed documents using some predetermined codes so as to identify different themes. This was carried out through identifying terms and phrases that were closely related to these codes and later on counting how many times they appeared in the impact tree diagrams and transcribed documents and in what contexts. To illustrate how the process was conducted, I will use examples of threats that were identified by the participants. These were lack of jobs, poor roads, drug abuse, insufficient food supply, alcoholism, prostitution, land grabbing, lack of market for products, lack of medical facilities, lack of water, neglect of disabled people, single mothers, and orphans, poor education standards, high cost of energy, diseases, poor communication networks, cattle rustling, influx of migrant community, and poor governance, among others. Using this example, threats that were closely related were coded under one category. Thus, threats such as drug abuse, alcoholism, and neglect of disabled people were coded as social issues, while lack of jobs and lack of markets for products were coded as economic issues. Initially, in my analysis, 17 themes emerged from the data. However, some of the themes overlapped in some way, so I condensed them into 12 categories that were integrated in the AHP model. Thus, in this research, the data analysis process involved two major steps: 1). Identification of the themes via reviewing the impact tree diagrams, field notes, and transcribed documents and, 2). Coding the data to correspond with the predetermined themes. As illustrated, the data analysis process was a rigorous process influenced by theory, the concept of vulnerability and the objectives of this study.

2.4 Establishing Rigor

In this study, I used various strategies to establish rigor. The first strategy was method and data triangulation. This involved using different methods and participants throughout the research process. By using a variety of methods (i.e., semi-structured interviews, focus group discussions, and observation), I was able to corroborate the findings from those methods and build a more holistic picture of what, how, and why the villages were vulnerable. As mentioned earlier, the participants who were involved in the semi-structured interviews had not participated in the focus group discussions. Using this strategy of data triangulation, I was able to produce greater breadth and depth of understanding. The second strategy utilized to ensure rigor was respondent validation. During the second phase of this study, I invited to the focus groups the same participants who were involved in the first phase of this research. During this second phase of the research, I reflected on the previous findings. This was critical for validating the findings

because the participants used results from the earlier assessment of their vulnerability to propose different alternatives for reducing vulnerability. As highlighted by Hadi and Closs (2016), respondent validation is the "most important method to ensure a study's credibility". The third strategy used was providing rich and thick verbatim descriptions of the participants' accounts as suggested by Krefting (1991). Using this method, I was able to support the findings and promote the study's credibility. Lastly, in the field, I had a prolonged engagement with the community, which was important in gaining their trust and also establishing rapport. By having a prolonged engagement with the community as suggested by Hadi and Closs (2016), a researcher can be able to promote the credibility of their work. This is because a researcher is able to get more in-depth information from the participants and hence identify pertinent issues being studied in order to focus on them more comprehensively.

2.5 Concluding Remarks

This research integrated a combination of observation, focus group discussions, and semi-structured interviews, which are the most popular qualitative research techniques. The observational techniques were used for contextual understanding of how the villages were vulnerable. The focus group approach explored people's views and opinions while the impact tree diagrams were useful for visualizing the spatial context of vulnerability across scale. The semi-structured interviews served the role of filling the gaps in knowledge that were left by other methods (Dunn. 2010), as well as collecting a diversity of opinions from marginalized members of the community. The combination of these methods worked well to complement any weakness that one approach may have. Because this research was dealing with social issues, it was important to employ multi-methods to examine the social vulnerability of these villages. Additionally, the use of GIS and remote sensing was important in obtaining the spatial and temporal information on landscape changes used to examine the vulnerability of the natural system.

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CHAPTER III

ASSESSING SOCIAL VULNERABILITY OF VILLAGES IN MT. KASIGAU, KENYA, USING THE ANALYTICAL HIERARCHY PROCESS

A version of this chapter was submitted to the *GeoJournal* by Njoroge Gathongo and Liem Tran. As the first author, I processed the data, performed the analysis, and wrote the article. Liem Tran offered advice on the work described here. He also reviewed early revisions of this manuscript.

The use of "we" in this chapter refers to myself, as the first author, and Dr. Liem Tran as my advisor.

Abstract

This research assesses the social vulnerability of five villages (Jora, Kiteghe, Makwasinyi, Bungule, and Rukanga) in Mt. Kasigau, Kenya. The goal was to develop a social vulnerability model by adapting a vulnerability conceptual framework that conceptualizes vulnerability into three major components: *exposure*, *sensitivity*, and *adaptive capacity* and using the Analytical Hierarchy Process (AHP). Employing the AHP, the three components of vulnerability were decomposed into its constituent components and structured into a hierarchical format where each component was represented by different societal and environmental criteria and stressors. Next, I performed pairwise comparison at each level of the hierarchy to obtain local priorities. Finally, I aggregated the local priorities from the bottom up to obtain global priorities of the social vulnerability of each village. The results from this study revealed that Makwasinyi was the most vulnerable village followed by Bungule, Kiteghe, Jora, and Rukanga respectively. Further, the results suggested that *adaptive capacity* and *exposure* played a critical role to determine the social vulnerability compared to sensitivity. Considering this, reducing social vulnerability in the area should focus more on improving the *adaptive capacity* of the people and reducing their *exposure* specifically in Makwasinyi village.

3.1 Introduction

The concept of vulnerability has been widely used in different fields but there has been no consensus on its meaning (Adger, 2006; Gallopin, 2006). Broadly speaking, vulnerability is defined as the "state of susceptibility to harms from exposure to stresses associated with environmental and societal changes and from the absence of capacity to adapt" (Adger, 2006; Eakin and Luers, 2006). At the very basic level, vulnerability is defined as "the potential of loss" of function, benefits, resources, equity, integrity among others (Cutter, 1996) or capacity to of a system to be wounded (Dow, 1992; Füssel, 2007). However, the definition of vulnerability varies across different disciplines (e.g. political science, geography, sociology) and topics (e.g. disasters, risk management or hazards) (Wu et al., 2002). Adger (1999) defines social vulnerability as "the exposure of groups or individuals to stress as a result of social and environmental changes, where stress refers to unexpected changes and disruption to livelihoods." Thus, social vulnerability involves a combination of environmental, economic, political, social, environmental, and cultural components that influences the degree to which a community or individual is threatened by a specific event or a series of events, chronic exposure or periodic exposure to a certain threat(s), their recovery potential, as well as the ability to mitigate these threats (Blaikie et al., 1994; Cutter et al., 2000). An important aspect in research on social vulnerability is the distinction between individual and collective vulnerability. Although the two terms are interlinked, at the individual level, vulnerability is determined by the social status of individuals, sources of income, and access to resource and/or capital (Adger, 1999). Collectively, as a community, society, or country, vulnerability is determined by political institutions, societal structures, infrastructures, and market structures, although environmental changes exacerbate collective vulnerability (Adger, 1999; Kelly and Adger, 2000). Thus, studies in vulnerability, particularly by researchers interested in building *adaptive capacity* as part of policy for reducing vulnerability, should focus on the collective level (Eakin and Luers, 2006). This, this research focused much on collective vulnerability.

The origin of social vulnerability studies can be traced back to the 1950s and 1960s in social and behavioral sciences which were interested in the quality of life and livability for human beings (Cutter and Emrich, 2006). During this period, research into social characteristics of people and places was emerging as a practical and meaningful method of understanding how people cope with issues such as social problems, sickness, and environmental inequities (Cutter

and Emrich, 2006). In the late 1960s, the idea of devastation to hazard-prone regions by natural disasters as a result of social and economic characteristics was introduced (Blaikie et al., 1994). However, the roles of social and economic conditions were not acknowledged as factors of vulnerability until the 1970s (Alcantara-Ayala, 2002).

In the past, socially constructed vulnerability was largely ignored, primarily, because of the difficulties in quantifying the causes of social vulnerability (Adger 1999; Cutter et al., 2003). Instead, considerable attention was paid to the built environment while social vulnerability was often described in terms of individual characteristics of people (e.g. the status of their health, income levels, type of housing, age etc.) (Cutter and Finch, 2008). Among the social science community, there is a general consensus about some of the factors that cause social vulnerability (Cutter et al., 2000). These include limited access to political power and representation; lack of access to resources (e.g. financial capital, knowledge, technology, and information); social capital; beliefs and customs; age; gender; physical disabilities; and environmental factors (Blaikie et al., 1994; Cutter et al., 2008). However, disagreement arises on which factors should be selected to measure social vulnerability (Cutter et al., 2000).

Social vulnerability is "multi-dimensional, and its assessment is complicated due to the social, economic, political, and institutional patterns of societies" (Roy and Blaschke, 2013: 40). However, numerous approaches have been developed and used to examine the causal structure of vulnerability vis-à-vis places and people (Chen et al., 2013; Luers, 2005; Shah et al., 2013). A large portion of those approaches use indicators to quantify and characterize multi-dimensional issues, often combining various "indicators into a single composite index of vulnerability" (Shah et al., 2013: 126). One such approach recognizes "vulnerability as a pre-existing condition and focuses on potential exposures to hazards" (Cutter, 1996: 537). Studies undertaken in accordance to this approach pay more attention to the distribution of hazardous condition, the occupancy of the hazardous zone by human beings, and the degree of loss resulting from a particular hazard (McLaughlin and Dietz, 2008). Another vulnerability assessment approach suggests that there is a differential pattern of loss to individuals or a group of people who are exposed to a certain kind of stress (Wu et al., 2002). In addition to the exposure of stress and/or perturbation, this differential vulnerability also depends on the coping capacity of the people who are affected by certain threats (Clark et al., 1998; Wu et al., 2002). The vulnerability of place conceptual framework views vulnerability as both a biophysical risk as well as a social response in a specific

location (Wu et al., 2002). Finally, Turner et al. (2003) distinguishes three dimensions of vulnerability: exposure to stresses, shocks, and perturbations; the sensitivity of people, ecosystem, and places to the shocks or stresses (sensitivity); and the recovery potential (also called adaptive capacity or resilience) (Birkmann et al. 2013; Fussel, 2007; Janssen et al., 2006; Turner et al., 2003).

3.2 The Analytic Hierarchy Process (AHP)

Decision-making is the act of choosing between two or more alternatives (Masud and Ravindran, 2008). In order to make a decision, the decision makers encounter multiple criteria for judging alternatives (Masud and Ravindran, 2008; Panahi and Meshkani, 2014). Multi-criteria decision-making (MCDM) techniques are a set of methods that can be applied to complex decision problems (Fernandez et al., 2016; Kiker et al., 2005; Mendoza and Martins, 2006; Thokala et al., 2016). MCDM's helps decision-makers make decisions based on their preferences, whenever there are more than one criteria involved (Ho, 2008; Mardani et al., 2015).

The Analytical Hierarchy Process is one of the most widely used MCDM that assists decision makers in simplifying a decision problem into a hierarchical structure and then developing priorities for criteria, sub-criteria, and alternatives based on the judgements of the experts or users (Delgado-Galvan et al., 2010; Gupta et al., 2005; Mu and Pereyra-Rojas, 2018; Saaty, 1990; Saaty, 2008). The AHP also integrates qualitative and quantitative information and derive priorities based on paired comparisons of alternatives (Saaty, 2008). In general, AHP involves structuring the problem into a hierarchy, conducting pairwise comparisons, deriving local priorities and checking consistency, and finally aggregating local priorities into global priorities (Ramanathan and Ganesh, 1995).

In social vulnerability studies, AHP has been used in several studies (e.g., Lee et al., 2015; Ouma and Tateishi, 2014; Stefanidis and Stathis, 2013). In a study that explored the social vulnerability in Pingtung County, Taiwan, associated with the impact of climate change impacts, Lee et al. (2015) used AHP to derive weights of multiple social vulnerability indicators and aggregated them into an integrated vulnerability index. In another study designed to develop indicators for assessing social vulnerability as a result of climate change for the Southwest coastal areas of Taiwan using the three dimensions of social vulnerability (susceptibility, resistance, and resilience) as defined by the researchers, Wu et al. (2016) employed AHP to

evaluate the weight of each social vulnerability indicator used in their study based on the perspective of experts that was collected through a questionnaire survey. Similarly, for assessing spatial vulnerability to floods in coastal Bangladesh, Roy and Blaschke (2015) employed AHP to assign weights to some selected vulnerability domains and indicators. In another study that analyzed the social vulnerability to hazards and the sensitivity of 26 influencing factors of social vulnerability in Beijing, China, Zhang and Huang (2013) utilized AHP to calculate the weights of various influencing factors. Lastly, Fernandez et al. (2016) used AHP to integrate various social vulnerability indicators to assess flooding risks in several municipalities in Portugal.

Aiming to assess the social vulnerability across five villages in Mt. Kasigau, Kenya, I developed a social vulnerability model using AHP whilst adapting Turner et al. (2003) vulnerability conceptual framework. I combined this framework, which conceptualizes vulnerability into three major components: *exposure*, *sensitivity*, and *adaptive capacity*, with the AHP model to assess the social vulnerability of the villages. Using the model, the three components of vulnerability were structured into a hierarchical format where each component was represented by different societal and environmental criteria and stressors. Next, I performed a pairwise comparison at each level of the hierarchy to obtain local priorities. Finally, I aggregated the local priorities from the bottom up to obtain global priorities of the social vulnerability of each village.

The remainder of this paper is organized as follows. In section 3.3 and 3.4, I give an overview of the study area and subject population respectively. Then I proceed and describe the field data collection methods in section 3.5 before focusing on the use of the AHP as a tool for realizing the vulnerability conceptual model in the subsequence sub-sections. In section 3.6, I provide the results of the study. Section 3.7 discusses the overall findings and, finally, section 3.8 presents the conclusion of this study.

3.3 The Study Area

Mount Kasigau is in Taita Taveta county in Southwest Kenya. It is one of the Eastern Arc Mountains, a chain of mountains that run Northeast to Southwest in Kenya and Tanzania (Figure 7) (Henkin et al., 2015). Specifically, Mount Kasigau is recognized as a biodiversity hotspot in East Africa (Burgess et al., 2007; Myers et al., 2000; Newmark, 2002). The mountain rises about 1,600m above the surrounding savannah plains and it is within a corridor of communal and private lands between Tsavo West and Tsavo East National Parks (Henkin et al.,

2015; Medley and Kalibo, 2005; Medley and Kalibo, 2007). The mountain consists of 203 hectares of gazetted evergreen forest that are managed by the Kenya Forest Service (KFS) in conjunction with local communities (Medley and Kalibo, 2007). The mountain rises steeply from 600 to 1641 m above sea level and has the capacity of capturing enough moisture from the Indian Ocean to support an evergreen forest above 1000m (Medley and Kalibo, 2005; Medley and Kalibo, 2007). However, the plains surrounding the mountain receive between 300 and 500 mm of rain per year and are classified as a semi-arid region (Kalibo and Medley, 2007). The vegetation within the plains is mainly composed of acacia bushland and supports a variety of wildlife including elephants, lions, zebras, giraffes, ostriches, and antelopes. Most of the bushland that surrounds the villages at the foot of the mountain has been converted into farmland, making some of the wild animals migrate deeper into the bushland or nearby parks and communal ranches.

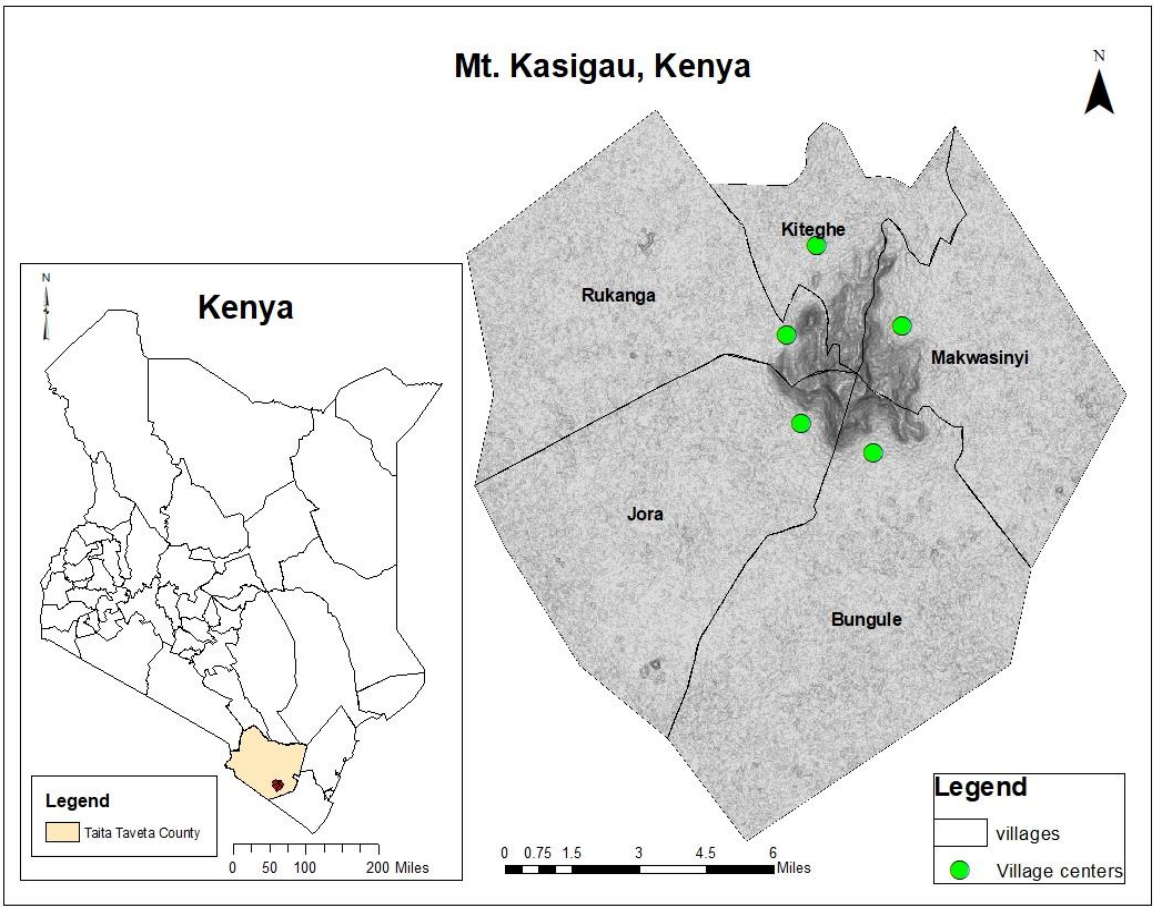


Figure 7: Location of the five Study Villages at Mt. Kasigau, Kenya.

3.4 Subject Population: The Kasigau Taita

The majority of people living around Mt. Kasigau are from the Kasigau-Taita, a sub-tribe of the Taita ethnic group that mainly inhabits Taita-Taveta County of Kenya (Kamau, 2017; Leiter et al., 2013). Sometimes referred to as Wakasigau, the Kasigau-Taita are predominantly small-scale farmers who raise livestock and cultivate crops (Kalibo and Medley, 2007; Leiter et al., 2013; Medley and Kalibo, 2007). According to the 2009 Government of Kenya population census report, there were a total of 9,721 people in 1,803 households in the five study villages (GOK, 2010). A section of the local people engages in small businesses, while others have joined formal employment locally or in other parts of the country. According to interviews with residents of these villages, the Wakasigau almost lost their ancestral land during World War I (Kamau, 2017). According to the residents, and information from the mass media[11], the Wakasigau were accused by the British colonial administration of collaborating with the Germans which led them to be violently removed from their ancestral land to a coastal town known as Malindi from about 1912 to 1936 (Kamau, 2017; Medley and Kalibo, 2007). Later, they were allowed to return to Mt. Kasigau in 1937, after Christian missionaries petitioned the colonial government to let them return to their land (Kamau, 2017). According to local leaders in the area, this forced displacement caused the community to miss development opportunities, explaining why the Kasigau-Taita lags behind their neighbors in social amenities such as hospitals, schools, and water supply.

[11] During the First World War the Wakasigau, as an ethnic group, were regarded by the colonial government as German collaborators and were deported to Malindi in Kilifi District. During this forced eviction, they suffered deprivation and were allowed back to Taita-Taveta (though not to their previous homes only after the war. However, in 1937, they were allowed back to their ancestral land after some Christian missionaries petitioned the colonial government to let them return to their land.

3.5 Data and Methods

3.5.1 Data Collection

For this study, I utilized multiple methods in an integrated fashion to collect data that would be used in assessing social vulnerability (Figure 8). The justification for using different methods when collecting data was to establish rigor, to ensure meaningful inference, and to validate the research findings (Baxter and Eyles, 1997; Baxter, 2010). The use of integrated methods from different approaches also promotes collaborative learning between the researcher and the researched (Baxter, 2010). For instance, during the focus group discussions, participants learnt from each other and from the researcher by "talking it out'" assimilating their ideas and information through interaction with other members of the community. Also, the researcher role changed from the function of being an "information giver" to being a “guide on the side," thereby learning from the community by carefully observing what they say and do. Such direct information both informs theory and improves the researcher’s knowledge. Thus, the main methods used in this research were: observation, focused group discussions, impact tree diagram, and semi-structured interviews.

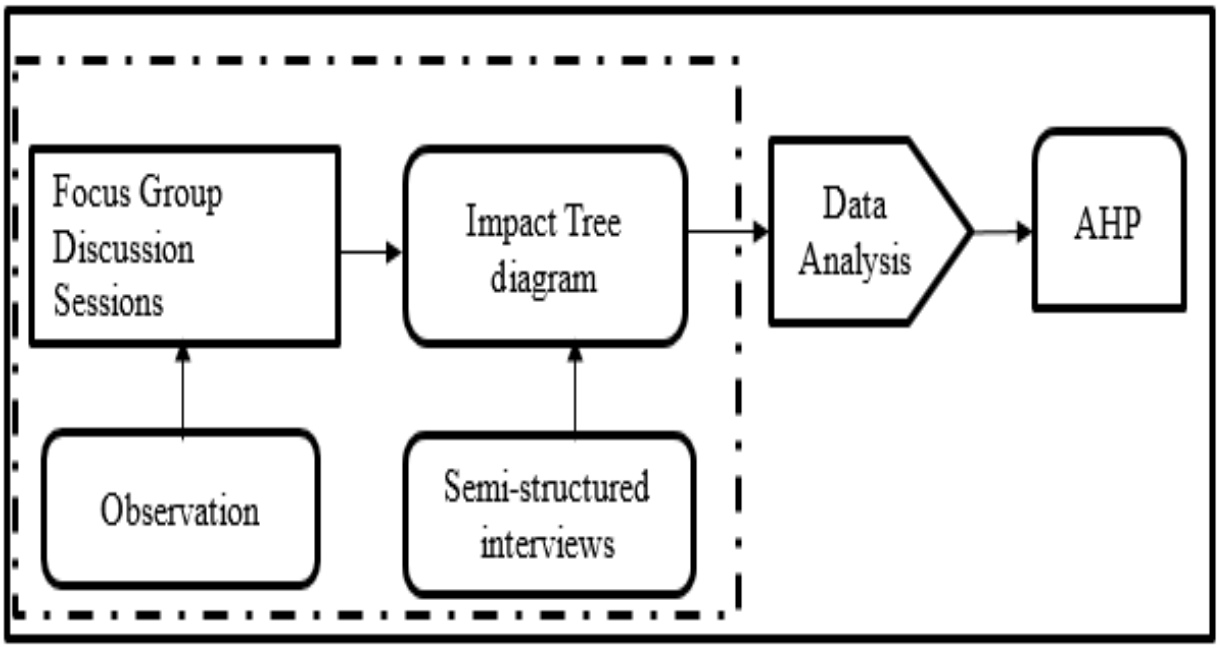


Figure 8: Fieldwork data collection framework starting from observation, focus group discussion where the impact tree diagrams were constructed, and the semi-structured interviews.

3.5.2 Participant Selection

In this study, a group of 78 residents from the five villages was invited to help in acquiring data used for this research. I used purposeful, snowballing, and criterion sampling techniques to select the participants. Baxter (2010) describes purposeful sampling as a strategy of finding participants who are rich in information related to the phenomenon of interest, whereas criteria sampling consists of selecting cases/participants who meet some predetermined criterions (e.g. age, income level etc.) (Baxter, 2010; Palinkas et al., 2015). Using these two strategies, I only recruited participants who were elderly and had ample knowledge of their respective villages. Thus, I only selected participants who had met some conditions such as; being elderly, born and raised up in the area, and had spent their entire adult life in these villages. This set of conditions ensured that the information collected from the participants was credible. I also employed snowballing sampling techniques to recruit other participants. Snowballing is a technique whereby one person refers the researcher to other samples for recruitment (Griffith et al., 2016). Thus, the initial informants identified in each village with the assistance of the field resource person were used to recruit other participants used in this study.

3.5.3 Observation

I used field observations, before, during, and after undertaking other qualitative methods. The aim of using observation at the start of the fieldwork was to gather background information of the villages and evidence of social vulnerability. Observation was also used to collect supplementary evidence that would add value to the other methods (Humphrey and Lee, 2004; Kearns, 2010). During the observation, I held in-depth conversations with non-governmental organization officials, village elders, and random village residents to gather background information of each village and understand threats that the residents of these villages encountered in their daily lives. Notes collected during the conversations formed the basis of the focused group sessions and semi-structured interviews.

3.5.4 Focused Group Discussion Sessions

A total of five focus group discussion sessions were held (one per village) with seven to fifteen participants participating in each village. During these sessions, participants discussed various threats they encounter in their respective villages. Specifically, the focus group discussion sessions yielded spontaneous and diverse views from the participants. During these sessions, participants engaged in an in-depth conversation to explore and identify the various

casual factors of social vulnerability in each village. It was during these sessions where participants mapped the direct and indirect causes of social vulnerability in each village from the local (village) to the national level using an impact tree diagram.

3.5.5 Impact Tree Diagram

I played the role of a facilitator when an impact tree diagram was developed by the residents of these villages to identify and map all the potential causes of social vulnerability in each village (Figure 9). An impact tree diagram is a powerful tool that can be used to identify, record, and visually represent all the possible causes of a problem hierarchically from direct and indirect causes to potential impacts (Knutson et al., 1998). As a starting point, during the focused group discussion sessions, participants were requested to identify and list all sort of threats they encountered in their respective villages while explaining their thoughts. For each possible threat, participants brainstormed about it and determined what were the direct causes of vulnerability in their respective villages. Thus, for each new threat listed, it was turned into a subject and further broken down into a more explicit element.

This figure illustrates an example of just one threat (i.e. food security) among several threats that were identified in these villages. Using this figure as example on how the impact tree diagram were constructed, the participants identified food insecurity as one of the threats in this specific village. For this threat, I asked the participants what the direct causes of this threat were (i.e. food insecurity) and the participants identified causes such as “farm sub-division between family members”, “lack of jobs”, “overdependence on agriculture”, “threat from wild animals”, and “lack of adequate rainfall”. Once the participants had exhausted naming the direct causes of this threat, I again posed another question on what were the causes of these direct causes. These causes became the indirect causes of food insecurity. Again, I followed up with the participants by asking them the major causes (i.e. indirect causes) of those direct causes from their perspectives. For example, from the diagram, I asked the participants what were the causes of “lack of jobs” in their village and the participants responded by naming causes such as “lack of investors” and “limited technology”. Hence, their answers became the indirect causes of this threat (i.e. food insecurity). This process continued until the residents had exhausted identifying all the potential direct and indirect causes of threats that were encountered in each village and for each threat.

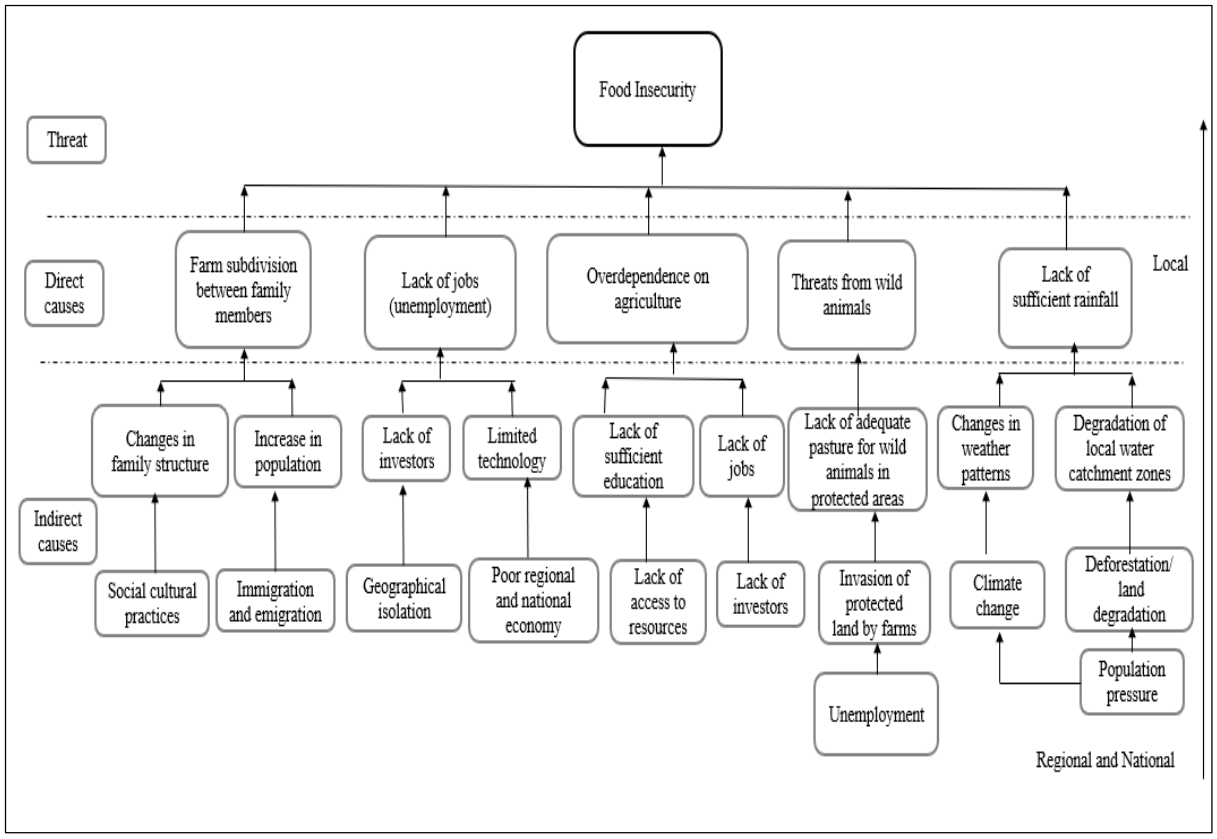


Figure 9: Example of one threat of social vulnerability (i.e., food security) extracted from the impact tree diagram that was developed in of the study villages.

At the end, there were multiple branches of the indirect causes of social vulnerability, but these underlying causes were either similar or closely related especially at the regional and national level. This was useful in grouping the underlying causes of social vulnerability into fewer categories. In addition, the use of the impact tree diagram allowed the residents to share the mental model of the situation and therefore work on it harmoniously while brainstorming on the direct and indirect causes of social vulnerability. Furthermore, the use of the impact tree diagram allowed the re-examination of parts of the analysis, and hence participants would change, remove or add any causes of vulnerability during the mapping process. Thus, the impact tree diagrams produced during these sessions were important in visualizing the spatial context of social vulnerability across scale.

3.5.6 Semi-Structured Interviews

I used semi-structured interviews with a different group of people, specifically women and younger people whose views or opinions might have been marginalized or overlooked by their counterparts during the focus group discussion sessions. During these semi-structured interviews, I asked participants to validate claims made during the focus group discussion sessions, specifically by reviewing the impact tree diagram mapped in their respective villages. The aim of using semi-structured interviews was to capture wide-ranging experiences, data triangulation, validate information collected through observation, focused group discussion sessions, and impact tree diagrams. Moreover, semi-structured interviews were utilized to fill gaps left by other methods, add input to the impact tree diagrams, and allow participants to explain their thoughts without fear of being rebuked by their peers (Dunn, 2010; Humphrey and Lee, 2004). Hence, by combining semi-structured interviews with other methods, I was able to overcome potential weakness or bias of the other qualitative methods (Dunn, 2010).

3.5.7 Integrating the Impact Tree Diagrams with the AHP

Following the construction of the impact tree diagrams, the next step was to synthesize the information from the impact tree diagrams and utilize it in structuring the AHP model for vulnerability assessment. Components on the impact tree were grouped based on their scope of influence (e.g., local, regional, and national). The main goal of grouping components at different levels of the impact tree diagram was to restructure the components listed in the impact tree diagram and collect data that would be incorporated into the AHP. In this study, groups of factors at the regional and national levels were considered as the indirect causes of the multiple

threats identified in each village, while those at the local levels were considered direct causes. To integrate components listed in the impact tree diagram into AHP, I utilized groups from the regional and national levels. My decision was based solely on the better understanding of the interconnectedness between the indirect causes and threats at this level compared to the direct causes of vulnerability at the village level.

For example, as highlighted in the previous Figure 9, some of the indirect causes of food insecurity were socio-cultural traditions, population pressure, immigration and emigration, poor regional and national economy, lack of access to resources, lack of investors amongst others at the regional and national level. These indirect causes were grouped under different categories such as coping with social issues, demographics, socio-economic status, and economic insecurity amongst other and later on integrated into the third level of the AHP hierarchy (Figure 10). However, since the focus was to assess the social vulnerability of the five villages, I excluded some of the indirect causes of social vulnerability such as climate change, geographical isolation, and poor governance because these villages were under similar condition and their inclusion would not affect the goal of the AHP model, which was to rank the villages from the most to least vulnerable. Altogether, the process of grouping of the indirect causes of social vulnerability at the regional and national level was performed for all the five villages resulting into 12 categories at the regional and national level that were integrated into the third level of the hierarchy while some of the direct causes of vulnerability used in analyses at the fourth level of the hierarchy.

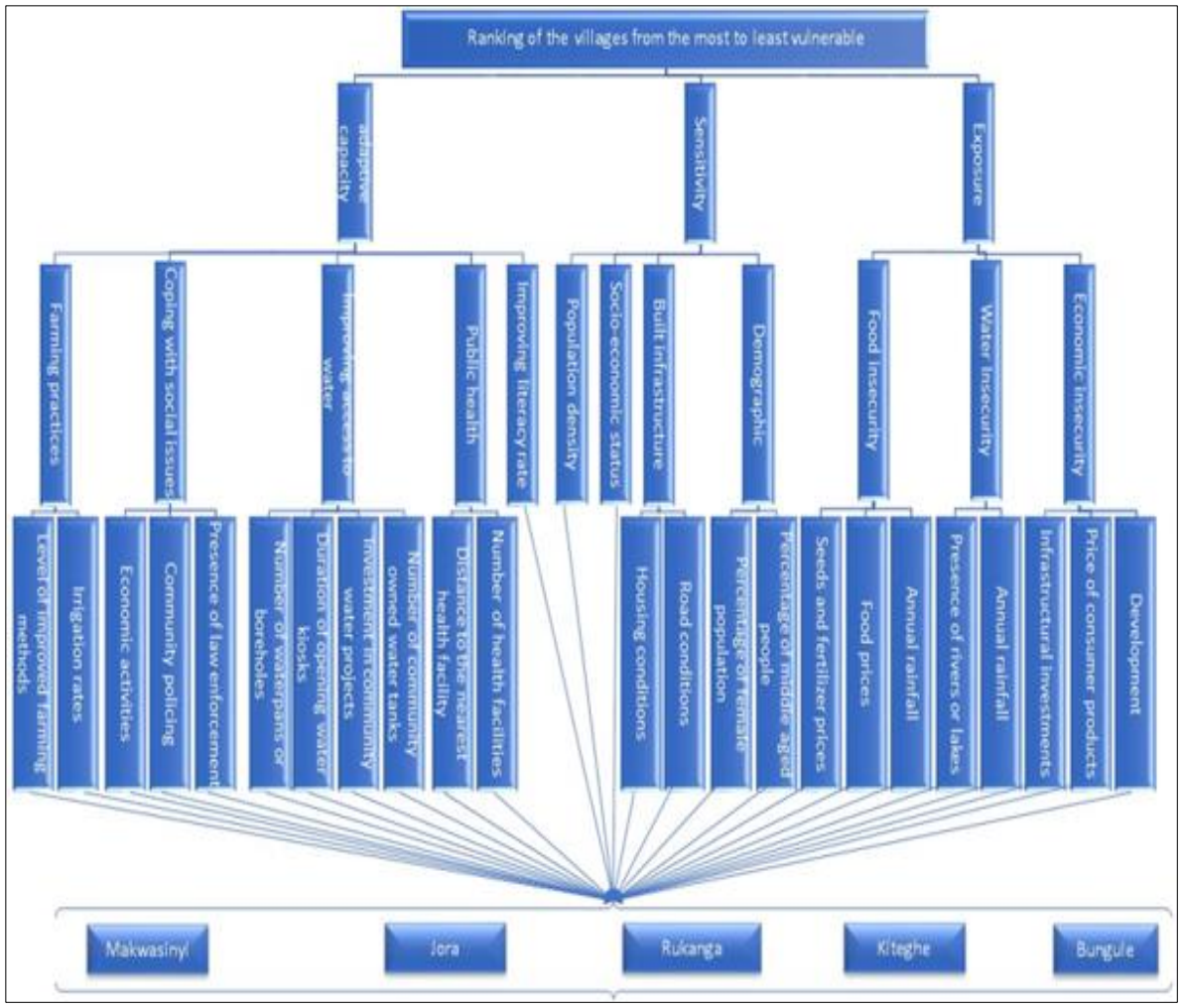


Figure 10: The Analytical Hierarchy Model developed for examining the social vulnerability of the five villages at Mt. Kasigau, Kenya.

3.5.8 Developing the AHP Social Vulnerability Model

The AHP was used to decompose the vulnerability conceptual framework adapted for this study into its constituent components – *exposure*, s*ensitivity*, and *adaptive capacity*. This was carried out by constructing a five-level hierarchy using AHP (Figure 10). The first level was the goal of my model, which was to rank the five villages from the most to least vulnerable. The second level in the hierarchy constituted the three components of vulnerability. At the third level were the societal and environmental stresses/threats that influenced the social vulnerability in those villages. These stresses/threats were based on the 12 categories of the indirect causes of social vulnerability. The fourth level consisted of different sub-criteria used for measuring the societal and environmental stresses in each village. These sub-criteria were derived from the direct causes of social vulnerability in each village and hence they were important in comparing the five villages. Finally, the fifth level consisted of the five villages that were being evaluated.

3.5.9 Performing Pairwise Comparison

Following Saaty's (2008) 1-9 scale of measurement (equally important to extremely important) (Table 4), elements at the same level of the hierarchy were compared against each other with respect to elements one level higher. The pairwise comparison was meant to convert qualitative and quantitative information into ratio scale. During the process, the researcher assigned equal weights to the three components of vulnerability, in the second level of the hierarchy, with the assumption that the three components contributed equally. At the third and fourth levels, weights were based on the input from the local community. Finally, weights at the fifth level were based on the researchers' observation and judgement. Throughout the pairwise comparison process, the judgment matrix was considered adequately consistent if their consistency ratio was less than 10% (Saaty, 2008; Royand Blaschke, 2015).

Table 4: The Fundamental Scale of measurement in AHP adapted from Saaty (2008) for Assessing the Social Vulnerability.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
N/B: 2, 4, 6 7 and 8	Intermediate values between the two adjacent judgments	When compromise is needed

When I compared the three vulnerability components, equal weights were assigned to each component with the assumption that the three components contributed equally. On the other hand, different weights were assigned to elements in the other levels of the hierarchy by the researcher, based on information collected during interviews and focus group discussions. For example, at the third level of the hierarchy, water insecurity was assigned more weight, followed by food insecurity and economic insecurity. Under the *sensitivity* node, population density was assigned more weight followed by demography, socio-economic status, and built infrastructure. Lastly, under *adaptive capacity* node, measures meant to improve access to clean water was assigned more weight, followed by improving literacy rates, improved farming practices/methods, public health initiatives, and measures for coping with social issues respectively. However, elements within the *adaptive capacity* node had their weights inverted so that lower weights represented lower vulnerability.

3.6 Results

3.6.1 Ranking of the Villages

The global weights as highlighted in Figure 11 reflect the order of ranking of these villages from the most to least vulnerable village. Therefore, from this study, it follows that Makwasinyi was the most vulnerable village followed by Bungule, Kiteghe, Jora, and Rukanga respectively.

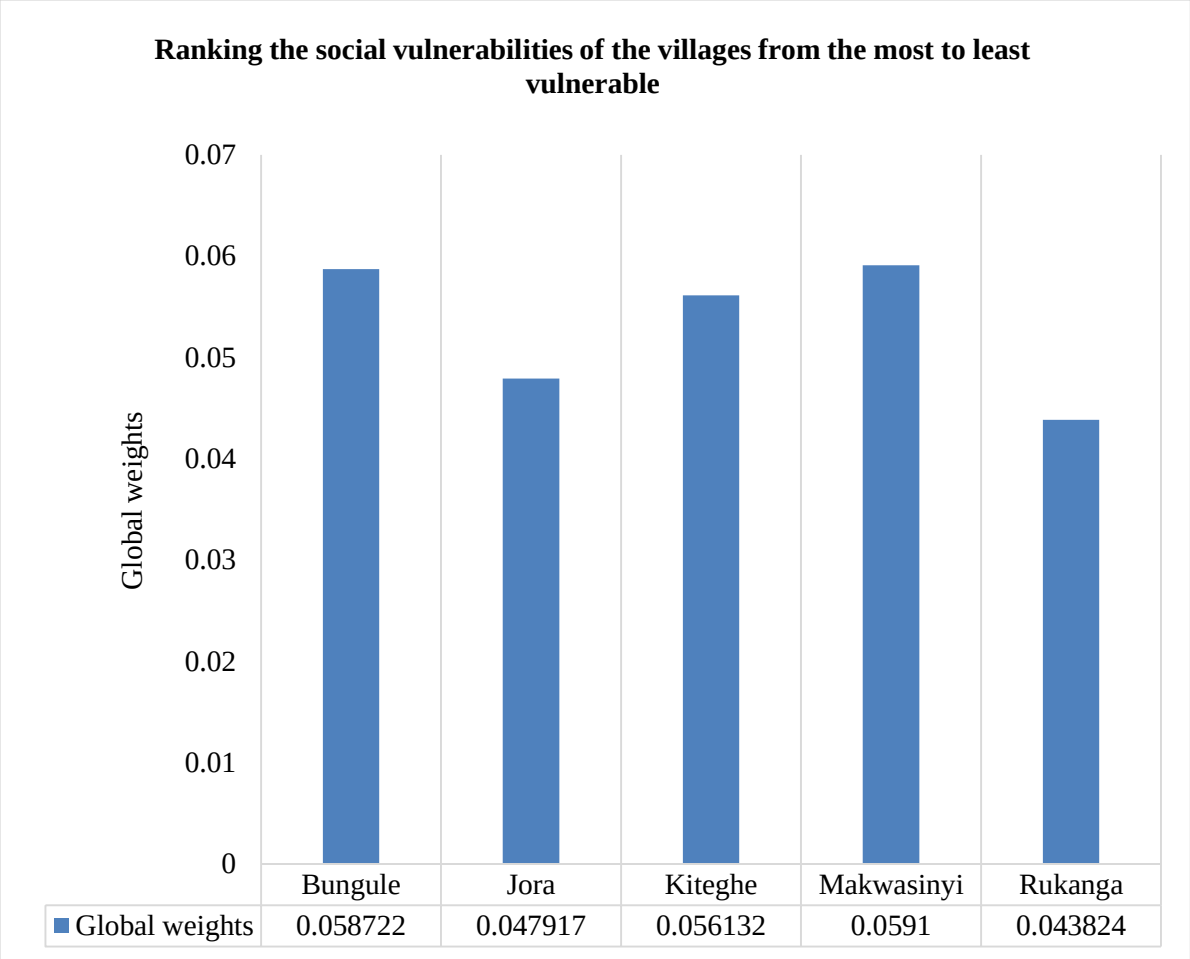


Figure 11: A graphical representation highlighting the social vulnerability ranking of the five villages at Mt. Kasigau, Kenya.

These global priority weights have mathematical validity, as measurement values derived from a ratio scale. Therefore, from this analysis, Bungule, Kiteghe, Jora, and Rukanga villages are approximately 99.36%, 94.98%, 81.07%, and 74.15% vulnerable as Makwasinyi respectively. Even though the isolation of location of Makwasinyi and Bungule villages can contribute to higher level of vulnerability in these villages, there are other factors that played an important role in making these villages more vulnerable. For example, in comparison to the other villages, Makwasinyi has fewer shops, restaurants, and tourists rarely travel to this village, hence fewer economic activities are undertaken in this village. With regards to Bungule, lack of a water reservoir and safe tapping points was a critical factor that increased the social vulnerability of the residents of this village. These findings are supported by the information collected from the residents of these villages. For example, in Jora village, eight out of the eleven participants who attended the focused group discussion sessions, said that accessibility of water was a major hindrance to their livelihood. One male participant said:

> *"Jora is a cursed village, no single stream flows to this side of the mountain. The villagers tapped some water from one of the catchments that flows toward Bungule. However, after six months, the residents of Bungule village broke those pipes. Now we don't have piped water and we are forced to buy water….We only have one borehole that was constructed in 2012 by our member of parliament using the Constituencies Development Fund (CDF)*[12] *. The borehole broke down last year and hasn't been repaired. We are really suffering a lot".*

As this comment references, each village, with the exception of Jora, has its 'own' water catchment from where water is trapped and piped to the villages. These pipes drain the water into large tanks that are connected to the water kiosks. In each village, water kiosks are constructed at specific locations where residents pay a small fee to get water. The fee caters for the maintenance of the pipes. Thus, with the absence of its own water catchment, the village suffers persistent water shortages hence higher social vulnerability because residents are sometimes

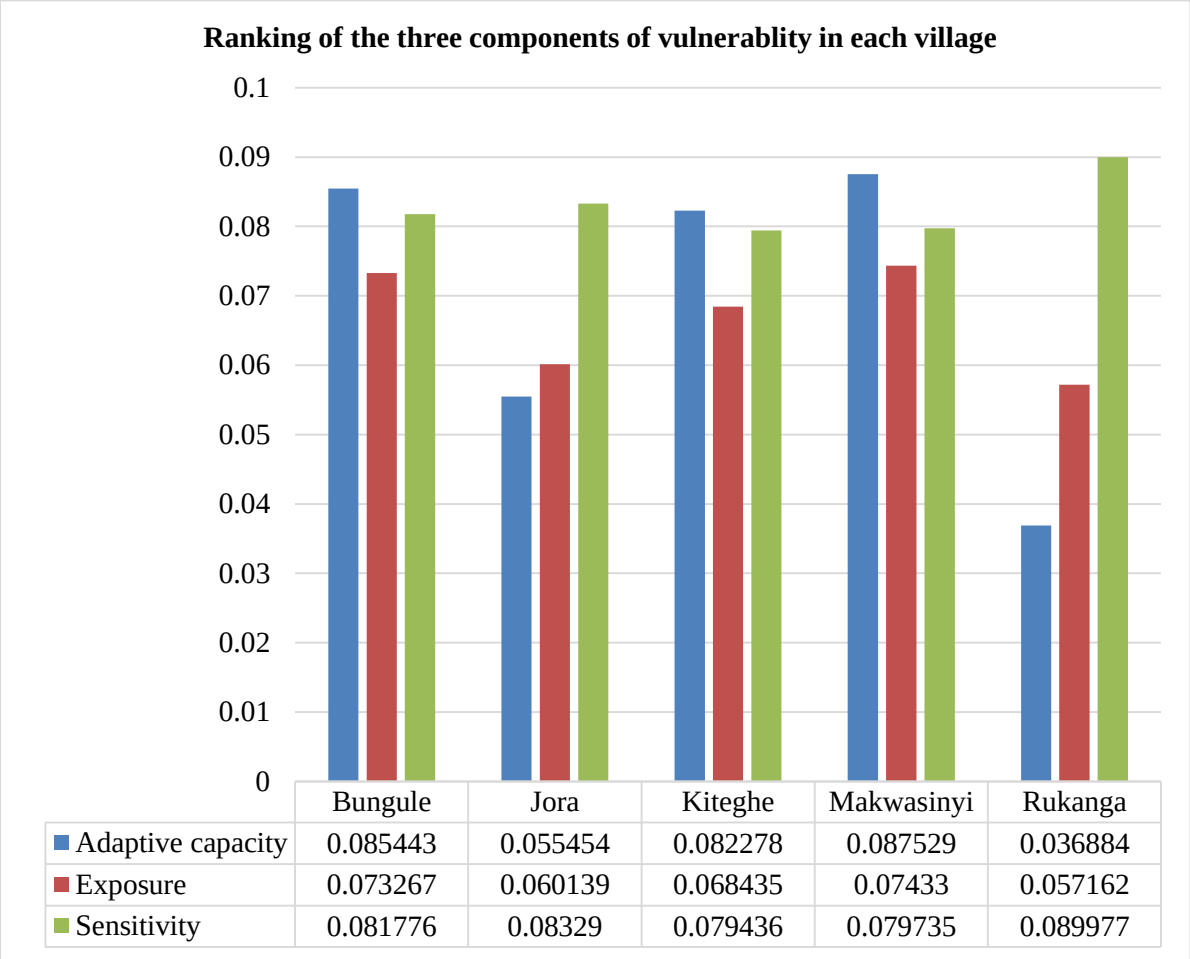
[12] The Constituency Development Fund (CDF) is constituency-level, grassroot development projects In Kenya that was launched in 2003 and aims at rectifying the imbalances created by partisan politics in different parts of the country.

forced to walk long distance to fetch water. Additionally, the time used for fetching water and efforts required to carry heavy water buckets has an opportunity cost, hence increasing the vulnerability of the residents of this village.

Using the global weights derived for the three components of vulnerability (Figure 12), results suggest that *adaptive capacity* and *exposure* played a critical role in determining the social vulnerability compared to *sensitivity*. For example, Makwasinyi, Bungule, Kiteghe had the highest global weights of *exposure* and *adaptive capacity* and this is in line with the overall ranking of the social vulnerability in these villages. On the contrary, Rukanga and Jora villages had the highest global weights for *sensitivity* but were the least vulnerable villages.

These findings are corroborated by the focus group discussions and the semi-structured interviews that were held with the residents of these villages. For example, when participants in these villages were asked what the leading causes of social vulnerability were, factors such as lack or limited access of resource, capital, jobs, knowledge, information, beliefs and customs, geographical isolation, and inadequate rainfall were mentioned. However, lack of sufficient rainfall was conspicuous in all the discussions conducted in the five villages. For example, in Makwasinyi village, seven out of nine informants who attend the focus group discussions reported that inadequate rainfall in the region was responsible for drought and famine that the residents were experiencing. For example, two of the informants in Makwasinyi village said:

> *"In the past, we used to receive a lot of rainfall and harvested a lot of crops, but those days are now gone. If you harvest crops that can sustain your family the whole year, you are lucky…."*.
>
> *"We don't receive enough rainfall nowadays. I was forced to sell all my cattle two years ago and remained with only two cows because the rivers and dams are dry. I buy water for domestic consumption and the little income I receive from my sons is not enough to buy water all the cattle I had in the past".*



	Bungule	Jora	Kiteghe	Makwasinyi	Rukanga
Adaptive capacity	0.085443	0.055454	0.082278	0.087529	0.036884
Exposure	0.073267	0.060139	0.068435	0.07433	0.057162
Sensitivity	0.081776	0.08329	0.079436	0.079735	0.089977

Figure 12: Global weights of the three components of vulnerability in each village.

These quotes clearly illustrate some of the direct causes of poverty, food insecurity, and drought in these villages. Given the fact that all the agricultural land is rain-fed and these villages at present are water stressed means that any climatic various that affects the patterns of rainfall are most likely to have dire consequences for agricultural and associated parameters of food, income, and employment. Thus, *exposure* of these village to environmental change, specifically rainfall were the main factors that causes social vulnerability in these villages. For instance, when the region experiences prolonged period of little or no rainfall, the community is faced with harvest that are too small to both feed their family and fulfill other financial commitments. Livestock, which acts as a buffer in times of hardship are sold, so as the residents can be able to provide their family. Usually, the first animals that are sold are the ones that makes minimal contribution to the community and these include goats, chicken, and sheep. However, as the drought worsen, villagers start selling animals such as cows and donkeys which are used in the farm. Therefore, from this analysis, it is evident that rainfall shortage tends to have a trick-down effect throughout the area.

To collect information about their adaptive capacity, I asked the informant what they believed were the factors that made them strong in the face of environmental and societal changes. Some of the strategies that were highlighted by the informants were specific to each village (e.g., number of community owned water tanks in Kiteghe village, presence of law enforcement in Rukanga village, and duration of opening the water kiosks), while other were similar in all the five villages. However, the issue of social capital emerged as a major strategy of increasing their adaptive capacity. Social capital entails the resources that the community hold and the informal networks among the members of the community. Therefore, when I asked them what they thought were the major factors that "pulled the community together", the common response from the information was "Harambee[13]" (i.e. the 'strength of the people'). For example,

[13] Harambee is a concept that started in 1963 and emphasizes the importance of community helping each other. In Swahili language, Harambee means "pull together" and is an official motto of the Republic of Kenya. The Harambee philosophy in Kenya has promoted the spirit of cooperation and understanding among various communities. It brings people together and promotes unity.

in an interview with four informants in Jora village, two women described how the spirit of "Harambee has invoked a sense of self-help amongst the residents and numerous development projects have been initiated and accomplished through this spirit. One woman said:

> *"I am glad that the 'nyumba kumi[14]' initiative in our village is working. We have been informing our community and urging them to report female genital mutilation, early marriage, security, and parents who deny their children a chance to go to school. Just the other week, we confiscated and destroy two tanks of illicit brew. I think if all the community cooperates, we will be able to shut down all the dens because we cannot watch other women cry about what this brew is doing our children and husbands and turn a deaf ear to their tears".*

As this comment reference, it is evident the community has been undertaking various measures that increases their *adaptive capacity*, hence reducing their social vulnerability. This approach of community policing that recognizes the voluntary participation of local community in collaboration with the government security personnel is useful in curbing social issues that affect the society. Additionally, community policing helps in fighting against cattle rustling and poaching within the region.

Despite the sense of togetherness within the community, the woman noted that there was still some friction and sense of competition among the resident of these villages. She further noted that "*They'll bicker and argue and scrap…but then something will happen and that's put aside and everybody pulls together*". Other participants from the other villages also emphasized the Harambee philosophy as well as the collaboration between the residents of these villages and other stakeholders. For example, in Rukanga village, two of the three interviewees spoke of this Harambee philosophy with reference to a period of drought and famine. One of the women interviewed provided examples of how members of the community checked on each other and shared resources. She said:

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[14] The Nyumba kumi is a nationwide government initiative encouraging citizens to be vigilant and to report suspicious activities in their neighborhoods.

"I am lucky that all my children are grown up and are working in Nairobi, the food I harvest from my farm is enough for me…. Actually, I don't have to farm all the five acres of land I own to feed myself…. Last year, we experienced a very bad drought. There were a lot of people who had nothing to eat. In our African traditions and customs, when you give, you are become blessed, so I decided to donate the extra food I have to people who are needy. Just last year alone I gave ten bags of maize and bean to needy families, single mothers, and widows. Isn't that a blessing"?

In the other conversation, the second woman told me:

"Before we started planting, we put in practice what I learnt from the World Vision[15]. It is important to rotate the crops and to keep some of the crop residues on the soil to retain the moisture and protect the soil. These new ways of working our land have improved our farming, and we now have a much better harvest".

As illustrated by these comments, villages that had effective function social groups including the informal networks of support, a shared sense of identity, understanding, cooperation, and values were less vulnerable since this form of cohesiveness strengthened their adaptive capacity. Additionally, the collaboration between the residents of these villages and other stakeholders fostered greater social greater social capital, through sharing of knowledge and skills, ultimately increasing the community adaptive capacity.

3.6.2 Sensitivity Analysis

I performed a sensitivity analysis to determine the most critical criteria to the final rankings of the social vulnerability at the five villages. The most critical criteria at any specific level in the hierarchy changes the final ranking of the alternatives when their current weights are adjusted compared with those of other criteria at the same level of the hierarchy. At the second level of the hierarchy with three vulnerability components – *exposure*, *sensitivity*, and *adaptive capacity, sensitivity* appeared to be the most critical criteria when the weights were adjusted by at

[15] World Vision is an international Non-Governmental Organization. Community members at Mt. Kasigau were being trained by the NGO officer on improved and sustainable agricultural practices.

least 66%. At the third level of the hierarchy, the most critical criteria appeared to be population density when the weights were adjusted by at least 45%. At the fourth level of the hierarchy, the only criteria that appeared to be critical was community policing when the weights were adjusted by at least 30%. The rest of the criteria within the hierarchy did not change the final ranking of the villages when their current weights were adjusted. Therefore, the results from the sensitivity analysis suggested that the AHP model developed for this study was robust.

3.7 Discussions

The social vulnerability at Mt. Kasigau is affected by multiple factors. In this study, the researcher utilized focus group discussion sessions, semi-structured interviews, observation, and impact tree diagram to identify various factors that threatened the livelihood of the residents of these villages. In each village, there was a huge disparity on the spatial patterns of factors that were identified to influence the social vulnerability of these villages, specifically, the *exposure* and *adaptive capacity* factors. Similarly, villages that were closer to a water source or had a considerable number of micro enterprises experienced little *exposure* to water and economic insecurity. Environmental exposure was the major theme that was identified by the residents of these villages. Particularly, the informants noted that soil erosion and low precipitation exposed them to food insecurity, ultimately leading to reduced income, productivity, as well as other health consequences.

Likewise, among the initiatives meant to improve the *adaptive capacity* the rate and level of implementation varied greatly. For example, some villages (e.g. Rukanga and Jora villages), had better *adaptive capacity* measures such as improved farming practices and community policing compared to Makwasinyi village. As some of the informants illustrated, villages that had adapted climate-smart agricultural techniques such as "sunken bed[16]" and diversified their range of crops had a better adaptive capacity compared to villages that relied on traditional farming practices. As one of the interviews from Rukanga village suggested. "*Nowadays I no*

[16] A technique where a valley instead of a mountain (raised bed) is created. The bed is filled with dry vegetation or crop matter mixed with green vegetation and covered with top soil. The area is then wetted and covered with the polythene sheet. This entire process is meant to facilitate decomposition of the plant matter while at the same time retaining water for a longer period.

longer rely on maize which has been failing virtually through all seasons. I am now making good returns from watermelons, cassava and groundnuts". This improved farming practices, also enhanced the environmental quality and the ability of the community to utilize and live in harmony with the land for generation to come and mitigating them from effects of environmental change as well as improving the productivity and farm yields, especially of maize and other food crops thereby increasing the *adaptive capacity* of the residents in these villages.

In terms of *sensitivity*, there was little disparity among the five villages since the *sensitivity* factors identified in each village were influenced by demographics, population density, and socioeconomic status of the residents of these villages and they were similar. Thus, results from this study indicates that to reduce social vulnerability in these villages residents should focus more on reducing the level of *exposure* to some of the factors identified while increasing the *adaptive capacity* of the residents because *sensitivity* did not play an important part in influencing the social vulnerability of these villages. Whilst the three components contribute towards vulnerability, the focus on intrinsic factors for *sensitivity* would have been responsible for not contributing much on the overall social vulnerability in these villages.

In terms of developing a framework for assessing the social vulnerability of the five villages, the use of AHP to construct the social vulnerability assessment model based on the three components of vulnerability was helpful in understanding the social vulnerability in these villages. Specifically, the ability of AHP to decompose the vulnerability conceptual model into its individual components and calculate the global weights of each component was useful to determine which vulnerability component was critical in determining the social vulnerability of these villages. Finally, by integrating the three components of vulnerability into a single vulnerability assessment model, I was able to measure the cumulative vulnerability of each village as well as individual representations of *exposure*, *sensitivity*, and *adaptive capacity*.

3.8 Conclusion

In this research, a multi-criteria decision-making model (e.g., AHP) for assessing the social vulnerability of five villages as a result of societal and environmental conditions emanating within and outside the study villages was developed. The model was useful in realizing the goal of this research, which was to assess the social vulnerability across the five villages at Mt. Kasigau. Results from this study highlight that the integration of AHP and the impact tree diagrams provide a powerful tool for assessing the social vulnerability of these

villages. Additionally, information collected using semi-structured interviews, focused group discussion sessions, and observations were helpful in comparing the five villages with respect to the criteria within the AHP hierarchy.

The results from the analysis highlight some of the caveats that decision-makers in every village must consider since vulnerability is socially created and processes that facilitate the outcomes of harmful events operates at the village level. Ultimately, it is the people of these villages that are vulnerable. Drawing from these results, Makwasinyi was identified as the most vulnerable village while *adaptive capacity* and *exposure* were identified as the most important components of vulnerability that affected the social vulnerability of these villages. Therefore, results from this study would be useful in assisting policy makers at the village level (e.g. chiefs, members of county assembly, village elders, communities, and individuals) in assessing their social vulnerability and identifying gaps that need to be addressed. Moreover, the methodology framework used in this research can be replicated by neighboring communities. Thus, it follows that village elders, chiefs, and social workers working in these villages should focus more on reducing *exposure* and increasing the *adaptive capacity* in each village. In that respect, the highest priority for any intervention measures aimed at reducing the social vulnerability in the area should be given to Makwasinyi village.

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CHAPTER IV

ASSESSING THE VULNERABILITY OF THE ENVIRONMENT AT MT. KASIGAU, KENYA, USING THE ANALYTICAL HIERARCHICAL PROCESS

A version of this chapter was submitted to the *Journal of Disaster Risk Studies* by Njoroge Gathongo and Liem Tran. As the first author, I processed the data, performed the analysis, and wrote the article. Liem Tran offered advice on the work described here. He also reviewed early revisions of this manuscript.

The use of "we" in this chapter refers to myself, as the first author and Dr. Liem Tran as my advisor.

Abstract

This study assesses the vulnerability of the biophysical environment at five villages (Jora, Kiteghe, Makwasinyi, Bungule, and Rukanga) in Mt. Kasigau, Kenya, under various anthropogenic threats, such as charcoal burning, expanding of farms, mining, and cattle grazing. The goal was to develop an environmental assessment model that was transparent, understandable, and usable by the communities at those five villages. Starting from a conceptual framework of vulnerability with three components – *exposure*, *sensitivity*, and *adaptive capacity*, I utilized the Analytical Hierarchy Process (AHP) to develop a vulnerability assessment model with relevant criteria and indicators in a hierarchical structure. Next, I performed the assessment (e.g., pairwise comparisons) at each level of the hierarchy to transform quantitative and qualitative information and judgments into ratio-scale priorities at each node (i.e., local priorities) in the hierarchy. Finally, I aggregated local priorities from the bottom up to derive the global priorities of environmental vulnerability surrounding those five villages. The study revealed that *adaptive capacity* played a critical role in determining the vulnerability among the five villages. In this context, measures for reducing vulnerability should emphasize on *adaptive capacity*, especially for the most vulnerable village (e.g., the Makwasinyi village).

4.1 Introduction

The concept of vulnerability has been proposed, applied, and studied in various disciplines in the last several decades, including natural hazards (Cutter, 1996; Wei et al., 2004), ecological/environmental studies (Benayas and Montana, 2003; Gunderson, 2000; Metzger et al., 2006), economic and social welfare studies (Adger, 1999; Murdoch, 1994; Watts and Bohle, 1993), and global climate change (Berry et al. 2003, Downing et al., 2001; Metzger et al. 2005; Moss et al., 2002). Generally speaking, vulnerability represents the degree to which human and/or environmental systems are likely "to experience harm due to a perturbation or stress" while also taking into account the capacity of the systems to cope with the risks (Bhamra et al., 2011). Given the diversity of systems, scales, and/or research foci, different disciplines often use different definitions of the concept of vulnerability and have consequently developed and used different methods to analyze and measure it (Alwang et al., 2001). In the early years, traditional vulnerability assessment often centered on single risk/hazard to single resource/receptor/target (e.g., human health risk assessment based on toxicology in 1960's-1970's). Nowadays there have been more vulnerability studies which focus on many aspects of the system being stressed, such as the synergistic effect of multiple risks on multiple resources, the system's ability to cope, adapt or recover from multiple risks, as well as the mechanisms that enhance or limit such ability (Clark and Dickson, 2003; Fussel, 2007; Luers, 2005). Furthermore, the current vulnerability research has been more multidisciplinary, integrating natural with social sciences, and more policy-oriented (Holm et al., 2013; Bohle, 2001).

While there have been many environmental vulnerability assessments reported in the literature, very few of them can be utilized directly by such lay people, as villagers in a remote area in Africa. In that context, this research focused on assessing the environmental vulnerability in five villages surrounding Mt. Kasigau, Kenya, under various risks caused by human activities, such as expanding of farmlands, mining, charcoal burning, and cattle grazing. Furthermore, my goal was to develop a vulnerability assessment model that can be understood and utilized by communities at those villages. I also aimed to assist the residents of these villages in understanding the various aspects of environmental vulnerability and how different factors contribute to the vulnerability of the natural environment.

Due to the various definitions and applications of vulnerability, different conceptual frameworks have been developed over time for assessing vulnerability (Adger, 2006; Eakin and

Luers, 2006). Therefore, the choice of a vulnerability conceptual framework is important, as it helps in identifying all the possible contributing factors and the interactions between them (Zou and Wei, 2010). With the village communities as stakeholders and model users in my mind, I selected the Turner et al. (2003) vulnerability conceptual framework, which is comprehensive and transparent to lay people. Fundamental to this conceptualization of vulnerability are the three major components of vulnerability: *exposure*, *sensitivity,* and *adaptive capacity* (Birkmann, 2006; Adger, 2006; Janssen et al., 2006; Turner et al., 2003). *Exposure* refers "to the nature or degree to which a system" or a system's components are subjected to potential loss (IPCC, 2001). *Sensitivity* is the degree or extent to which a system or its components are adversely affected by a disaster (IPCC, 2001; Adger, 2006; Birkmann, 2006). In addition, *sensitivity* also shows the degree to which species or organisms are modified or affected by a disturbance (Berry et al., 2003). *Adaptive capacity* refers to how a system or a system's components cope with negative effects (Gallopin, 2006; Turner et al., 2003). In other words, *adaptive capacity* is the potentiality to adapt or cope with negative changes without changing the system functions and structure, thus reducing vulnerability (IPCC, 2001; Luers, 2005).

Within the Turner et al. (2003) framework, I utilized the Analytical Hierarchy Process (AHP) to structure vulnerability and its three components in a hierarchical format. Each vulnerability component in the AHP was represented by a set of landscape and/or stressor/receptor indicators. I then, assessed and compared the five villages based on the indicators and criteria in the hierarchy to rank the natural environment surrounding those villages with respect to their vulnerability.

The rest of the paper is organized as follows. In section 4.2, I give an overview of the study area. Section 4.3 highlights how the data was processed. Then, I describe the method used in this research to analyze the data, specifically focusing on how the AHP was used as tool for realizing the vulnerability conceptual model in section 4.4 to 4.5. Section 4.6 provides the results of the study followed by a discussion of the overall findings in section 4.7. Finally, section 4.8 presents the conclusion of the study.

4.2 Study Area

Mt. Kasigau (3°49`S and 38°39`E) is located in Taita Taveta county in Southeastern Kenya on a community trust land, within a corridor that links Tsavo East and West national park (Kalibo and Medley, 2007; Medley and Kalibo, 2005). The mountain rises steeply from the

surrounding arid plains from 600 to 1,641 meters above sea level in less than 2km (Henkin et al., 2015; Medley and Kalibo, 2005). The mountain is a part of the Eastern Arc Mountains, a range comprised of diverse material resources and ecosystem services that are critical to human livelihood (Kalibo and Medley, 2007; Hurni, 1999).

The area is inhabited by the Wakasigau community, a sub-tribe of Taita community (Medley and Kalibo, 2005). Due to the high number of endemic species, high species richness, and high degree of fragmentation, the area is recognized as a biodiversity hotspot (Myers et al., 2000). Being an area occupied by a large farming community, the environment is threatened due to external and internal perturbations. Thus, the productivity and sustainability of the natural resources in the area depend on how the resources are utilized and managed over time (Gathongo, 2012).

The mountain includes the evergreen montane forests, the woodlands just below the montane forests, the farmlands and settlements at the base of the mountain, and the lowland dryland forests, predominantly of *Acacia commiphora* species (Kalibo and Medley, 2007). The region is classified as a semi-arid area and it experiences two rainfall seasons (long rains from March-May and short rains from mid-October-December) (Henkin et al., 2015; Medley and Kalibo, 2005). Yearly precipitation in the region ranges from 300mm to 500mm (Medley and Kalibo, 2005). However, at higher elevation, more precipitation and moisture is experienced because of the cloud forests (Kalibo and Medley, 2007).

The five study villages (Kiteghe, Makwasinyi, Jora, Bungule, and Rukanga) are clustered around the base of the mountain (Figure 13), and are vulnerable to human activities, especially charcoal burning, expanding farmland, cattle grazing, mining, and poaching of endemic species such as *Santalum album* (saddle wood). Thus, this research is important as it offers an opportunity for assessing the vulnerability of the environment and understanding the factors that contribute to the vulnerability of the environment.

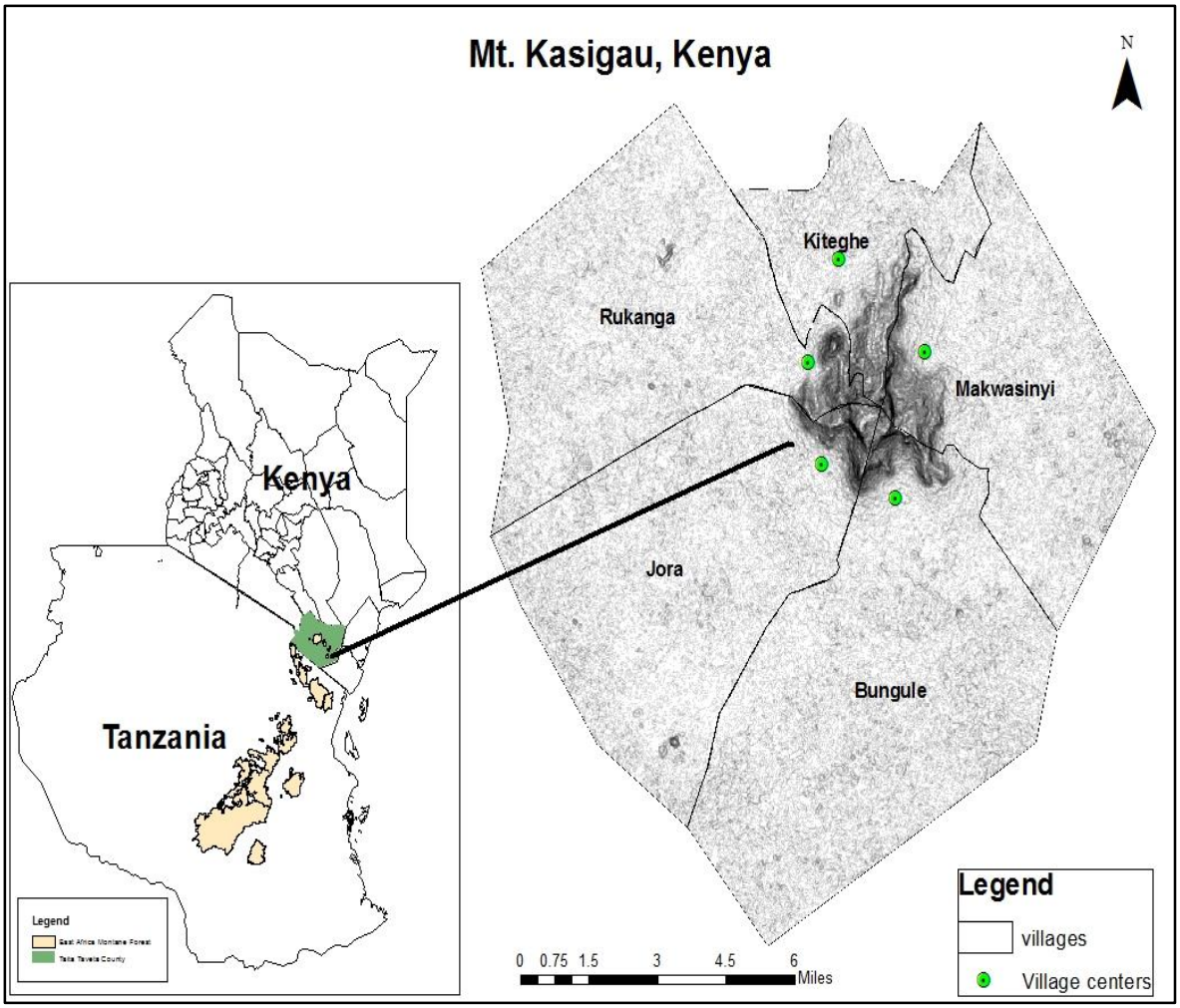

Figure 13: Location of the five Study Villages at Mt. Kasigau, Kenya, the most north-eastern mountain in the Eastern Arc Mountain in southeastern Kenya. The green dots denote each village's center.

4.3 Data Processing

The US Geologic Survey (USGS) maintains the Landsat archive, which was explored to obtain four Landsat images (MMS 1975, TM 1995, ETM+ 2003, and OLI/TIR 2014) and a Digital Elevation Model (DEM). To minimize seasonal variation, all images acquired were from the same dry season. The months of February, October, and July are the dry seasons in Taita Taveta County.

The approach used in preparing the data involved supervised classification techniques to produce land cover maps for the four years, later deriving class level landscape metrics from the classified images using FRAGSTATS 4.2 software. The class level metrics generated included: class area (CA), percentage of landscape (PLAND), number of patches (NP), effective mesh size, among others, although CA was the only metric used in this study. A 30m DEM was used in generating different slope categories for the area. Finally, a Normalized Difference Vegetation Index (NDVI) time series was computed for each village to assess changes in vegetation cover over time. Qualitative information used in this research was collected during the focus group discussion sessions held in each village.

4.4 Methodology

In the assessment, I used AHP, a multi-criterion decision-making method (MCDM) to construct the vulnerability assessment model. AHP structures complex problems into a hierarchical framework of goals, objectives, criteria, sub-criteria, and alternatives before deriving priorities of alternatives based on the judgments of the experts or users (Saaty, 2008). It is a method that derives ratio scales via pairwise comparison (Al-Harbi, 2001; Saaty, 2004). In addition, AHP allows the incorporation of qualitative and quantitative data in the same decision framework (Ramanathan and Ganesh, 1995).

Many researchers use AHP or other multi-criteria decision methods in studies concerned with complex decision-making (Roy and Blaschke, 2015). In environmental management, Tran et al. (2002) used AHP to determine areas that would be vulnerable to environmental deterioration utilizing data from stream, roads, topography, population, and land cover in a vulnerability assessment for mid-Atlantic regions. In another study, Sharifi et al. (2002) applied AHP to select suitable locations for a national park boundary. Qureshi and Harrison (2001) used AHP in evaluating “four riparian revegetation policy options for Scheu Creek, a small sub-catchment in the Johnstone River catchment in north Queensland, Australia” (101). Similarly,

Zhu et al. (2014) used AHP to generate weights for several indicators based on three components of vulnerability in Guangdong Province, China while assessing heatwave vulnerability on human health. Yuan et al. (2015) applied AHP to obtain weights of different indicators in order to analyze components of vulnerability that were responsible for drought in a regional vulnerability assessment for drought in some provinces in China. In this research, results highlighted causes of vulnerability to drought as the result of shortfalls in adaptive capacity, exposure of the population and the region, as well as their sensitivity (Yuan et al., 2015). Lastly, in an assessment of spatial vulnerability to floods in coastal Bangladesh, Roy and Blaschke (2015) employed AHP for assigning relative weights to selected components of vulnerability (sensitivity and adaptive capacity) and 44 other indicators. Therefore, this research relies heavily on earlier work conducted in the same field.

An advantage of using AHP over other multi-criteria methods in this study was its flexibility, ease of use, and its ability to check for inconsistencies (Al-Harbi et al., 2001; Ramanathan and Ganesh, 1995). The capability of AHP to decompose the decision problem into a well-structured hierarchy of the goal, criteria, sub-criteria, and alternatives was another advantage of this method. In this study, I was able to use AHP to structure vulnerability and its three components in a hierarchical format in which each vulnerability component was represented by a set of landscape and/or stressor/receptor indicators. Thus, AHP presented an advantage in developing a vulnerability assessment model with relevant criteria and indicators in a hierarchical structure. Additionally, using AHP was advantageous as I was able to convert qualitative and quantitative data into ratio-scale priorities which were used to rank the villages and to determine which component contribute towards the environmental vulnerability of these villages.

Under the AHP hierarchical structure, the three components of vulnerability were put at the second level, just below the goal of assessing the overall environmental vulnerability at the five villages (Table 5). At the third level were the major anthropogenic risks that were considered to be significant in influencing the three components of vulnerability. The fourth level of the hierarchy included several landscape and/or stressor/receptor indicators, while the fifth level were the five villages that were being ranked from the most to the least vulnerable (see Appendix 3, Figure A.1).

Table 5: An explanation of the different criteria, indicators and indicators used in the AHP.

	Primary Criteria (2nd level)	**Sub-Criteria – Major anthropogenic threat causes vulnerability (3rd level)**	**Landscape and/or stressor/receptor indicators used to evaluate the human activities (4th level).**
Goal- Ranking of the five villages from the most to least vulnerable	*Exposure*	Cattle Grazing	Extent of the bushland - class area (CA).
		Charcoal Burning	Local fuelwood consumption needs in each village.
			Extent of the *Acacia commiphora* land cover type- class area.
			Unemployment level in each village.
		Expanding of Farmland	Percentage of flat area in the bushland
			Extent of the black cotton soil land cover type- class area
			Extent of the bushland land cover type- class area.
			Proximity of the bushland from the settlement – distance of the bushland from the respective villages.
			Total length of roads in each village (extent of the road network).
		Mining	Number of mines.
			Size of the mining area.
	Sensitivity	Cattle Grazing	Mean Normalized Difference Vegetation Index (NDVI) within the bushland
			Percentage area of the bushland with steep slopes.
		Charcoal Burning	Class area of the *Acacia commiphora* bushland.
		Expanding of Farmland	Percentage area of steep slope in the bushland for each village.
			Percentage of erosion prone soil – class area of the farmland and settlement.
	Adaptive capacity	Cattle Grazing	Cattle grazing practices in each village.
		Charcoal Burning	Charcoal burning control measures in each village.
		Expanding of Farmland	Rate of good farming practices observed in each village.

4.5 Performing Pairwise Comparisons

Throughout the hierarchy, I performed pairwise comparisons to transform quantitative and qualitative information and judgments into ratio-scale priorities at each node (i.e., local priorities) in the hierarchy. Finally, I aggregated the local priorities from the bottom up to derive the global priorities of environmental vulnerability surrounding those five villages. During the pairwise comparisons, the judgmental matrix was considered to be adequately consistent if the consistency ratio was less than 10% (Saaty, 2008; Roy and Blaschke, 2015).

The pairwise comparisons of elements relied on the judgment of the researcher and the landscape metrics/indicators computed for each village. The scale used (Table 6) was consistent with Saaty's (2008) one to nine numerical scale, where a verbal judgment preference of "equally importance" is given to numerical rating of one and a verbal judgment preference of "extremely importance" is given a numerical rating of nine (Saaty, 2008).

At the second level of the hierarchy, the three components of vulnerability components were assigned equal weight. I assumed that the three components contributed equally to the environmental vulnerability surrounding the five villages. At the third and fourth level of the hierarchy, the elements were assigned weights based on the researchers' knowledge of the area. To that effect, expanding of farmland was assigned more weight, followed by cattle grazing, charcoal burning, and mining respectively in the third level. Finally, at the fifth level of the hierarchy, the pairwise comparison of the villages was based on the computed landscape metrics/indicators with the exemption of a few elements in the *adaptive capacity* node and some element such as "unemployment rate" and "local fuelwood consumption needs" under the charcoal burning sub-criteria within the *exposure* node.

Table 6: The Fundamental scale of measurement in AHP adapted from Saaty (2008) for Assessing The Environmental Vulnerability.

Weight	Definition	Explanation
1	Equally important	Two factors contribute equally to the objective.
3	Moderately important	Experience and judgement slightly favor one over the other.
5	Strongly important	Experience and judgement strongly favor one over the other.
7	Very strongly important	Experience and judgement very strongly favor one over the other, as demonstrated in practice.
9	Extremely important	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate preference between two adjacent judgements	When compromise is needed.

4.6 Results

4.6.1 Ranking of the Villages

After deriving the local priority weights for the criteria, sub-criteria, and alternatives through pairwise comparisons, the weights were aggregated from the bottom up to derive the global weights of environmental vulnerability surrounding those five villages. Figure 14 highlights the most to the least vulnerable village in the study area. From these results, it is evident that Makwasinyi was the most vulnerable village with a global weight of 0.2799, followed by Kiteghe (0.2141), Bungule (0.2114), Rukanga (0.1505), and Jora (0.1442) respectively. Therefore, from this analysis, Kiteghe, Bungule, Rukanga, and Jora were approximately 76.50%, 75.52%, 53.76%, and 51.50% as vulnerable as Makwasinyi respectively.

To understand the degree of vulnerability of each village in terms of the three components of vulnerability, I used the priorities weights of the three components derived from the vulnerability assessment model (Table 7). Based on the priority weights, it is evident that there were some differences on how each component of vulnerability contributed towards the overall vulnerability of each of the villages.

For example, there was some minimal difference among the villages in terms of *exposure* and *sensitivity* (Figure 15). In terms of *adaptive capacity*, villages that had the highest priority weight were Makwasinyi followed by Kiteghe and Bungule, which was in line with the ranking of the villages. Based on these results, higher priority weights for *exposure* and *sensitivity* implied higher vulnerability. However, for *adaptive capacity* lower priority weights reflected lesser vulnerability since adaptive capacity is inversely related to the other two vulnerability components. So, the higher the *adaptive capacity* priority weights from the model, the lower the village's vulnerability.

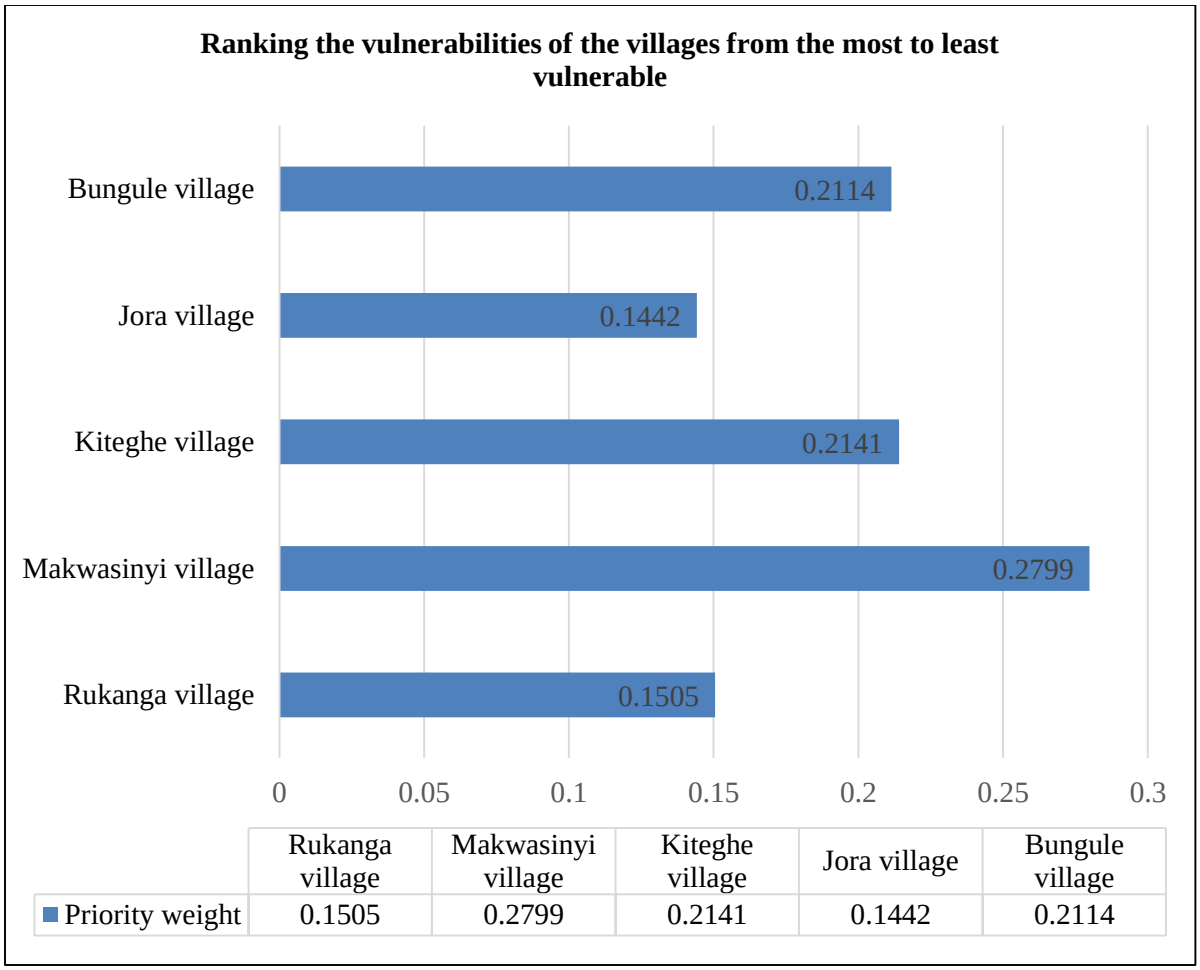

Figure 14: A graphical representation of the most to least vulnerable villages at Mt. Kasigau, Kenya.

Table 7: Priority weights of the three components of vulnerability in each village.

	Adaptive capacity	***Exposure***	***sensitivity***
Bungule village	0.1043	0.0673	0.0833
Jora village	0.0377	0.0699	0.0572
Kiteghe village	0.1024	0.0777	0.0776
Makwasinyi village	0.2168	0.0828	0.0620
Rukanga village	0.0388	0.0676	0.0652

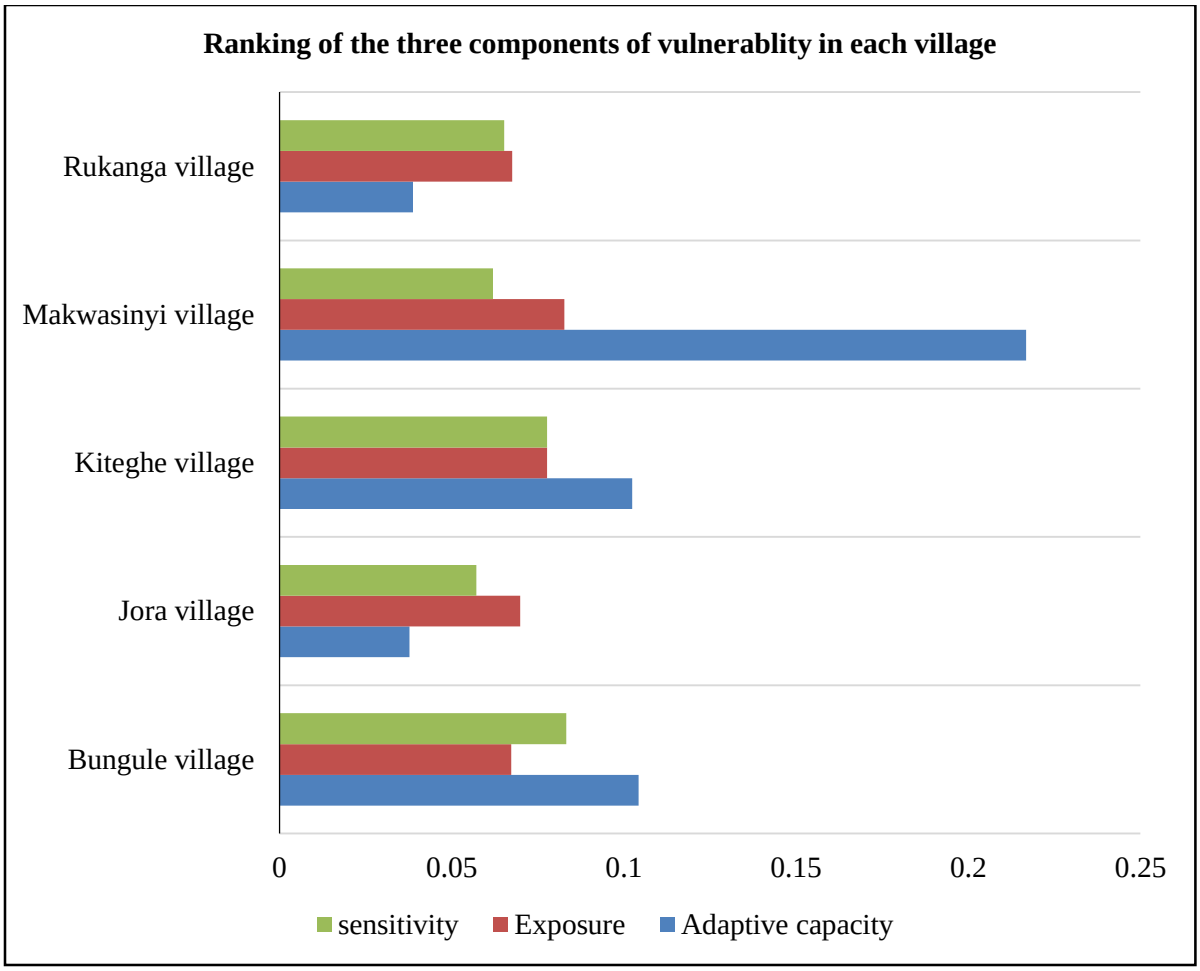

Figure 15: A graphical representation of the three components of vulnerability in each village.

4.6.2 Sensitivity Analysis

A sensitivity analysis was conducted to determine the most critical criteria to the rankings of the environmental vulnerability at the five villages. The most critical criteria at any specific level in the hierarchy is defined as the criteria that changes the ranking among the villages with the smallest change of the current weight compared with those of other criteria at the same level. At the second level of the hierarchy with the three components of vulnerability (i.e., *exposure*, *sensitivity*, and *adaptability*), *sensitivity* appeared to be the most critical criterion. Among the criteria at the third level of the hierarchy with the major anthropogenic threats in the area (i.e., expanding of farmland, mining, charcoal burning, and cattle grazing), "mining" appeared to be the most critical criteria within the *exposure* node, while "charcoal burning" and "cattle grazing" appeared to be the most critical criteria in the *sensitivity* and *adaptive capacity* nodes, respectively. In the fourth level of the hierarchy, under the "expanding of farmland" node, contained five different elements: class area of the bushland, total length of the roads, distance from the main settlement, percentage of flat area in the bushland, and class area of the black cotton soil land cover type. "Total length of the roads" appeared to be the most critical metric. Similarly, the "charcoal burning" node contained three criteria: local fuelwood consumption needs, the class area of *Acacia commiphora* bushland, and unemployment. The "class area of the *Acacia commiphora* bushland" appeared to be the most critical criteria. None of the criteria under the "mining" node appeared to be critical. The "expanding of farmland" node, under sensitivity contained two elements: "The percentage area with steep slopes within the bushland in each village and the percentage of erosional prone soil (i.e. the class area of the farmland). The "percentage of erosional prone soil" appeared to be the most critical criteria. Finally, between the "mean NDVI" and the "percentage area with steep slopes within the bushland in each village" under the "cattle grazing" node, none of the elements seemed to be critical. Note that change to ranking among the villages only happened if the weights of the most critical criteria described above were changed by at least by 66%. Thus, these results indicate that AHP model developed in this study for the five villages was robust.

4.7 Discussions

Among the three components of vulnerability, *adaptive capacity* played a critical role in influencing the vulnerability of each village. Apparently, it is due to the fact that there was no significant difference between *exposure* and *sensitivity* among the five villages. These results

align with other studies that show the lack of *adaptive capacity* contributing to the exploitation of natural resources by humans as they try to sustain their livelihoods (Fisher and Christopher, 2007; Muriuki et al., 2011). For example, Scherr (2000) highlights how socio-economic marginalization leads to environmental degradation. Therefore, lack of sufficient *adaptive capacity* by the residents of Makwasinyi village might have contributed to the vulnerability of the environment as the residents attempted to support their livelihoods and improve their well-being by exploiting the natural resources.

The findings from this research are in line with other studies conducted in this area. For example, in a study that focused on understanding land cover changes using remote sensing, geographical information system, and local knowledge at two of those villages (Jora and Makwasinyi), Gathongo (2012) observed that Makwasinyi was more geographically isolated compared to the other villages (e.g., being significantly off the main road). Consequently, Makwasinyi had higher incidences of charcoal burning, poor law enforcement, and fewer economic activities/opportunities. In another study, Falcetto (2012) noted that "there was an apparent difference in conservation and ecotourism attitudes between Makwasinyi and the other villages, arguably due to the relatively lower level of education in Makwasinyi." Additionally, Falcetto (2012) mentioned that Makwasinyi village had fewer shops and restaurants compared to other villages and tourists rarely visit the area. Thus, Makwasinyi's geographical isolation, fewer economic activities, low education level, as well as other factors have led to lower *adaptive capacity* of the residents of this village. As a result, the residents were forced to exploit natural resources in the area to sustain their livelihoods, likely explaining Makwasinyi's relative vulnerability as compared to the other villages in this study.

The use of AHP to construct an environmental vulnerability assessment model based on the Turner et al. (2003) vulnerability conceptual framework with three components of *exposure, sensitivity, and adaptive capacity* was important in understanding the complexities of the environmental vulnerability in those five villages. Specifically, the study highlighted that *adaptive capacity* at the five villages played a critical role in determining the vulnerability of the natural environment compared to the other vulnerability components. Thus, these results would be useful in assisting the community in improvising mitigation measures that would build their *adaptive capacity*, hence reducing the vulnerability of the natural environment.

Finally, the model developed in this study would be useful to the local community, local policymakers, and communities surrounding these villages that have similar environmental conditions. As the model is simple and understandable, local policymakers in collaboration with leaders of these villages could utilize this model as a framework for assessing the environmental vulnerability of multiple villages, in order to determine "hot spots" of environmental vulnerability for mitigation actions to improve environmental conditions at individual villages and/or of the whole region.

4.8 Conclusion

This research explored the vulnerability of the environment in five villages at Mt. Kasigau, Kenya. I focused on risks posed by human activities in examining factors that contribute to environmental vulnerability. By utilizing the AHP, I was able to structure vulnerability and its three components into a hierarchical structure for assessing the vulnerability of the five villages, generate a weight for each village via pairwise comparisons, and obtain a ranking for each village from the most to the least vulnerable. In this research, the use of AHP for vulnerability assessment was an effective method as it allowed us to integrate qualitative and quantitative information in the same decision framework and develop a vulnerability assessment model.

Vulnerability assessment involves complex decision-making situation that requires discerning abilities and methods to make sound decisions. Therefore, this research adapted AHP due to its unique advantages of organizing and analyzing complex decisions. AHP model developed for this study was effective in revealing differences in vulnerability among the five villages. In particular, the results from this study could be used by policymakers and other stakeholders in making decisions concerning the environment in each of the village. The results suggest that Makwasinyi should be given the highest priority by the county government and non-governmental organizations working in the region in terms of intervention measures aimed at reducing environmental vulnerability, such as investing in extension services, social services, creating markets for farm products, and bursary programs among others.

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CHAPTER V

AN ANALYTICAL HIERARCHY PROCESS (AHP) FRAMEWORK FOR EVALUATING AND PRIORITIZING OPTIONS FOR REDUCING HUMAN AND ENVIRONMENTAL VULNERABILITY AT MT. KASIGAU, KENYA.

A version of this chapter will be submitted to the *GeoJournal* by Njoroge Gathongo, Liem Tran, Robert Jones, and Nicholas Nagle. As the first author, I processed the data, performed the analysis, and wrote the article. The co-authors offered advice on the work described here. They also reviewed this manuscript.

The use of "we" in this chapter refers to myself, as the first author, Dr. Liem Tran as my advisor, and Drs. Robert Jones, and Nicholas Nagle as my dissertation committee members.

Abstract

The vulnerability of the human and natural systems at Mt. Kasigau, Kenya is an obstacle to sustainable development. Reducing vulnerability in these villages is a prerequisite for sustainable development. Therefore, this study focused on developing a framework that helps the residents of Mt. Kasigau evaluate and prioritize different options for reducing vulnerability as a result of human activities and environment changes. My goal was to develop a vulnerability reduction model that was understandable and could be used by the communities at those five villages. Starting by examining the benefits, opportunities, costs, and risk factors that would affect the community decision, I used the analytical hierarchy process (AHP) to develop a vulnerability reducing model with relevant criteria and sub-criteria in a hierarchical structure. Then, I incorporated a vulnerability conceptual framework that treats vulnerability as a function of exposure, sensitivity, and adaptive capacity. The aim was to reduce community members' exposure and sensitivity as well as to increase their adaptive capacity. Next, the residents of each village performed the assessment (pairwise comparisons) and the qualitative and quantitative information was transformed into ratio scale priorities (local priorities) at each node of the hierarchy. Finally, the local priorities were aggregated from the bottom up to derive the global priorities of the alternatives (options for reducing vulnerability) for each village. The study revealed that measures that are geared towards environmental conservation (i.e. *tree planting and banning of charcoal burning*" and "*increased supply of water for domestic consumption and agricultural use*") were the best options for reducing vulnerability in these villages. Therefore, to attain sustainable development in these villages, in is important to reduce the vulnerability of human and natural systems by implementing such options, as environmental conservation.

5.1 Introduction

The concept of sustainable development has been studied and applied in various disciplines, such as in global environmental studies (Goodland, 1995; Magis, 2010; Ostrom, 2009; Turner et al., 2007), economic/business studies (Baumgartner and Quaas, 2010; Springett, 2003), urban planning (Naess, 2001; Rees and Wackernagel, 1996; Wu, 2014), and social studies (Vallance et al., 2011). The interest on sustainable development emerged after the publication of the Brundtland Commission's report on the state of the global environment and development in 1987 (Redclift, 2005; WCED,1987). This report emphasized the need to address and reconcile two issues: human development and the natural environment (Kuhlman and Farrington, 2010; WCED; 1987). It defined sustainable development as the development that "meets the needs of the present without compromising the ability of future generations to meets their own need" (WCED,1987). Accordingly, the goal of sustainable development is to improve the economic, social, and ecological systems (Folke et al., 2002).

In Mount Kasigau, like any other rural landscapes in Kenya, sustainable development encompasses positive transformation of the environment and people's livelihood to ensure high quality of life in terms of improved healthcare, gender equality and equity, better education, access to safe drinking water and basic sanitation, access to electricity, better infrastructure, protection of forests, and food security (GoK, 2017). However, human activities such as cattle grazing, clearing of forests for farmland, and charcoal burning, as well as environmental changes such as deforestation and variability in precipitation patterns have rendered the entire human and natural systems vulnerable, thereby impeding sustainable development. Therefore, it is important to identify, evaluate, and reduce vulnerabilities that are produced by human activities and environmental changes. It is also essential to increase the adaptive capacity of the community so that sustainable development can be achieved.

Human activities and environmental changes are the major threats for sustainable development in Mt. Kasigau, with severe impacts on human livelihoods, food security, economic activities, and ecosystem services. Therefore, reducing these vulnerabilities is a prerequisite for sustainable development (Cohen et al., 1998; Eriksen and O'brien, 2007). This objective demands a careful understanding the nature of vulnerabilities and where they exist (Kelman, 2011), which can be achieved by performing a vulnerability assessment. Various models have been proposed and used for vulnerability assessment (Soares et al., 2012). For example, the

International Institute for Environment and Development (IIED, 2013) in collaboration with other stakeholders, conducted a vulnerability assessment to help pastoralists in Northern Kenya reduce vulnerability to drought and build resilience, hence tackling poverty and hunger within the context of sustainable development.

The majority of vulnerability reduction strategies include measures that reduce biophysical risks as well as addressing the environmental and social factors that impact the human well-being (Brooks, 2003; Eriksen and O'brien, 2007; Mata-Lima et al., 2013). In that context, the focus of this research was to develop a framework that could help residents of five villages at Mt. Kasigau evaluate different options for reducing vulnerability. To accomplish this goal, I first developed a vulnerability reduction model using the analytical hierarchy process (AHP). The AHP is a heuristic model that assists users in identifying the best decision based on different objectives, criteria, and sub-criteria (Saaty, 2004). In this study, the AHP enable me to deal with the benefit, opportunity, cost, and risk (BOCR) objectives of the decision (Saaty, 2004). Next, under the objective benefit, I incorporated the Turner et al. (2003) vulnerability conceptual framework, which treats vulnerability as a function of exposure, sensitivity, and adaptive capacity. Finally, the model was utilized by the residents of these villages to examine and prioritize different options that would help them reduce vulnerability in their respective village. The results from this study can serve as the basis for achieving sustainable development.

5.2 The Analytical Hierarchy Process (AHP)

A good decision requires decision makers' knowledge of a problem and ability to define it (Russo and Camanho, 2015; Saaty, 2008). For a decision to be made, certain criteria are involved. The AHP developed by Saaty in 1980 is one of several multi-criteria decision-making methods (MCDM) that have been used in various disciplines to help users/decision-makers find solutions to complex multi-criteria decision problems (Lee and Chan, 2008; Vaidya and Kumar, 2006; Handfield et al., 2002). The AHP is based on "measurement through pairwise comparisons and relies on the judgments of experts to derive priority scales" (Saaty, 2008; Handfield et al., 2002). AHP is often preferred by researchers and decision makers because it is simple and powerful as it structures a decision problem into a hierarchy (Russo and Camanho, 2015; Forman and Gass, 2001; Sambasivan and Fei, 2008). The basic principle of AHP consists of defining a problem, structuring it into a hierarchy, conducting pairwise comparisons for each element in the hierarchy, checking for consistency, and finally synthesizing the local priorities from the

hierarchy to obtain global priorities (Lee and Chan, 2008; Ramanathan and Ganesh, 1995; Saaty, 2008).

AHP is widely applied in project design, urban planning, resource allocation, policy evaluation, human resources management, industrial development, risk analysis, and sustainable development, among other fields (Cheng et al., 2005; Quaddus and Siddique, 2001; Mahdi and Alreshaid, 2005; Mardle et al., 2004; Saaty et al., 2007; Saaty, 2008;). In vulnerability studies, AHP has been used to map natural and human-induced disasters. For example, AHP has been used for soil erosion hazards (Kachouri et al., 2015; Rahman et al., 2009), flood hazards (Stefanidis and Stathis, 2013), coastal inundation risks (Hu et al., 2009), landslide hazards (Neaupane and Piantanakulchai, 2006; Othman et al., 2012) drought mapping (Yuan et al., 2015), and earthquake hazards (Aghataher et al. 2008; Ishita and Khandaker, 2010). For this study, AHP was utilized to evaluate and prioritize alternatives for reducing vulnerability.

5.3 The Study Area

Mt. Kasigau (3˚49’ S, 38˚40’E) is located in Voi sub-county, Taita Taveta County and lies between Tsavo East and Tsavo West national parks in southeast Kenya (Henkin et al., 2015; Kalibo and Medley, 2007) (Figure 16). The mountain rises steeply from the surrounding dryland Acacia Commiphora bushland from around 600 m to the evergreen forested summit of the mountain, at 1641 m (Medley and Maingi, 2014; Kalibo and Medley, 2007). Mt. Kasigau is the most northeastern mountain in the Eastern Afromontane Biodiversity Hotspot (Lovett, 1998). These mountains are renowned for their high concentration of endemic species, high degree of fragmentation, and high species richness ((Myers et al., 2000; Newmark, 2002). They are recognized as a biodiversity hotspot in East Africa (Newmark, 2002).

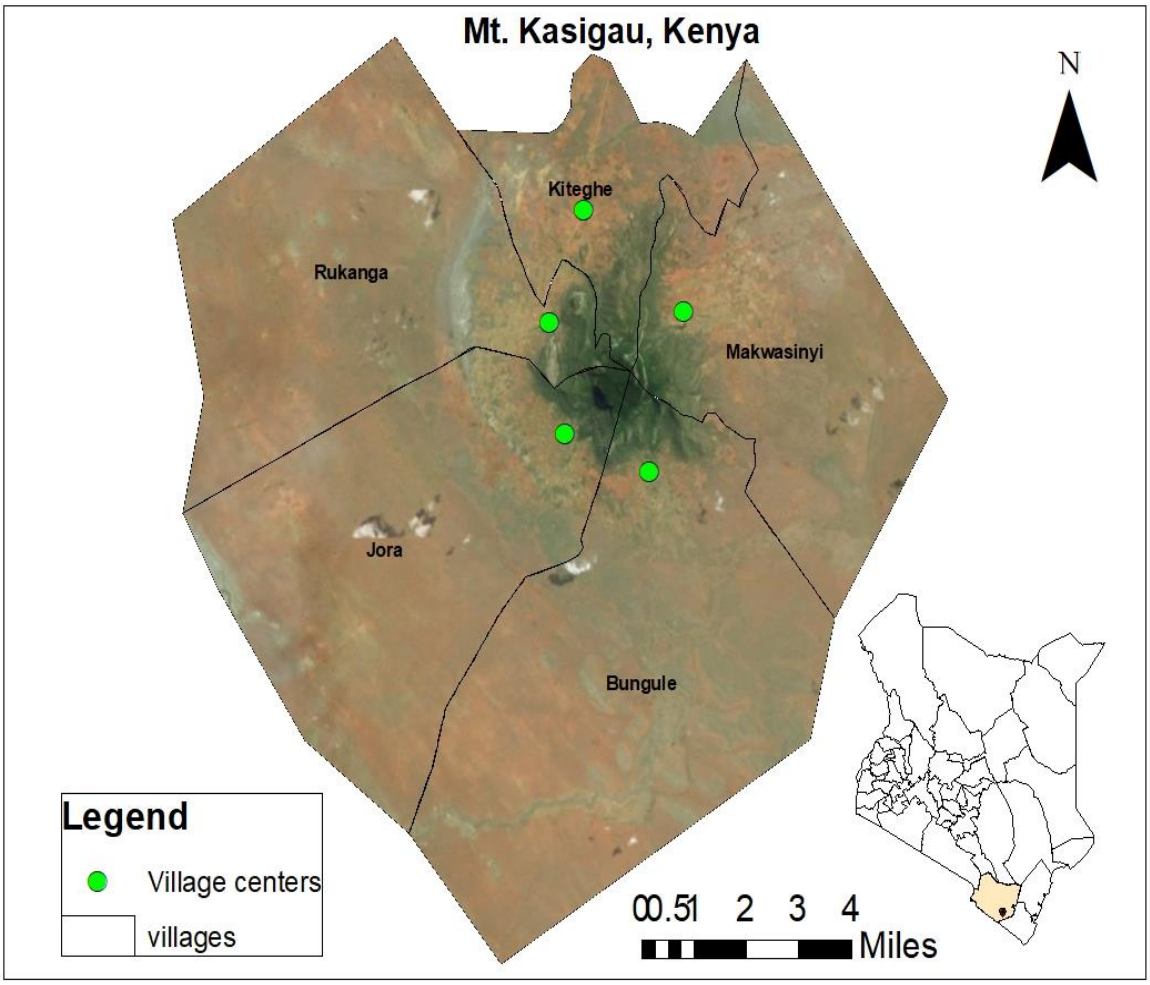

Figure 16: Location of the five Study Villages at Mt. Kasigau, Kenya.

The study focused on five villages – Jora, Kiteghe, Makwasinyi, Rukanga, and Bungule – that are geographically isolated from major roads and urban centers. These villages are situated at the base of the mountain and are characterized by the montane forest on the mountain and the surrounding bushland. According to the 2009 Kenya population census report, there were a total of 9,721 people in 1,803 households in the five study villages (GoK, 2010). The area is inhabited by members of the Wakasigau, a sub-tribe of the Taita tribe, whose main occupation is subsistence farming, including raising livestock and growing beans, maize, pigeon peas, and cassava (Kalibo and Medley, 2007; Kamau, 2017; Medley and Maingi, 2014; Medley et al., 2017). Families also sustain their livelihoods by engaging in small-scale businesses such as shops, locally made handcrafts, mining, and ecotourism activities (Myers and Medley, 2018). The dry conditions and unpredictable rainfall often cause crop failure, making the residents vulnerable to droughts and famine and necessitating outside food aid from government and non-governmental organizations (Leiter et al., 2013). In addition, it is the combination of this region's geographic isolation coupled with other human activities such as charcoal burning, cattle grazing, mining, and conversion of the bushland into farmland that exacerbates the vulnerability of the human and natural systems.

5.4 Data and Methods

This research involved the community in the decision-making process, thus, qualitative research forms its basis. The analysis was done in different phases as highlighted in Figure 17. First, the researcher developed the hierarchy based on the input from the community. Second, focus group discussion sessions were held in each village, where the residents identified different options for reducing social and environmental vulnerability. Third, the alternatives identified were integrated to the fifth level of the hierarchy by the researcher. Fourth, residents of each village conducted pairwise comparisons of all the elements in the hierarchy except for the three components of vulnerability that were performed by the researcher. Finally, all of these judgements were synthesized to generate the global priorities for each option.

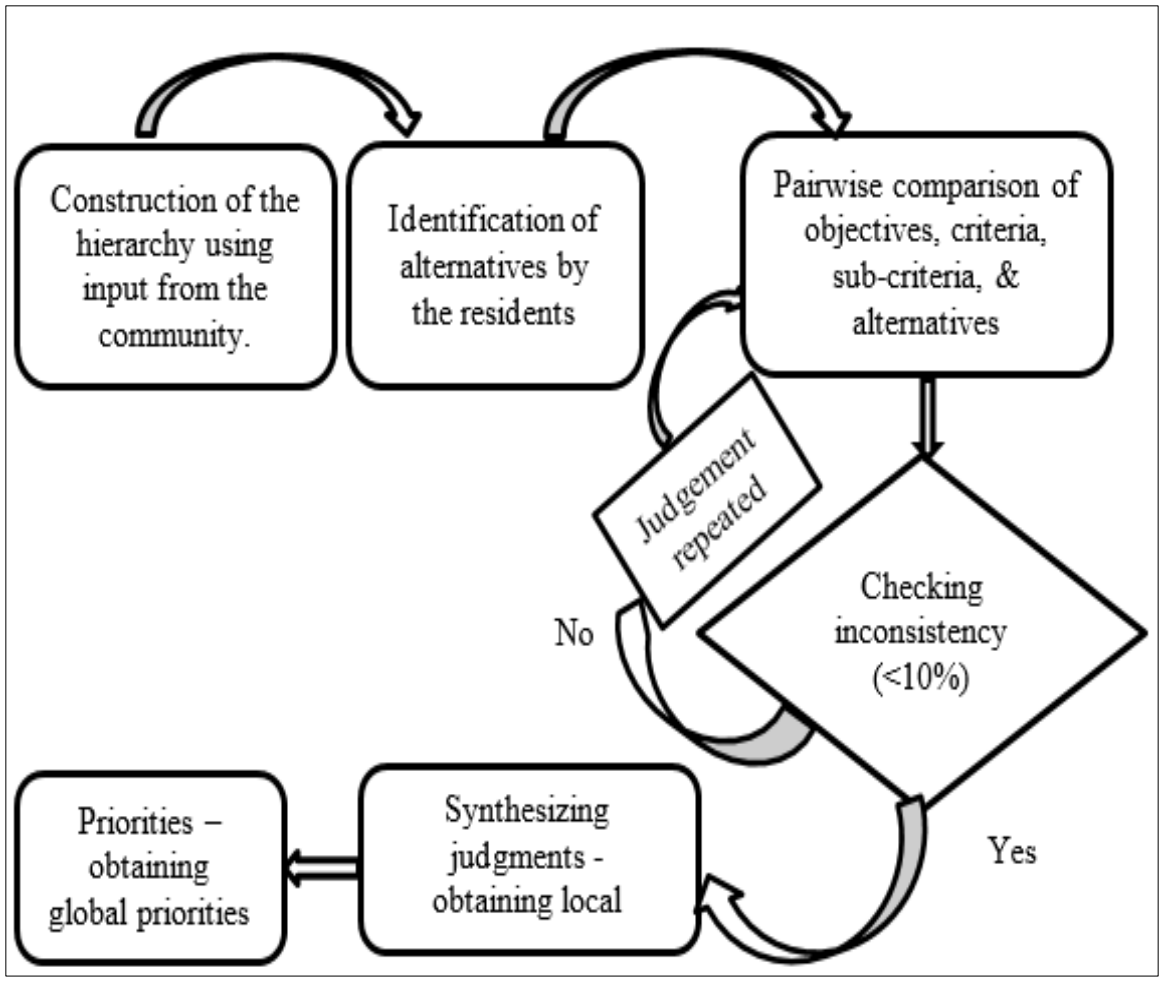

Figure 17: A flowchart depicting the method followed in evaluating and prioritizing the alternatives in each village.

5.4.1 Selection of Participants

In each village, seven to ten participants were selected to participate in this study. I used purposeful and criterion sampling techniques to select the participants. Purposeful sampling is a research technique that is used to identify and select participants who are rich in information related to the phenomenon of interest (Baxter and Eyles, 1997; Suri, 2011). Criterion sampling techniques involve selecting participants who meet certain conditions and eliminating participants based on various conditions that are set by researcher (Bradshaw and Stratford, 2010). Thus, for this study I only selected participants who were conversant with issues pertaining the vulnerability of the social and environmental systems and had also participated in an earlier study that assessed the vulnerability of these villages.

5.4.2 Focus Group Discussion Sessions

Focus groups are a form of group interviews where the researcher capitalize on the communication between the research participants to collect data (Kitzinger, 1994). They also involve a small group of people (between 6-10) discussing an issue that the researcher has defined (Cameron, 2010). The interactive aspect of a focus group provides an opportunity for participants to explore, formulate, and reconsider their own ideas and understanding about a certain issue (Cameron, 2010; Kitzinger, 1994). Focus groups are often preferred methods that are used for conducting action research or empowering the "researched" because the participants can become an active part of the process of analysis (Kitzinger, 1994). Indeed, these focus groups may actually develop particular perspectives as a consequence of talking with other people who share similar experiences. For instance, the opportunity that was presented to the participants to be involved in the decision making process was empowering for many participants because, the participants were actively involved in something that they felt would make a profound difference in their villages (i.e. making decisions on how to reduce vulnerability, hence achieving sustainable development).

Thus, in this study, a total of five in-depth focus group discussion sessions were held (one per village) in an informal setting that was easily accessible (i.e. local schools and community centers). During these sessions, the participants engaged in an in-depth conversation exploring and identifying different options that they considered important in reducing social and environmental vulnerability. Once the participants in each village had agreed on the options, the researcher incorporated them to the fifth level of the hierarchy. It was during these sessions, that

the participants performed pairwise comparisons of all elements in the AHP, except for the three components of vulnerability that were evaluated by the researcher. Throughout the process, the researcher played the role of a facilitator.

5.4.3 Developing the Hierarchical Decision Model using AHP

For this study, the researcher developed a five level AHP model. The basic structure of the model was similar for all the five villages, except for the alternatives that were proposed by the residents. Figure 18 highlights the basic structure of the model, while the levels represent the respective elements. The top-most level was the goal of the AHP model (i.e. ranking of the alternatives for reducing social and environmental vulnerability). Level two contained the *benefits*, *opportunities*, *costs*, and *risks* (BOCR) objectives of the decision. At the third level were the various criteria that would explicitly affect the BOCR objectives, followed by the three components of vulnerability (exposure, sensitivity, and adaptive capacity). Finally, level five consisted of various options for reducing social and environmental vulnerability.

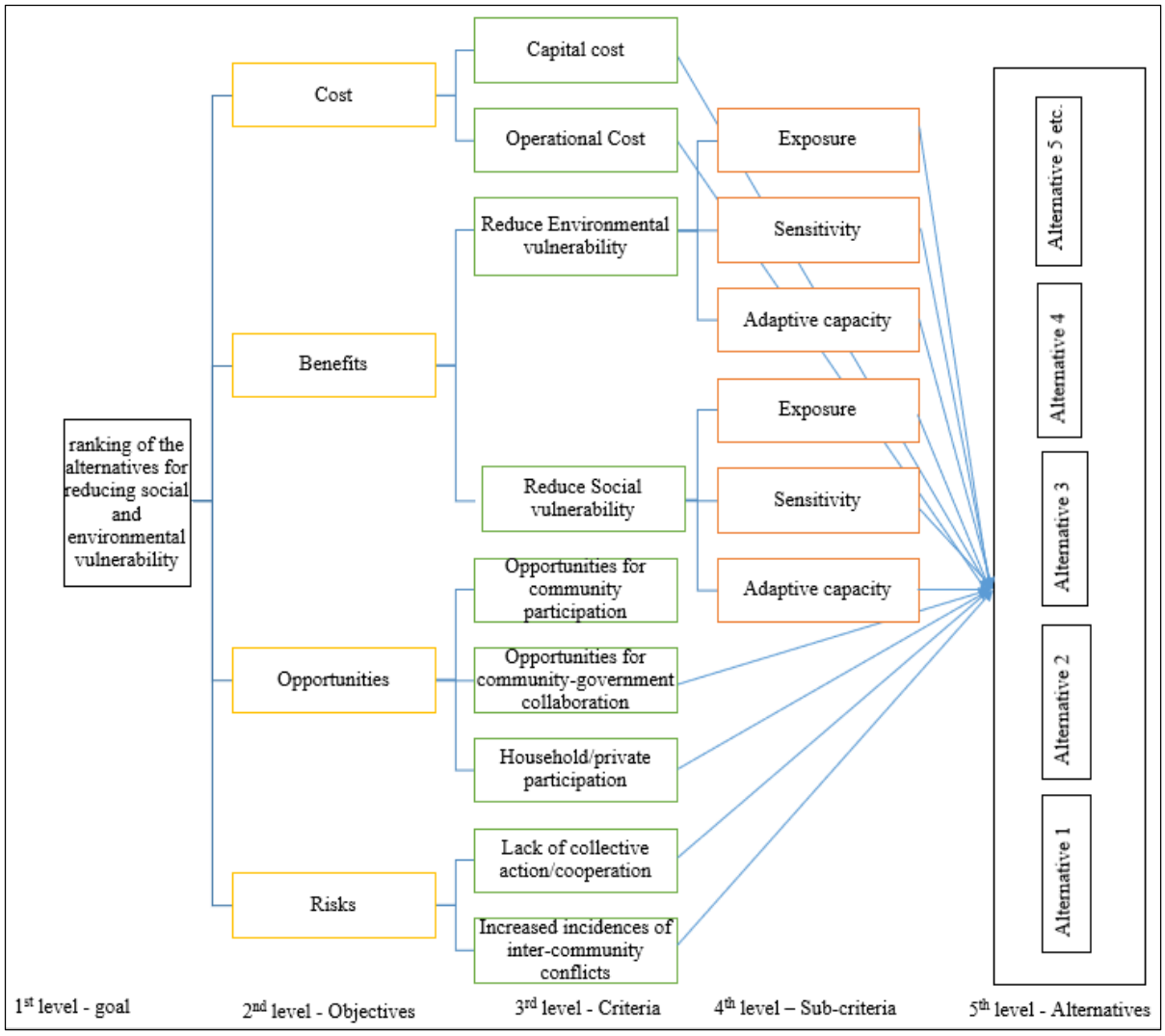

Figure 18: The AHP model developed for ranking and prioritizing alternatives.

5.4.4 Deriving Priorities in the Hierarchy via Pairwise Comparisons at the Villages

Throughout the hierarchy, a series of pairwise comparisons was conducted so that all the elements of the same level were compared and weighted with respect to elements one level higher. The aim of performing the pairwise comparisons at each level was to transform both the quantitative and qualitative information into ratio scales (local priorities) (Ishizaka and Labib, 2009) and then synthesize those ratio scales into a rank-order from the bottom up to determine the global priority of the options in each village. Furthermore, the pairwise comparisons were meant to independently judge the contribution of each objective and criteria to the overall goal of the AHP model.

For this study, the pairwise comparisons were performed by the residents of each village themselves, except for the fourth level, which was carried out by the researcher. The procedure was carried out verbally, following the Saaty scale of measurement 1-9 (equally important to extremely important) (Table 8) and took place with the aid of a computer software called *Superdecision*. A side benefit of using the software in the field was that during the pairwise comparisons process in each village, it was possible for the researcher to detect inconsistencies in the resident's judgments. When such situations arose, the participants reviewed their judgements, making sure that all the participants understood the elements that were involved in the comparison, and working together until an acceptable consistency level was achieved. Throughout the process, a judgmental matrix that had less than 10% consistency was accepted.

Table 8:The Fundamental scale of measurement in AHP adapted from Saaty (2008) used by the Residents of Mt. Kasigau.

Weight	**Definition**	**Explanation**
1	Equally important	Two factors contribute equally to the objective.
3	Moderately important	Experience and judgement slightly favor one over the other.
5	Strongly important	Experience and judgement strongly favor one over the other.
7	Very strongly important	Experience and judgement very strongly favor one over the other, as demonstrated in practice.
9	Extremely important	The evidence favoring one over the other is of the highest possible validity.
2, 4, 6, 8	Intermediate preference between two adjacent judgements	When compromise is needed.

5.5 Results

5.5.1 Ranking of the Alternatives

Local priorities obtained through pairwise comparisons at the different levels of the hierarchy were synthesized to deriving the global priorities in each village. The global priorities take into account not only the judgement among the alternatives themselves, but also the local priorities of the objectives, criteria and sub-criteria. In this study, the most preferred options for reducing vulnerability in Makwasinyi, Kiteghe, Rukanga, and Jora villages was "*promoting of tree planting activities and banning of charcoal burning*". In Bungule village, the most preferred option was "*supply of piped water from the mountain by the county governmen*t". The numerical priorities (i.e. ranking) for the alternatives are highlighted in Figures 19-23.

In Kiteghe village, it is evident that "*promoting of tree planting activities and banning of charcoal burning*", was the most preferred alternative for reducing the vulnerability of the human and natural systems, with a global priority weight of 0.2371. This was followed by "*drilling of boreholes and construction of water storage tanks*", while the least preferred alternative was "*electrification of the national park borde*r".

In Makwasinyi village, the most preferred alternative for reducing the vulnerability of the human and natural systems was "*environmental conservation imitative*", with a global priority weight of 0.2297. This was followed by "*construction of water storage tanks and drilling of boreholes*", while the least preferred alternative was "*fencing of the national park border*".

In Bungule village, the most preferred alternative was "*county government to supply piped water to the community*" with a global priority weight of 0.2381, followed by "*tree planting and banning of charcoal burning*". The least preferred alternative was "*electric fencing of the national park border*" with a global priority weight of 0.00674.

In Jora village, the most preferred alternative for reducing the vulnerability of the human and natural systems was "*tree planting and banning of charcoal burning*", with a global priority of 0.229, followed by "*reducing livestock and promotion of zero grazing practices*". The least preferred alternative was "*electric fencing of the national park*".

In Rukanga village, the most preferred alternative for reducing the vulnerability of the human and natural systems was "*tree planting and banning of charcoal burning*" activities, with a global priority weight of 0.2482, while the least preferred alternative was "*upgrading the existing health center and provision of medical personnel*".

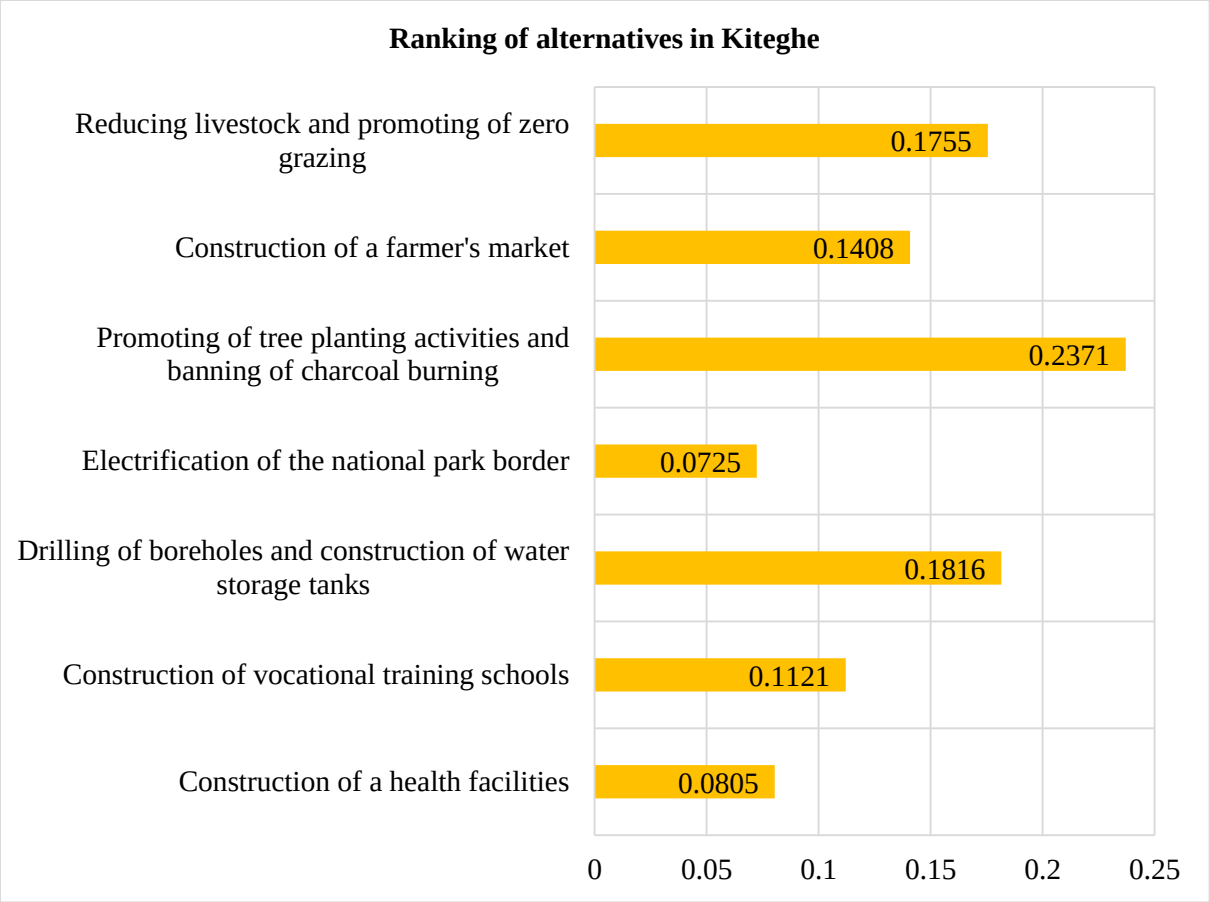

Figure 19: Global priority weights for different alternatives in Kiteghe village.

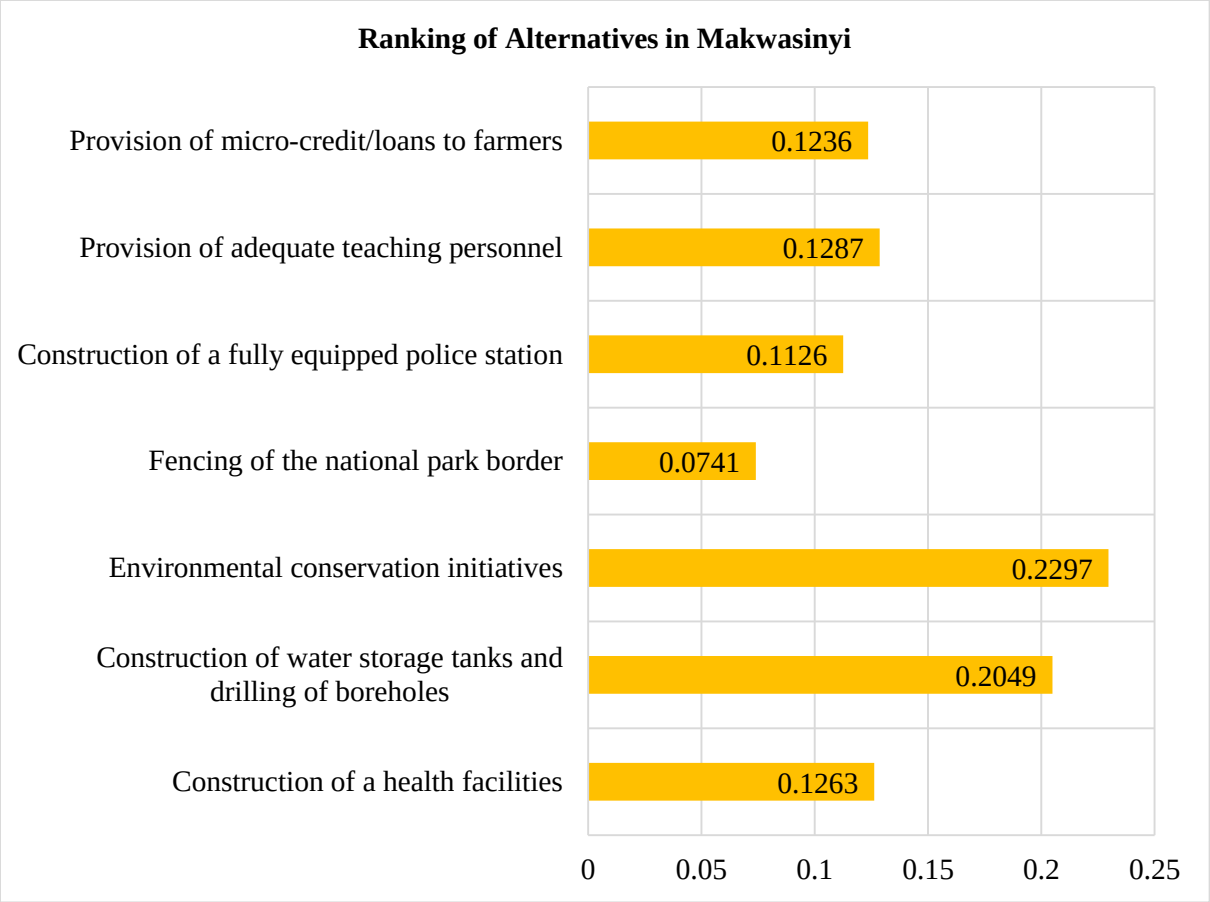

Figure 20: Global priority weights for different alternatives in Makwasinyi village.

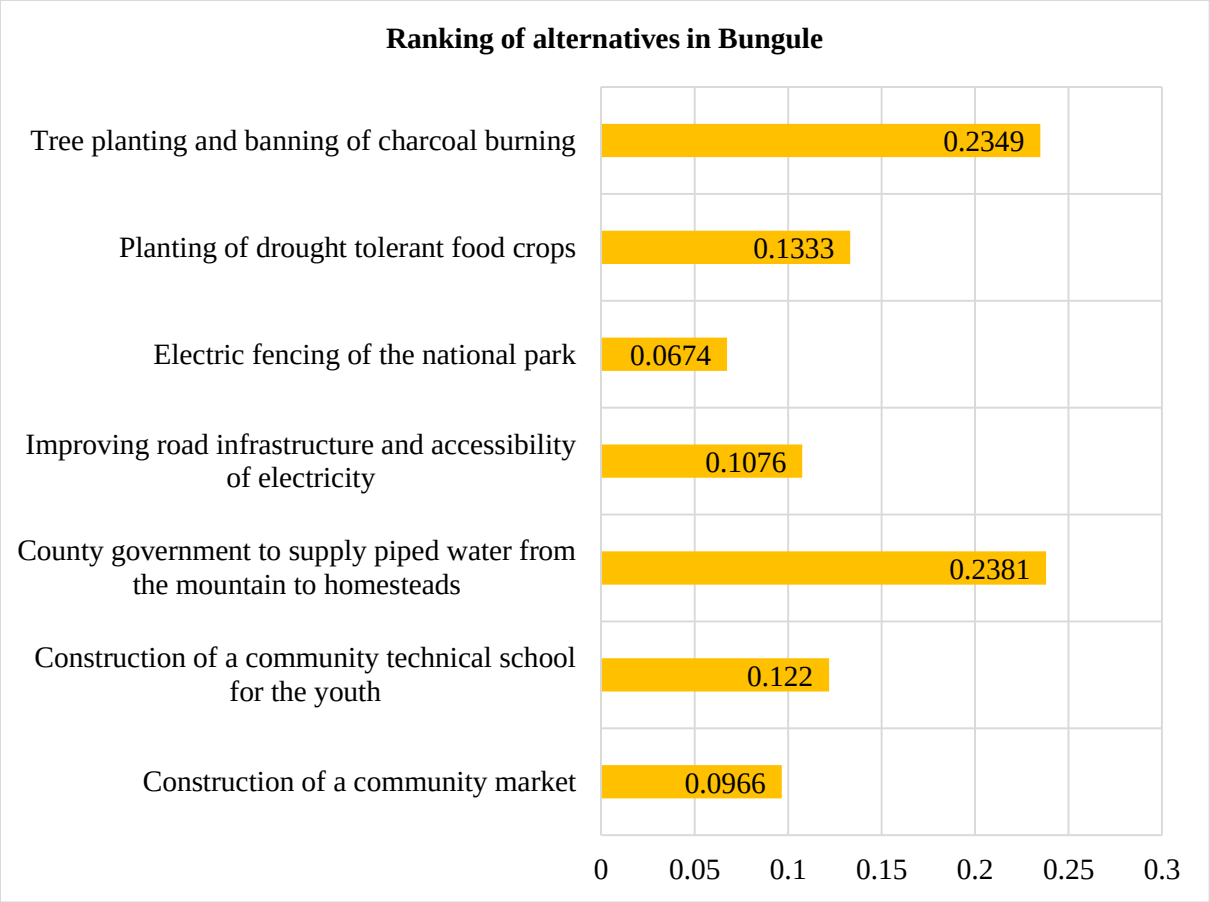

Figure 21: Global priority weights for different alternatives in Bungule village.

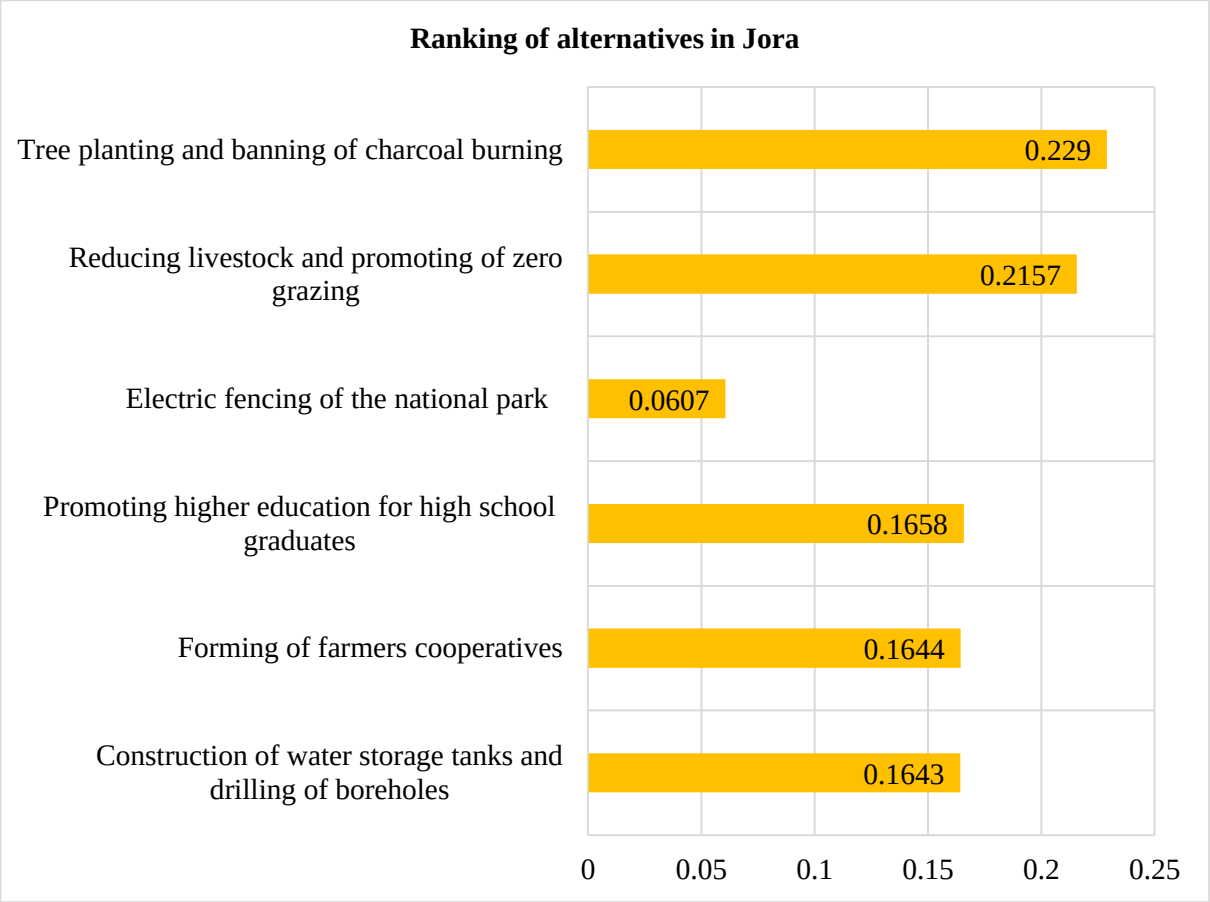

Figure 22: Global priority weights for different alternatives in Jora village.

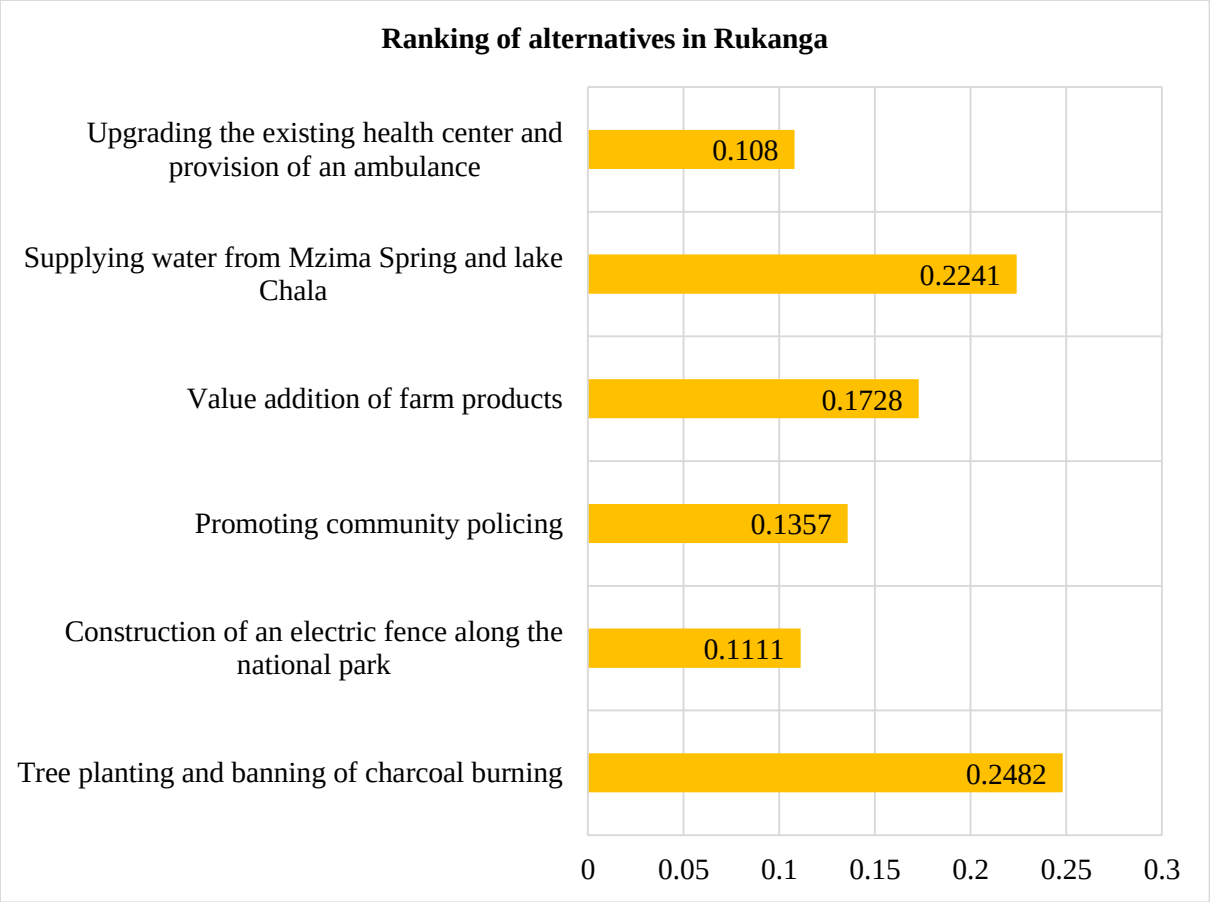

Figure 23: Global priority weights for different alternatives in Rukanga village.

5.5.2 Sensitivity Analysis

The final ranking of the alternatives is dependent on the weights attached to the main objectives and criteria. A very small change in the relative weights may cause significant changes to the final ranking (Chang et al., 2007). Since the weights of the objectives, criteria, sub-criteria, and alternatives are based on subjective judgement, it is important to test the stability of the final ranking under varying criteria weights (Chang et al., 2007). Thus, the main objective of conducting sensitivity analysis is to determine the most critical criteria to the final rankings of the alternatives. The most critical criteria at any specific level of the hierarchy is defined as the criteria that changes the final rankings with the smallest variation of the current weights compared to those of other criteria at the same level. For that purpose, a sensitivity analysis was carried out to determine the most critical criteria that changes the final ranking of the alternatives.

At the second level of the hierarchy, all four objectives (*cost*, *benefits*, *opportunities*, and *risk*) were critical when their weights were adjusted as highlighted in Table 9. For instance, in Kiteghe village when the relative weight of the objective - *cost* was increased by 16%, the final ranking of the alternatives changed. In Makwasinyi, when the objectives *benefit* and *cost* were increased by 76% and 5% respectively, the final priorities of the alternatives changed.

At the third level of the hierarchy, a considerable number of criteria were critical when their relative weights were adjusted by the percentages shown in Table 10. For example, in Bungule village, when the *capital cost* and *operational cost* criteria were increased by 27% and 74% respectively, the final priorities of the alternatives changed. Finally, none of the sub-criteria at the fourth level of the hierarchy appeared to be critical.

Throughout the hierarchy, most of the objectives and criteria were critical. The overall ranking of the alternatives changed significantly when the relative weights were adjusted to almost all the elements in the hierarchy. Therefore, the sensitivity analysis results were important in allowing us to understand how robust the original decision was and which criteria influenced the original results. An example of how the final ranking of the alternatives changed when the relative weights of the *cost* and *risk* objectives were adjusted by 5% and 2% respectively can be visualized in Figure 24 and 25.

Table 9: The percent change of the relative weights to the objectives at the second level of the hierarchy that triggered a change of the final rankings of the alternatives.

	Goal of the AHP: Selecting the best alternative for reducing vulnerability			
Villages	**Cost**	**Benefits**	**Opportunities**	**Risks**
Kiteghe	16%	37%	17%	15%
Jora	26%	25%	17%	4%
Makwasinyi	5%	35%	21%	2%
Rukanga	20%	76%	-	35%
Bungule	17%	24%	8%	14%

Table 10: The percent change of the relative weights to the criteria in the third level of the hierarchy that triggered a change of the final rankings of the alternatives.

	Cost		**Benefits**		**Opportunities**			**Risks**	
Village	**Capital cost**	**Operational cost**	**Reduced Environmental vulnerability**	**Reduced Social vulnerability**	**Household participation**	**Community-Government collaboration**	**Community participation**	**Inter-community conflict**	**Lack of cooperation**
Kiteghe	-	-	13%	22%	48%	17%	52%	-	-
Jora	13%	78%	2%	31%	7%	55%	7%	51%	16%
Makwasinyi	-	-	8%	31%	32%	38%	43%	26%	50%
Rukanga	-	-	11%	15%	-	92%	77%	-	-
Bungule	27%	74%	25%	25%	21%	17%	33%	74%	26%

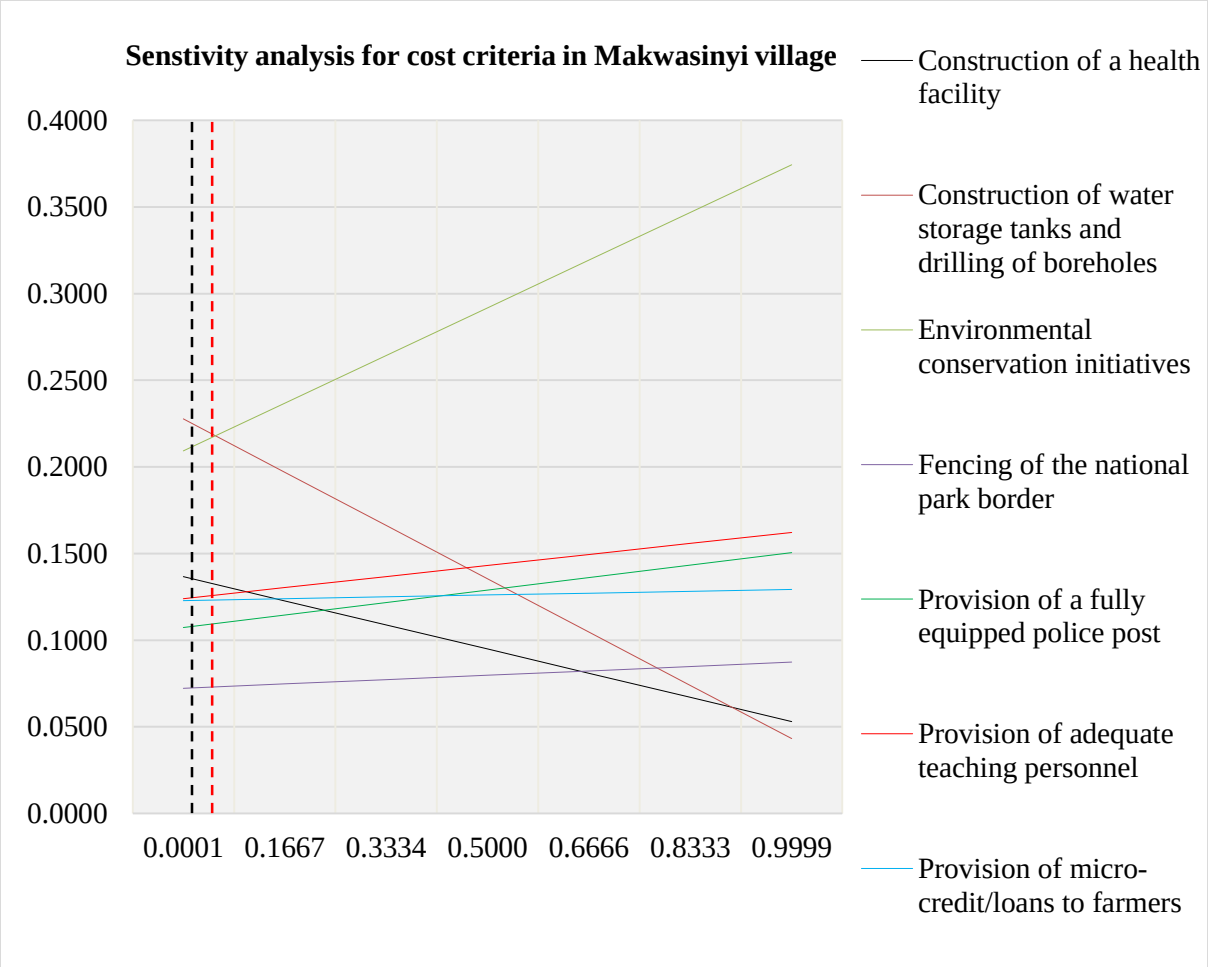

Figure 24: An example of sensitivity analysis for cost objective at Makwasinyi village highlighting how the alternatives behaved when the relative weight was adjusted by 5%.

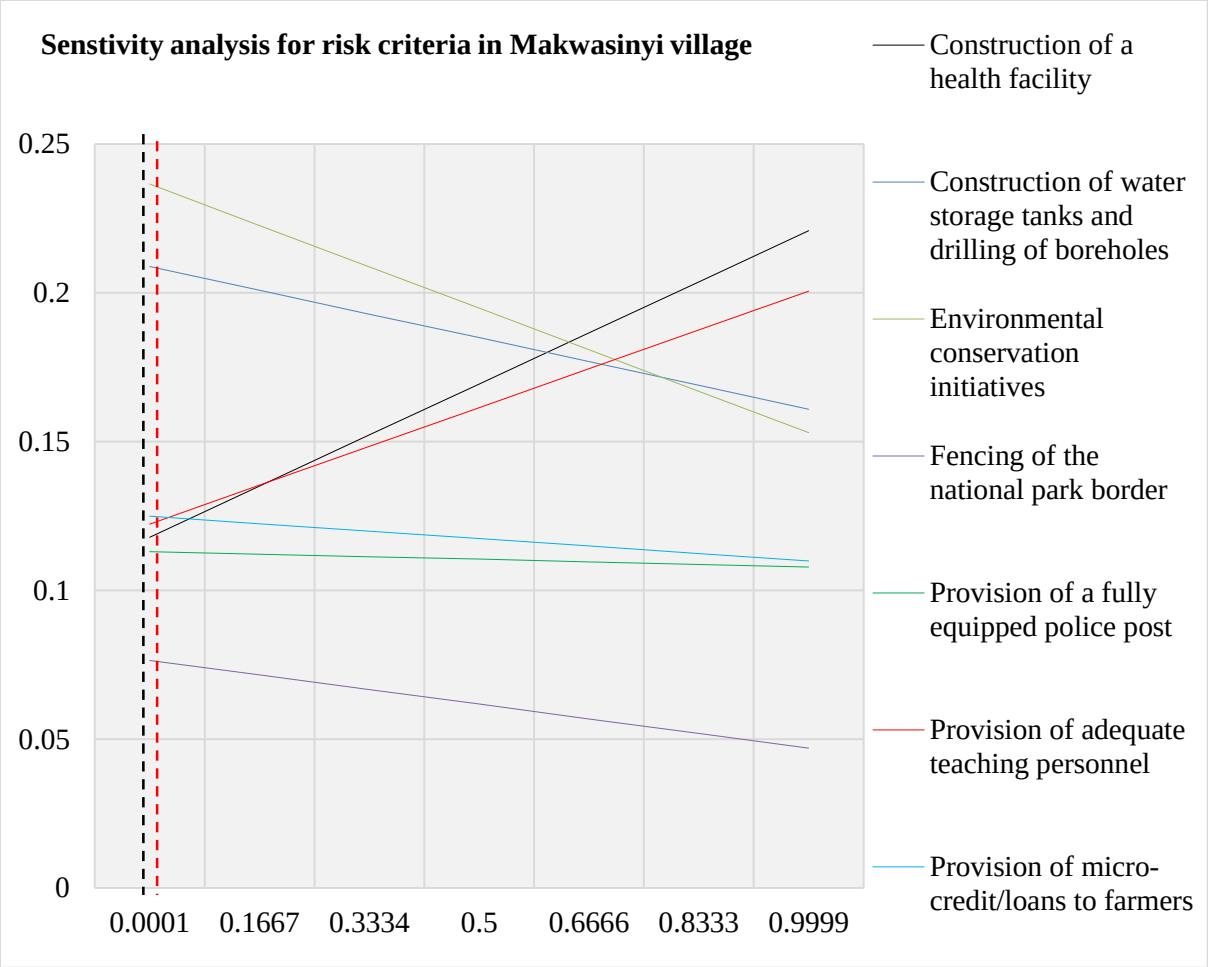

Figure 25: An example of sensitivity analysis for risk objective at Makwasinyi village highlighting how the alternatives behaved when the relative weight of risk was adjusted by 2%.

Figure 24 depicts how the final priorities of the alternatives changed, when the relative weight of *cost* objective was increased by 5% in Makwasinyi village. The black dotted line shows the current weight while the red dotted line highlights the percentage where the final priorities begin to change. As highlighted in the figure, a 5% adjustment of the *cost* objective, made "*provision of adequate teaching personnel*" become the second most preferred alternative, while "*construction of water storage tanks and drilling of boreholes*" becomes the least preferred alternative. This is a huge change, since the present weights have "*construction of water storage tanks and drilling of boreholes*" as the second most preferred alternative and "*fencing of the national park border*" as the least preferred alternative. Likewise, the final priorities of the other alternatives changed as can be visualized from the figure.

Figure 25 shows how the final priorities of the alternatives changed when the risk objective was increased by 2% in Makwasinyi village. The black dotted line shows the current weight, while the red dotted line highlights the percentage where the final priorities begin to change. As the figure highlights, a 2% increment in the *risk* objective caused "*provision of micro-credit/loans to farmers*" become the fifth most preferred alternative, compared to the current ranking where it is the fourth preferred alternative. Equally, "*provision of adequate teaching personnel*" becomes the third preferred alternative in comparison to the current position where it is the fourth preferred alternative. Likewise, the final priorities of the other alternatives changed as can be visualized from the figure. Hence, from these two (i.e., Figure 24 and 25), it is evident that the relative weight of each element at the third level of the hierarchy was critical since a small increase in weight of any of those elements, changed the final priorities of the alternatives. Hence, the models were not robust.

5.5.3 Outcome of Judgements at the Five Villages

The pairwise comparisons in the five villages yielded outcomes that were diverse to some extent. For example, in four of these villages, the *benefits* objective was assigned more weight followed by *opportunities*, *costs*, and *risk* respectively (Figure 26). However, in Makwasinyi, more weight was assigned to objective - *costs*, followed by *benefits*, *opportunities*, and *risk*.

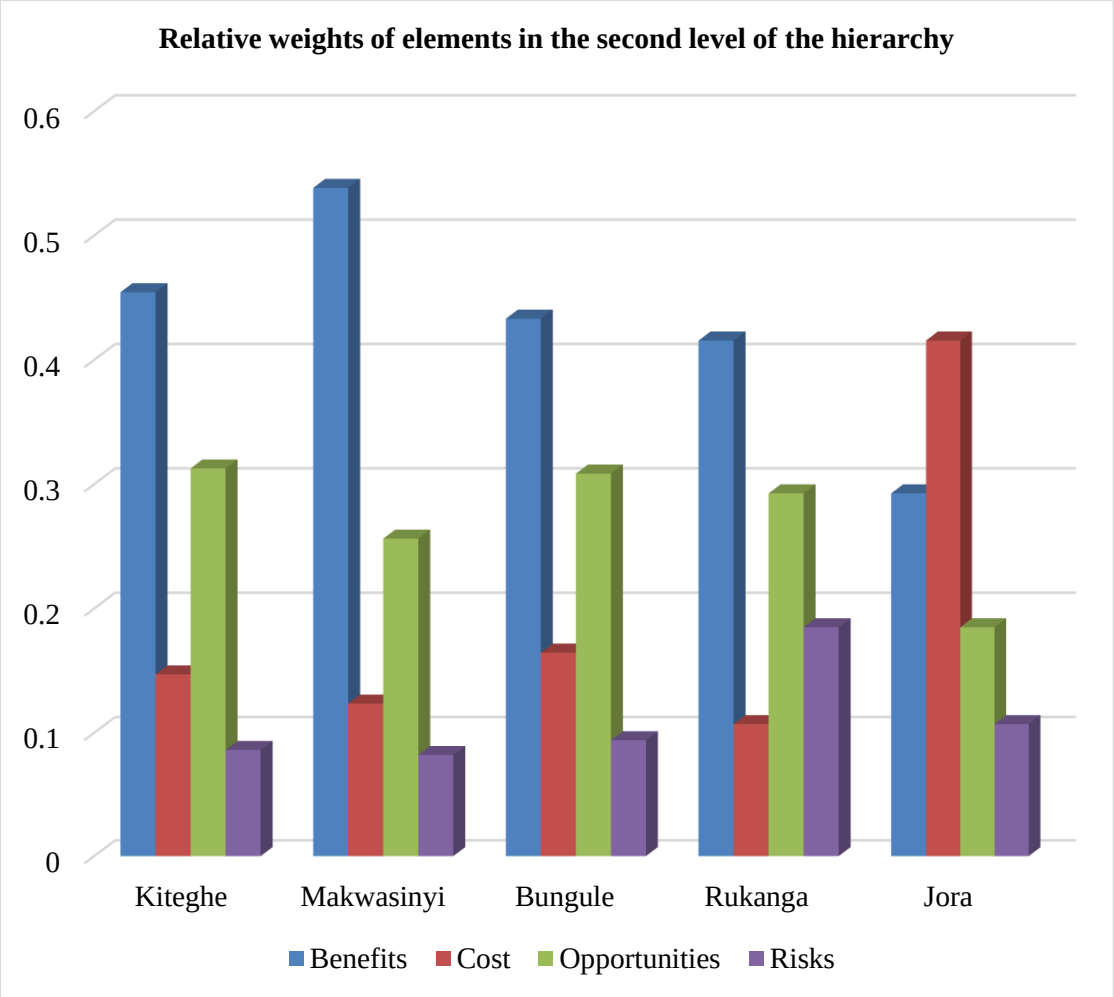

Figure 26: Relative weights of elements in the second level of the hierarchy in the five villages.

At the third level of the hierarchy, there were some similarities and differences on how the residents assigned weights to these elements. Starting from the objective - *benefit*, the two criteria ("*reduced social vulnerability*" and "*reduced environmental vulnerability*") were assigned equal weight in Kiteghe and Jora villages, while Makwasinyi, Rukanga, and Jora village assigned more weight to "*reduced social vulnerability*" (Figure 27). With respect to criteria under the *cost* objective, more weight was assigned to "*capital costs incurred*" in Rukanga, equal weight in Bungule and Makwasinyi village, while the "*operational cost incurred*" criteria were assigned more weight in Kiteghe and Jora villages (Figure 28).

Regarding the criteria under the *opportunity* objective, all the five villages assigned more weight to "*increased opportunities for community-government collaboration*", followed by "*opportunities for community participation*", and "*household/private participation*" respectively (Figure 29). Finally, with respect to the criteria under the *risk* objective more weight was assigned to "*increased incidences of inter-community conflict*" in Kiteghe, Makwasinyi and Rukanga villages, equal weights in Bungule, while in Jora village, more weight was assigned to "*lack of collective actions/lack of consensus/lack of cooperation*" criteria (Figure 30).

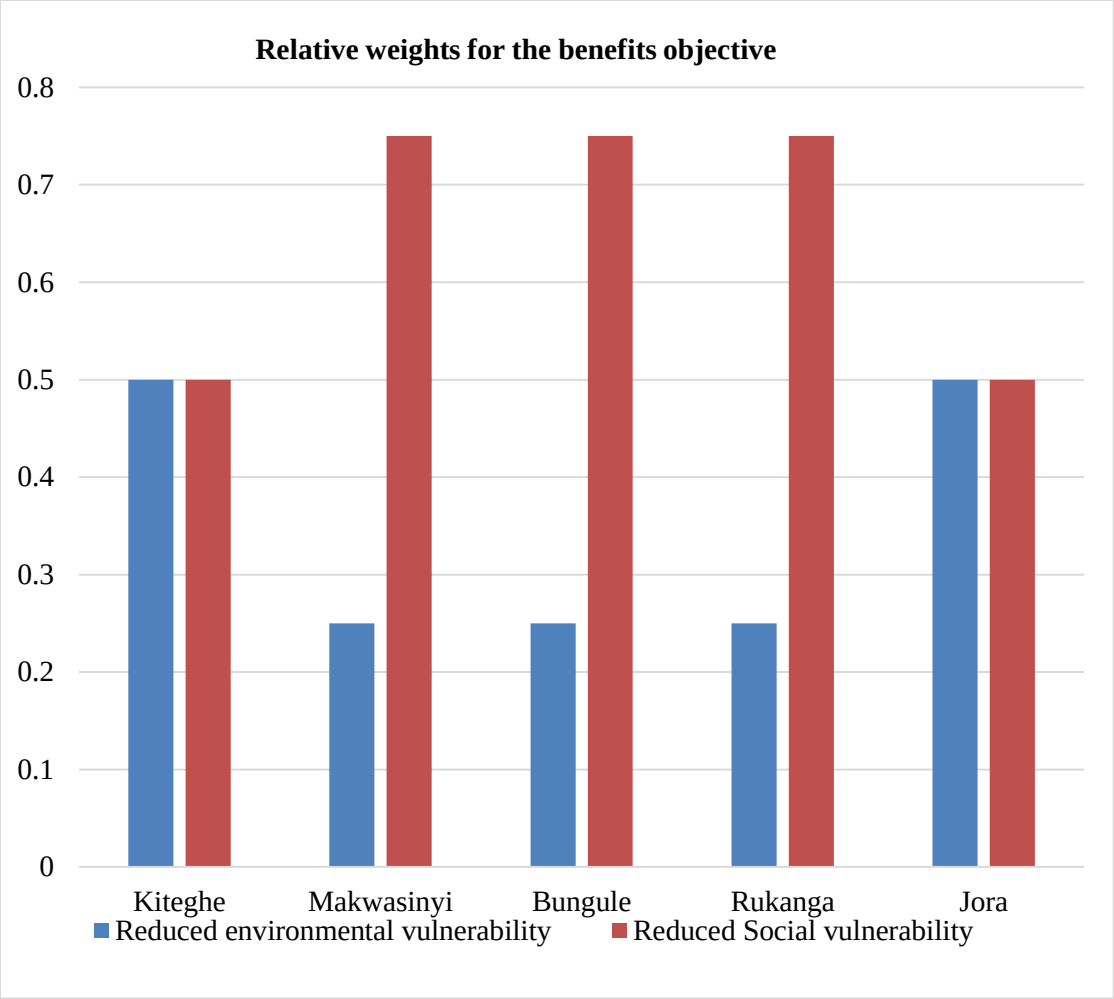

Figure 27: A graphical representation highlighting the relative weights assigned to the benefit objectives in the five villages.

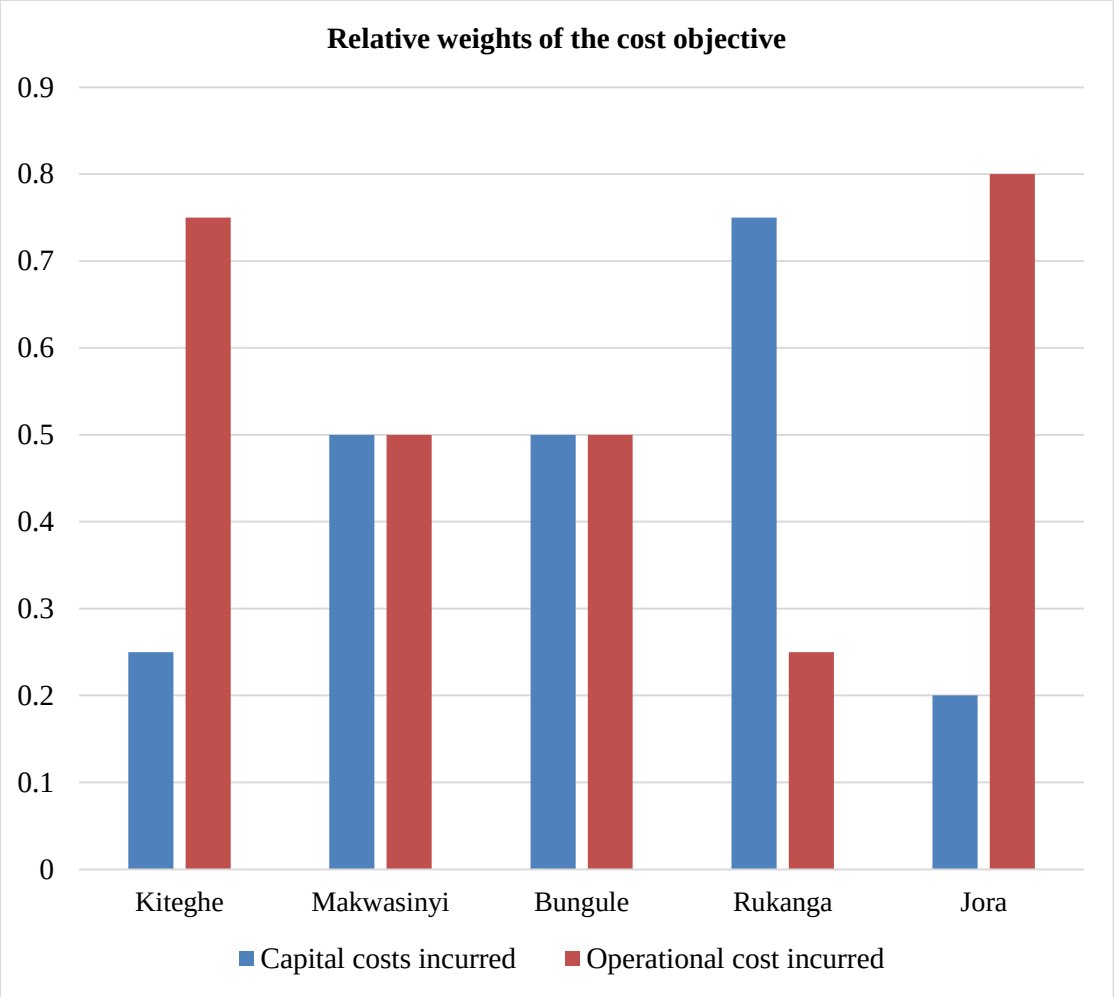

Figure 28: A graphical representation highlighting the relative weights assigned to the cost objectives in the five villages.

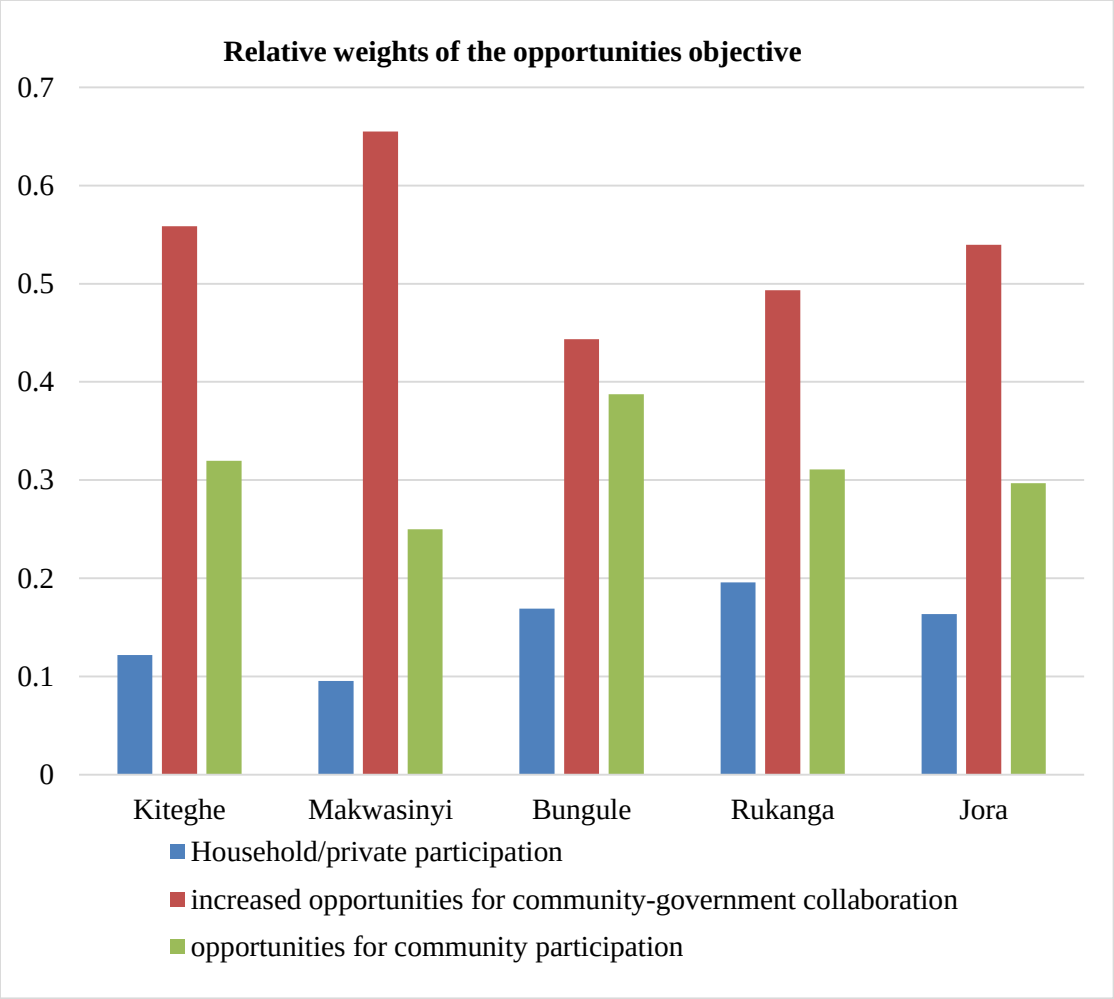

Figure 29: A graphical representation highlighting the relative weights assigned to the opportunities objectives in the five villages.

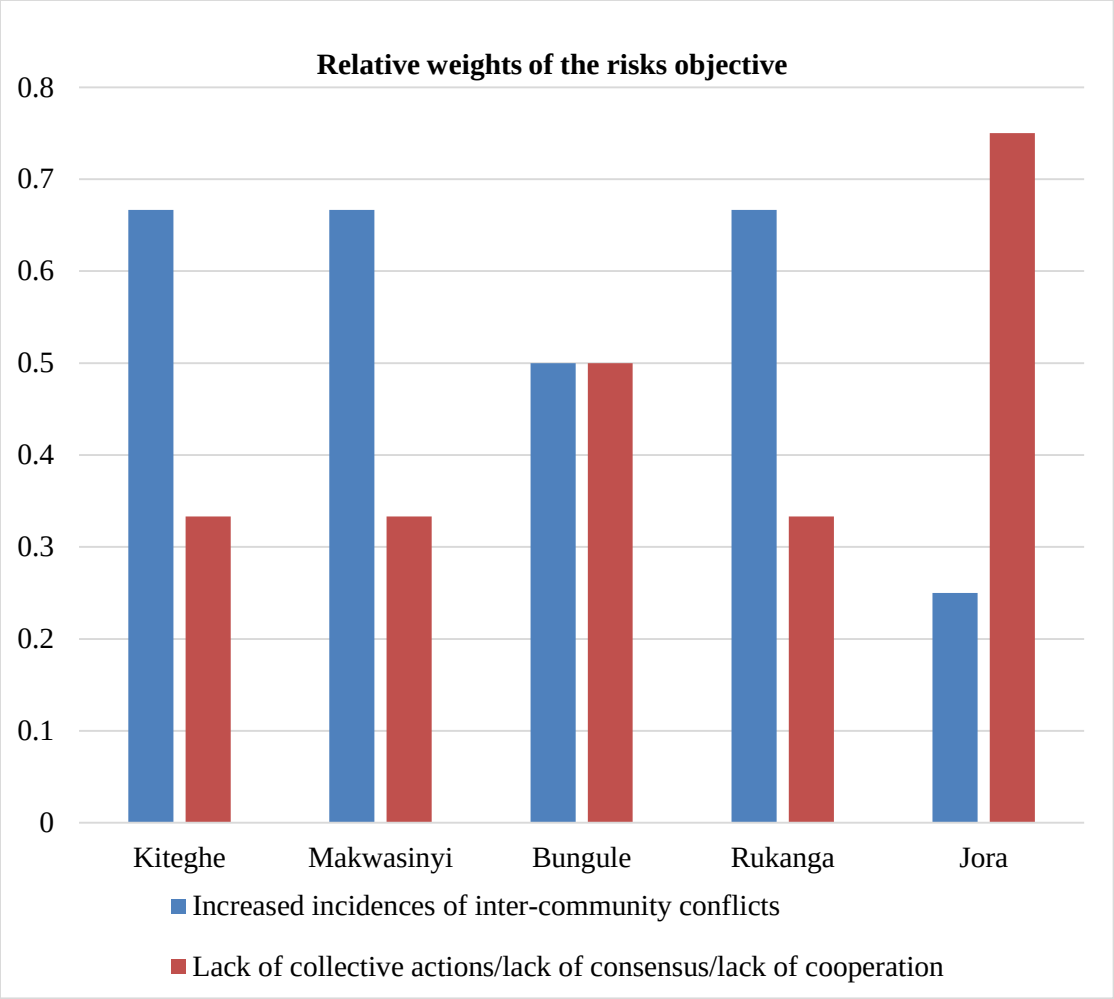

Figure 30: A graphical representation highlighting the relative weights assigned to the risk objectives in the five villages.

5.6 Discussion

The vulnerability of the human and natural systems at Mt. Kasigau is an obstacle to sustainable development. It is also caused by human activities and environmental changes. However, it is possible to reduce it and achieve sustainable development, if the community make the right priorities. In this study, different alternatives were suggested by the residents of these villages as a mechanism for reducing vulnerability. Some of the alternatives were specific to a certain threat, while others were broad.

In addition, the alternatives suggested in the five villages were similar with only a few exemptions (e.g. "*forming of farmer's cooperatives*" in Jora and "*value addition of farm produce*" in Bungule). The major reason for similarities was because these villages shared similar geographical and societal characteristic and encountered same threats. Therefore, reducing vulnerability in these villages is a prerequisite for sustainable development, which can be achieved by the community if they implement some of those alternatives. Across the five villages, the best alternatives for reducing vulnerability were "*tree planting and banning of charcoal burning*" in Makwasinyi, Kiteghe, Jora, and Rukanga while "*provision of water for domestic and agricultural use*" was ranked as the best option in Bungule village. Thus, the results suggest that to reduce vulnerability, which is an obstacle to sustainable development, the community ought to pay close attention to measures that are geared towards environmental conservation.

For instance, during the focus group discussions in Kiteghe village, when I asked the participant what the best option was for reducing the vulnerability of the human and natural systems, nine out of the thirteen informants highlighted tree planting and banning of charcoal would be beneficial to the environment and the community. The other four mentioned drilling of borehole or construction of a dam would solve most of the problems that the community was experiencing. They said:

> *"As you walk across this village and even the park, there are many trees you won't see because the bushland is diminishing. These species have declined because of charcoal burning and people expanding their farms towards the bushland. This has worsened the drought in this area, and we are unable to harvest enough food. I think if we can collaborate and work with wildlife works in planting trees, we can solve a lot of problems that we are experiencing…."*.

"Water is a problem in this village. We do not have adequate water like the way we did in the past because we destroyed our forests. We buy water for cooking and cleaning, a single Jeri can (20 liters) goes for 25 Kenyan shillings (Ksh), so sometimes we go for weeks without bathing because we do not have money to buy water every day..."

"Our fore fathers were right, they told us, if we destroy the environment, we will end up suffering. Now, we are experiencing what they had prophesied. The water is diminishing very fast, the droughts are becoming more severe and we have to rely on relief food. Unless we plant more tree in this country and protect our forests, we will continue experiencing more problems….".

The trend was similar in other villages. Based on these conversations, it is clear that the people of Kasigau, have a good grasp on the importance of conserving the environment. Therefore, attitudes towards tree planting could be linked to various benefits derived from conservation. For example, individuals believe that, it is important to plant tree and also protect the remaining forest because increasing the tree cover in the area would prevent soil erosion, replenish the water sources, provide economic opportunities among other benefits. While most people believe that tree planting and banning of charcoal burning is important, almost all the participants in Makwasinyi village reported cutting trees for firewood and charcoal, therefore representing a disconnect between what they believed and their actions.

It must be highlighted that, prioritizing environmental conservation is a critical component to any vulnerability reduction plans because better management of the environment can minimize the severity and frequency of disasters such as floods, soil erosion, and drought among others (McEntire, 2012; Mileti, 1999). In these villages, tree planting programs would be helpful in stabilizing soil in times of heavy rains, improve soil fertility, and conserve water resources. Subsequently, the community can gain from environmental conservation by deriving various ecosystem services, hence reducing their social vulnerability. For example, agroforestry practices, which are ecologically based natural resources management practices that involves the mixing of trees with crops have been shown to derive social, economic, and environmental benefits to humans and nature (Scherr and Franzel, 2002; Jose, 2009; Depommier, 2003). Hence, environmental conservation can support sustainable development in these villages because tree planting program supports the sustainable development of degraded lands while conserving

natural resources. Additionally, environmental conservation measures, will provide the residents of these villages some economic, environmental, and social benefits, hence contributing to the sustainable development of the community. Since, the residents of these villages primarily depend on agriculture production for their livelihood, measures geared towards environmental conservation are of essence in reducing vulnerability. Hence, this would likely explain why "*tree planting*" initiatives were ranked as the best alternatives for reducing vulnerability. However, addressing the natural dimension of vulnerability is not the only mechanism for supporting the sustainable development, since vulnerability is caused by the actions of humans and environmental changes (Cutter, 1996; McEntire et al., 2010). Therefore, to achieve sustainable development in these villages, communities should also address the economic, social, institutional, and political factors that cause vulnerability.

It is worth noting that there were some differences among the five villages in terms of the relative importance assigned to some of the objectives and criteria. These differences were more noticeable at the second and third level of the hierarchy. For example, in Makwasinyi, the costs objective was assigned the highest priority weight unlike the other four villages that emphasized on the benefits. A possible explanation on why *cost* was prioritized in Makwasinyi might be due to the state of economy in that village or the alternatives that were suggested required some form of financial expenditure from the community. Similarly, villages that prioritized the "*capital costs incurred*" criteria might have also considered the financial implication of the alternatives to the community if they were to implement them. Likewise, villages that emphasized on the "*operational costs*", might have weighed on the long-term financial implication of the alternatives to the community. For instance, if a project was to be funded by the government, and the government pulled out its financial resources once the project had been set, how would be the community run the project. These are some of the questions that might have been in the minds of the residents when they were assigning weights to *capital cost* and *operational cost* criteria. However, in the five villages, more weight was assigned to the "*increased opportunities for community-government collaboration*", criteria. The most plausible explanation to this is that the residents were very much interested in implementing options that have support from the community and government.

In this research, the AHP was used as a tool to develop a framework for evaluating and prioritizing different options for reducing vulnerability. An advantage of using AHP, was its

ability to decompose complex problem into a simple hierarchy of goal, objectives, criteria, sub-criteria, and alternatives. The method was also simple, flexible, and easily understandable to the community. Therefore, the community was able to use their own knowledge, experience, preference, and rationale while making judgement. The ability to handle inconsistency during the pairwise comparisons was also another advantage of using AHP. Additionally, the AHP was advantageous as it allowed the integration of multiple and conflicting criteria into a single decision framework as well as evaluating quantitative and qualitative criteria and alternatives on the same preference scale (Saaty, 2008). Finally, the model developed by the researcher and utilized by the community in this area can be adapted by policy makers in the county, residents of other villages, non-governmental organizations, and practitioners that are involved in making policies or decisions that tackles vulnerability of places and peoples.

5.7 Conclusion

In this research, a framework that helps the community at Mt. Kasigau evaluate different options for reducing vulnerability was developed. The analytical hierarchy process was used to develop a vulnerability reduction model, which was eventually utilized by the community in evaluating and prioritizing different alternatives. These alternatives were critical in reducing vulnerability, hence achieving sustainable development in these villages. Results from the study highlighted that environmental conservation "*tree planting and banning of charcoal burning"* and "*supply of water for domestic consumption and agricultural use*" were ranked as the top two options for reducing vulnerability. Additionally, results from the sensitivity analysis revealed that almost all the objectives and criteria in the model were critical, hence the models were not robust. Therefore, to attain sustainable development in these villages, it is important to reduce the vulnerability of human and natural systems in these villages by addressing the causal factors of vulnerability. With this information, the residents should consider implementing the alternatives that were prioritized especially environmental conservation and supply of water for domestic and agricultural use. However, for sustainable development to be attained in these villages, residents and local policymakers should also pay close attention the economic, social, institutional, and political factors that cause vulnerability.

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CHAPTER VI
CONCLUSION

This final chapter summarizes the whole dissertation as well as providing a synopsis of the results from each chapter, specifically the three publishable articles. I also discuss in this chapter the policy implication of this dissertation and explain how my research contributes to the discipline of Geography. Additionally, I highlight the limitations encountered during the study. Lastly, I highlight the future research directions.

6.1 Summary of Dissertation Research

The impetus for this research was concern about human activities and environmental changes that are occurring in Mt. Kasigau, Kenya. These actions impede sustainable development of the environment and the people. Human activities such as cattle grazing, mining, conversion of forest into farmland, charcoal production as well as environmental changes such as deforestation and variability in precipitation patterns have rendered the entire coupled human and natural systems vulnerable. In this research, I have focused on assessing the vulnerability of the human and natural environment at five villages in Mt. Kasigau Kenya. Specifically, I studied the vulnerability of Kiteghe, Jora, Makwasinyi, Rukanga, and Bungule villages, emphasizing how human-environment interactions exacerbate the vulnerability of the people and the environment. I integrated GIS, remote sensing, observation, focus group discussions, semi-structured interviews, and impact tree diagrams to gain a rich understanding on the vulnerability of the human and natural systems. I adapted a vulnerability conceptual framework developed by Turner et al. (2003) as a guide for my analysis. Central to this conceptual framework were the three components of vulnerability: exposure, sensitivity, and adaptive capacity (Adger, 2006; Turner et al., 2003; Janssen et al., 2006). I then utilized the analytical hierarchy process (AHP) to develop two models for examining the vulnerability of the human and natural systems. Finally, I developed a vulnerability reduction framework using AHP, which helped the residents of these villages evaluate and prioritize different options for reducing vulnerability. Results from this study could be helpful in developing policies that promote sustainable development. Additionally, the models developed for this study can be adapted by local policymakers, residents of other villages, non-governmental organization, and other practitioners who are interested in assisting communities to achieve sustainable development.

6.2 Summary of Results by Chapters

6.2.1 Assessing the Social Vulnerability at the Five Villages

Chapter 3 takes the first step to carefully examine the vulnerability of the social system across the five villages. For this assessment, focus group discussion sessions, semi-structured interviews, observations, and impact tree diagrams were utilized to collect data on causal factors of social vulnerability. Next, I adapted Turner et al. (2003) vulnerability conceptual framework to develop a social vulnerability assessment model using the AHP. In my analyses, some interesting patterns on the causal factors of social vulnerability were disclosed. Inspired by these observations, I applied the model to perform a comparative assessment of social vulnerability across the five villages. The assessment revealed that Makwasinyi was the most vulnerable village. In addition, to the comparative assessment, I also evaluated the roles played by the three components of vulnerability in influencing social vulnerability. The findings showed that social vulnerability was more closely associated with adaptive capacity and exposure than sensitivity. For example, for the two components, (i.e. adaptive capacity and exposure) villages that had the highest priority weights were the most vulnerable (i.e. Makwasinyi, Bungule and Kiteghe villages respectively). On the contrary, Rukanga and Jora villages had the highest priority weights for sensitivity but were the least vulnerable villages. While exposure, sensitivity, and adaptive capacity influence social vulnerability, more emphasis should be given to exposure and adaptive capacity. In addition, Makwasinyi village should be given the highest priority in terms of vulnerability reduction measures. The model developed for this study was effective in revealing the differences across the five villages and it can be adapted by the surrounding villages for a similar analysis.

6.2.2 Examining the Vulnerability of the Natural Environment at the Five Village

Another focus of this dissertation was to assess the environmental vulnerability surrounding five villages in Mt. Kasigau, Kenya, under various risks caused by human activities, such as expanding of farmlands, mining, charcoal burning, and cattle grazing. I began this effort by mapping land cover changes of the study area for four different time periods (1975, 1995, 2003, and 2014). These data were used to compute various landscape metrics that served as proxy indicators for vulnerability. I also used qualitative research techniques to collect supplementary information regarding the vulnerability of the natural system. Similar, to chapter 3, I adapted Turner et al. (2003) vulnerability conceptual framework to develop a vulnerability

assessment model. For this analysis, the anthropogenic risks that were identified as the major causes of vulnerability were integrated within the hierarchical model, under the three components of vulnerability. The various landscape metrics derived from the land cover change maps and qualitative information pertaining the vulnerability of the natural systems were incorporated into the AHP hierarchy. The assumption underlying the usage of the landscape metrics was that they would quantify the spatial patterns of the landscape and act as proxy indicator for examining the vulnerability of the natural system across the five villages. For example, metrics such as the class area (CA) were used to measure the absolute area of the bushland land cover type, thereby revealing how vulnerable the bushland was to expanding of farmland and cattle grazing. Finally, I conducted a comparative assessment of vulnerability using the AHP model, the results of which showed that Makwasinyi was the most vulnerable village followed by Kiteghe, Bungule, Rukanga, and Jora respectively. In addition, the findings indicated the that adaptive capacity of the residents played a critical role in influencing the vulnerability of the natural systems. Therefore, to reduce vulnerability in these village, the adaptive capacity of the residents must be strengthened so that the impacts of human activities on the natural environment can be minimized.

6.2.3 Developing a Framework for Assisting Residents Evaluate and Prioritize Options for Reducing Vulnerability.

Chapter 5 focuses on developing a framework that helps the residents of the five villages evaluate and prioritize different alternatives for reducing the vulnerability of the human and natural systems and to achieve sustainable development. For this assessment, I employed the analytical hierarchy process to develop a vulnerability reduction model using information collected from the community. This model evaluated the alternatives according to the merits of benefits, costs, opportunities, and risks of the decisions. With the aim of minimizing cost/risk and maximizing benefits as well as opportunities of the alternatives, I incorporated Turner et al. (2003) vulnerability conceptual framework, that treats vulnerability as a function of exposure, sensitivity, and adaptive capacity, under the benefit objective. The goal was to reduce the exposures and sensitivities, but increase the adaptive capacities of the human and natural systems. Next, focus group discussion sessions were conducted in each village, where the residents identified various options for reducing vulnerability. These options were incorporated into the model by the researcher, and the residents of each village performed a pairwise

comparisons of all the elements in the model, except for the three components of vulnerability that were analyzed by the researcher. The model was then used by the residents of each village to evaluate and prioritize different alternatives for reducing vulnerability. Across the five villages, the model showed that environmental conservation was the most preferred option for reducing vulnerability. Therefore, this whole AHP process can serve as a roadmap for achieving sustainable development.

6.3 Policy Implication

Findings from this study can inform policy-makers at local and national levels as to what measures should be taken to reduce the vulnerability of human and natural systems. In particular, findings from this study can be utilized by policymakers and community members to improve the decision-making process. Better decision-making will result in better resource utilization by the community. The major significant results from this study indicate that environmental conservation initiatives should be implemented in order to achieve sustainable development. Putting greater emphasis on environmental conservation could reduce the vulnerability of the natural system. While the strategy covers a wide range of general issues, the actions identified by the community (i.e., banning of charcoal burning and tree planting) focus on solving a specific problem (environmental degradation). Hence, undertaking environmental conservation initiatives without addressing the direct causes of vulnerability (e.g., poverty, unemployment, hunger etc.) might not lead to the desired outcomes. Before implementing this specific option that was identified by the community, policymakers should address the root causes for the problem. So, for example, the county government may need to first promote policies that would stimulate economic growth and reduces poverty in the area. As Zhen et al. (2014) highlights, poverty causes environment degradation, and when people lack sufficient food, they are often forced to farm more land so as they can produce more food. This degrades the environment and subsequently driving them into deeper into poverty. Therefore, environmental conservation alone cannot be a panacea to the vulnerability of the human and natural systems.

Hence, the practical policy based on the results obtained from this study should first aim at raising agricultural productivity, since the community solely depends on farming for their livelihood. This can be done through provision of subsidized seeds and fertilizers as well as promoting agroforestry practices. For example, agroforestry practices can help farmers increase their yield and provide fuelwood and poles for construction. After achieving this, second

generation issues should be addressed (e.g., value addition, marketing of agricultural products, and promotion of ecotourism activities). Such moves would further boost the incomes of the residents of these villages. Additionally, the community should create some form of regulatory measures to monitor how the resources in the area are used. For example, working with the local chief and member of county assembly, the community can enforce the county by-laws through community policing initiatives. In general, the issue of environment and development is trans-disciplinary: It involves cultural, environmental, ethical, social, ethical, economic, political, and technological aspects (Furtado et al., 2000). For this reason, experts from different backgrounds ought to conduct joint research program in this region, and policymakers should develop policies that are feasible and community driven. Simultaneously, wider participation among community members and other stakeholders is needed to promote sustainable development in Mt. Kasigau. By advocating for the immediate needs of vulnerable individuals and groups vulnerability can be lessened. My specific recommendations to policymaker at the regional and national levels are:

1. The County Ministry of Water and Irrigation should enhance opportunities for small-scale irrigation and water harvesting. However, irrigation investment should guarantee high water use efficiency, besides building farm level managerial capacity. This will require revision of existing policies and institutional frameworks in water and agricultural sectors.
2. The county government through its Ministry of Lands, Environment and Natural Resources should promote alternative sources of energy; initiate aggressive campaign on tree planting and reforestation; increase surveillance and enforcement of existing regulation on charcoal trade; offer agricultural extension services; and promote an integrated approach of conservation initiatives in addition to afforestation activities in forests and farms.
3. The county social development department should promote formation of local rural institutions and farmer's groups and create more opportunities for livelihood diversification.
4. To reduce vulnerability in each village, the county government should develop a sustainable land use policy and involve the community.
5. To ensure a sustainable development the country government should raise awareness on the important of environmental conservation.

6.4 Contribution to Geography

This dissertation contributes to the discipline of geography and helps to advance the literature of sustainable development and vulnerability. Geography has a tradition of investigating how humans alter the environment and how those environmental changes impact human societies in return. In this study, I focused on assessing the vulnerability of the human and natural systems as a result of human activities and environmental changes. Moreover, I was interested in understanding how vulnerabilities that are created through human-environment interactions can be reduced. Therefore, this dissertation contributes to the human-environmental interaction theme of geography by giving an insight on how social and environmental vulnerabilities are produced by human activities such as farming, cattle grazing, mining, and charcoal burning as well as environmental changes. Geographical analysis of vulnerability and sustainable development is based on location and proximity, which implies that place and spatial attributes define the type and extent of vulnerability. As Day (2017) highlights, geographers not only "look for explanations of what is happening in the world, they recognize that explanations may be unique to a particular" (3). Similarly, research in vulnerability or sustainable development should also considers the household, community, regional, national and global as the scale of analysis. Thus, this place-based research contributes to the discipline of geography by emphasizing how vulnerabilities vary geographically, over time and space, and among different social groups. For example, results from the comparative assessment of vulnerability across the five villages could yield insight on how vulnerability varies over space, and among different places or communities. The discipline of geography contributes to the literature in sustainable development, in particular to the integration of knowledge that emanates from social and natural science. In this way, this research played a crucial role in incorporating knowledge from diverse disciplines. Moreover, my research seeks to inform what the residents of these villages ought to undertake in order to improve their livelihood in the face of environmental changes.

6.5 Limitation of the Study

Notwithstanding, the efforts undertaken in this dissertation to minimize bias, it must be acknowledged that there were some limitation and shortcoming. First, the spatial scale used in this study does not allow generalizability of the results. Being a place-based study, it may raise concerns among policymakers about the regional applicability of the recommended policies. For

example, national and county government policymakers may not develop policies that targets only certain places (villages) and leave out the rest. Thus, the suggested policies that have been made in this dissertation may not be generalizable to the whole region because communities across the region demonstrate diverse biophysical and social characteristics. Secondly, vulnerability literature recognizes that individual vulnerabilities plays an important role in community vulnerability. In this study, no attempt was made to identify individual vulnerability despite its importance in vulnerability assessment research. In a comprehensive place-based vulnerability assessment, it would be important to include aspects of individual vulnerability. Irrespective of these limitations, this research has laid a foundation for future vulnerability assessments in this region. Fourth, the great variety of theoretical frameworks and conceptual models presented a major limitation to this study, making it challenging to select a model that could capture all aspects of vulnerability in one framework. Fifth, in this research only a limited number of participants were interviewed or participated in the focus group discussions. The inclusion of only a limited number of informants can affect the findings to some degree. For example, the issues that were raised by these individuals during the focus group discussions or the semi-structured interviews may not necessarily be representative of the entire village. a final limitation of this study is related to how the data were collected. Information based only on the perceptions of individuals (i.e., informant who attended the focus groups and interviews) can sometimes be misleading. Thus, any form of bias by the participants could change the results.

6.6 Recommendation for Future Research Directions

On one hand, the three studies in this dissertation were carried out scientifically and professionally given the amount of time and resource available to conduct field work and analyses. On the other hand, similar studies using AHP for vulnerability/sustainability analysis in the future can be improved in several aspects with respect to enhancing the decision-aid process and/or gaining more scientific knowledge of stakeholders' preferences/priorities.

First, the assessment (i.e., pairwise comparisons) in this study relied on information collected from the focus group discussion sessions. In a group setting, an outspoken individual can take over and dominate a discussion or some participants may feel under pressure to agree with the dominant person/view (Cameron, 2010). Such potential shortcomings can be overcome in a couple of different ways. For instance, while all participants (e.g., individuals in a focus group) work together to structure the problem at hand and develop alternative solutions, each

participant can individually conduct pairwise comparisons of all the elements in the hierarchy. Their individual inputs can then be aggregated using the geometric mean method (Basak and Saaty, 1993) to form group preferences/priorities. The geometric mean is computed by averaging each individual response at each point of the pairwise comparisons to form a composite matrix that is used to obtain the relative weights of the consensus model (Wu and Kou, 2016). As the group model takes into account inputs from all participants, its results arguably could represent the group better than those from the models presented in this dissertation. Furthermore, results from individual models can be analyzed to gain insight on differences/diversity in preferences/priorities of different stakeholders (e.g., male versus female, young people versus elderly, etc.).

Second, the process of developing the models in this study can be expanded to include more stakeholders (e.g., regional government officials, resource managers, international/national environmental organizations, etc.) who might share the community's concerns and goals in addressing vulnerability and sustainability. By collectively developing models and alternatives to assess and reduce vulnerability, consensus among diverse stakeholders could arguably to be cultivated leading to more understanding and collaboration towards sustainable development. In view of this, future research to improve and evaluate the effectiveness of these models would be useful.

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APPENDICES

Appendix 1

The Impact Tree Diagrams Developed in the Study Villages

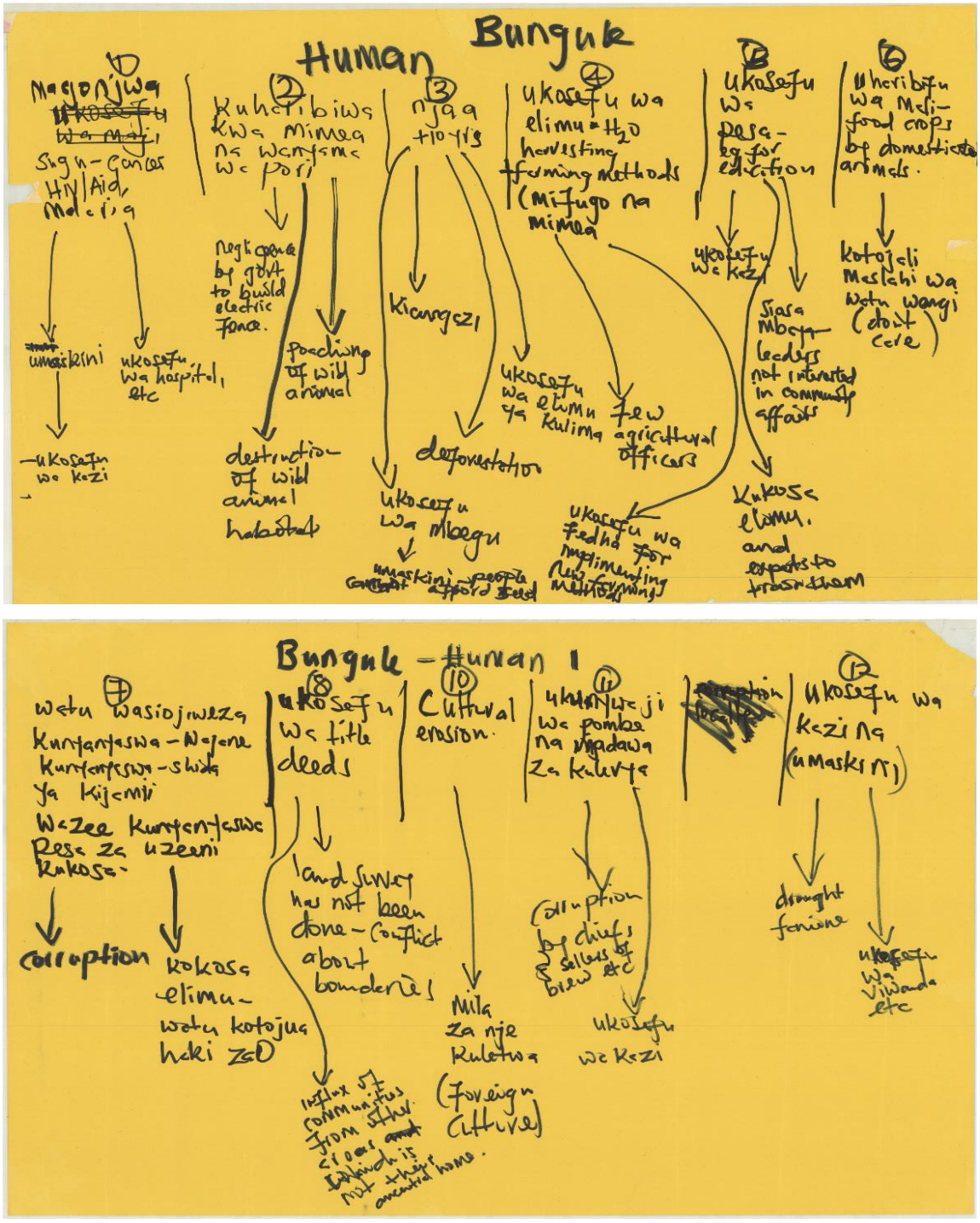
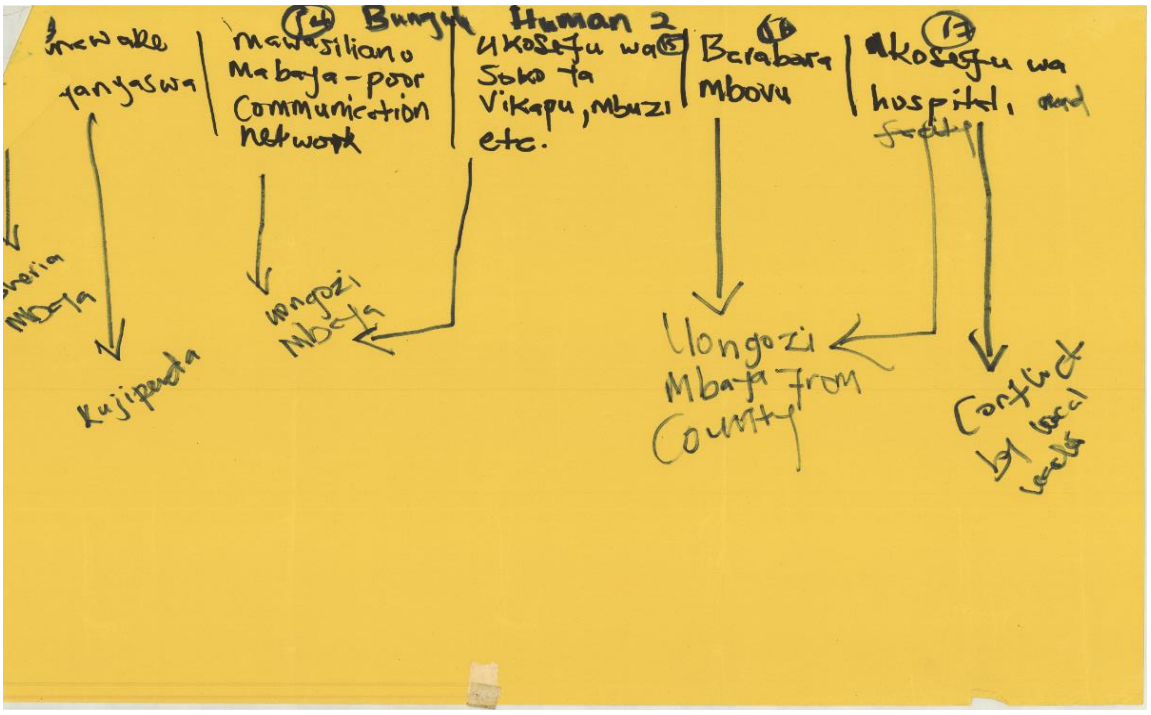


Figure A.1: Impact tree diagram developed in Bungule village (continued 4).



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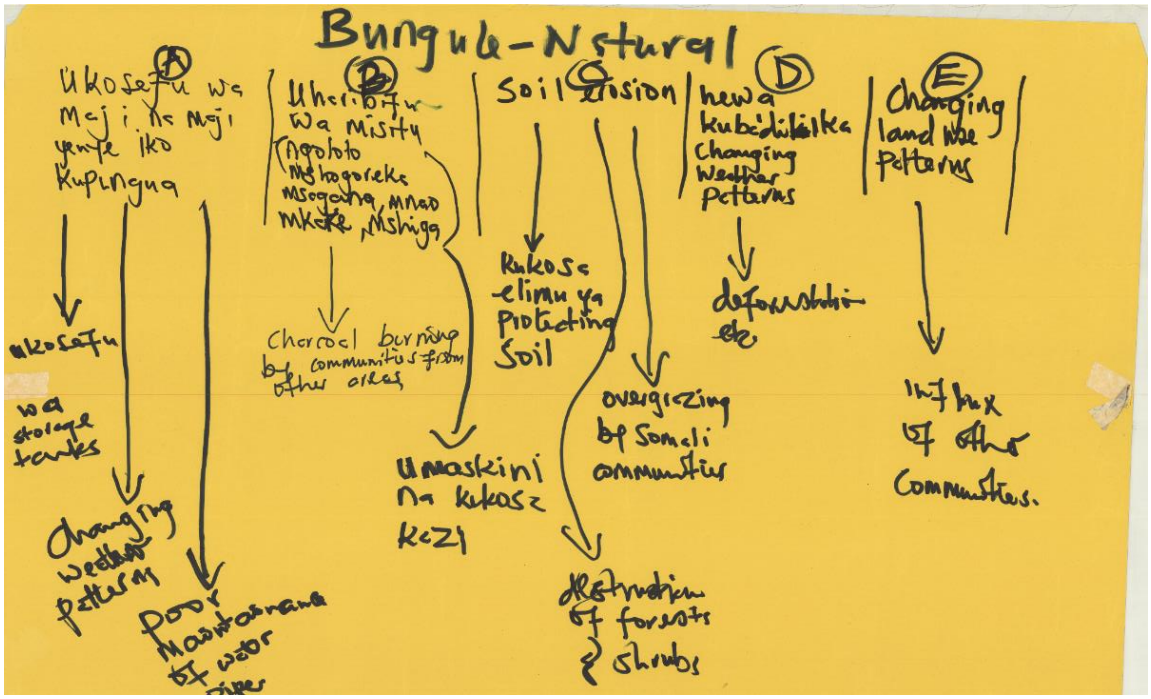

D

Figure A.1 Continued

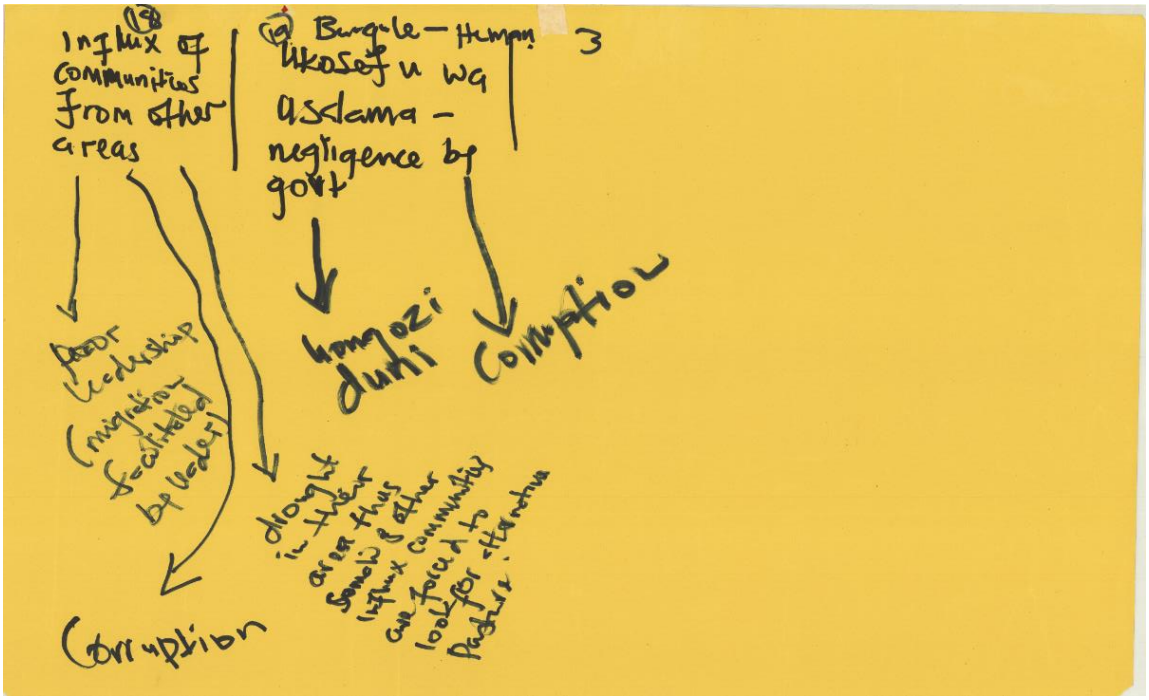

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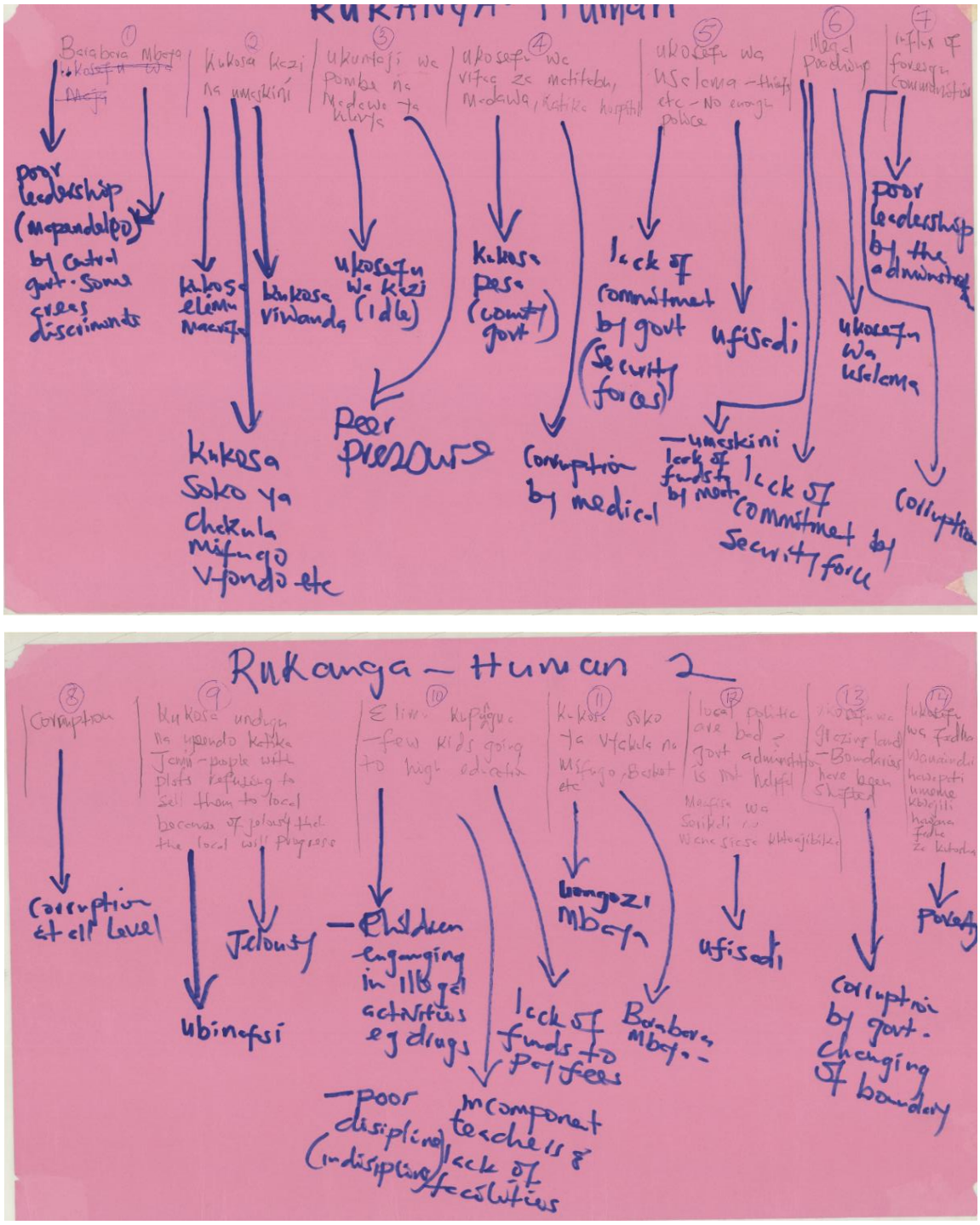
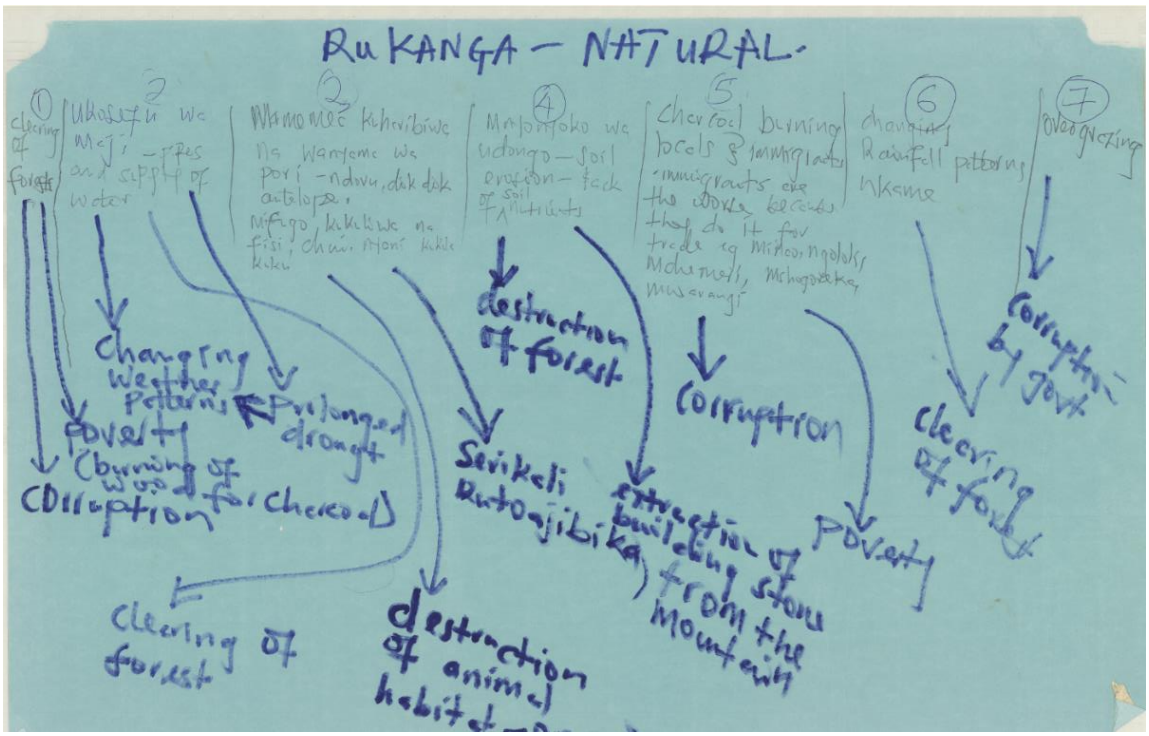
Figure A.1 Continued



A

B

Figure A.2: Impact tree diagram developed in Rukanga village.



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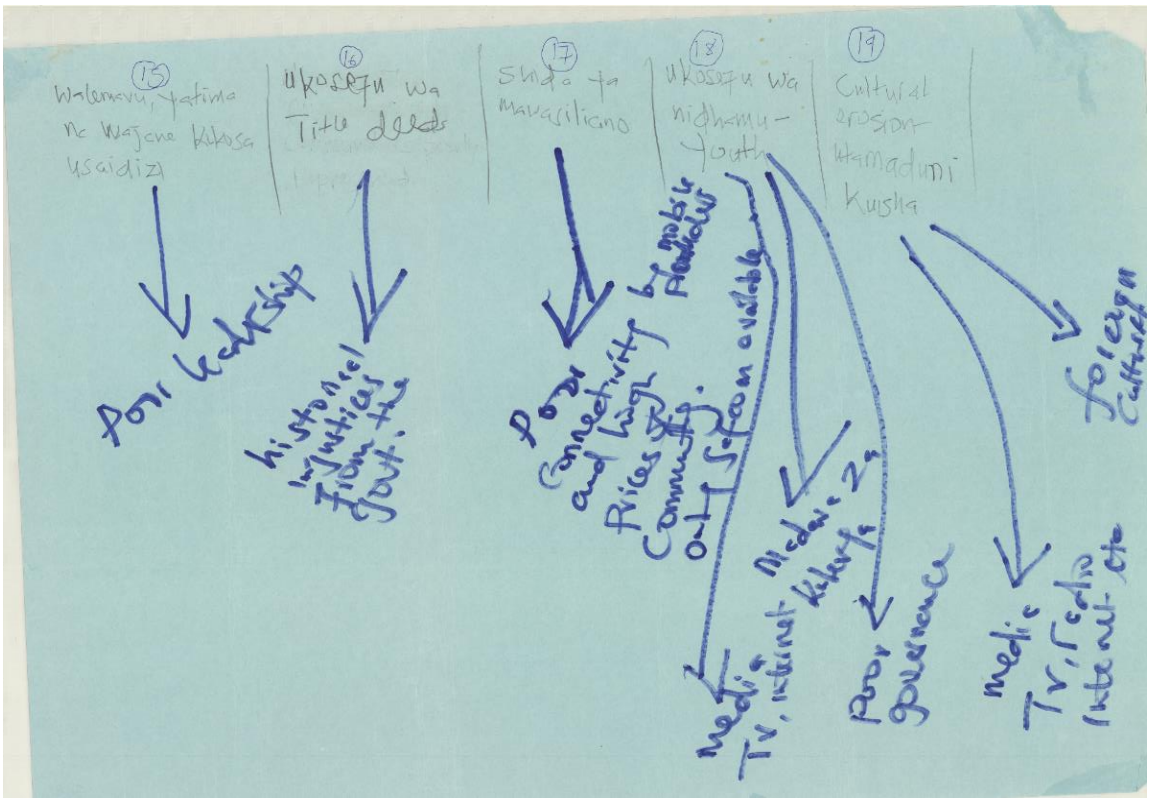

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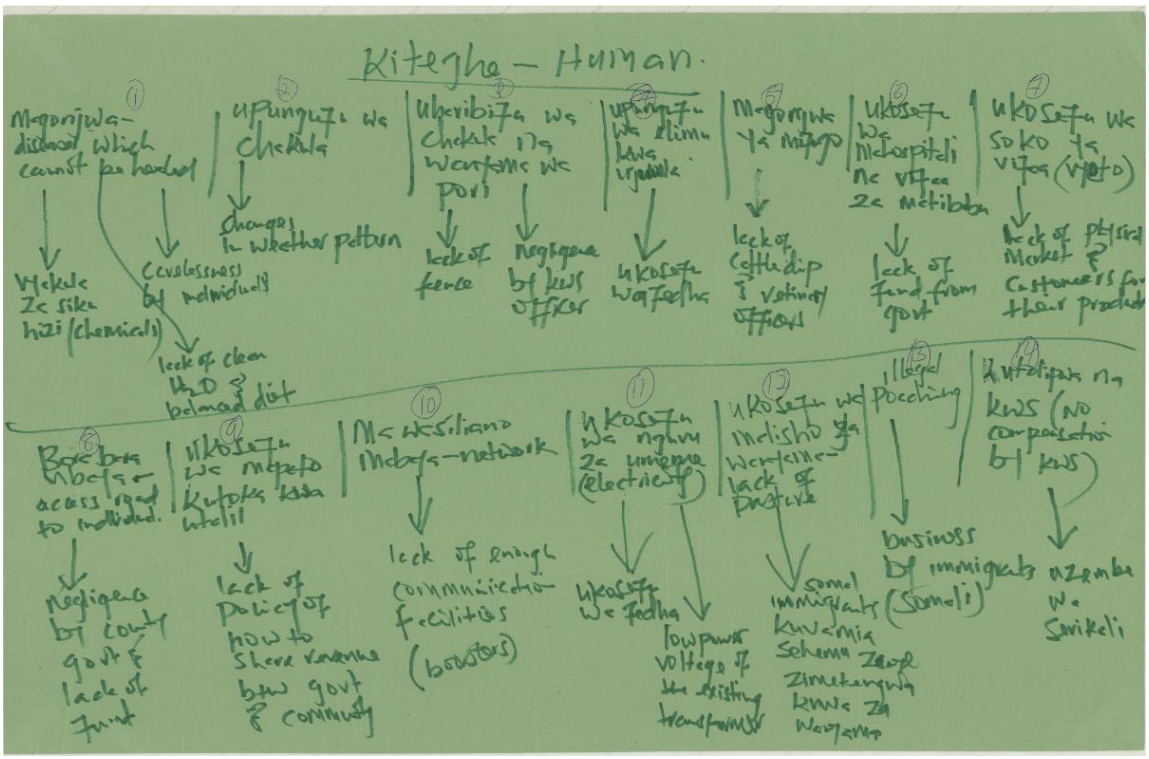
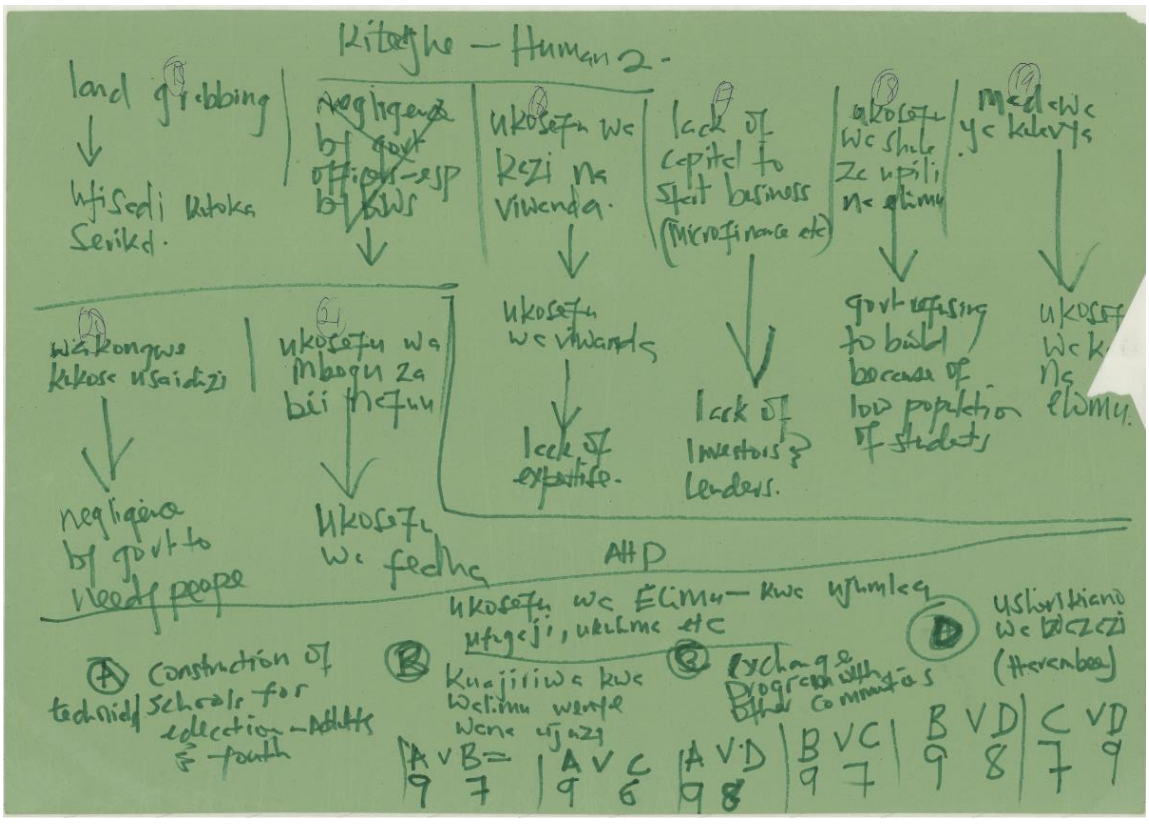
Figure A.2 Continued

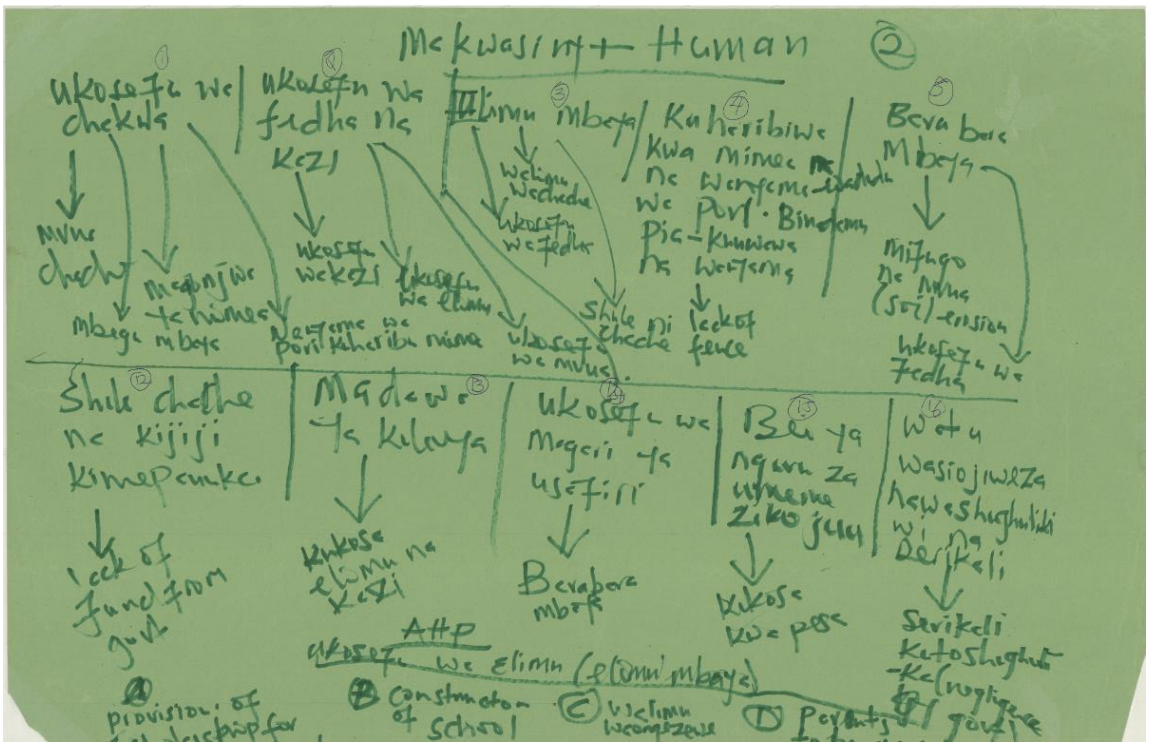


A



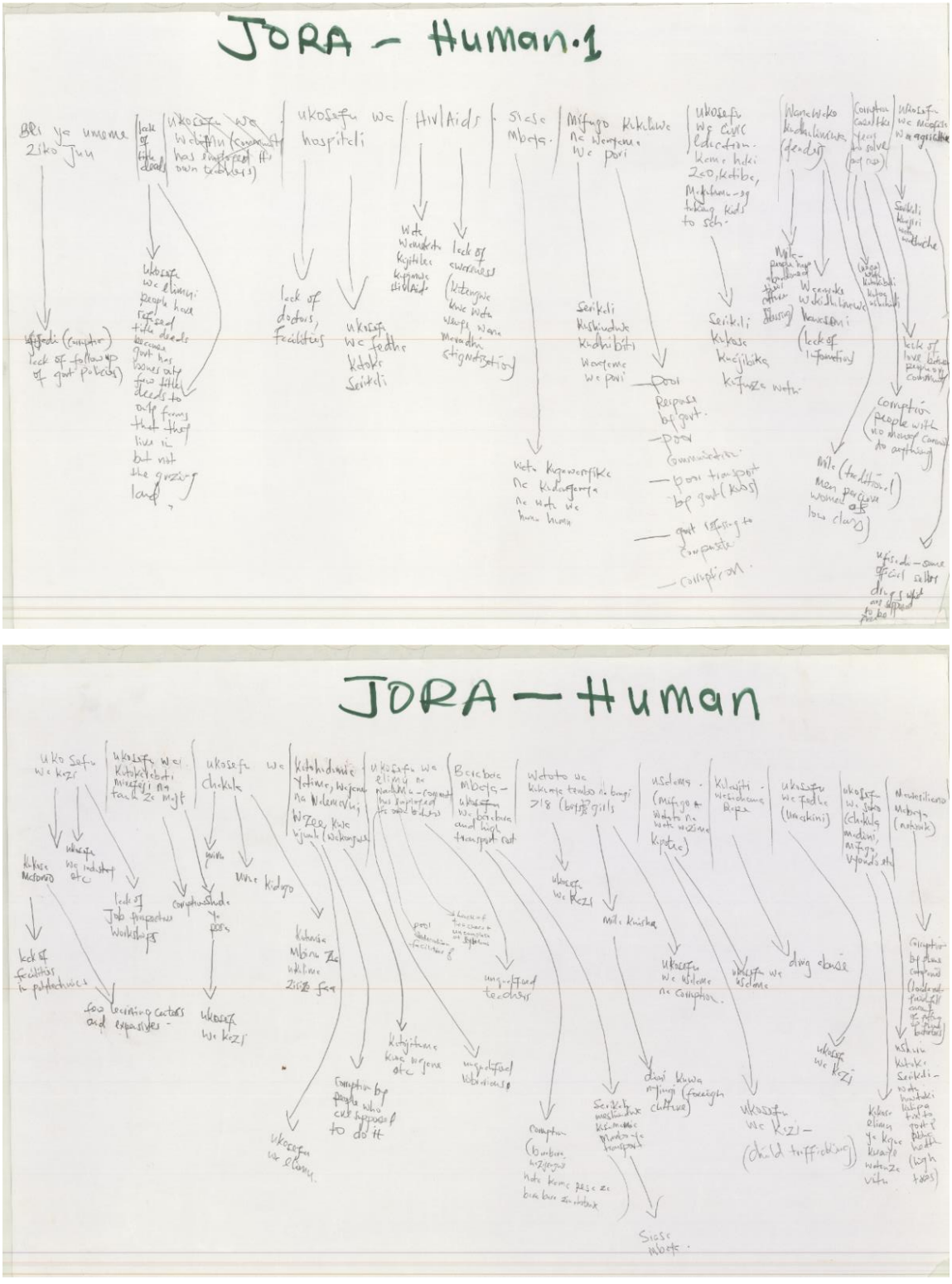
B

Figure A.3: Impact tree diagram developed in Kiteghe village.



A

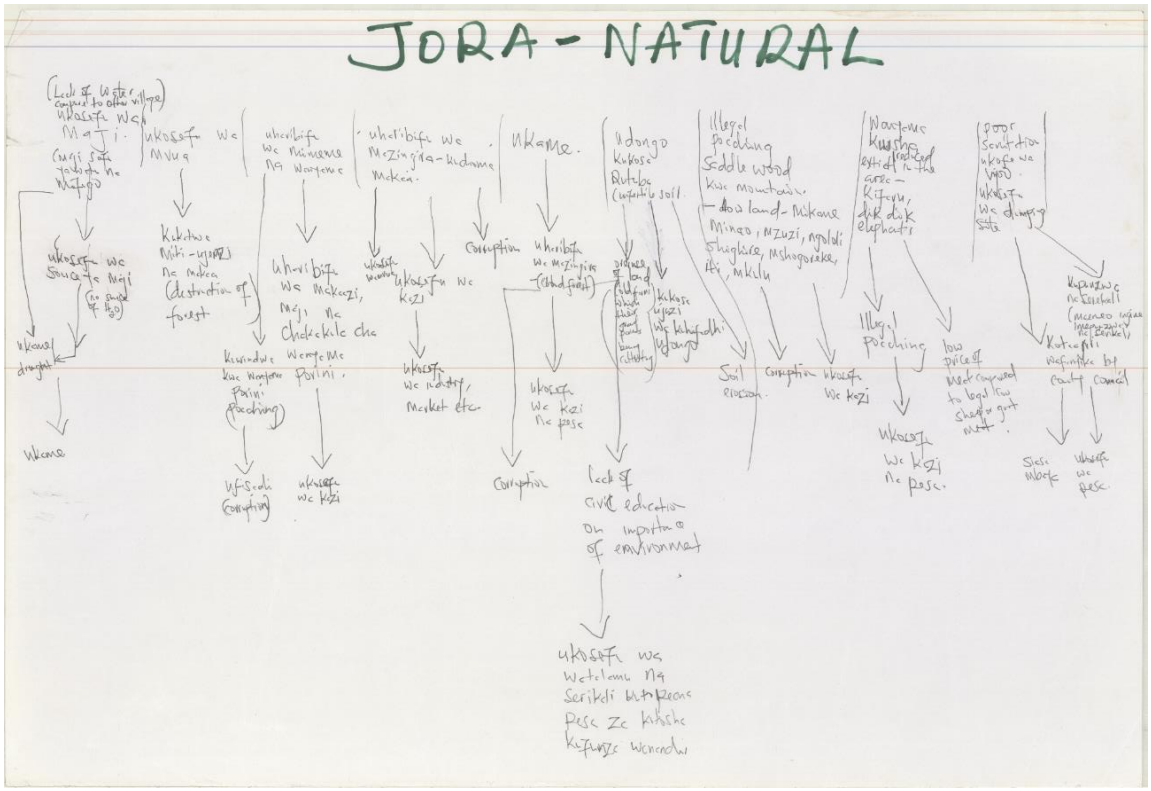
Figure A.4: Impact tree diagram developed in Makwasinyi Village.



A

B

Figure A.5: Impact tree diagram developed in Jora village.



C

Figure A.5 Continued

Appendix 2
Interview Guide

Name…….

Age/Gender……...

Occupation…….

Village…….

How long have you lived in this village?

List of Issues

- What is source of your livelihood?
- What social structures if any, challenge your ability to improve your livelihood?
- In your own opinion what type of threats do women, young people and children encounter in this village?
- Are those threats specific to certain a gender or they are general threats to the society?
- What do you think are the causes of these threats?
- Looking at these tree diagrams that were produced by the residents of this village, what is your opinion about them?
- Do you think they covered all the threats that are encountered in this village (especially by women and young people)?
- Do you have anything that you would like to add or change in these diagrams?
- If so, what are the reasons?
- Do you have anything else you would like to inform me?

Figure A.6: The Interview Guide used During the Semi-structured Interviews.

Appendix 3

The AHP Model used for Assessing the Biophysical Environment in the Study Villages

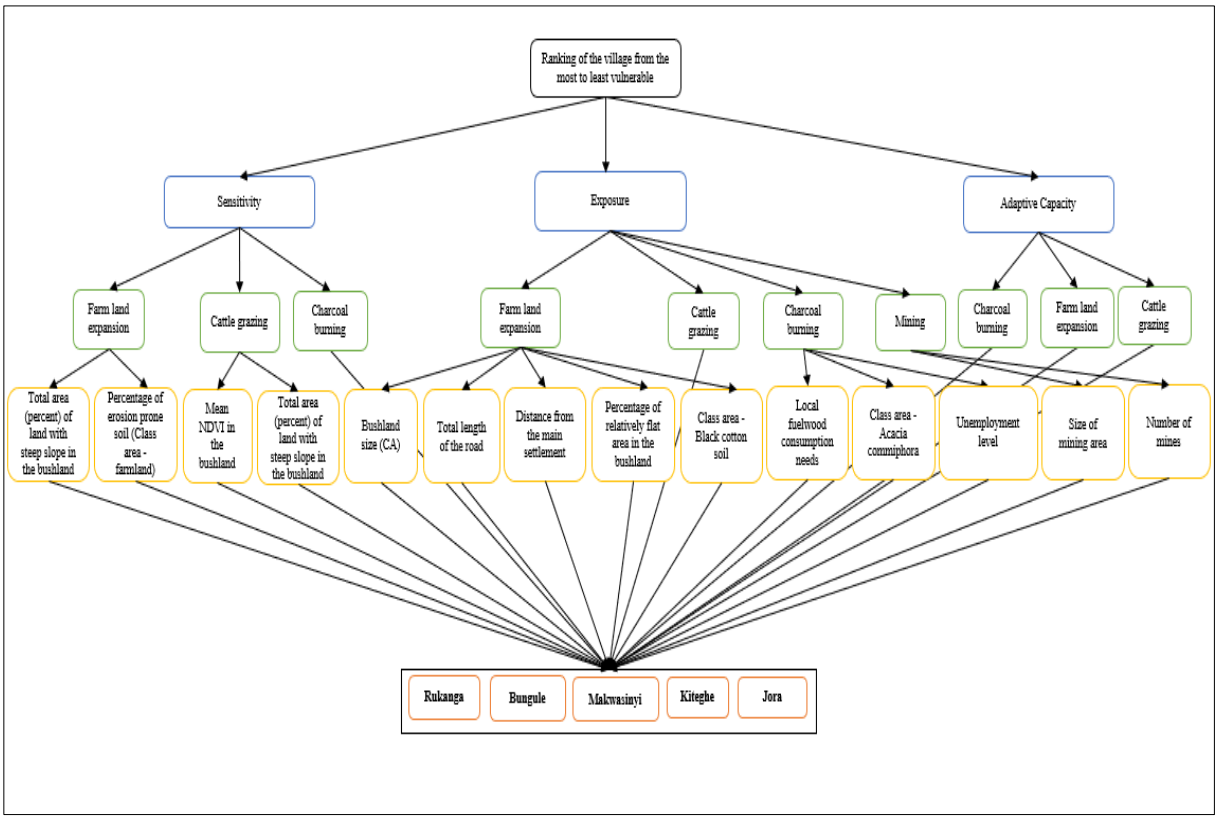


Figure A.7: The Analytical Hierarchy Process Model developed for assessing the environmental vulnerability for this study.

VITA

Njoroge Ikonye Gathongo was born and grew up in Molo, Kenya.

Mr. Njoroge Graduated from Moi University in 2004 with a Bachelor of Science in Forestry. From 2005 to 2008 he worked with The Greenbelt movement – a nongovernmental environmental organization that empowers communities, particularly women, to conserve the environment and improve livelihoods.

With great enthusiasm for environmental conservation, he headed to the U.S. and started his graduate education at Miami University, Oxford, Ohio. His thesis involved "Validating Local Interpretations of Land Cover Changes at Mt. Kasigau, Kenya". After graduation he entered the Geography department at the University of Tennessee, Knoxville in 2013 where he completed his Doctoral of Philosophy degree in December 2018. He was awarded The W. K. McClure Scholarship during his second year to conduct field work for his dissertation at Mt. Kasigau and worked as a Graduate Teaching Assistant in the Department of Geography.

He has maintained an active research agenda and submitted three manuscripts in peer-reviewed journals. He has presented his research at a number of professional conferences and forums, including the SouthEastern Division of the Association of American Geographers (SEDAAG) and the American Association of Geographers (AAG).

His areas of research focus include coupled human nature systems, remote sensing and GIS with focus on land use land cover changes, and qualitative methods.