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RESILIENCE AND SUSTAINABLE LIVELIHOODS: CLIMATE CHANGE AT THE INTERFACE OF PARKS AND PEOPLE

BRITTA LEE SCHUMACHER
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Reviewed and approved* by the following:

Larry Gorenflo
Professor of Landscape Architecture
Thesis Supervisor

Roger Downs
Professor of Geography
Honors Adviser

* Signatures are on file in the Schreyer Honors College.
ABSTRACT

One of the greatest challenges faced in the 21st century is developing comprehensive policy and management methods that maintain the diversity of life on Earth while meeting the demands of an increasing global population in an ever-changing world. This challenge is especially evident in areas where rural peoples depend heavily on natural capital and resources to supplement their livelihoods and where the effects of climate change are most immediately felt. Uncovering these plausible management and policy solutions is of extreme importance in the Udzungwa Mountains region of the Eastern Arc Mountains in Tanzania, in particular due to the proximity of the Udzungwa Mountains National Park (UMNP) to a population of at least 60,000 commercial and subsistence agriculturalists it supports on its eastern border. To begin to uncover the possible indirect consequences of climate change on UMNP first requires understanding the likely impacts of climate change on people. For agriculturalists, the most meaningful impact is on crop yields. Thus, establishing a baseline of production and food security in one village, Mang’ula B, acts to provide a basis for considering possible impacts of climate change on UMNP through the lens of sustainable livelihoods. Fieldwork and interviews, providing insights on people’s perceptions of climate change and its impacts on agricultural production, complemented the analysis of sustainable livelihoods. Quantitative climatological and agricultural data, coupled with insights of local people, are the basis of this study, the latter helping to understand better the challenges of decreasing food security and livelihood sustainability from changing climate faced by residents of Mang’ula B. The results of this research suggest a bleak future where traditional agricultural methods yield minimal production and food security and livelihood sustainability falters, possibly threatening the integrity of UMNP and the Udzungwas.
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Chapter 1. Food Security & Biodiversity Conservation Under a Changing Climate

In the coming century, climate change will impact every individual and community on Earth. The question in recent years has become to what extent it will occur and what its ramifications will be for particular places. This planet and the life it supports have never before experienced changes in climate of the magnitude projected over the short period of time in which they are expected to occur. Modern climate change, therefore, poses unprecedented challenges. These challenges are particularly apparent in human populations that depend heavily on relative climatic stability and historical predictive capacity to survive, such as subsistence agriculturalists.

By definition, subsistence agriculturalists produce crops for their own consumption, or subsistence use. They rely on annual production to meet daily requirements and often have little to no financial capital to fall back on. All profits that these agriculturalists might make from selling surplus crops beyond those required to meet their own demand, or from the small amount of wage labor available to some, are used for fertilizers, school fees and to purchase any food stuffs they cannot produce themselves. These purchases leave little, if any, cash to rely on if a harvest falls prey to disease, drought decreases yield, or excessive rains destroy crops. Thus, impacts of reduced crop productivity for any reason, is felt quickly and directly. The impacts of climate change will exacerbate current vulnerabilities to disease, pests, weeds, floods and droughts, with results that can be truly devastating.

In some settings, other constraints add further challenges. One seemingly insurmountable challenge is maintaining and increasing production in an area that is resource-limited and constrained geographically as population increases. Such is the case on the western edge of the Kilombero Valley in south-central Tanzania (Figure 1). Several villages on the western edge of the Kilombero Valley are constrained by a protected area, Udzungwa Mountains National Park (UMNP), immediately to their west and commercial agricultural production immediately to their east. In addition to limited space for
expansion, the threat of climate change increases the likelihood of food insecurity and, possibly, the threat that communities pose to UMNP. The real possibility of agricultural shortfalls in the coming decades raises concern regarding the status of UMNP—as households begin lacking food and cash resources, they may begin to look to the neighboring resource repository, UMNP, to meet their needs.

Figure 1 Map of the Study Area: The Kilombero Valley, UMNP and Mang’ula B. Data Source: Larry Gorenflo.

To explore the above issues in more detail, in this thesis I examine subsistence agriculture in a particular community—the village of Mang’ula B, a rural village on the eastern edge of the UMNP. Mang’ula B is composed mainly of individuals who practice subsistence agriculture and supplement their earnings with small amounts of wage labor. Through interviews with selected individuals, community mapping, identification of likely temperature and precipitation changes over coming decades in south-central Tanzania and spatial analysis, I examined recent and likely future impacts of climate change on agricultural productivity, and in turn use these impacts to determine the possible implications of climate change for the neighboring national park if subsistence practices are disrupted.
Research Design & Objectives

The subject of this thesis was established gradually, beginning with an interest in the conservation of biodiversity and endemism in a world increasingly focused on meeting the social, physical and economic needs of people. It has become evident in conservation science and nature-society geography that one of the greatest challenges faced in the 21st century is developing comprehensive policy and management methods that maintain the diversity of life on Earth while meeting the demands of an increasing global population in an ever-changing world. This challenge is especially evident in areas where rural peoples depend heavily on natural capital and resources to supplement their livelihoods and where the effects of climate change are most immediately felt.

Uncovering these plausible management and policy solutions first requires understanding the likely impacts of climate change on people. For agriculturalists, the most meaningful impact is on crop yields. The primary aim of my research is to understand patterns of agricultural productivity through subsistence agriculturalists perceptions. Establishing a baseline of production and food security provides a basis for considering possible impacts of climate change on UMNP through the lens of sustainable livelihoods. These indirect impacts of climate change on UMNP are of secondary importance to the analysis of food security in this thesis, but are exceedingly important in this area due to the high volumes of poor agriculturalists that border it. Thus, though the primary goal of this project is to understand food security in Mang’ula B, insights into the future impacts of people on park resources due to climate changes impacts on agriculture represent a secondary focus of this thesis.

Fieldwork and interviews, providing insights on people’s perceptions of climate change and its impacts on agricultural production, complemented the analysis of sustainable livelihoods. Quantitative climatological and agricultural data, coupled with insights of local people, are the basis of this study, the latter helping to understand better the challenges of decreasing food security and livelihood sustainability from changing climate faced by residents of Mang’ula B.
My research fits into a larger context as it supplements the research of my advisor, Professor Larry Gorenflo, which focuses on community design and the identification of resource harvesting patterns by local communities. Moreover, it addresses important questions of potential implications of climate change for conservation, through changing the behavior of local people.

**Methodological Approach**

I spent four weeks, from May 26, 2014 to June 22, 2014, at the Udzungwa Ecological Monitoring Centre (UEMC), a research station dedicated to studies of UMNP and beyond, extending into the wider Udzungwa Mountains. During that time, I was in Mang’ula B for five days, completing both social and ecological fieldwork. On each of these five days I was accompanied by an interpreter, Mohammed Kambi, Professor Gorenflo and two fellow Penn State Students, Alison Caruso and Chris Frey.

**Social Research Methods**

The research methods employed in this study included community mapping, key informant group interviews and formal and informal interactions with interpreters and other community leaders. These methods provided information about the location and state of agriculture in the community and the perceptions of recent trends in production, with a focus on the impacts of climate change.

Upon arrival to the Monitoring Centre, I scheduled key informant group interviews with village councilmen, focusing exclusively on people familiar with community conditions and whose official duties included representing Mang’ula B and its sister village, Mang’ula A. These interviews, along with formal and informal interactions with interpreters and park rangers, and observations of *shambas* (agricultural fields, including kitchen gardens near houses), provided much of the data I gathered while in the village. Interviews and interactions with interpreters provided information regarding: a) perceptions of climate
change and variability; b) changes in agricultural production in recent memory; and c) qualitative and quantitative data about agricultural production. The information gleaned from these interviews and interactions are reported throughout the body of this thesis and are the basis for the spatial analysis of agricultural land use in Mang’ula B and my interpretation of that analysis.

A community mapping exercise was completed during two of the five days we spent in Mang’ula B (see Figure 2). Hard-copy printouts of high-resolution GeoEye-1 satellite imagery of the community were taken into the field and signatures for different crops were identified and labeled by our research team. These signatures were identified for later use with geographic information system (GIS) analysis for the classification of agricultural fields as row crops, sugar cane, or rice paddy (see Figure 3). During these same community mapping exercises, surveying tapes were used to measure agricultural fields and the spacing between different crop types, for later analysis. Community mapping enabled identification of different land uses and the identification of spatial patterns of crop types on the landscape.
The imagery printed and brought into the field was also brought into a GIS interface for analysis. Professor Gorenflo’s data, reflecting the spatial pattern and classification of infrastructure in Mang’ula B, was overlaid with the imagery. I digitized different agricultural fields in the community, creating a new layer relating to field location, size and crop type. Once all fields were classified as row crops (a stand-in for all primarily subsistence crops grown in small amounts, such as tomato, cassava and sweet potatoes), sugar cane or rice paddy, the area of each field was calculated. Data from the key informant group interviews was used to depict baseline production (circa 1997) and current (2014) production potentials (based on optimal climatic conditions) for sugar cane, rice and maize (used as an indicator for row crops in general). Publications discussing percent changes in yield based on specified increases in temperature enabled projection of productivity changes throughout the landscape. For example, rice production is expected to decline by 13% percent with a temperature increase of 1.5-4.5° C, or a doubling of current carbon dioxide levels (Mohandrass et al. 1995; Peng et al. 2004; Nelson et al. 2009; Rowhani et al. 2011). I converted productivity to kilocalories, to calculate the number of people who could be supported by varying agricultural production levels, focusing in particular on subsistence. I also estimated the financial impacts of climate change due to reduced productivity, focusing on commercial agriculture.
Research Objective

The objective of this study is not only to tell the story of the people of Mang’ula B and the future they face due to a changing climate, but also to use this understanding to make informed predictions about potential community impacts on UMNP. It is well understood that vulnerable peoples, including those who depend on subsistence agricultural production as their main livelihood strategy, rely heavily on natural capital (the natural base of resources that surround them) to augment subsistence activities. Understanding how changes in agricultural productivity might increase reliance on these natural resources, including resources located within protected areas, is key in developing management and policy strategies that maintain reserves while encouraging development beyond their bounds. This thesis seeks to understand the likely impacts of climate change on subsistence agriculture in Mang’ula B, and the implications of these impacts for neighboring UMNP, as a first step in developing solutions for development strategies and park management sensitive to likely shifts in climate.

Project Outline

The remainder of this thesis is organized as follows.

Chapter 2 presents a review of the literature related to climate change and variability on the African continent and within Tanzania. Here, I explore my first research question: How will precipitation and temperature regimes in Tanzania shift as the climate changes?

In Chapter 3, I review the literature related to social-ecological systems, livelihoods and food security to present a theoretical framework from which I address issues of vulnerability and exposure to climate change. In this chapter, I explore my second and third research questions: What is the role of climate change in exacerbating current vulnerabilities? How do the effects of climate change on agricultural production influence vulnerability and livelihood security?
Chapter 4 presents the results of my social-ecological and spatial analysis. I present the analysis as a series of maps, figures and tables that demonstrate the spatial distribution of different types of agricultural productivity and the financial and caloric impact of climate change.

Finally, in Chapter 5 I summarize results and the conclusions drawn from them. In discussing these results, I explore the likely negative effects of climate change on food security and livelihood sustainability. I also present suggestions on first steps toward increasing the adaptive capacity of Mang’ula B. I examine these ideas in the hope that my predictions of the effects of climate change on UMNP may be lessened by implementing agricultural adaptation methods.
Chapter 2. The State of Global & Regional Climate Change

The climate system exists in a continuous state of dynamic equilibrium, responding to changes in the atmosphere, biosphere, land and ocean, on various temporal and spatial scales. For millennia, climatic response to these changes resulted in variability that oscillated around the same relative mean. Though dramatic, extended climatic anomalies occurred on inter-annual, decadal and millennial scales due to natural variability within the system, relative consistency within interim years persisted. Such shifts in the climate system, including glacial and interglacial cycles as well as annual variability, are expected as a result of complex climatic interactions. Changes in recent decades, however, have resulted in a shift in climatic equilibrium, pushing the issue of climate change to the front of scientific and public concern.

Today the pattern of climatic variability is changing, due in part to dramatic anthropogenic influences on the system. Increases in greenhouse gases (GHGs) from human activities have affected Earth’s energy budget, causing global temperature rise. According to the Intergovernmental Panel on Climate Change (IPCC 2014), the leading international body on climate science, the warming of the earth on a global scale is unequivocal. In fact, each decade since 1980 has been successively warmer at the earth’s surface, with temperatures exceeding any preceding decade since 1850 (see Figure 4) (ibid.). Additionally, the nine hottest years on record (1880-2014) have occurred since 2000, making the start to the current millennium extraordinary (NOAA 2014).
Figure 4 Annual Global Mean Observed Temperatures: The y-axis shows anomalies relative to the 1961 to 1990 average and the x-axis shows the estimated actual temperature. Reprinted from Trenberth et al. 2007.

In the years since the Industrial Revolution (1750-1850) atmospheric concentrations of carbon dioxide have risen more than 100 parts per million (ppm), peaking in September of 2014 at a concentration of 395 ppm (Hartmann et al. 2013). According to Hansen et al. (2008), the upper limit for safe carbon dioxide concentrations is 350 ppm, a concentration that has been surpassed, increasingly, every year since 1988. Increasing concentrations of GHGs, which enhance the greenhouse effect and warm the earth, have caused a surface warming of 0.72 °C since 1951 (see Figure 5), producing cascading, unprecedented impacts on physical, biological and human systems (Hartmann et al. 2013). Increasing temperatures have coincided with glacial retreat, sea level rise (see Figure 5), increasing storm intensity, rising ocean temperatures, coral reef bleaching, species distribution shifts, increasing fire
intensity and species extinction (IPCC 2013). These consequences, in combination with a growing body of evidence regarding shifting precipitation patterns, increasing intensity of extreme weather events and changing climatic variability, confirm the scientific understanding of climate change. Moreover, they make evident the risk climate change poses as it cascades through natural and built systems, touching all life on Earth.

Figure 5 Multiple observed indicators of a changing global climate system. Reprinted from Pachauri et al. 2014.
Human Dimensions of Climate Change

A changing climate poses enormous and diverse challenges to all life on our planet. Of interest here are the direct impacts and consequences of climate change on people. All people will feel the impacts of climate change, but the consequences associated with change will vary spatially. In many places positive change will precede negative change—growing seasons will lengthen as frost retreats to earlier in the spring, carbon dioxide fertilization will increase productivity—though with medium to high increases in temperature, net positive changes would start to turn negative (Smith et al. 2001). Coastal peoples will suffer sea level rise and coastal erosion, experience local fresh water resources threatened by saltwater intrusion, and witness coastal ecosystem degradation due to rising sea temperatures. Agricultural societies will see traditional crop production practices fail and experience reduced food security and livelihood sustainability due to changes in precipitation and temperature patterns. Polar peoples will experience hardship as permafrost melt destroys their homes and sea ice erodes the coast, forcing them inland and away from traditional approaches to adaptation. These risks—rising sea levels, shifts in soil moisture, shifting landscape patterns—will affect all people to some extent. They pose even greater challenges, however, to those populations that are currently vulnerable, such as those who live in poverty (Bohle et al. 1994, p. 1; Molua et al. 2010). Without the economic capacity necessary to buffer against change, vulnerable communities find themselves exposed. This is especially true in parts of the world where people’s livelihoods depend on relative climatic stability and consist mainly, if not entirely, of subsistence agriculture (Fisher et al. 2014). Such is the case in most of rural Africa.

The African Climatic System

Africa’s climatic system is controlled on large spatial scales by a complex interplay of terrestrial and maritime interactions (Christensen and Hewiston 2007). These interactions reflect the impacts of climate change in varying ways across the continent at local and regional scales. On average, across
Africa mean surface temperatures increased by more than 0.5°C during the 20th century (Hulme et al. 2001; Case 2006; Christensen and Hewitson 2007; Niang et al. 2014). The IPCC projects that by the end of the current century, the continent may be expected to warm another 3 to 4°C, 1.5 times the global mean response to climate change (Christensen and Hewitson 2007; Niang et al. 2014). Precipitation is likely to show variable responses, but it is expected to decrease by 20% in West Africa and North Africa, and increase by 7% in tropical and East Africa, by 2100 (Figure 6) (ibid.).

Figure 6 Map of observed and projected average annual temperature and precipitation changes across the African Continent. Reprinted from Niang et al. 2014.
The projections presented in Figure 6, summarized by the IPCC, are inherently uncertain. This uncertainty arises from the complexity of the interactions governing responses from the climate system (Maslin and Austin 2012). Models rely on multiple factors: dynamic ocean currents, carbon emissions, human behavior, volcanic activity and more. The inherent uncertainty associated with many of these factors makes modeling difficult. At large scales, the models created by the IPCC are accurate with reasonable amounts of certainty (IPCC 2014). As scale decreases, however, local variability introduces greater uncertainty in model results, decreasing the accuracy of projections. It is at these local and regional scales that probable impacts and risks on specific localities must be identified. Understanding probable impacts at local scales is integral in understanding decision-making and vulnerability. Thus, despite greater uncertainty, the following discussion will consider only the variability and change in climate that have occurred, and are projected to occur, in East Africa, and in particular the East African country of Tanzania (see Figure 1).

Tanzania lies just south of the equator, between 1 and 11° on the east coast of Africa. The highlands and mountain regions of inland Tanzania, of interest in this study, have annual temperatures ranging from 17-25°C (Lizcano et al. 2010). Over the course of the past century, Tanzania has warmed significantly more, and significantly more quickly, than the continental average of 0.5°C (see Figure 7) (Hulme et al. 2001; Case 2006; Christensen and Hewitson 2007). According to the United Nations Development Program (UNDP), an observed warming of 1.0°C has occurred in Tanzania since 1960, with most warming occurring during January and February, the dry season following the short rains (Lizcano et al. 2010). This season is the period of the year during which people find themselves most vulnerable, when stored food supplies and savings (for purchasing food) are dwindling and new crops must be planted. The implications of warming, and the irregular spatial and temporal rainfall patterns often accompanying it, disrupt agricultural production and undermine food security for tens of thousands of subsistence agriculturalists.
In East Africa in general, precipitation is increasing; however, rapid warming of the Indian Ocean is currently increasing convection and precipitation over the ocean, and decreased precipitation over land due to subsidence over East Africa (Case 2006; Niang et al. 2014). Despite declining amounts of precipitation, the intensity of rain events is increasing and is expected to continue on this trajectory. These rainfall patterns are driven seasonally by the migration of the Intertropical Convergence Zone, a narrow belt of low pressure that forms at the thermal equator (Barry and Chorley 2010; Lizcano et al. 2010). Annual migration of this convergence zone causes the highland region to experience biannual wet seasons, with the “long rains” occurring from March to May and the “short rains” from October to December (ibid.). As climate changes, so too will the course the thermal equator takes on its annual migration. How it will shift, and how the seasonality of rains will change, remain uncertain.

The combination of rising temperatures and increased variability in seasonal rains is complicating agricultural production and threatening livelihood sustainability, and will continue to do so throughout the next century (Lizcano et al. 2010). The central role that agriculture plays in Tanzania makes this of particular concern. The arrival, retreat and amount of seasonal rainfall influence rural livelihoods (Cooper et al. 2008). If rains arrive too early, farmers may not have enough cash to purchase seed. If rains arrive too late, planting delays occur, possibly disrupting the availability of food later in the season. If rains continue too long, as occurred this past long rainy season (2014), farmers may have a difficult time harvesting crops, possibly losing much of the yield in the process. Increasing variability thus increases the vulnerability of rural livelihoods, particularly in a country such as Tanzania where agriculture is so important commercially and for subsistence.
Figure 7 Trends in annual mean temperature and precipitation for the recent past (1960) and projected future (2100) for Tanzania. Climate model projections are based on three of the IPCC’s SRES emissions scenarios, A2 (“low”) A1B (“medium”) and B1 (“high”). Reprinted from Lizcano et al. 2010.

The changes that have occurred over the past half-century are projected to continue and become both increasingly significant and devastating (see Figure 7). In coming decades in Tanzania, models suggest that temperatures will continue to rise as precipitation patterns change and increase in amount and intensity. Mean annual surface temperatures are projected to increase by 1.5 to 4.5°C by the end of this century, increasing by more than 1.5 times the global mean of 3°C (Agrawala et al. 2003; Lizcano et al. 2010). Precipitation is expected to change between -4% and 30% during the wet seasons (ibid.). Models also suggest that intense rain may increase by 24 mm in 1-day events and 37 mm in 5-day events by 2100, inundating already flooded sugarcane and rice fields (Lizcano et al. 2010). During the dry season in June, July and August, rainfall is projected to decrease by 5 to 10%, amplifying current food security and livelihood threats (Hulme et al. 2001; Agrawala et al. 2003).

Changes in East African climate in part relate to global-scale shifts. Unfortunately, variability in the seasonality of rains likely is due to large-scale events that affect climate, such as El Niño Southern Oscillation and the Indian Ocean Dipole, but this process is not well understood (see Figure 8). Their impacts, however, are key in understanding the sustainability of agricultural production. According to people across the study area who rely on the yields from subsistence agriculture, increasing variability is already affecting people’s ability to survive (Paavola 2008). Such variability thus requires adaptive measures to make communities resilient to these changes.
In Tanzania, like many other less-developed countries where subsistence agriculture is important, few livelihood options are available. Negative impacts on farmers cascade through families, communities and villages. As food security decreases, livelihood sustainability falters and the economy fails, a subsistence agrarian society has the potential to collapse. Climate change has the potential to further exacerbate seasonal vulnerabilities and cycles of debt and starvation, strip communities of their health and security and shatter community resilience to change. This, then, is the theme of the following chapters—the tangible impact that climate change and variability is having and will likely have on the lives and
livelihoods of people in particularly vulnerable communities—specifically, residents of Mang’ula B, in the Eastern Arc Mountains region of south-central Tanzania.
Chapter 3. The Study Area & Issues of Food Security

The Geographic Setting

The Eastern Arc Mountains of Tanzania and Kenya are globally renowned for their high concentrations of endemic species (species that occur nowhere else) and high levels of biodiversity (Burgess et al. 2006). These mountains stretch from the Taita Hills of Kenya southward to the Udzungwa Mountains (hereafter referred to as the Udzungwas) of south-central Tanzania, the product of continental uplift more than 30 million years ago (Figure 9) (Dineson et al. 2001). The 13 separate mountain blocks compose much of the Eastern Afromontane biodiversity hotspot, one of the world’s 35 hotspots (Mittermeier et al. 2004). The 3300 km² area of sub-montane, montane and upper montane forest in the

Figure 9 The Eastern Arc Mountains and UMNP (Missing from map: Taita Hills of Kenya and Nguus, no spatial data available). Source: Eastern Arc Mountains Conservation Endowment Fund.
Eastern Arc Mountains supports more than 160 near-endemic and endemic vertebrate species, over 800 endemic vascular species, 32 endemic bryophytes and many hundreds of potential endemic invertebrates (Burgess et al. 2006). Despite the now fragmented nature of the forest, comprising less than 30% of the estimated original forest area, the importance of the Eastern Arc to biodiversity conservation in Africa is virtually unrivaled (Topp-Jørgensen et al. 2009).

Since the Eastern Arc Mountains were originally mapped in 1985, numerous studies have been completed that demonstrate their importance globally for the conservation of endemism and biodiversity (Burgess et al. 2006). Consistently ranked among the top three most important of the 13 blocks are the Udzungwas (see Figure 10). The Udzungwas are the largest of the block of mountains in the Eastern Arc, covering more than 10,000 km² of moist forest blocks interspersed with grassland, woodland, human settlements and agricultural areas (Rovero and Jones 2012). With a total forest area of more than 1300 km² and altitudinal forest range of 300-2580 meters, the Udzungwas are home to remarkable levels of endemism, which, according to recent studies, are under increasing threat (Burgess et al. 2006; Harrison 2006; Rovero et al. 2012).

![Figure 10 A view of UMNP. Photo by: Andrew Vargo.](image-url)
This threat to endemic biodiversity is, in great part, due to the proximity of the Udzungwas to the dense and ever-increasing (3.4% annual growth, according to the 2002 census, the most recent census released with sub-district population figures) human population of the Kilombero Valley to their east (Harrison 2006; MTSN 2007). The floodplains of the valley form one of Africa’s largest wetland systems and support some of Tanzania’s most fertile agricultural lands (Kangalawe and Liwenga 2005). The Kilombero Valley directly borders UMNP (refer to Figure 1), one of two national parks and three gazetted nature reserves created and maintained to protect, conserve and support biodiversity in Eastern Arc habitats in Tanzania (Burgess et al. 2007). UMNP contains 1900 km² of mountain forest and grassland that, as of 2011, are no longer legally accessible for community access or resource extraction (ibid.). This protected status has important implications both for the health of the park and for the wellbeing of the populations that border it.

Most people in the Kilombero Valley and resident villages, such as Mang’ula B (adjacent to the main UMNP office), rely on a mixed wage-subsistence economy, where subsistence activities, mainly agriculture, are supplemented by earning small amounts of money (see Figure 11) (Harrison 2006). These agriculturalists, and increasing numbers of in-migrants, are restricted to a narrow strip of land bounded by UMNP to the west and commercial-scale sugarcane and rice cultivation to the east, making land for subsistence crop production a scarce commodity (Kikula et al. 2003; Gorenflo and Orland 2011). Increasing population requires more land for subsistence cultivation. In the case of Mang’ula B,
experiencing heavy resource demand already with a population estimated at more than 5,200 individuals in 2014, very little land remains for agricultural expansion (based on satellite imagery and population estimates) (Harrison 2006; Tanzania National Bureau of Statistics n.d.). Current population was estimated based on the average annual growth (2.31%) for the Mang’ula Ward between 2002 and 2012. In 2002, as reported in Harrison 2006, the population of Mang’ula B was 3,992. Here we assume that ward population growth applies to village population growth as well, giving a population of about 5,026 in 2012 and about 5,251 for 2014, while I was in the field (Tanzania National Bureau of Statistics n.d.).

The inability of agriculturalists to expand is exacerbated by lack of capital for the adoption of new agricultural techniques. Without the means to adopt new economic practices, or to diversify their livelihood portfolio, and with the threat of a changing climate, subsistence agriculturalists find themselves with few options (Lema & Majula 2009). If agriculture fails, which is the source of capital for 96% of individuals in the area, the first natural source of vital, possibly life-saving resources is UMNP directly bordering the western edge of Mang’ula B (Harrison 2006). Thus, climate change will not only negatively impact agricultural production, but will also may cause residents to extract resources illegally from UMNP, threatening conservation in this highly biodiverse park.

The Udzungwas have played a role as a source of vital resources, but more important is their critical role in stabilizing the local, regional and national economy of Tanzania as a perennial source of water. The mountains are catchments feeding streams and rivers that provide healthy, clean water throughout the year (MTSN 2007). Water is not only essential for agriculture in the Kilombero Valley, but also powers two hydroelectric installations that provide 52.6% of the country’s total energy (ibid.). If the health and biological integrity of the forests falters, so too does the economic stability of the local, regional and national economies. Thus, it is in everyone’s interest to protect the Udzungwas, not only to conserve biodiversity, but also to help maintain Tanzania’s most important source of fresh water and electric power.
Issues Associated with Food Security

Much of the challenge of conserving UMNP lies in the condition and sustainability of rural livelihoods in the communities bordering the park. Rural livelihoods depend on diverse resources and assets other than agriculture for security, including natural (e.g., forests, fresh water), human (e.g., knowledge, skills), physical (e.g., infrastructure), social (e.g., cooperatives, community groups) and financial (e.g., credit institutions, savings) assets (IFAD 2014). The combination of these resources may be thought of as the capital base from which different livelihoods may be built (Scoones 1997).

Access to the capital base and the associated livelihood security ample capital provides, is strongly influenced by the vulnerability of rural livelihood strategies. Vulnerability can be defined as “the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover” from stresses associated with environmental and social change (Blaikie et al. 1994, p. 9; see also Adger 2006). The vulnerability of any system involves social, environmental, economic and political exposure that may put people’s lives and livelihoods at risk (Bohle et al. 1994; Jannssen et al. 2006). Vulnerability includes three key elements: 1) the stressor a system is exposed to, 2) the system’s sensitivity to stress and possible change, and 3) the system’s adaptive capacity (Adger 2006). Central to the idea of vulnerability and the idea of sustainable livelihoods are the “shocks and stresses experienced by social-ecological (systems)” (ibid. p. 269). The sensitivity of agricultural production to inter- and intra-annual climatic variability (stressor), and thus the vulnerability of subsistence agriculturalists to the subsequent impacts of a changing climate (shock) on agricultural production, emerge as extremely important considerations (Howden et al. 2007).

The idea of vulnerability emerges from the recognition that the extent to which people suffer from disasters is based not only on their likelihood of being exposed to shocks affecting their assets, but also their capacity to withstand those shocks (Scoones 1997; Dilley and Boudreau 2001). Ultimately, this capacity depends upon individual and community socioeconomic circumstances and the systems’ sensitivity and resilience to change (ibid.; Adger 2006; Veisi et al. 2014). The extent to which individuals
and communities can utilize these assets fundamentally rests upon socioeconomic conditions, which in turn are influenced by economic, political and social patterns, exposure to external shocks and seasonal market and production fluctuations (IFAD 2014). Therefore, patterns, shocks and seasonal fluctuations are fundamental determinants of livelihood sustainability in any rural community.

A rural livelihood is considered *environmentally* sustainable when it maintains or enhances the local environmental resources on which livelihood depends, and *socially* sustainable when it is capable of recovering from shocks to the system and can provide for future generations under conditions of global change (Chambers & Conway 1992). The global change factor of particular interest here is climate change. The impacts of climate change on communities (both human and biological) typically expose people, ecosystems and assets. This exposure often leads to adverse effects that can increase a system’s vulnerability, decreasing ability to cope and make it unlikely to achieve sustainable livelihoods (Scoones 1997; Field et al. 2013). Considering that rural livelihood systems already are vulnerable, the increasing pressure of climate change has the potential to cause the subsistence agricultural system, which depends largely on traditional agricultural methods and the relative consistency of climatic events, to collapse.

In the context of this study, a collapse refers to the inability of residents of Mang’ula B to continue to rely on subsistence agricultural production as a primary livelihood strategy. The threat that climate change poses to livelihood sustainability in Mang’ula B is mainly due to the potential decrease in food production and, therefore, a decrease in *food security*. Food security, as defined by the World Food Conference in 1975, is the “availability at all times of adequate world supplies of basic food-stuffs to sustain steady expansion of food consumption and to offset fluctuations in production and prices” (CFS 2012, p. 4). In 1985, this definition changed when the World Bank argued that food security at the household level is only achieved if all households have the ability to purchase food (cited in Jarosz 2014, p. 171). In other words, the link between *self-sufficiency* and food security is a false one—communities unable to purchase food or trade in the market are still considered food insecure (*ibid.*).

Achieving food security is linked inherently with achieving food sovereignty—whereby “each
nation (has a right) to maintain and develop its capacity to produce its basic foods respecting cultural and productive diversity” (Via Campesina, cited in Jarosz 2014, p. 173). The link between food sovereignty and security makes small-scale, sustainable agriculture preferable over industrialized, globalized, Genetically Modified Organism (GMO)-focused production as it prioritizes the small-scale producer and necessarily makes them more resilient. It is this link that this study is interested in—and from now on the term “food security” will refer to the intersection of food sovereignty and security. This intersection marks the place where rural agriculturalists, the majority of the population in Mang’ula B, not only have the wherewithal to produce enough food crops for food- and market-sufficiency, but are able to do so using sustainable techniques and non-GMO, traditional crops.

Maintaining food security is threatened by the current vulnerability of the Mang’ula B system. Considering that the poor disproportionately suffer from famine, hunger and food insecurity, and that the health and security of individuals in Mang’ula B are currently sensitive to climatic variability, climate change has the potential to compromise their fragile sociocultural systems (Bohle et al. 1994). This fragility not only rests on the vulnerability of the agricultural system to change, but also on the already compromised economic system, where residents find themselves in debt each month and even deeper in debt during the dry season following the short rains (Harrison 2006; Mang’ula B village council, personal communication, June 12, 2014). A continuous cycle of debt leads to a life of poverty and can produce one of total food insecurity.

By definition, those assets and strategies that constitute a livelihood provide buffers against change and relief against system collapse. Rural subsistence agriculturalists constitute a group of individuals and collective communities who presently have low food security but currently have sufficient assets to sustain themselves *(ibid.)*. When climate change begins to affect local productivity, however, the resilience of those vital buffers becomes questionable. Many residents, without access to surplus growing season stocks, currently struggle to feed their families during the non-growing seasons (Mang’ula B village council, personal communication, June 11, 2014). If production continues to decrease, which has
been the trend in recent years for subsistence agriculturalists in the area (see Appendices A and B for further evidence of this), current cycles of poverty, debt and hunger will leave residents with few options (ibid.).
Chapter 4. What is the Fate of Agriculture in Mang'ula B under Climate Change?

Fertile soils and historically ideal climatic conditions for agriculture led Britain’s East African Royal Commission to complete a survey of the Kilombero Valley in the years between 1953 and 1955. The result of this study was a published report that deemed the valley an “agricultural zone of high potential” (Beck 1964, p. 37). This publication had important implications for the valley, which was virtually undeveloped at the time. The attention the report brought drew the valley’s first commercial investor, the Kilombero Sugar Company, to break soil in 1962, limiting the geographic range of peasant farmers mainly of the Pogoro, Ndamba Mbunga and Ngindo people (ibid.). Since then, commercial agriculture has spread across the valley, often restricting residents who practice subsistence crop production to a narrow strip of land between the Udzungwas to the west and commercial agricultural fields to the east (refer to Figure 1).

The attraction of fertile soils, ample water and stable climate brought commercial investors to the Kilombero Valley and in recent decades has caused thousands of in-migrants to relocate to the valley to farm community land (Harrison 2006). This community land exists under a customary land-tenure system where the village council allocates land within its village bounds as it sees fit (Proches Heronimo, personal communication, May 25, 2014). Increasing numbers of in-migrants have decreased available arable land for agricultural expansion. This, in combination with agriculturalists becoming out-growers (men and women participating in contractual partnerships with larger firms for the production of commercial products) for Illovo’s Kilombero Sugar Company’s commercial sugar cane production, leaves less land available for the production of food crops. Less available food has the potential to produce greater food insecurity and threatened livelihoods; more commercial production may, on the other hand, provide jobs, steady wages and capital accumulation.

According to a publication resulting from discussions at the Seminar on Food and Nutrition Security, Agriculture and Climate Change, promoting out-growing schemes to couple smallholder producers with large commercial enterprises is a key international goal (Deering 2014). And if properly
executed, the development of sustainable economic, environmental and ecological value chains has the
potential to raise standards of living and bring financial success to smallholder contributors and the
village itself. In the case of villages near UMNP and the Illovo scheme, the attractiveness of income from
cash crops can sometimes lead to net decreases in assets (Mang’ula A village council, personal
communication, June 12, 2015). The out-grower scheme still exists because it is, in part, successful for
smallholders. To make the scheme more successful, smallholders must be empowered with practical
knowledge (currently lacking, according to village council members) and sustainable value chains must
be maintained (Mang’ula B village council, personal communication, June 12, 2014).

A cycle of declining land availability, decreasing food production and variable net income, has
decreased the sustainability of people’s livelihoods in recent years. In order to combat this cycle and to
harness all potential productivity from the valley, subsistence and commercial growers alike have
continued the process of agricultural intensification. The current methods are not sustainable, however,
and researchers and subsistence agriculturalists alike have already documented decreased soil fertility and
environmental degradation (Mang’ula A village council, personal communication, June 12, 2015). As the
climate changes and environmental stressors increase, processes of intensification, degradation and
decreased productivity will continue. The question is what the perceived and actual effects of climate
change have on agricultural production for Mang’ula B considering current vulnerabilities of the
subsistence agricultural economy, projected climate change and historical changes in production
potential.

The Impacts of Climate Change on Agriculture

According to recent research, Tanzania and the Morogoro Region (where the Kilombero Valley
and Mang’ula B occur) will become 1.5 to 4.5 °C warmer by century’s end. Precipitation is expected to
change during the wet seasons by -4 to 30% and decrease during the dry seasons by 5 to 10% (Agrawala
et al. 2003; Lizcano et al. 2010). Wet season inundation and dry season drought, in combination with increased temperatures and increased rates of evapotranspiration, will reduce soil moisture, prolonging dry seasons and worsening periodic droughts (Paavola 2008). Such droughts will diminish water available for crop cultivation and have the potential to decrease growing seasons for many crops currently cultivated in Mang’ula B. According to community members, irrigation schemes for smallholders are out of the question—there is not enough capital to invest in them, materials for irrigation systems must be purchased from far away at markets at high costs, and the frequency of repairs all render them unsustainable. Reliance on rain-fed agriculture, and shared knowledge regarding rainy seasons and weather cycles, will persist.

Warming will not only increase the frequency and intensity of droughts, causing crop loss, but will also increase crop loss due to the impacts of disease, pests and weeds (already noticeable on the landscape). The prevalence of rice smut, for example, reduces yields for nearly every farmer in Mang’ula B and neighboring Mang’ula A—the disease is new and according to farmers (and literature) a product of a warming climate (Niang et al. 2014). This fungus attacks the kernel at flowering and replaces the original kernel in the husk, rendering the rice unusable (ibid.). To ease weeding, stalks of maize are currently spaced about 2.5 feet from one another, in the process reducing yields below levels that might be achieved.

In addition, increased flooding from flash rainfall events has the potential to ruin crops nearing harvest, and has historically done so, knocking the grain from the stalk to rot in the field (Paavola 2008). Finally, research suggests that in combination with high temperatures, altered precipitation patterns and the possibility of increased frequency of extreme weather events, the possible positive effects of elevated carbon dioxide will not be realized—instead, local villages will experience depressed yields and increased production risk (Fisher et al. 2014). Under likely climate change scenarios, the future of smallholder agriculture in the Kilombero Valley, and Mang’ula B, does not look bright.
Agriculture in Mang’ula B: Perceptions of Change & Projections for the Future

Seen from above, Mang’ula B looks like an organic sprawl of one-level rectangular homes spaced heterogeneously between permanent footpaths and large mango and palm oil trees (see Figure 2). In the near vicinity of each home lies a *shamba*, where residents grow subsistence crops such as cassava, banana, maize and cow beans. These crops are cultivated for home use and are kept close to the home to ease tending and gathering. In larger plots, often some distance from the home, dedicated to crops that can be sold for cash, the topography of the land is a major determinant of what crops can be grown where. The area of Mang’ula B that borders the park sits higher in elevation and remains drier throughout the rainy season. Here maize, sorghum, vegetables (e.g., tomatoes, pumpkins) and leguminous crops (e.g., pigeon peas, cow peas, beans) are grown (see Figure 12). This is also the area where most houses are built in attempts to avoid flooding during the rainy season. For many crops, agriculturalists create mounds or ridges after tilling that raise the seeds above the typical flood level to ensure they are not washed away towards the beginning of the growing season, when germination and early plant growth take place. In these higher areas fruit and fuel crops are also grown—these include *Brachystegia spiciformis* (zebrawood, used for fuel), *Acacia albida* (apple ring acacia, also used for fuel), *Mangifera indica* (mango, used for food and fuel) and *Carica papaya* (papaya, used for fruit).

Figure 12 Small household gardens (*shambas*), where cassava, pumpkin, tomatoes, spinach, maize and other subsistence crops are grown. Photos by: Andrew Vargo.

In lowland areas, on the other hand, paddy rice, sugarcane, banana, cassava and sweet potatoes
are grown. In Mang’ula B, row crops and scatter-seeded or rooted crops (rice and sugar cane, respectively) are separated into the northwest and southeast quadrants of the village, respectively (see Figure 13). Row crops, as mentioned above, are grown in small *shambas* usually located adjacent to the household for subsistence purposes, while rice (subsistence and commercial) and sugar cane (commercial) are typically grown in larger fields outside of the populated (built-up) part of the village where larger tracts of land occur. These fields are visited daily during the growing season and worked as necessary. Rice and cane are extremely important for farmers in Mang’ula B, representing two of the few crops that have any economic value or trading potential. Rice is particularly important as it accounts for many of the calories consumed in Mang’ula B, especially during the months following the short rains.

![Figure 13 The Agricultural Landscape of Mang’ula B, Tanzania. Data Source: village infrastructure, Larry Gorenflo; agricultural fields, Britta Schumacher.](image)

Unfortunately, according to Mang’ula A and Mang’ula B village council members, harvests have been decreasing for the past 5-10 years. According to these village representatives, decreases are due to
three factors: 1) intense, excessive rain during optimal harvest times; 2) intense sun and drought during critical periods (reproductive stages) of crop production; and 3) lack of best-use agricultural practices (which are not available to them due to lack of agricultural education and outreach) (Mang’ula A and B village council, personal communication, June 12, 2014). During the 2014 long rainy season, intense, rains lasted into the month of June, several weeks beyond when they normally cease. For agriculturalists trying to harvest their rice crop for the year, this caused major problems as the rice fell off the stalk when rain hit the ripe grains, or became wet and rotted after being cut and laid out to dry prior to removing the stalks from the field. In the recent past, farmers have been able to harvest rice beginning at the end of May without fear of problems from heavy rains. Recently, however, including last year, climatic variability shifted outside of the realm of community experience—no one had a sense of when the rains would finally stop—and as a consequence, a large number of smallholders lost part or all of their rice crop. For many families, losing a large percentage of the annual rice harvest means that they will have no grains saved for the coming year, decreasing their food security and also preventing them from selling surplus rice during high demand months. Though the caloric intake of rice in no way meets all nutritional needs, it is filling and a traditional staple; without it, the risks of hunger and starvation increase.

Agriculturalists in the vicinity of UMNP do not have the skills, flexibility or training to implement certain best-use techniques. One of such technique rarely implemented is allowing land to lie fallow; however, with steady in-migration, and scarce land left for cultivation, most fields are cultivated every season. This has reduced soil productivity and increased the appearance of weeds, reducing yields. In addition to over-use, arable land is often also planted as a monoculture, which in turn tends to degrade the soil. Moreover, monocultures also make farmers more susceptible to shocks to the system (e.g., if the rice crop is lost, most if not all of the food for the remainder of the year is gone).

Reduced yield and its impacts on security open a controversial topic: what will the effects on UMNP be due to the effects of climate change on agriculture in the communities that border it? According to Dr. Kim Howell of the University of Dar es Salaam, the biggest conservation challenges
Tanzania faces in the coming century are: 1) climate change; and 2) population (notably meeting food demands) (K. Howell, personal communication, May 22, 2014). Howell stated that the government is urging individuals to plant drought-resistant crops in order to increase resiliency against future climate change. Unfortunately, because of climatic variability, agriculturalists in and around Mang’ula B often have their food crops ruined by flooding and excessive rains, not drought. Moreover, farmers do not understand how to adapt to a climate that is changing in unprecedented ways, limiting their potential adjustments climatic shifts. Certainly yield reductions have serious implications for peasant farmers in Mang’ula B and other villages. In addition, without approaches for adapting to unfamiliar shifts in climate, UMNP may be in danger as farmers unable to provide for themselves and their families will likely turn to the park as a source of key resources in times of shortfall.

**A Sense of Mang’ula B’s Possible Agricultural Future**

Strategic adaptation is integral when considering the projections of declining agricultural production of key staple subsistence and cash crops due to climate change. For instance, maize yields are projected to decrease by 23% with a warming of 1-4 °C (Mwandosya et al. 1998; Jones and Thornton 2003; Rowhani et al. 2011; Thornton and Cramer 2012; Mbungu et al. 2014). Considering that maize is grown frequently as a row crop in and around Mang’ula B, its future is an important indicator of food security without agricultural and livelihood adaptation. With this same warming, rice yield is expected to decrease by about 13% (Mohandrass et al. 1995; Peng et al. 2004; Nelsen et al. 2009; Rowhani et al. 2011).

Those same village council members that provided insights as to why production has been declining also provided rough estimates as to how much production has declined since 1997, which they claim was the last good agricultural year. These men stated that the harvest in 1997 yielded 12-16 (100 kg) bags of rice per acre for long and short grains varieties respectively, amounting to 1,200 to 1,600 kg
per acre (Mang’ula A village council, personal communication, June 12, 2014). Now, farmers are only producing 8 to 12 bags of rice per acre, 800 to 1,200 kg (Mohamed Kambi, personal communication, March 23, 2015). A 13% decrease from current levels of production due to warming of 1.5 to 4.5 °C (projected for 2100), or a doubling of carbon dioxide, would leave farmers with 7 to 10.4 bags of rice per acre, 700 to 1,040 kg. From the baseline maximum production potential in 1997, the impact of climate change has the potential to decrease rice production by 42% in the long grain variety and 35% in the short grain variety.

There is no climatic scenario in Tanzania where agricultural productivity increases without the addition of agricultural intensification. Understanding how exactly climate scenarios impact food security requires converting production from kilograms into kilocalories, which can in turn be converted through daily caloric requirements into people potentially supported. Implications of changing production, and the reduced caloric availability accompanying it, are the subjects of the next chapter.
Chapter 5. Implications for Food Security & Livelihood Sustainability: The Results

Restatement of Purpose

This thesis seeks to understand the likely impacts of climate change on subsistence agriculture in Mang’ula B. These impacts, projected across the landscape as changes in production and converted to: 1) available kilocalories for consumption; and 2) number of individuals that could be supported by total caloric production, demonstrate the likely impacts climate change will in turn have on food security and livelihood sustainability. Changes in food availability and food stress provide the first glimpse as to what the implications of climate change are for the neighboring UMNP.

Figure 14 Built up and agricultural areas lie directly next to UMNP (seen in the background). Photo by: Chris Frey.
Results: Yield & Income per Acre

Rice Paddy

As noted, key informants identified 1997 as the last high productivity year in recent memory where 12 bags of local long grain rice and 16 bags of local short grain rice could be harvested per acre at the end of the growing season (see Table 3, Appendix A; see Figure 15). In the past two decades, production has decreased by 33% in the local long grain variety and by 25% in the local short grain variety (see Table 3, Appendix A). Farmers attribute this loss to a changing climate and lingering effects from El Niño events that affected through Tanzania in 1998 (Mang’ula A village council, personal communication, June 12, 2014).

As stated previously, farmers today are able to harvest 8 bags (at 100 kg each) of local long grain rice and 12 bags of local short grain rice per acre. Long grain rice is planted in November/December and harvested in May/June while the short grain variety is planted in November and harvested in April (see Table 4, Appendix A). Local strains of rice sold at a price of 75,000 Tsh (price in June 2014) yield profits of US$327 to US$491 per acre in the long and short strains, respectively (see Table 2, Appendix A).

Given sufficient capital, farmers are also now able to purchase seed for and plant a hybrid variety, planted in November/December and harvested in May/June, which yields over 100% more bags of rice per acre. The agricultural extension agent for the area recommended this hybrid strain above all others, but failed to describe: 1) necessary and expensive fertilizer use; 2) susceptibility to pests and disease; 3) lack of taste; and 4) seasonal seed purchases, which village councilmen deemed all as reasons not to use the hybrid strain (Extension Agent, personal communication, June 12-13, 2014). Current use of the hybrid variety is low due to high cost, necessary inputs and lack of desirability. The results of analysis for the hybrid variety appear in Tables 3 and 4, Appendix A.
Based on available literature, rice production is expected to decrease by about 13% by 2100 with a warming of 1.5-4.5 °C, or a doubling of carbon dioxide concentrations in the atmosphere (Mohandrass et al. 1995; Peng et al. 2004; Nelsen et al. 2009; Rowhani et al. 2011). This projection will decrease current yields to 7 and 10.4 bags per acre in the long and short grain varieties, respectively (see Table 4, Appendix A). Using current prices, as no projections are available, profits will also decrease by 13%, to US$285 to US$427 per acre in long and short grain varieties, respectively (see Table 4, Appendix A).

**Row Crop (Maize)**

Key informant interviews identified numerous plants used primarily (if not entirely) for subsistence use (Mang’ula A and B village council, Mohamed Kambi, personal communication, June 12-13, 2014). These include but are not limited to cow peas, tomatoes, spinach, cassava, banana, sweet potatoes, maize, yam, pigeon peas, Chinese (a type of green), pumpkins, okra, watermelon and papaya (see Figure 16) (*ibid.*). In this analysis, maize, a staple crop for which there is significantly more data
regarding the projected effects of climate change on yield changes, will serve as a representative crop for all of these aforementioned subsistence crops.

![Figure 16 Mixed agroforestry and subsistence row crops (featuring maize, cassava, banana, and coconut). Photo by: Chris Frey.](image)

Maize is an entirely subsistence crop planted in November and harvested in February/ March. The crop is eaten as is or used to make *ugali* (similar to polenta) or traditional beer. Currently farmers are able to harvest 8 to 10 bags per acre depending on rains and temperature (personal communication, June 11-12, 2014). According to the literature, maize yields are expected to decrease by about 23% by 2100 with a warming of 1-4°C or a doubling of carbon dioxide (Mwandosya et al. 1998; Jones and Thornton 2003; Rowhani et al. 2011; Thornton and Cramer 2012; Mbungu et al. 2014). This projection will decrease current yields to 6.2-7.7 bags/acre (see Table 8, Appendix B). If average fields stay the same size, farmers will be able to produce an average of 2.6 bags on 0.37 acres (see Table 1 for average field size).
Sugar Cane

Sugar cane is an important commercial crop under the Illovo out-grower scheme. Sugar cane is planted in December and harvested in August. Currently farmers yield 35 tons per acre at a unit price of 58,000 Tsh per ton, yielding profits of US$104 per person (see Table 9, Appendix C).

Results: Current Acreage (Spatial Analysis) & Availability

Table 1 Results of spatial analysis: agricultural area.

<table>
<thead>
<tr>
<th>Type</th>
<th>Acres</th>
<th>Number of Fields</th>
<th>Average Field Size (ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Cane</td>
<td>495.26</td>
<td>794</td>
<td>0.85</td>
</tr>
<tr>
<td>Row Crop</td>
<td>139.59</td>
<td>380</td>
<td>0.37</td>
</tr>
<tr>
<td>Rice Paddy</td>
<td>417.18</td>
<td>583</td>
<td>0.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Agricultural Area</th>
<th>Total Land Area</th>
<th>Agricultural Area Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1052.03</td>
<td>1510.14</td>
<td>69.66%</td>
</tr>
</tbody>
</table>

Figure 17 Graphical representation of spatial analysis results for agricultural land use.
Rice Paddy

According to the spatial analysis, where each agricultural field was digitized and its area calculated, 794 fields (417.2 acres) are currently dedicated to rice paddy production (see Table 1 and Figures 13 and 17). This production is focused in the lowland areas, typically near waterways. Based on available data, white short grain rice provides an average of 3,580 kcal/kg while white long grain rice provides 3,650 kcal/kg (see Table 2, Appendix A). Currently, 2,920,216 and 4,296,000 kcal are available per acre from long and short grain local varieties (see Table 3, Appendix A). Based on the population known in 2002 census, 3,992 individuals lived in Mang’ula B (Harrison 2006). Based on The 2002 and 2012 census data for the Mang’ula ward, there was an average annual change of 2.31% over this 10-year period,

![Kcal available under current (left) and projected (right) productivity.](image)

For this population, under today’s production capacity, a total of 636 kcal (long grain) and 935 kcas (short grain) per day are available to all 5,251 individuals (see Table 3, Appendix A; Figure 18). Based on this same production capacity and a minimum daily energy requirement (MDER) of 1,730, identified for Tanzania by the Food and Agricultural Organization (2008), a total of 1,929 (long grain) and 2,838 (short grain) individuals can be supported under a strictly rice-based diet (see Figure 19).

Based on the 13% decrease projected due to climate change, a total of 553 kcas (long) and 814 kcas (short) per day will be available by 2100 (see Table 4, Appendix A; Figure 18). The number of
people future production will be able to support also decreases by 13% resulting in 2,469 individuals as the maximum supported under traditional agricultural practices (relying solely on rice, using short local grain varieties).

**Row Crop (Maize)**

According to the spatial analysis, 380 fields (139.6 acres) are currently dedicated to row crop production (see Table 1 and Figures 13 and 17). These fields are located near homes and are typically small in area. Based on available data, maize provides an average of 3,400 kcal/kg (see Table 6, Appendix B) (Morgan et al. 1975; Wiseman et al. 1982; Heartland Lysine 1996; NRC 1998). Currently 2,720,000 to 3,400,000 kcal are available per acre depending on low or high yielding seasons. For a population of 5,251 individuals a total of 198 to 248 kcal per day are available to residents of Mang’ula B (see Table 7, Appendix B; Figure 18). Based on this same production capacity and a MDER of 1,730, a total of 602 to 752 individuals can be supported on an entirely maize-based diet (see Figure 19).

Based on the 23% decrease projected due to climate change, a total of 153 to 191 kcal will be available per day by 2100 (see Table 8, Appendix B; Figure 18). The number of people future production will be able to support also decreases by 23% resulting in 464 to 581 individuals supported under traditional agricultural practices and land-use (Figure 19). Refer to Tables 7 and 8 in Appendix B for more detail.

![Figure 19 Population supported under current (left) and projected (right) productivity.](image)
Sugar Cane

According to the spatial analysis, 583 fields (417.2 acres) are currently dedicated to sugar cane production (see Table 1). These fields are located to the east part of the village and interspersed along the edges of the built-up community (see Figure 13). Sugar cane is currently sold at a price of 58,000 Tsh per ton, yielding profits of US$104 per person. This price fluctuates throughout the year depending on supply and demand and will invariably change in the coming years (personal communication, Mohamed Kambi, March 23, 2015) There is a lack of data for the impacts of climate change on sugar cane production in East Africa, thus, no projections were made as to its impacts on production or financial security/assets.
Chapter 6. Discussion, Conclusions & Recommendations

Discussion

Most residents of Mang’ula B currently find themselves in cycles of debt and food insecurity. The narrative generated from interviews with key informants tells a story not uncommon in the developing world, but a novel one regarding specific perceived implications of climate change in Mang’ula B. Village council members regard climate change and its ecological and biophysical consequences as key factors in decreased production and food security. The literature suggests that a changing and more variable climate poses unprecedented challenges to agriculturalists in this area, potentially substantially reducing food security and productive capacity. In the past decade alone, production has decreased by more than 25%, exacerbating stress and increasing seasonal vulnerability.

By 2100, under the lowest production scenario, just over 2,100 individuals could be supported by rice and maize under a MDER of 1,730 kcal. This represents a population less than half of the current population of Mang’ula B—a population that is still increasing and putting increasing demands on the agricultural landscape and natural environment. By 2100, under the highest production scenario (hybrid rice with irrigation), just over 7,200 individuals could be supported by rice and maize under a MDER of 1,730 kcal. This represents a population over one and a half times the current population of Mang’ula B.

The highest production scenario is unlikely to ever be implemented, but must, nonetheless, be considered until other, more sustainable and sovereign, options are uncovered. Even under this scenario, increasing numbers of Mang’ula B residents will likely outstrip its ability to support the village. If growth continues as it did (at 2.31%) from 2002 to 2012, the highest production scenario will no longer be able to feed Mang’ula B by the year 2028.
These figures represent a world where agriculturalists sell none of their rice for cash to buy products they cannot grow and where irrigation and fertilizer are used (in the case of the highest production scenario)—it represents an idealized version of Mang’ula B’s agricultural landscape and agri-management system. In reality, most agriculturalists rely on selling surplus rice, not utilizing their entire harvest for consumption. For farmers with larger fields, typically about half of their rice crop each season is stored and saved to sell when the demand is highest (during the dry season following the short rains). Currently, surpluses are small and for some agriculturalists simply do not exist, pointing to the necessity of developing new cash-income schemes and new agricultural schemes.

The above findings have many implications. For example, residents of Mang’ula B might realize their subsistence strategy is failing and migrate away from the Kilombero Valley that supported them and their ancestors, in some cases, for hundreds of years. This response option seems fairly unlikely, given the comparatively high crop production potential in the valley. A more likely response is that residents see that enough rice and row crops are produced to support every individual but at a highly reduced level. This option would suggest that residents need to seek to supplement their diets with natural, edible capital and/or cash to purchase a greater percentage of foodstuffs. Considering the geography of the landscape and its history, turning to UMNP seems the most likely resource repository for Mang’ula B residents to fall back on.

We can all understand or at least try to understand the embodiment of hunger—physical, mental and emotional consequences from not being able to support your family, or feed your children and other dependents. It is possible to imagine that if productivity falls and harvests do not yield enough rice or maize or cassava or mango or banana to feed their families, villagers will not consider the moral complexities of illegally gathering or hunting in a neighboring national park. We too can see the fundamental importance of conserving our world’s increasingly threatened pockets of biodiversity and endemism. If we see both sides, and can actively understand both the perspectives of conservationists and subsistence agriculturalists and the rural and urban poor, then we might see the solution as compromise.
Compromise might require the active participation of governments and other funding agencies that concurrently have the needs of people and the natural world in which they have lived and work, and will continue to live and work and change, in mind. If organizations guiding conservation and development do not have this dual, multifaceted framework in mind, maintaining the integrity of local people or UMNP will fail.

**Limitations**

This study was limited by a number of factors: 1) time in the field with interpreters; 2) tree cover in the GeoEye-1 imagery, making it impossible to identify land use, including crop type, in some fields; 3) little literature regarding productivity change with climate change; 4) lack of reliable/existing data regarding physical attributes of the landscape; and 5) limited access to socio-economic baseline information (i.e., what are individuals consuming on a daily basis, what are monthly expenditures, etc.). Spending more time in the field would invariably have revealed more information regarding perceptions of climate change impacts on agriculture and have provided a better sense of the socioeconomic baseline that this study clearly misses. Limited time in the field meant my spatial analysis relied heavily on spatial signatures of fields I could see—those covered by tree cover are not a part of my analysis as their inclusion would have required more time for community mapping. This compromises the accuracy of estimates of row crop field area and, notably, maize currently in production. Lack of literature pertaining to agricultural productivity changes due to climate change mark a gap in knowledge that must be filled if we are to understand how to make subsistence agriculturalists more resilient in a changing agricultural landscape. I was limited in my ability to study the physical attributes of the landscape, some of which may promote production in some areas that could offset some losses due to climate change (e.g., new areas with optimal elevation for necessary inundation for rice cultivation under expected climate change conditions). Finally, with more time, I would have analyzed a set of diaries Professor Gorenflo and Brian
Orland have collected from agriculturalists regarding daily activities and household economic patterns—possibly providing insights on daily hardships and livelihood burdens.

Despite the above limitations, this study provides results that are consistent with other studies of food security impacts under a changing climate. This study also supports the assertion by modern geographers and conservationists that climate change impacts on people have the potential to change nature-society interaction and dependence.

Conclusions & Recommendations

To date there have been no agricultural schemes in Mang’ula B that focus on the promotion of substance agricultural livelihoods under climate change. It is vital to recognize the potential agriculturalists have to reduce their vulnerability via adaptive management practices. These practices—maintenance of seed diversity, empowerment over decision-making, market accessibility, promotion of indigenous crop production, inclusions of agroforestry—have the potential to change the agricultural mosaic to one where the threat of climate change to food security is at least reduced to more manageable levels.

These adaptive measures also have the potential to decrease the threat that people pose to UMNP. For millennia, residents of this area have managed to obtain all of their unmet needs from nature—human systems essentially relying on natural systems. If rural populations are to pose no threat to protected areas, they must have food production and other development schemes available to increase their resilience. Higher productivity and resilience to climate change may result if social and ecological diversity are harnessed at the community scale. Before the threat to UMNP is eradicated, subsistence agriculturalists must be able to realize their right to food and their right to choose the means of production, with the ultimate aim being to meet subsistence requirements using resources outside of the park. Without meeting
these requirements, residents of Mang’ula B as well as conservationists committed to the integrity of UMNP face a challenging future.
## Appendix A Rice

### Table 2 Rice Calorie Counts (Calorie Lab)

<table>
<thead>
<tr>
<th>FOOD</th>
<th>Measure (g)</th>
<th>Kcal</th>
<th>Kcal/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice, white, short-grain, raw, enriched</td>
<td>cup (200.0 g)</td>
<td>716</td>
<td></td>
</tr>
<tr>
<td>Rice, white, short-grain, raw, unenriched</td>
<td>cup (200.0 g)</td>
<td>716</td>
<td></td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td></td>
<td>200</td>
<td>716</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>FOOD</th>
<th>Measure (g)</th>
<th>Kcal</th>
<th>Kcal/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice, white, long-grain, regular, raw, enriched</td>
<td>cup (185.0 g)</td>
<td>675.3</td>
<td></td>
</tr>
<tr>
<td>Rice, white, long-grain, regular, raw, unenriched</td>
<td>cup (185.0 g)</td>
<td>675.3</td>
<td></td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td></td>
<td>185</td>
<td>675.3</td>
</tr>
</tbody>
</table>

**TOTAL AVERAGE** | 192.5 | 695.65 | 3615 |

### Table 3 Rice Baseline Production Potential

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop Type</th>
<th>Planting Time</th>
<th>Harvesting Time</th>
<th>Baseline Production (1997)</th>
<th>Baseline Change from Baseline to 2014</th>
<th>Baseline Production (kcal/acre)</th>
<th>Baseline Price per Bag (Tsh)</th>
<th>Baseline Possible Income, All Rice Sold (Tsh/acre)</th>
<th>Baseline Possible Income, All Rice Sold (SUS/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Long Grain Rice Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>12 bags/acre (30 bags/ha); 1,200 kg/ha (3,000 kg/ha)</td>
<td>-33%</td>
<td>4,051,800</td>
<td>8,000-9,000</td>
<td>96,000-108,000</td>
<td>$52.33-$58.87</td>
<td></td>
</tr>
<tr>
<td>Local Short Grain Rice Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>16 bags/acre (40 bags/ha); 1,600 kg/ha (4,000 kg/ha)</td>
<td>-25%</td>
<td>5,728,000</td>
<td>8,000-9,000</td>
<td>128,000-144,000</td>
<td>$69.77-$78.50</td>
<td></td>
</tr>
<tr>
<td>Hybrid Rice Grain Hybrid</td>
<td>November-December</td>
<td>May-June</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Hybrid Rice Grain (with Irrigation)</td>
<td>November-December</td>
<td>May-June</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>
Table 4 Current Rice Production Potential of Mang’ula B, TZ

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Long Grain Rice</td>
<td>Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>8 bags/acre; 800 kg/acre</td>
<td>2,020,216; 3,337 bags; 334,000 kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,218,255; 801</td>
</tr>
<tr>
<td>Local Short Grain Rice</td>
<td>Food/Cash</td>
<td>November</td>
<td>April</td>
<td>12 bags/acre; 1,200 kg/acre</td>
<td>4,296,000; 5,006 bags; 501,000 kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,792,205; 501</td>
</tr>
<tr>
<td>Hybrid Rice Grain</td>
<td>Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>25 bags/acre; 2,500 kg/acre</td>
<td>9,062,500; 10,400 bags; 1,040,000 kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3,780,693; 719</td>
</tr>
<tr>
<td>Hybrid Rice Grain (with Irrigation)</td>
<td>Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>32-36 bags/acre; 3,200-3,600 kg/acre</td>
<td>11,600,000; 13,350-15,000 bags; 1,335,000-1,500,000 kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4,839,288; 921</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Available Food per Person (kcal/day)</th>
<th>Total Number of People Possible to Support Under Current Production</th>
<th>Current Price per Bag (Tsh)</th>
<th>Current Possible Income, All Rice Sold (Tsh/ha)</th>
<th>Current Possible Income, All Rice Sold (SUS/ac)</th>
<th>Current Possible Income Per Person, All Rice Sold (Tsh)</th>
<th>Current Possible Income, All Rice Sold (SUS/ac)</th>
</tr>
</thead>
<tbody>
<tr>
<td>636</td>
<td>1,029</td>
<td>75,000</td>
<td>600,000</td>
<td>$327.06</td>
<td>47.668</td>
<td>$25.98</td>
</tr>
<tr>
<td></td>
<td>925</td>
<td>2,838</td>
<td>75,000</td>
<td>$490.60</td>
<td>71.502</td>
<td>$38.98</td>
</tr>
<tr>
<td></td>
<td>1,973</td>
<td>5,987</td>
<td>40,000</td>
<td>$545.11</td>
<td>79.477</td>
<td>$43.31</td>
</tr>
<tr>
<td></td>
<td>2,525</td>
<td>7,664</td>
<td>40,000</td>
<td>$697.74-$784.96</td>
<td>101,700-114,400</td>
<td>$55.43-$62.36</td>
</tr>
</tbody>
</table>
Table 5 Projected Rice Production Potential of Mang’ula B, TZ

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop Type</th>
<th>Planting Time</th>
<th>Harvesting Time</th>
<th>Production with Change from Current</th>
<th>Projected Production Potential of Mang’ula B (total kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Long Grain Rice</td>
<td>Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>7 bags/acre; 700 kg/acre</td>
<td>2,540,588; 2,920 bags; 292,000 kg</td>
</tr>
<tr>
<td>Local Short Grain Rice</td>
<td>Food/Cash</td>
<td>November</td>
<td>April</td>
<td>10.4 bags/acre; 1,040 kg/acre</td>
<td>3,737,520; 4,340 bags; 434,000 kg</td>
</tr>
<tr>
<td>Hybrid Rice Grain</td>
<td>Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>21.8 bags/acre; 2,180 kg/acre</td>
<td>7,884,375; 9,100 bags; 910,000 kg</td>
</tr>
<tr>
<td>Hybrid Rice Grain (with Irrigation)</td>
<td>Food/Cash</td>
<td>November-December</td>
<td>May-June</td>
<td>27.8-31.3 bags/acre; 2,780-3,130 kg/acre</td>
<td>10,092,000; 11,600-13,060 bags; 1,150,000-1,306,000 kg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Projected Total Available Food per Person (kcal/day)</th>
<th>Total Number of People Possible to Support Under Projected Production</th>
<th>Current Price per Bag (No Projected Data Available) (Tsh)</th>
<th>Income Possible with Change from Current Possible, All Rice Sold (Tsh/acre)</th>
<th>Income Possible with Change from Current Possible, All Rice Sold ($US/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>553</td>
<td>1,678</td>
<td>75,000</td>
<td>522,000</td>
<td>$284.55</td>
</tr>
<tr>
<td>814</td>
<td>2,469</td>
<td>75,000</td>
<td>783,000</td>
<td>$426.82</td>
</tr>
<tr>
<td>1,716</td>
<td>5,209</td>
<td>40,000</td>
<td>870,000</td>
<td>$474.24</td>
</tr>
<tr>
<td>2,197</td>
<td>6,669</td>
<td>40,000</td>
<td>1,110,000-1,250,000</td>
<td>$605.07-$682.91</td>
</tr>
</tbody>
</table>
Appendix B Maize

Table 6 Maize Calorie Counts

<table>
<thead>
<tr>
<th>FOOD</th>
<th>Kcal/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn (Wiseman et al. 1982)</td>
<td>3262</td>
</tr>
<tr>
<td>Corn (Morgan et al. 1975)</td>
<td>3522</td>
</tr>
<tr>
<td>Corn (NRC 1998)</td>
<td>3420</td>
</tr>
<tr>
<td>Corn (Heartland Lysine 1996)</td>
<td>3397</td>
</tr>
<tr>
<td><strong>AVERAGE</strong></td>
<td><strong>3400.25</strong></td>
</tr>
</tbody>
</table>

Table 7 Current Maize Production Potential of Mang’ula B, TZ

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop Type</th>
<th>Planting Time</th>
<th>Harvesting Time</th>
<th>Agricultural Area (square ac)</th>
<th>Current Production (2014)</th>
<th>Current Production Potential of Mang’ula B (total kcal)</th>
<th>Total Available Food per Person (kcal/yr)</th>
<th>Total Available Food per Person (kcal/day)</th>
<th>Total Number of People Possible to Support Under Current Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Food (Subsistence)</td>
<td>November</td>
<td>February/March</td>
<td>139.594969</td>
<td>8-10 bags/ac (800-1,000 kg/ac)</td>
<td>2,720,000-3,400,000</td>
<td>380,000-475,000</td>
<td>72,400-90,500</td>
<td>198-248</td>
</tr>
</tbody>
</table>

Table 8 Projected Maize Production Potential of Mang’ula B, TZ

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop Type</th>
<th>Planting Time</th>
<th>Harvesting Time</th>
<th>Agricultural Area (square ac)</th>
<th>Production with Change from Current</th>
<th>Projected Production Potential of Mang’ula B (total kcal)</th>
<th>Projected Total Available Food per Person (kcal/yr)</th>
<th>Projected Total Available Food per Person (kcal/day)</th>
<th>Total Number of People Possible to Support Under Projected Production</th>
<th>Percent Decrease in Food Available from Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>Food (Subsistence)</td>
<td>November</td>
<td>February/March</td>
<td>139.594969</td>
<td>6.2-7.7 bags/ac (620-770 kg/ac)</td>
<td>2,090,000-2,620,000</td>
<td>293,000,000-367,000</td>
<td>55,800-65,900</td>
<td>153-191</td>
<td>464-581</td>
</tr>
</tbody>
</table>
**Appendix C Sugar Cane**

**Table 9 Current Sugar Cane Production Potential**

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar Cane</td>
<td>Cash (Commercial, outgrower scheme)</td>
<td>December</td>
<td>August</td>
<td>35 Tons/ac (86 Tons/ha)</td>
<td>17,334</td>
<td>58,000</td>
<td>1,005,386,214.35</td>
<td>191,466</td>
<td>$104.37</td>
</tr>
</tbody>
</table>
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ACADEMIC VITA

Britta Schumacher
31 Sweet Corn Drive • Kutztown, PA 19530 • E-mail: bls5435@psu.edu

EDUCATION
The Pennsylvania State University & Schreyer Honors College University Park, PA
B.S. in Geography, Physical and Environmental Concentration Graduation: May 2015
Minors in Climatology, and Science, Society & the Environment in Africa
Honors in Geography

TRAVEL EXPERIENCE
Parks and People: Tanzania Udzungwa Ecological Monitoring Center, TZ
Field Intern & Independent Researcher Summer 2014
• Initiated funded research assessing the impacts of climate change on food security and livelihood sustainability in Mang’ula B, Tanzania and the consequences of decreased production on the Udzungwa Mountains National Park.
• Developed creative, agricultural, design-based solutions to intensify production while maintaining agro-biodiversity and cultural cropping techniques.

Parks and People: South Africa Eastern Transkei, SA
Field Intern & Student Spring 2013
• Demonstrated effective understanding of the challenges associated with conservation in the Eastern Transkei by collaboratively writing and presenting an extensive report to stakeholders and the South African Parks Board, recommending the creation of a new conservation area.
• Assessed the ecological integrity of the Manubi Forest; discovered and recorded the southern-most extent of the endangered Kloof frog (Natalobatrachus bonebergi).

WORK & RESEARCH EXPERIENCE
Riparia at the Pennsylvania State University University Park, PA
GIS Intern July 2014-Present
• Responsible for creating and managing geospatial data related to watershed and wetland assessments for Riparia clients.
• Established protocols and models for efficiency in the ArcGIS interface.

Vegetation Dynamics Lab at the Pennsylvania State University University Park, PA
Undergraduate Research Assistant May 2014-Present
• Responsible for completing the processing and organization for isotope analysis of five different forest sites from fieldwork in Algeria; created and maintained data structure and analysis protocol.
• Prepared and cross-dated tree cores from a Ponderosa Pine-Douglas Fir stand in Idaho; mapped stand-age structure and fire history and created a local climatology chronology to inform forest managers about post-fire disturbance patterns.

Fire Works Lab at the Pennsylvania State University University Park, PA
Undergraduate Research Assistant January 2014-July 2014
• Researched and prepared a comprehensive synthesis of tropical forest degradation scenarios and carbon emissions trajectories for Amazonia.
• Assessed the socio-economic and social-political readiness of individual countries to adapt the UN-REDD and REDD+ programs; assessment used in policy recommendations made by advising professor, Dr. Jennifer Balch.
HONORS, AWARDS & SCHOLARSHIPS

Association of American Geographers Conference Presenter, 2015
Undergraduate Discovery Grant Recipient, The Pennsylvania State University, 2014
Pine Creek Watershed Association Scholarship Recipient, The Berks County Conservation District, 2014
Africana Research Center Undergraduate Research Exhibitionist, The Pennsylvania State University, 2013
Recipient of Four Geography Academic Merit Scholarships, The Pennsylvania State University, 2013
Recipient of Two Schreyer Honors College Travel Grants, The Pennsylvania State University, 2013-2014

INVolVEMENT, LEADERSHIP & VOLUNTEER EXPERIENCE

State of State, Content Committee Member
Gamma Theta Upsilon Honors Society, Treasurer
THON, Dancer Relations and Special Events Committee Member and Volunteer
South Halls Residence Association, Vice President
Residence Life, Resident Assistant
Schreyer Honors College, Orientation Mentor
Volunteers in Public Schools, Tutor