HUMAN-ENVIRONMENT INTERACTIONS ON A COASTAL FOREST-SAVANNA MOSAIC IN SOUTHERN MOZAMBIQUE

by

LAURA JEAN SHAFFER

(Under the Direction of Theodore L. Gragson)

ABSTRACT

This research investigates how indigenous Ronga residents of two rural communities (1) use the spatial and temporal heterogeneity of the landscape for livelihood activities and to manage environmental risk; (2) perceive and respond to social and ecological factors that influence their decisions about resource use; and (3) contribute to landscape processes that shape vegetation patterns. Ethnographic and ecological data collection, as well as archival research in Lisbon, Portugal and Maputo, Mozambique concerning the region's historic occupation and use, support my interdisciplinary analysis of human-environment interaction in Matutúine District, Mozambique. Results show that adaptive strategies used by Ronga swidden farmer-foragers access and create the spatial and temporal heterogeneity of the landscape in response climate variability, poverty, and food insecurity issues. Changes to resource access policy limit adaptive capacity, increase local vulnerability to predicted future climate change, and could change Matutúine District's landscape. Interviews concerning local climate change generated two models that highlight local ecological patterns and processes, as well as social changes, and reveal connections between parameters of change that are not obvious in regional models. Residents made observations in the context of livelihood activities where knowledge of expected climate and environmental patterns is used to make decisions about household production. Model differences between communities may be a consequence of predominant habitat within communities. Research with Ronga fire managers demonstrates that residents carefully manipulate the landscape with fire for immediate food production and to ensure a sustainable resource base for future harvest. Environmental knowledge and beliefs about climate, vegetation, and fire behavior assists decision-making about where, when, and how to build controlled fires for locally important livelihood activities. Local residents use and maintain Ronga traditional ecological knowledge to sustain their livelihood activities and respond to environmental change, yet this same knowledge is valuable to scientists and managers interested in conserving the biodiversity of Matutúine District. This study underscores the value of conducting research on human-environment interactions that contribute to savanna landscape generation, as results can be applied to the development and maintenance of sustainable practices that support both human livelihoods and conservation.

INDEX WORDS: adaptation, Africa, anthropogenic fire, climate change, climate modeling, ecological anthropology, food security, interdisciplinary, landscape, livelihoods, savannas, traditional ecological knowledge, vulnerability

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CHAPTER 1

INTRODUCTION

> Until the lions have their historians, tales of hunting will always glorify the hunter.
> -- African Proverb

Research Problem Description And Justification

This research explores human-environment interactions on a coastal forest-savanna mosaic in Southern Mozambique. I focus on the interaction between social institutions and ecological processes that shapes the landscape of this region through a livelihood lens. In particular, I investigate how residents (1) use the spatial and temporal heterogeneity of this landscape for livelihood activities and to manage environmental risk; (2) perceive and respond to social and ecological factors that influence their decisions about resource use; and (3) contribute to landscape processes that shape vegetation patterns. My interdisciplinary analysis of human-environment interaction is supported by ethnographic and ecological data collection in two Ronga communities in Matutúine District, Mozambique, as well as archival research in Lisbon, Portugal and Maputo, Mozambique concerning the region's historic occupation and use. Given the political, economic, and environmental risks that rural Africans currently face, research exploring human-environment interactions that contribute to savanna landscape evolution can be used in the development and maintenance of sustainable practices that support both human livelihoods and conservation.

A high diversity of flora and fauna thrives on the complex mosaic of savanna, forest, and wetland comprising the coastal landscape of Southern Mozambique (Conservation International 2006). Ronga residents, indigenous to this region, exploit the spatially and temporally variable habitats and resources available to them via livelihood activities like swidden agriculture, wild plant foraging, herding, fishing, hunting, small-scale mat, honey and charcoal production, and ecotourism. Furthermore, archived documents and oral histories record the continuous occupation of Ronga people on this landscape in excess of 500 years (Felgate 1982, Junod 1927). The long-term use of this highly diverse forest-savanna mosaic suggests that Ronga livelihood activities helped shape the landscape and may contribute to its maintenance.

Dissertation research activities centered on two rural Rongan communities in Matutúine District, Mozambique: Madjadjane and Gala. Three additional factors make this location a viable research site in addition to the long history of Ronga occupation and use, and the region's high biodiversity.

(1) A combination of swidden agriculture and foraging form the basis of the local economy (Felgate 1982). While residents practice swidden agriculture, they also depend heavily on wild plant resources to meet their needs for food, medicinal, shelter, and warmth (DeBoer and Baquete 1998, Ribeiro 2004, Shaffer 2005, Soto et al. 2001).

(2) The communities encompass a range of habitats available to district residents for resource exploitation. Riverine woodlands, open woodland, and sand thicket and forest give Madjadjane, stretched along the Futí River, a predominantly forested landscape. The predominantly savanna landscape of Gala incorporates open and

wooded savanna, hygrophilous grassland, sand forest-woodland mosaic, patches of swamp forest, and the shores of Lakes Pití and Ntiti (DEIBI 2000).

(3) The communities are located within the boundaries of a proposed transfrontier conservation area (TFCA). Recent codification of traditional access rights to plant resources for personal consumption into Mozambican national law means that successful conservation plans will need to account for spatial and temporal landscape use differences in the proposed TFCA (Smith et al. 2008, Soto et al. 2001). To create conservation plans sensitive to coastal forest-savanna mosaic complexity and Ronga traditions, needs and rights, it will be necessary to understand the underlying social and ecological factors directing Ronga landscape use and management.

Chapter Objectives

In Chapter 2, I review the literature concerning human-environment interactions in Southern African savannas from an ecological anthropology perspective. Many socially and ecologically oriented researchers have analyzed human use of savannas, and the ecological and biophysical effects of this use, along disciplinary lines. However, I focus my literature review on interdisciplinary studies that explore the interactive nexus between social institutions and ecological processes that shapes savanna landscape. I define human-environment interaction in the context of ecological anthropology and demonstrate the utility of this perspective as a framework for investigating of human-environment interactions. I then review the landscape concept and show how it contributes to this research framework. Finally, I highlight key studies assessing human-environment interactions in Southern African savannas and discuss ideas for future work. This literature review provides context for my dissertation research results.

Chapter 3 examines adaptive strategies practiced by two Ronga communities in Southern Mozambique in response to vulnerabilities stemming from a combination of stressful environmental and social factors including climate instability, poverty, and food insecurity. In this chapter, I argue that access to spatially and temporally variable resources across the landscape is central to the reduction of vulnerability to current climate instability and adaptation to future climate change by indigenous and other traditional rural subsistence communities through a case study of my field site. I explore contemporary and historic adaptive strategies to manage climate events and political and economic instability. I also investigate locally important sources of vulnerability and highlight how communities are strengthening their adaptive capacity through new uses of the landscape.

The research described in Chapter 4 follows up on the previous chapter, and explores perceptions and experiences of change to local climate patterns and climate-associated environmental changes by residents at my field site over the past 45 years (1963-2008). Climate, particularly rainfall, plays a key role in regulating vegetation production and distribution in Southern Mozambique (Rutherford and Westfall 2003). Dependency on domestic and wild vegetation suggests that residents of Matutúine District are highly aware of any climate and climate-associated environmental changes that affect their survival, and that their perceptions and experiences of climate change and risk directly impact decision-making about how they use the landscape. Interview analysis produced two local climate change models. Comparisons between models, and between the models and measured climate data for the last 45 years from the nearest weather station, were used to provide insight into local landscape patterns and processes.

The research presented in Chapter 5 investigates how, when, and why local people use fire in their daily livelihood activities and how these activities contribute to the fire disturbance processes on the coastal savanna of southern Mozambique. Prescribed burn regimes for protected areas in Southern Africa are often based solely on modeling of historic data and onsite experimentation. Most rural communities in this region continue to rely on fire to manage natural resources for subsistence needs, yet relatively few detailed studies of local fire knowledge and practices exist. The long history of anthropogenic fire disturbance in Southern Africa suggests that traditional ecological knowledge of fire could provide further insight into location-specific anthropogenic contributions to savanna fire regimes. In this chapter, I address three issues particular to the development of appropriate fire regimes and management policies for the coastal savanna of Southern Mozambique and Northern KwaZulu-Natal, South Africa: anthropogenic fire intentionality, community fire knowledge-practice, and fire regulation at local and national levels.

Chapter 6 summarizes the main findings from each chapter and their broader significance. I also address some of the potential problems of my research and discuss future research.

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CHAPTER 2

HUMAN-ENVIRONMENT INTERACTIONS ON SOUTHERN AFRICAN SAVANNAS: A LITERATURE REVEIW

Introduction

Southern African savannas and the contemporary African communities that consider these landscapes their home are the outcome of long-term, human-environment interaction. Environmental characteristics, like soil fertility, water supply, and biodiversity, constrain the activities and decisions humans undertake for survival. Human responses to these characteristics alter ecological structure and functioning and shape savanna species' diversity, abundance, and distribution. Therefore, this ongoing interaction between social systems and ecological systems shapes both savanna culture and landscape (Crumley 1994). In this paper, I review the literature concerning human-environment interactions in Southern African savannas from an ecological anthropology perspective. I begin by defining human-environment interaction in the context of ecological anthropology, showing why this perspective provides an excellent framework for investigation, demonstrating the importance of landscape to this framework, and highlighting key components of Southern African savannas. This setup allows me to then review several examples of human-environment interaction research projects conducted on Southern African savannas and make suggestions for future research.

For many years, scientists working in savanna landscapes throughout Southern Africa have pursued separate research agendas, often along disciplinary lines, in livelihood related studies and wildlife conservation. This divide can result in conflict that negatively impacts savanna biodiversity, including human communities. Disciplinary-focused research will always remain important; however, interdisciplinary study of human-environment interactions is also necessary. Livelihood activities and cultural institutions throughout Africa are intricately linked to the African ecological systems where they are practiced – distinctions between human and natural create a false dichotomy. Current problems in Southern Africa associated with food security, poverty, disease, human health, and climate risk, as well as land management, biodiversity conservation, and livelihood change will require reassessment of human-environment interactions in savanna landscape (Boko et al. 2007,Vitousek et al. 1997, Western 2001). Interdisciplinary study provides insight into human-environment interactions, as well as highlights intervention points to promote mutually-beneficial, sustainable connections between human populations and the Southern African savannas on which they live.

Defining Human-Environment Interactions from an Ecological Anthropology Perspective

"Many ecosystems are dominated directly by humanity, and no ecosystem on Earth's surface is free of pervasive human influence" (Vitousek et al. 1997: 494). Ecosystems are thus better described as socio-ecological systems, although other terms such as coupled human-natural systems and human-environment systems have been used. The inherent complexity of these systems requires an interdisciplinary approach to better reveal how various social, ecological, and physical variables interact and influence one another (Liu et al. 2007, Newell et al. 2005). Ecological anthropologists draw on theory and methods from both ecology and anthropology. Practitioners analyze and articulate the ties between social and ecological patterns and processes, and contribute a unique perspective to the interdisciplinary milieu.

Defining and understanding human-environment interactions is the heart of ecological anthropology research. Ecological anthropology bridges disciplinary boundaries and seeks to assess human culture and behavior in the context of the surrounding environment. It looks at the interactions between humans and their surrounding environment and asks how culturally-influenced, resource-use choices and activities affect environmental patterns and processes, and how environment influences human behavior and culture (Gragson 1998). Critical dimensions for analysis include decision-making at the group and individual levels, cultural knowledge and social institutions affecting resource use and management, environmental and historical constraints on human activity, and political influences on resource allocation and management. These analyses fall under the purview of human behavioral ecology/social learning, ethnobiology, historical ecology, and political ecology subfields. Each of these subfields contributes to our overall understanding of human-environment interactions.

Human behavioral ecology (HBE) and social learning provide complementary approaches for understanding why individuals make particular decisions about the resources that they use and the livelihood activities they pursue (Henrich 2002, Winterhalder and Smith 2000). The human brain evolved as a general problem solver, and HBE focuses on how humans use this adaptation to make consistent, rational choices to improve personal fitness. Borrowing from optimal foraging models developed by ecologists to study diet breadth, patch choice, and time allocation to patch use, HBE researchers seek to elucidate the simple rules individuals follow when faced with a choice constrained solely by ecological and biological factors (Winterhalder and Smith 2000). However, critics point out that individual learning and behavior, and thus decisions, can be biased by framing, errors in perception and judgement, and culture (Henrich 2002). Social learning approaches, including gene-culture coevolution and dual inheritance theory, address the cultural component that many feel is missing from HBE and look at how individuals acquire knowledge of ideas, beliefs, behaviors, and values from others (Flinn 1997, Guglielmino et al. 1995, Henrich 2002). Social learning theorists recognize that both the capacity to learn and cultural information evolve in response to environmental and evolutionary constraints. Cultural knowledge and mimicking provide information for decision-making in situations where there is not enough time or capacity to do cost-benefit analyses or when environmental conditions are novel or uncertain.

Ethnobiological research focuses on how people think about the environment where they live, and the ways that this knowledge is both shaped by the environment and shapes it in turn (Nazarea 1999). Subjects of interest include folk taxonomies, specific knowledge of species, abiotic factors, and ecological processes, resource management practices and institutions, and worldviews. The study of traditional ecological knowledge (TEK), a type of cultural knowledge, provides an emic perspective of human-environment interactions. TEK is defined as

> "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (Berkes 1999: 8).

Long-term interactions allow social institutions to co-evolve with changing environmental conditions. Feedback from socio-ecological linkages helps groups develop adaptive and sustainable management practices that may promote species and habitat diversity directly or indirectly (Berkes et al. 2000, Folke 2003). While some TEK is accessible and readily understood by western trained scientists, other knowledge and practices are encoded into religious symbols and beliefs, kinship/social status hierarchies, music, art, story, and worldviews (Berkes 1999, Shipton 1994). As a result, TEK research strives to understand how humans perceive and interact with their environment, as well as translate local knowledge into more accessible forms.

Historical ecologists strive to resolve the human/nature divide by exploring the two-way interaction between humans and their surroundings as an ongoing dialogue beginning with our origins as a species and continuing through to the present day (Baleé and Erickson 2006, Crumley 1994). Lacking a central theory, this branch of ecological anthropology is seen as a set of methodologies and a framework designed to synthesize a holistic view of a region through the analysis of data from the social, biological, and physical sciences. Issues of time and space are emphasized in the effort to study "past ecosystems by charting the change in landscapes over time" (Crumley 1994: 6). Landscape, which I address in the next section, is the unit of analysis and, like culture, emerges from the interactions between human and their surroundings. A focus on landscape means that researchers must also concern themselves with scale and hierarchy. Small changes to human practices and institutions or local ecologies at one scale may create emergent properties at a larger scale (Baleé 1998, Crumley 1994, Young 1994). Furthermore, problems with hierarchical organization of information require researchers to shift their scalar focus in and out to gain a better perspective on the dynamic nature of human-environment interactions within a landscape.

Political ecologists evaluate the structure of social institutions and the power they wield over resource control and allocation. Research focuses on discursive analysis of different actors in the attempt to link small-scale environmental change to broader political and ideological change both directly and indirectly (Scoones 1999). Critics of political ecology cite a lack of concern over biophysical ecology and vague definitions of environment or ecology within this field due to an overemphasis on analyzing the social/political interface of degradation and marginalization, environmental conflict, conservation and control, and environmental identities and social movements (Robbins 2004, Walker 2005). Overcoming this critique remains vital for the study of human-environment interactions. Individuals and community struggles with governments, corporations, and international institutions for access to various resources can affect the environment directly and indirectly. In developing countries, resource conflict is often attributed to economic and political changes originating under colonial rule, and this conflict results in increased vulnerability for marginal groups living in those countries (Bryant 1998). Alliances between various local and national or international groups can determine the value of indigenous scientific knowledge to conservation practice and management, and thus affect landscape pattern and process (Bryant 1998, Robbins 2004).

Why Include Landscape in the Study of Human-Environment Interactions?

In ethnographic research, landscape has traditionally served as the background conditions shaping local culture or referred to emic meanings given to physical and cultural conditions by a local community (Hirsch 1995). The idea of landscape analysis as part of ecological anthropology studies is rooted in research by ecologically-oriented geographers and anthropologists like Carl Sauer and Julian Steward who attempted to move beyond debates surrounding environmental determinism and possibilism. In his 1925 essay, *The Morphology of Landscape*, Sauer articulated the importance of culture and human history in shaping the environment (Sauer 1925). Steward's ideas of culture change formed the basis for early anthropological approaches concerned with linking social and ecological systems (1979). Dissatisfaction with some of the questions Steward's cultural ecology theory raised concerning a materialist approach, a focus only on subsistence, and vague adaptive mechanisms, led to the incorporation of ideas like energy flows, feedback loops and analysis of cultural traits like religion and demographics to explain human-environment interactions (Lansing 1991, Rappaport 1968). However, these approaches relied on a static view of ecosystems. Ideological developments in ecology in the 1990s surrounding landscape, built on previous efforts by ecological anthropologists and bridged disciplinary boundaries between geography, ecology, and anthropology (Scoones 1999). Inclusion of landscape and "new ecology theory" in anthropological analysis afforded greater consideration of the role of dynamic reciprocal interactions between humans and their surroundings in shaping both landscape and culture.

Habitat patterns produced by natural and social processes driven and constrained by abiotic, biotic, and anthropogenic factors create landscapes. Ecological definitions of landscape focus on the "reciprocal effects of spatial pattern on ecological processes" and the resulting change at a geographic scale greater than ecosystem but smaller than region (Pickett and Cadenasso 1995: 331). Anthropologic views refine the ecological definition by acknowledging landscape as a human construct (Baleé and Erickson 2006, Crumley 1994). Ingold (2000) writes that landscape results from the tasks and activities people conduct over time. As such, landscape becomes a historical record of past lives and actions that can be read. Concepts like complexity, uncertainty, non-equilibrium dynamics, and spatial and temporal variation in ecosystems, ecological processes, and species interactions introduced by new ecology theories challenge previous views of static and balanced ecosystems, and better describe human-environment interactions (Scoones 1999). Scale issues become important to ecological anthropology research because decision motivations and outcomes, species patterns, and processes vary at different spatial and temporal scales. An ecosystem, including human and non-human components, may experience non-equilibrium dynamics at a fine scale but appear to be in balance when the scale increases.

All subfields of ecological anthropology study landscape, directly or indirectly. Landscape is the primary unit of analysis in historical ecology, and can be focus of ethnobiological and political ecological research assessing the outcomes of land management and control. Less directly, the patterns and processes contributing to a landscape may be studied with respect to how they affect decision-making about patch choice, resource use behaviors, and site specific TEK (Berkes 1999, Gragson 1998, Nazarea 1999).

Key Interacting Components of Southern African Savanna Landscapes

African savannas are a biologically-rich, disturbance-maintained ecosystem in which species and communities have evolved to persist under variable and unpredictable conditions. Following Shorrocks (2007), four general savanna landscape types exist in Southern Africa: grass and shrub, tree and shrub, woodland, and forest-savanna mosaic (See Figure 2.1). The combinations of limiting physical factors, species interactions, disturbance processes and histories that interact to create savanna landscapes vary regionally. As a result, the subsistence alternatives and decision choices available to societies also vary.

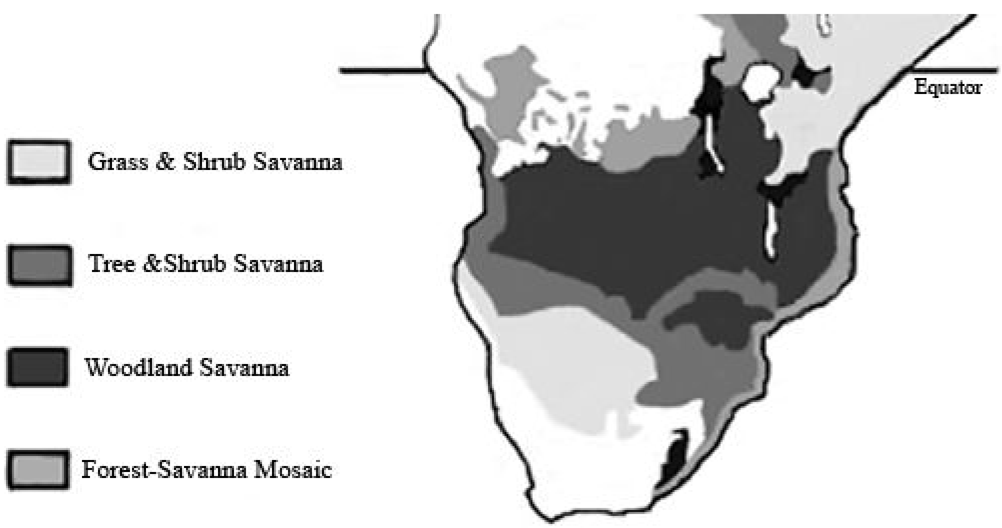

Figure 2.1 Savanna distribution in Southern Africa (adapted from Shorrocks 2007).

Long-term ecological studies of Southern African savannas, many conducted in conjunction with national parks and protected areas, have identified multiple physical and biological factors important for maintaining savanna landscapes (duToit et al. 2003, Scholes and Walker 1993, Shorrocks 2007). Climate, soils, and fire are limiting physical factors. The Intertropical Convergence Zone, a low atmospheric pressure belt that moves back and forth over the equator annually, creates Africa's wet/dry season cycles. Its interaction with sea surface temperatures influences intrannual rainfall variability. Other climate influences for this region, including the El Niño-Southern Oscillation and an 18-year oscillation, affect interannual rainfall variability and the production of drought and flood events (Coelho and Littlejohn 2000, Tyson et al. 2002). Rainfall levels affect both soil fertility and species distribution (Scholes 1990, Shorrocks 2007, Zeng and Neelin 2000). High precipitation rates generate high primary and secondary production, as well as leach nutrients out of soils. Therefore, dry savannas (<600 mm/yr) have higher quality forage and a greater diversity and density of grazing animals compared to moist savanna (>600 mm/yr) (Rutherford and Westfall 2003). Rainfall also determines the frequency and magnitude of fire. Fire, both anthropogenic and lightning produced, has always been an important disturbance mechanism for maintaining savanna. Climate and vegetation models, consistent with fire exclusion experiments in protected areas, suggest that fire facilitated the spread of C_4 grasses, and thus expansion of Southern African savannas, into areas that would otherwise be forested (Bond et al. 2005).

Vegetation diversity, abundance and distribution, constrained by rainfall, soils, and fire disturbance, determine the abundance and distribution of upper level trophic species. However, certain species facilitate savanna landscapes. Predators like lions, hyenas, and leopards indirectly affect savanna vegetation by changing ungulate prey behavior and population structure.

Evidence suggests predation is tied to rainfall cycles, habitat differences, and interspecific competition (Mills 2005). Frugivorous birds and primates disperse tree seeds across the landscape. Elephants also disperse tree seeds, but their greatest contribution is destruction of trees and shrubs during foraging. This keystone activity opens gaps for colonization by savanna grasses and facilitates fire (Cumming et al. 1997, Shorrocks 2007). And of course, humans play a keystone role in savanna creation and maintenance as they interact with other species and the physical aspects of their savanna surroundings.

Interdisciplinary Human-Environment Interaction Research

Numerous studies throughout Southern Africa focus on the knowledge, management, and use of savanna resources like vegetation, fauna, and soils for livelihood and cultural purposes (Botha et al. 2004, Mithöfer and Waibel 2003, Shackleton 2001, Shipton 1994, Krüger and Grotzke 2008). This research reflects concerns with wildlife conservation and conflict, land degradation, climate risks, and food security. Interdisciplinary research explicitly addressing the interactive nexus of social institutions and environmental processes that shapes savanna landscape is less common. The lacuna is due, in part, to the newness of this field. However, tensions between conservation ideals, indigenous claims to savanna resources, and economic goals may hinder efforts as well (Mathers and Kruger 2008, Singh and van Houtum 2002). Some suggest that conservation remains a tool for post-colonial governments to control indigenous peoples and valuable resources, and in many cases gain access to international aid. Differences between the desire to maintain “pristine” African landscapes for tourists and land or resource claims by those dispossessed under Apartheid and colonial governance help to create an unfriendly atmosphere for research that places living communities and their culturally-informed activities in the savanna landscape. However, the extremes of fortress-like protected areas visited only by tourists and scientists, and dense human communities surrounded by heavily-used and degraded lands, sometimes adjacent to protected areas, cannot be sustained given the dynamic nature of savanna landscapes and the current and future environmental risks Southern Africans face. Research exploring human-environment interactions that shape savanna landscape highlights the interdependency of human and non-human communities. Results can be applied towards the development of economic and landscape management plans that promote sustainable practices supporting both human livelihoods and wildlife conservation.

One of the oldest studies of human-environment interactions examined the role of humans in establishing *Acacia tortilis* patches in wet savanna areas dominated by *Burkea africana* at Nylsvley, South Africa (Blackmore et al 1990, Scholes 1990). Soil testing revealed significantly increased soil fertility within the *A. tortilis* patches that could not be explained geologically, since all soils shared the same origin. Archaeological excavation found evidence for pre-colonial human occupation of the *A. tortilis* patches, and comparisons with contemporary Tswana community cattle herding practices and kraal preference locations suggested a human origin for patch establishment (Blackmore et al. 1990). High precipitation levels leach out nutrients from the soil, so wet savannas generally do not have soil fertility high enough to sustain *Acacia* trees over the long-term. The researchers suggested that enclosing cattle within the kraals at night and bringing in firewood for cooking and smelting imported the nutrients required to establish *A. tortilis*. Once the human communities moved on, ungulate grazing preferences likely maintained *A. tortilis* patches as these animals stay longer to graze the higher quality forage and fertilize the soil with their droppings. Anthropogenic origins for spatial heterogeneity in soil fertility and vegetation have been reported elsewhere in Southern African savannas. However, Scholes (1990) points out that geological and biological mechanisms, including the presence of old termite mounds, ungulate grazing, and allelopathic chemicals in tree roots, may be more important at other savanna sites.

Successful mixed herd grazing in the Mkambati area of Eastern Cape Province, South Africa requires extensive knowledge of grasses, rangeland management, and safe fire-handling practices, as well as strong community political structures. Kepe and Scoones (1999) used a variety of sources, including interviews, oral histories, archival sources, transect walks, mapping and air photos, to identify different grassland states within the Mkambati savanna and build a history of that landscape from 1900 to the mid-1990s. They interviewed locals about their savanna TEK to uncover the combination of conditions and processes that would cause a particular transition from one grassland type to another. Variable burn regimes, soil enrichment from livestock, and different length pasture "rest" periods contributed to the transitioning process. Cattle herders, hunters, and thatchers prefer different grassland types, which reflects their different economic goals. Challenges to the authority of local chiefs and traditional councils following the end of Apartheid led to alterations in community burning and grazing practices. Kepe and Scoones' investigation demonstrates that individuals actively manage savanna with particular economic goals in mind, and that power differentials between individuals and the institutional relationships that support these differences ultimately determine vegetation patterns (1999). While recognizing that their study is site specific, they suggest that grounding knowledge of ecological processes with an understanding of how social institutions affect transitions between vegetation states will be useful for range and resource managers in South Africa and beyond.

In rural, northeast Botswana, research on pastoralism and land degradation brought together a variety of data sources, including air photos, results from vegetation sampling in communal areas, oral histories, and colonial documents, to construct a picture of landscape change during the 20th century (Dahlberg 2000a, 2000b). Dahlberg showed that while the distribution of vegetation changed, abundance and diversity did not. These changes were attributed to government policies following Independence in 1966 that condensed settlement and forbade traditional burning practices. Historically, burning for livestock forage and swidden clearing around settlements maintained the vegetation in a particular pattern. When burn practices and settlement distributions changed, so did the vegetation patterns - even though overall species abundance and distribution did not change (Dahlberg 2000a). The use of various data sources and methods allowed Dahlberg to construct a fuller, more accurate picture of a human community constantly changing in response to fluctuating environmental conditions (2000b). Differences in landscape change perceptions led to variable and sometimes competing value judgements and decisions about landscape management. Complex interactions between spatially and temporally variable rainfall, soil fertility, individual and community decisions about land use, and outside intervention generated the visible landscape. However, "one can seldom measure more than a few variables which means that many descriptions of process dynamics are inherently incomplete" (Dahlberg 2000b: 560). If a particular vegetation pattern is an important goal for landscape management, effective conservation management planning will need to incorporate local perspectives and account for locally important human activities.

An interdisciplinary team looked at the importance of settlement and livelihood strategies in the production of savanna soil fertility and distribution of native fruit trees on the savanna of central northern Namibia (Verlinden et al. 2006). Previous research found that soil fertility, elevation, and the availability of surface water were critical features for farmers selecting land for crop and livestock production. However, an interdisciplinary analysis of multiple data sources, including local TEK interviews, air photos, maps and field observations, revealed a more complex picture. To manage drought risk, the agro-sylvi-pastoralists used their TEK to choose land units that are not necessarily the most fertile, but are part of a diverse landscape and have access to different types of land units. Individuals take features like drainage, plant indicator species, termite activity, landform, and micro-relief into account, as well as the availability of surface water and soil fertility (Verlinden et al. 2006). The interaction between termites, humans, and soil fertility requires homestead and kraal movement. People desire fertile soils for crop and fodder production so they choose areas with termite activity. Choosing sites with termite activity means farmers will move sooner rather than later, as eventually termites encroach on homestead structures. The practice of rotating homesteads and kraals within land units was found to increase overall soil fertility by supplementing termite enrichment. The increased soil fertility also encourages the establishment and survival of indigenous fruit trees that are casually sown or, more rarely, planted (Verlinden et al. 2006). This finding was contrary to previous beliefs that farmers choose land units based on the presence of already established trees.

Giannecchini et al. (2007) use the socio-ecological system idea as a framework for understanding how changing biophysical and socio-economic forces shaped the landscape of Bushbuckridge in Limpopo Province, South Africa between 1974 and 1997. During this period, human settlements grew and became more densely populated while woodland cover decreased. Their analysis of multiple factors found that complex interactions at different scales shaped the savanna landscape, but the direction and size of the changes was site specific and often nonlinear. Significant factors contributing to change included the arrival of Mozambican refugees during the 1980s, the decreasing importance of traditional authority following the end of Apartheid, and livelihood strategies centered on quick cash generation (Giannecchini et al. 2007). As the

researchers note, however, the differences in change throughout this rural cultural landscape cannot be attributed to a single factor, one-to-one relationship, or causal chain.
Their research shows that using a broader framework to capture complex human-environment interactions provides insight into the production of resilient and sustainable resource management plans that will contribute to socio-economic development in rural South Africa.

Disease may shape landscapes over time as well. In southern Zimbabwe, concerns over foot-and-mouth disease have generated two distinct pastoral landscapes (Scoones and Wolmer 2007). The development of a commercial beef export industry and land privatization in Zimbabwe during the early 1930s coincided with the first outbreak of foot-and-mouth disease. As traced through various archived documents, the colonial government seized this opportunity to enclose grazing areas with fences, remove wildlife, and control the movement of African pastoralist communities and their cattle. Wildlife and native cattle herds were identified as disease reservoirs and separated from commercial cattle herds. Formal concessions with exclusive grazing rights were granted to white commercial cattle ranchers who had different economic goals, breed preferences, stocking rates, and range management approaches than the indigenous herders who had previously shared grazing rights in the southern Zimbabwe region (Scoones and Wolmer 2007). Wildlife removal altered landscape pattern and process further. Since the 1970s, war and independence, major drought, economic instability, reintroduction of wildlife species, and the growth of wildlife conservation have placed various pressures on the dual pastoral savanna landscape of southern Zimbabwe causing further changes. This historical/political ecology analysis of disease demonstrates how ideological differences between the commercial cattle industry, indigenous pastoralist systems, and wildlife conservation can promote landscape-level change.

Approximately 50 years of ethnographic work with the Gwembe Tonga Research Project provides insight into how people quickly adapt to new environmental conditions and the long-term effects of relocation on both culture and landscape (Cliggett et al. 2007). Following the 1958 Kariba Dam relocation, Gwembe Tonga culture changed and new landscape relationships were forged. A general “make use of opportunities while they exist” strategy emerged in the new location in response to two types of environmental fluctuation: chronic uncertainty generated by multiyear droughts, occasional floods and pest infestations, and intermittent collapse driven by a boom-and-bust cycling of the Zambian political economy (Cliggett et al. 2007: 20). This strategy involves key practices such as migration and mobility, economic diversification, and natural resource exploitation. A second, recent wave of migration into frontier areas draws on those strategies acquired following the first relocation. Population pressures creating conflict over key resources and environmental change affecting farming success currently drives migration by Gwembe Tonga into new areas (Cliggett 2000). Economic diversification and natural resource exploitation accompanying this movement has resulted in landscape changes including extensive woodland clearing for agriculture, growth in market centers, extension of the bushmeat trade, rising HIV/AIDS rates, and an increase in economic class differentiation (Cliggett et al. 2007). Long-term data collection in Zambia’s Southern Province allows researchers to examine the complex interactions between a multitude of social and ecological variables over time and space. This perspective generates a deeper understanding of how very small demographic and economic changes at the household and community level influence the choices people make about resource and land use, thus contributing to vegetation patterns at the landscape level.

A meta-analysis of land tenure changes in four Southern African countries found that sustainability of savanna landscapes depended upon the interconnectedness of social, economic, and environmental factors. Losses to the sustainable capacity of one of these factors generated declines in the other two (Clover and Eriksen 2009). Changes to land tenure practices during the colonial period were the key to upsetting this interaction. Later, failure by post-independence land reforms to address land tenure has maintained, and in some cases, increased inequalities that threaten human security and landscape sustainability in this region. The land serves multiple functions for indigenous residents of savanna landscapes in South Africa, Botswana, Zimbabwe, and Mozambique. As the Clover and Eriksen note, many of the livelihood and risk management strategies practiced by savanna residents depend on landscape diversity (2009). The human security perspective the authors take allows them to approach the human-environment interaction from a different angle than the usual livelihood perspective. As a result, they also examine the interaction between land rights and cultural issues like social status, cultural values, political power, indirect access to resources, and conflict because these social variables affect adaptive capacity and thus security against future risk. Access to land and agricultural production remain critical for economic growth and poverty reduction in Southern Africa. To maintain the adaptive capacity necessary to survive potential environmental risk in the future, land tenure will need to be addressed to improve human security and maintain savanna landscape sustainability (Clover and Eriksen 2009). The authors suggest that resolving issues of environmental and social justice, primarily economic inequalities that arise from prioritizing commercial farming over the majority of small-scale livelihood practitioners and little to no investment in sustainable livelihood development for the poorest of households, would contribute to this land tenure reform.

Several themes emerge from the studies reviewed here that are central to human-environment interaction research in Southern African Savannas. As seen in Dalhberg (2000a) and Verlinden et al. (2006), this sort of investigation necessitates synthesis of multiple data sources, disciplinary perspectives, and the active participation of the communities where research work is undertaken. As such, it is neither easy nor short-term. Good and productive relationships between researchers, and between researchers and savanna communities, take time to develop. A long-term relationship can yield insight into cyclical patterns of interaction, as well as allow the researcher to draw on observations that may not be significant on their own, but contribute to a richer understanding of landscape process drivers and outcomes (Cliggett et al. 2007).

Research results are frequently site specific due to the complex combinations of interacting biological, physical and anthropogenic components, but can speak to potential interactions elsewhere on Southern African savannas (Blackmore et al. 1990, Scholes 1990). Analysis at multiple spatial scales can provide insight into how small-scale changes at the household level contribute to large-scale landscape change and indicate intervention points for increasing human security and sustainability (Giannecchini et al. 2007, Clover and Eriksen 2009). The discussion of scale highlights a secondary point concerning background knowledge of the biophysical and ecological patterns and processes, including the human components, shaping a landscape. This knowledge is key to understanding when change has occurred, identifying potential sources of change, and placing the experiences and perspectives of savanna community residents into context to develop appropriate lines of inquiry (Kepe and Scoones 1999, Verlinden et al. 2006).

Comprehending interactive processes to generate landscape patterns requires time depth, as all of the studies reviewed here show. Methods like archival research, image analysis, oral histories, and archaeological excavation allow researchers to access the perspectives and views of people and landscapes that may no longer exist. Historic events, both locally and nationally important, can trigger landscape changes (Clover and Eriksen 2009, Dahlberg 2000, Giannecchini et al. 2007, Kepe and Scoones 1999, Scoones and Wolmer 2007). In some cases, it is a history of policy interventions and their manipulation by those in power for the benefit of a particular group that creates change. Furthermore, social memories of historic political machinations influence reactions to contemporary events and policy changes (Kepe and Scoones 1999).

Finally, conservation and livelihood are not the only research themes amenable to interdisciplinary studies of human-environment interactions on Southern African savannas. Human security and adaptive capacity, livestock disease, relocation and migration, traditional ecological knowledge, land management policy, and ecological factors like soil fertility provide interesting avenues of inquiry (Blackmore et al. 1990, Clover and Eriksen 2009, Cliggett et al. 2007, Scoones and Wolmer 2007, Verlinden et al. 2006). However, even within these studies livelihood and biodiversity conservation themes inform the analysis. By shifting the primary focus to other themes at various spatial and temporal scales, researchers may be able to capture details that would not necessarily emerge from a study focused on livelihood activities, resource use, and conservation.

Implications: A Future Agenda?

Humans and African savannas coevolved, and the interaction between humans and the physical and biological components of this ecosystem continues to shape savanna landscape and culture in the southern African region. Historically, understanding different cultural lifeways, livelihood, and concerns for wildlife conservation has motivated research concerning humans living on southern African savannas. This research in many cases was linked to colonial projects used to justify control over indigenous populations (Clover and Eriksen 2009, Mathers and

Kruger 2008, Scoones and Wolmer 2007, Singh and van Houtum 2002). To create a sustainable landscape that can support multiple species and uses, including those of humans, new research approaches that place the interaction between social institutions and ecological processes at the center of inquiry are required – in addition to traditional disciplinary studies of savanna ecology and culture.

Contemporary issues such as poverty, health and disease, climate change, food insecurity, sustainable land management, and biodiversity conservation that Southern Africans currently face, and that will continue to affect them in the future, have neither simplistic origins nor simplistic solutions. Building on past ecological and cultural studies, interdisciplinary research could explore the effects of climate change on landscape and culture; fire and land management by indigenous communities; environmental risk management strategies for disease, poverty, and political instability; and interactions with biodiversity including the bushmeat trade, conservation policy, and wild plant harvest. Interdisciplinary research investigating the human-environment interaction in savannas is relatively new in the southern African region. Hopefully, its introduction will contribute positively to current interactions and help shape a more sustainable landscape future.

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CHAPTER 3

"OUR LAND PROVIDES MANY THINGS:" USING LANDSCAPE HETEROGENEITY TO REDUCE VULNERABILITY IN SOUTHERN MOZAMBIQUE[1]

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Abstract

This paper examines adaptive strategies practiced by two rural communities in southern Mozambique in response to vulnerabilities stemming from a combination of stressful environmental and social factors including climate instability, poverty, and food insecurity. Strategies at both the household and community levels target livelihood activities and require access to spatially and temporally variable resources throughout the landscape. Residents identified household vulnerability sources during a community-wide economic survey, while community vulnerability sources were identified through interviews with residents and representatives from government and non-governmental agencies. Poor health, problems with local food supply, the residual effects of Civil War, and recent conservation policies contribute to household and community vulnerability. Non-governmental agencies have recently introduced adult education programs that assist residents in generating sustainable income through access of known resources in new ways like ecotourism and market honey production. These programs reduce vulnerability and build adaptive capacity. Local level analyses of current adaptations and vulnerabilities to stressful environmental and social factors offer insights into how communities may react to future changes. Indigenous and other traditional rural communities often rely on spatially and temporally variable resources to reduce vulnerability. As a result, national and international policies limiting resource access for these groups' increase their vulnerability to current and future risks.

Introduction

Climate variability has shaped cultural knowledge, practices and institutions in Southern Africa through the adaptive strategies that different groups developed to reduce their vulnerability from anticipated climate patterns and less predictable events (Coelho and Littlejohn 2000, Colson 1979, Tyson et al. 2002). Many of the adaptive strategies people developed to reduce their vulnerability from floods, major drought, and dry periods in Southern Africa maximize the use of landscape heterogeneity, as well as human and social capital. However, these strategies may not be enough to withstand predicted climate change when combined with non-climatic vulnerability factors such as endemic poverty, limited access to financial and physical capital, HIV/AIDS and other diseases, ecosystem degradation, and political and economic instability (Blaikie et al. 1994, Boko et al. 2007, Morton 2007). Such non-climatic factors can limit access, directly and indirectly, to spatially and temporally variable resources across the landscape that support food and livelihood security. Analysis of culturally adaptive strategies is key to vulnerability assessments because it provides insight into possible reactions to future climate change and highlights potential intervention points to assist communities as they encounter new climate conditions (Smit et al. 2000). Due to the historic and contemporary reliance on landscape heterogeneity by many Southern African cultural groups, one potential intervention point for strengthening adaptive capacity to future climate change may be maintaining policies that allow continued sustainable access, and supporting communities as they explore new ways to access variable resources across the landscape in sustainable ways.

In this paper, I use a case study to show how access to landscape resources that vary spatially and temporally is central to the adaptive strategies that swidden farmer-foragers in Matutúine District, Mozambique practice to reduce their vulnerability to climate variability. I first examine the range of household- and community-level adaptive strategies implemented by residents of two rural communities in Matutúine District and assess the reliance of these strategies on landscape heterogeneity. I then explore the context of locally important historic, economic, environmental, health, and demographic factors that could contribute to increased vulnerability to predicted climate change and reduce landscape resource access. While the circumstances of this case study are specific to southern Mozambique, the adaptive strategies and vulnerabilities reported here remain illustrative of indigenous and other traditional rural communities throughout Southern Africa and beyond as they face future climate change (Salick and Byg 2007). Climate change vulnerability for these groups encompasses issues of endemic poverty, food and livelihood security, and the struggle to maintain resource access, sometimes under conditions of political and socio-economic instability, as well as vulnerability created by the changing climate itself.

Using Landscape Heterogeneity to Reduce Vulnerability

Severe warnings for Southern Africa's rural sector by the fourth Intergovernmental Panel on Climate Change predict increased temperatures and drought frequencies, as well as changes to the timing and amount of annual precipitation (Boko et al. 2007).[2] Agricultural models for this region suggest a drop of 20-50% in total livestock and crop production during severe climate change-induced drought (Stige et al. 2006). As in other Southern African countries, the population and economy of Mozambique, where this case study originates, rely heavily on agriculture.[3] Rural smallholders account for 70% of Mozambique's population, and at least 44%

[2] Floods also generate extensive agricultural damage, as seen in the more than 250,000 ha of crops destroyed by floods across Southern Africa following Cyclone Eline in 2000 (Mpofu 2000). However, increased temperatures, aridity, and drought frequencies remain the greater concern under future climate change scenarios.
[3] FAO (2007) statistics show that 80% of Mozambique's economically active population is involved in agriculture and that 30% of the national GDP comes from agricultural production. This population figure would likely increase

of their production is consumed within the household (Arndt et al. 2003).[4] Thus, the reliance of Mozambican smallholders and rural communities on subsistence production makes research concerning contextual vulnerability and adaptations to historic and contemporary climate variability critical, as it may provide insight into future climate change responses.

Individuals, households and communities respond to stressful environmental and social factors by developing and practicing adaptive strategies that reduce their vulnerability to conditions generated by these factors. Adaptive strategies include

> "the decision-making process and the set of actions undertaken to maintain the capacity to deal with future change or perturbations to a social-ecological system without undergoing significant changes in function, structural identity, or feedbacks of that system while maintaining the option to develop" (Nelson et al. 2007: 397).

Many adaptive strategies exploit environmental and cultural diversity, both spatially and temporally, in the landscape (Agrawal 2008, Colson 1979, Halstad and O'Shea 1989, Winterhalder et al. 1999). Studies of contemporary, historic, and ancient societies group adaptive strategies into five categories: storage, exchange, knowledge, diversification, and mobility. Agrawal (2008) defines a sixth category of communal pooling, which involves joint ownership of resources and assets that are shared or mobilized during times of scarcity. I address communal pooling in my results through separation of household and community strategies for each of the five categories. In the descriptions that follow, and in the results, I focus on the use of landscape heterogeneity to reduce vulnerability.

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if non-market production were included. Even in urban areas, many households maintain small vegetable plots and keep livestock to supplement food purchased with money earned in the formal and informal labor sectors.

[4] Mozambican smallholders are defined by the Instituto Nacional de Estátistica as households with less than 10 ha under cultivation, less than 10 cattle, 50 or fewer goats, sheep or pigs (can be a mixed group of animals), and/or 5 ha or less of intensive horticulture (FAO 2000).

Storage stabilizes food supply to ensure future consumption and survival in times of scarcity**.** Livestock act as a direct form of storage investment, however animals also access variable forage as herders move animals across a landscape (Forstater 2002). Maintenance of wild trees and plants distributed throughout the landscape provides another type of subsistence resource storage (Shackleton et al. 2002). *Knowledge* acts as a specialized form of cultural storage that supports other strategies by preserving the information necessary to find and use resources that vary spatially and temporally. Rural Kenyan, South African, and Zambian households maintain extensive traditional ecological knowledge (TEK) about local plants and animals for use as medicines and famine foods during and after droughts (Colson 1979, Eriksen 2005, Shackleton et al. 2002). TEK about climate patterns and weather indicators aids households in determining activity timing to reduce harvest losses, plan hunting trips, or prepare for seasonal changes. Individuals also actively seek new knowledge and skills to diversify employment options in times of local production failure.

Diversification strategies use landscape heterogeneity to expand the range of household production options. Scattering agricultural fields throughout the landscape and planting mixed crops and multiple varieties takes advantage of spatial variation in soils and microclimates, while reducing risks from agricultural pests and climate events (Thomas et al. 2007). Herders move livestock from pasture to pasture and keep mixed species herds to benefit from forage and browse that vary in quality and quantity (Forstater 2002, Campbell et al. 2006). Additional strategies that exploit landscape heterogeneity include practicing multiple livelihood activities and harvesting wild species for personal consumption or small-scale production (Shackleton et al. 2002, Waters 2007, Winterhalder et al. 1999). Individuals and communities build up financial and social capital through *exchanges* of small-scale production, livelihood surplus, and wage labor (Adger 2003, Halstad and O'Shea 1989). Social networks within and between communities created during good years can be drawn upon in times of scarcity. As a strategy of last resort, *mobility* takes particular advantage of spatial and temporal resource patchiness in a landscape. Individuals and communities move from places with resource scarcity to places with adequate or abundant resources (Halstad and O'Shea 1989, Tyson et al. 2002). Extensive kin and social networks may be accessed to facilitate the migration and settlement process.

As stated previously, adaptive strategies are developed and practiced to reduce vulnerability – the susceptibility of an individual, household, or community to disturbance or harm. This susceptibility is a function of exposure and sensitivity to stressful environmental or social factors, as well as the capacity to adapt to or overcome the effects of such factors (Agrawal 2008, Eakin and Luers 2006). The context of location, history, current social and environmental conditions, and predicted future change affect the importance of individual vulnerability factors from one community to the next. Additionally, many of these factors are outside individual or community control. Household herd management and community regulation of pasture and water rights historically reduced vulnerability from various environmental and social factors for the entire Maasai community (Forstater 2002). Current regional vulnerability to land degradation and food insecurity finds its origins in colonial and neocolonial government interference with this East African pastoral production system. However, differences in government policies maintaining communal land tenure mean that Tanzanian Maasai communities are slightly less vulnerable than those Maasai living in Kenya.

Climate change discussions about adaptation in Southern Africa must simultaneously address multiple environmental and social factors that increase vulnerability. These factors frequently act in concert to generate vulnerabilities greater than what is expected when considering each factor individually. In the absence of cash, adaptive strategies to reduce vulnerability maximize the use of diverse resources in the landscape, as well as human and social capital. Political and economic policies that limit this resource access also undermine the ability of households and communities to help themselves. In Tanzania, rural residents continue to practice locally reliable, diverse subsistence production systems because poor transportation infrastructure and non-existant cash reserves prevent them from accessing food during food insecure periods (Waters 2007). Studies of recent famines throughout Africa show that even when markets are well stocked and prices are low, many households become food insecure because they cannot afford to buy staple foods (Devereux 2009, Misselhorn 2005). Political instability adds another lay of complication that can overwhelm the capacity of current adaptive strategies. A meta-analysis of 49 case studies of household and community livelihood strategies in Southern Africa found that 50% of food insecurity was driven by three factors acting synergistically over variable time scales to create greater than expected vulnerability of the food supply – poverty, environmental factors including climate variability, and conflict (Misselhorn 2005).

Resource Availability and Environmental Risk in Matutúine District

Matutúine District, the study location, is part of Maputo Province and the southernmost district in Mozambique (See Figure 3.1). Beginning south of Maputo Bay, this 5,403 km^2 district is bordered by the Indian Ocean to the east, Swaziland to the west, and KwaZulu-Natal, South Africa to the south. Rural population remains low at 6.9 people per square kilometer despite the close proximity to the national capital of Maputo. The current population of 37,165 residents is roughly 65% of the population living there in 1986 prior to the main Civil War conflicts in this

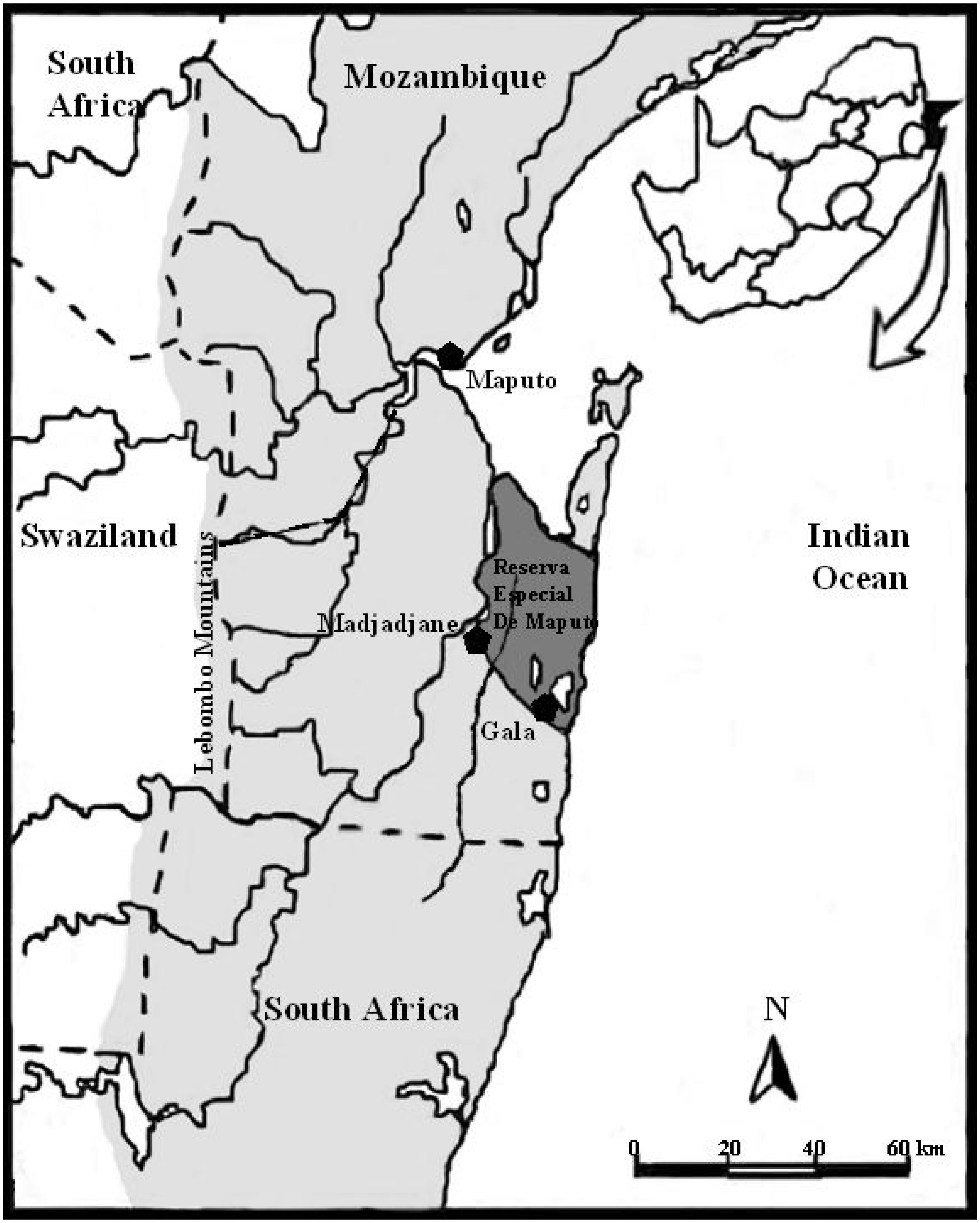


Figure 3.1 Map of Matutúine District, Mozambique. Dashed black line indicates district boundary within Mozambique. Light grey signifies the Maputaland Centre of Endemism and the dark grey is the Reserva Especial de Maputo. Madjadjane and Gala are indicated with black pentagons.

region (Gaspar 2002). I conducted ethnographic research in Madjadjane and Gala, two communities having populations of 331 and 114 respectively. Approximately 90% of residents identify themselves as Mazingiri Ronga. Ronga occupation of Matutúine District dates back at least 500 years based on evidence from oral histories, archived documents, and archaeological materials (Bruton et al. 1980, Felgate 1982, Junod 1927). The local economy is based on a combination of swidden agriculture and foraging. Livelihood activities like fishing, goat and cattle herding, mat and charcoal production, beekeeping, reserve work, and tourism supplement household resources and generate income.

A mosaic of grassland, wetland, woodland and thicket, swamp forest, and rare sand forest covers the sand dunes comprising Matutúine District's landscape. Freshwater and brackish lakes, along with the Maputo and Futí Rivers, also contribute to ecosystem diversity and provide permanent water sources for both human and non-human communities. Pans between the dunes hold water during wetter periods. This wide range of habitats contributes to a high diversity of flora and fauna. In fact, Matutúine District sits at the heart of the Maputaland Centre of Endemism, a 17,000 km^2 region containing 2500+ plant species including 225 endemic or near-endemic species and three endemic plant genera, 100 species of mammals, and 470 bird species including four species and 43 subspecies that are endemic or near endemic (Smith et al. 2008, van Wyk 1994). While only 19 km separate Madjadjane and Gala, the communities encompass a range of habitats available to residents for resource exploitation. Riverine woodlands, open woodland, and sand thicket and forest give Madjadjane, stretched along the Futí River, a predominantly woodland landscape. The predominantly grassland landscape of Gala incorporates open and wooded savanna, hygrophilous grassland, sand forest-woodland mosaic, patches of swamp forest, and the shores of Lakes Pití and Ntiti (DEIBI 2000).

Figure 3.2 shows average monthly precipitation and temperature for Matutúine District. Hot, rainy summers prevail from October to April, while the months of May to September bring cooler, drier winters. An ~18 year oscillation, producing nine relatively dry years followed by nine relatively wet years, overlays the annual precipitation cycle (Tyson et al. 2002). Rain generally falls heaviest along the coast (~1000 mm/yr) and on the eastern slopes of the Lebombo Mountains (~800 mm/yr). Madjadjane and Gala, located on the plains midway between the mountains and the coast, receive an average of 600mm annually (Tello 1972). Temperatures average 25.3°C during summer and 20.5°C during winter. Mean temperatures rose 1°C over the past 45 years, and rainfall timing and amount has become more erratic since 1984 (Coelho and Littlejohn 2000). District residents are vulnerable to both floods and droughts.

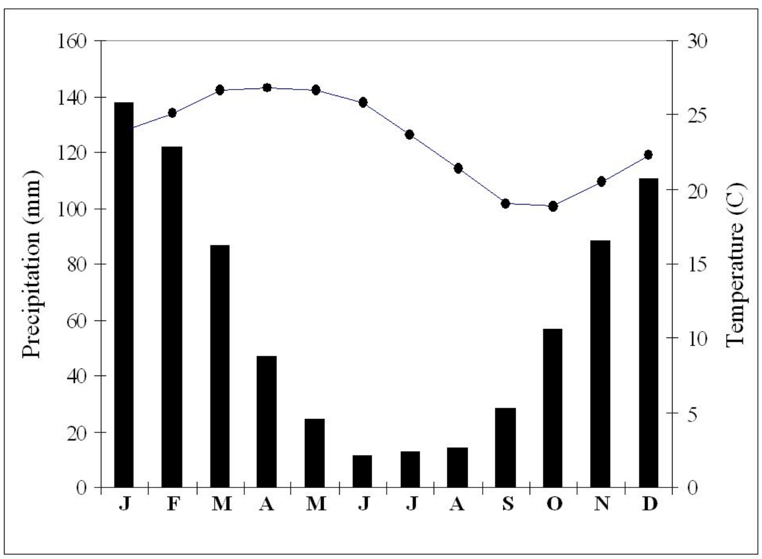


Figure 3.2 Climate data for Matutúine District, Mozambique. Monthly means are based on measurements taken from 1963-2008. The total annual average precipitation is 739.04 mm. Black bars indicate mean monthly precipitation in millimeters, measured along the left y-axis. The dotted line indicates mean monthly temperature, measured along the right y-axis.

Climate significantly affects both the ecological and human communities of Matutúine District. Average precipitation levels, particularly on the plains, hover around the transition from moist to arid savanna. This precipitation ecotone likely contributes to high biodiversity, and gives district residents access to diverse subsistence options. However, the timing and amount of rainfall also regulates vegetation production. Rainfall at the beginning of summer in October stimulates the annual growth of wild plants, and signals people to clear fields and plant crops like maize, cassava, peanut, and pumpkin. Additional rain over the months that follow determines actual production quality and quantity (Stige et al. 2006). Risks from interannual variation in precipitation to wild and domestic production ensure that most residents practice both swidden agriculture and foraging. Dry years are hard on rainfed production, and drought wipes out crops completely. People use wild plants and purchase what food they can afford to make up the difference. During very bad drought or flood years both domestic and wild plant sources can fail, placing all livelihood activities at risk.

The high biodiversity of the Maputaland Centre of Endemism also attracts various conservation interests. The Reserva Especial de Maputo (REM), gazetted as a hunting reserve in 1932, incorporates approximately 800 km^2 of Matutúine District's savanna-forest mosaic (Tello 1972). The reserve is adjacent to the communities of Madjadjane and Gala, and a number of residents work for REM as guards and day laborers. Residents of Madjadjane and Gala retain rights to harvest plants within the reserve boundaries for personal consumption under Mozambican law. Designation of the Licuáti Forest Reserve has protected 400 km^2 of rare sand forest since 1943, although it has been under Ronga protection for much longer (Izidine 2003). Ronga people regard sand forest areas as sacred and their laws restrict access to these habitats for special purposes like ceremonies. Plans for the 8,601 km^2 Lebombo Transfrontier Conservation

Area (LTCA) will link REM and Licuatí Forest Reserve in Mozambique with protected areas in Swaziland and South Africa (Smith et al. 2008). Local residents have developed small ecotourism enterprises with the IUCN and other non-government organizations, and the designation of the LCTA will likely bring more opportunities to Matutúine District.

Research Methods

I used participant observation and interviews with diverse community members in Gala and Madjadjane from May to July 2004 and July 2007 to April 2008 to generate a list of adaptive strategies practiced in response to climate variability and identify activity locations. I conducted 33 semi-structured interviews with men and women – aged 18 to 79 – that investigated the effects of climate variability on contemporary livelihood activities and the strategies people use to counter these effects. Oral history interviews with 16 men and women – ages 55 to 100+ – in both communities explored historic adaptive strategies to climate variability. Agricultural drought conditions during both fieldwork periods provided the opportunity to observe and ask extensive questions about the practice of livelihood activities under drought or dry conditions. Additional inquiry allowed me to compare strategies for flooded and "normal" conditions. Community members made initial recommendations for livelihood and oral history interviews and chained referral during interviews connected me with additional participants.

I employed a grounded theory approach to code interview texts and my field notes during analysis (Corbin and Strauss 1990). This allowed me to distinguish emergent phrasing and group concepts together that could be used to build lists of adaptive strategies, describe strategies in fuller detail, and identify livelihood activity locations. Adaptive strategies were divided into five categories: storage, knowledge, diversification, exchange, and mobility. I separated household and community strategies within each category. Individual families practice different combinations of strategies depending upon their access to resources, personal skills, and knowledge. Community strategies require participation by the majority of the community to succeed, and involve planning and direction by the local chief and council of elders.

As a final check on the data concerning the use of landscape heterogeneity for adaptive strategies, 30 heads of households in Madjadjane (N=22) and Gala (N=8) were asked two open-ended questions. Why did you build your home in this particular location? Why do you like living in this place? Households participating in this final interview check were chosen based on the presence of either the female and/or male head of household when my field assistant and I visited. As before, the emergent phrasing I used to code responses for analysis came from applying a grounded theory approach to the interview texts.

Observations, interviews and household surveys were used to build a contextual picture of environmental and social factors contributing to community and household vulnerability. I carried out an economic survey with all households in Madjadjane (N=64) and Gala (N=24). The female or male head of household present at the time was asked about household composition, livelihood activities, income, food security, and health. Statistical analysis of their answers generated a description of community demographics and current resource access. I used this information, in combination with observations and open-ended interviews about local history and economics with residents and representatives from government and non-governmental agencies working in the region, to construct a general picture of community vulnerability. Survey participants also free-listed the biggest problems their household faces. I analyzed the lists using ANTHROPAC 4.0 to assess the relative importance of specific, self-reported problems within households and across communities. These self-reported problems represent environmental and social factors contributing to household vulnerability. I grouped the free-list results into categories reflecting related problems including: local food supply, non-local food supply, health, income, education, social support, and other, a group of miscellaneous problems.

<u>Adaptive Strategies</u>

Table 3.1 lists adaptive strategies practiced by residents of Madjadjane and Gala. While a wide variety of strategies are listed, I focus on describing adaptive strategies that use the spatial and temporal variation of the landscape.

Household storage strategies included livestock ownership and maintenance of useful wild trees and plants in yards and agricultural plots. All but the poorest households own livestock. Most residents own chickens and goats because they are easy to raise and may be eaten by the household, used ceremonially and consumed by the community, or sold for profit. Cattle remain the most desirable livestock to own. Herds historically grazed the grassland and open woodland habitats in Madjadjane and Gala, but these cattle were lost during Mozambique's Civil War. Some residents are slowly replacing lost herds by raising goats for sale and purchasing cattle with the profits. Residents do not actively plant trees, but they take care when harvesting fruits, leaves and bark from useful native and domesticated trees and plants in their homestead yards and fields. Firebreaks are used to prevent killing trees when burning fields and coppicing practices allow trees harvested for timber to resprout. At the community level, useful trees and plants are also maintained in communal areas for harvest by all residents. Customary hunting restrictions act as another community storage strategy that ensures future access to animal resources.

Table 3.1 Adaptive strategies practiced by residents of Madjadane and Gala, Mozambique.

	Household	Community
Storage	- Store rainwater and hauled water in barrels - Store maize, peanut, and other crops - Make and store mfumo (dried *Strychnos madagascariensis* pulp) - Dry and store fish - Keep livestock - cattle, goats, chickens, ducks - Maintain native and domesticated trees and plants in yards and fields for food, medicines, and construction materials	- Maintain native and non-native trees and plants in communal areas for food, medicines, and construction materials - Restrictions on hunting newborn and pregnant animals and hunting within sacred forest boundaries
Knowledge	- Maintenance of TEK about wild plants and animals used for food, medicine, and construction materials - Maintenance of TEK about weather, climate, and landscape disturbance factors like fire - Send children to school when money available - Acquire new knowledge when possible, e.g. English, beekeeping and ecotourism classes	- Use community funds and/or labor to build primary school - Work with NGOs and experts to offer classes to community members (tourism, language) - Document TEK with help of NGOs and outside researchers
Diversification	- Increased reliance on wild plants and animals to meet household food, medicine, and construction needs - Diversify range of wild plants and animals used - Greater reliance on wild fruits - Diversify livelihood activities - Adjust timing of activities to account for heat, humidity, and rainfall - Diversify field locations for different crops - Diversify crops planted - Reduce production of some crop types - Develop commercial farming operation - Dig extra wells - Use river water for personal consumption - Build homestead in wooded area for resource access, shade, and climate protection - Build homes on elevated sites to reduce flood risk - Have dual citizenship South Africa-Mozambique - Obtain food from NGOs (WFP, churches, etc.)	- Work with NGOs to develop regional ecotourism infrastructure - Work with NGOs to develop local honey production industry - Parcel out land for homesteads and agricultural fields so that families have access to both wet and dry fields

Table 3.1 Adaptive strategies practiced by residents of Madjadane and Gala, Mozambique (continued).

	Household	Community
Exchange	- Family member works in South Africa and sends remittances of money, food, and clothing - Family members in Maputo send food and/or money - Multiple generations live together at homestead - Young person lives with and assists elder relative, usually a widow, living alone - Maintain second family in South Africa - Sell labor to neighbor for food and/or money - Sell dried fish, honey, mats, charcoal - Purchase food at markets and stores - Seek paid labor with NGO-Community programs - Participate in Work for Food government program	- Rain Ceremonies - Food, money, and other materials are shared between related households and close friends - Redistribution of part of hunt and harvest (historic)
Mobility	- Seasonal labor migration to South Africa or other parts of Mozambique - Move to South African homestead - Move to city - Maputo, Durban, Johannesburg - Walk farther for water	- Move homes closer to Futi River

Intergenerational transmission of ecological and cultural knowledge remains strong in Madjadjane and Gala. Survival depends upon accessing the wide range of wild and domesticated resources scattered throughout the landscape via the local mixed subsistence-based economy. Children assist with daily household activities from a young age, and adults teach them necessary environmental knowledge and subsistence skills at this time. Youths solidify their knowledge between the ages of 15 and 30, seeking out new information from family members as well as community experts. However, young men and women leave home at this age for secondary schooling and for paid work in Maputo or South Africa. Worried that local knowledge will be lost, older residents have been working with conservation NGOs, the IUCN, and outside researchers to document TEK for future generations. Residents also value formal education for their children and themselves because they believe it expands the range of livelihood opportunities households can draw upon during difficult periods. The community has assisted households in their educational endeavors by inviting and working with conservation NGOs and the IUCN to provide educational and employment opportunities in ecotourism, domestic beekeeping, and market honey production. The new knowledge allows residents to access known resources in new ways and new resources in familiar surroundings. Residents also pool labor and financial resources to construct primary schools within their communities.

The diversification strategies practiced in Madjadjane and Gala take advantage of landscape spatial and temporal heterogeneity. Horticulture and foraging underpin Ronga household economies, but each household practices a variety of livelihood activities to meet their needs. The effort put into each of these activities depends upon resource access, personal skill sets, the anticipated climate conditions, and timing. During drought, a household may first shift its efforts towards adjusting the timing of cultivation, the types of crops planted, or the location of agricultural fields. If the drought continues or worsens, households shift to greater reliance on wild foods. Dual citizenship with South Africa allows residents to access resources over the border, and if available, residents obtain food aid from NGOs. At the community level, the chief and council of elders parcel out land to new households or to those seeking to work new agricultural fields in such a way that everyone has access to both wet and dry fields. This allows each household to grow crops year round. Community-wide efforts working with NGOs to develop artisanal honey production or ecotourism reflect new uses of older, well-known resources.

The extensive social networks used for exchange in Madjadjane and Gala cross both district and national borders to access resources in urban landscapes. Cash remittances and food from kin in Maputo and South Africa help households weather the annual hunger season and years when crops fail. Residents know that amounts will be small because living expenses in urban areas are higher, but appreciate the help. In return, friends and relatives from urban areas receive fresh produce and meat when available, a place to stay during holidays and important cultural events, and may retain claims to land. Within the physical boundaries of communities, kin and close friends pool food and other resources between households to reduce vulnerability during scarce periods. In the past, chiefs claimed a portion of every hunt and harvest and redistributed most of this portion to the elderly, sick, and those otherwise unable to procure food. Residents maintain this tradition during the first fruits harvest festival in early February. At this time, the chief collects a portion of the first batch of canhu beer (*Sclerocarya birrea*) to use as a sacrifice to the ancestors during a rain and thanksgiving ceremony. Traditional community ceremonies maintain social relationships between the ancestors and residents, reinforce cultural institutions and social networks, and access kin networks in the spiritual realm. In a more earthly landscape, these ceremonies are held in sand forest patches made sacred by the interment of ancestral remains.

Madjadjane and Gala residents move when environmental conditions overwhelm their adaptive strategies. Many families maintain a second homestead just over the border in KwaZulu-Natal headed by a sibling, a second wife, or an older child. Northern KwaZulu-Natal's landscape is similar to that of Matutúine District, and the South African government offers assistance programs and monies to citizens that the second household can share with their Mozambican kin. Residents regularly migrate to Maputo or South Africa for short-term labor opportunities in the agricultural, mining, or service sectors. However, labor migration is seen as an unviable long-term solution because high crime rates, lost contact with family, reduced access to clean water and air, and the high cost of living lower the household's overall quality of life. In 2003, Madjadjane's chief, consulting with the council of elders, asked residents to move their homes closer to the Futí River because of drought. The chief explained to me that under normal conditions cultivation adjacent to the river is forbidden, but during drought and drier periods soils and surface wells in this location retain water longer. The move potentially improved crop production and reduced time spent acquiring water for household needs. The community decision to move closer to the river likely reflects a historic Ronga practice of moving settlements to reduce vulnerability under drought conditions.

Role of Landscape Heterogeneity

Table 3.2 shows where livelihood activities, homestead sites, and ceremonies occur by habitat type. All habitat types found in REM and the two communities are included even if, like mangroves, the habitat is rarely accessed. The five most heavily used habitats for livelihood activities and homesteads are wooded grassland, open woodland, woodland, floodplain, and sand

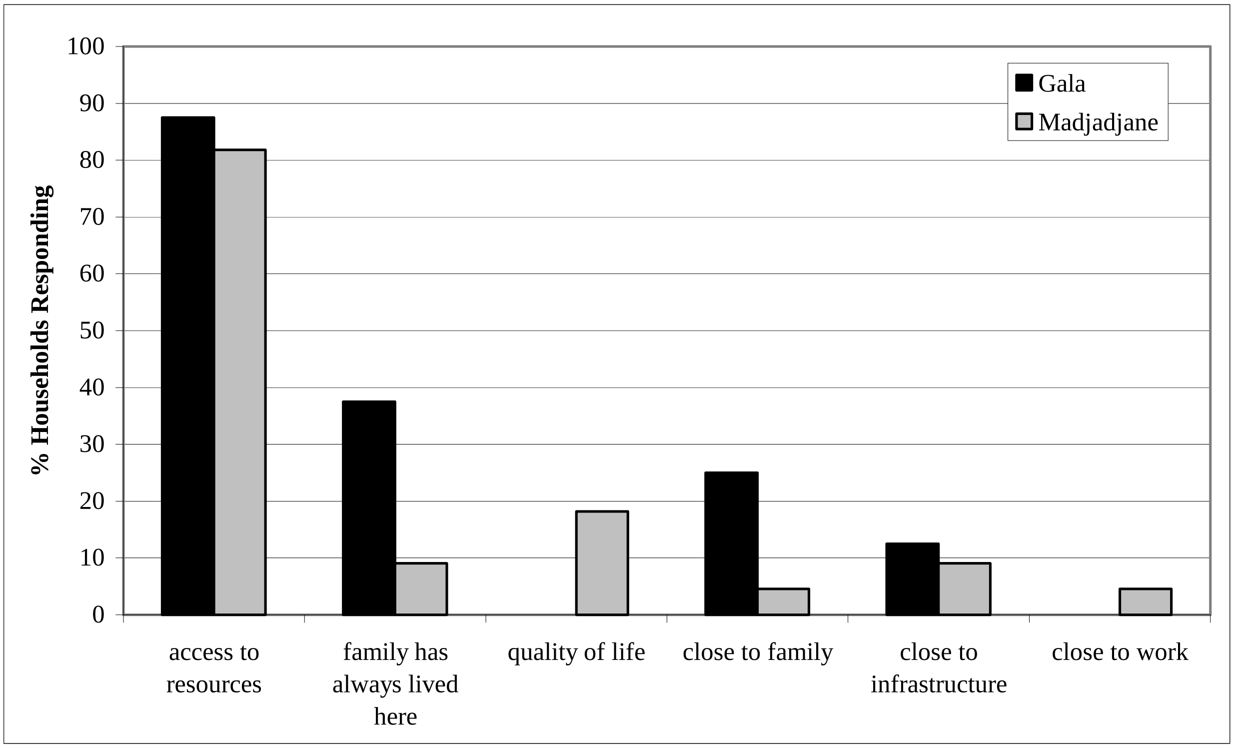
Table 3.2 Habitat locations of important livelihood activities for residents of Madjadane and Gala. All habitat descriptions come from DEIBI (2000), except for floodplain, lake and river. Abbreviations for habitats are as follows: DF = dune forest, DG = dune grassland, EP = eucalyptus plantation, FLPL = river or lake floodplain, HG = hygrophillus grassland, LK = lake, LR = lacustrine reedbed, MA = mangrove, OW = open woodland, RV = river, SF = sand forest, SFM = sand forest-woodland mosaic, ST = sand thicket, SWF = swamp forest, WG = woody grassland, and WL = woodland. In this paper, I use LK and RV to refer to open and flowing water areas while FLPL refers to areas adjacent to lakes and rivers that may flood following summer rains.

	WG	OW	WL	FLPL	SFM	DG	EP	ST	SWF	HG	DF	MA	RV	LK	SF	LR	Total Habitats/Activity
Ceremonies (rain, harvest, etc.)																	1
Mat Production																	2
Sura Production																	3
Fishing																	3
Horticulture:																	
Bananas, Taro, Sugar Cane																	2
Winter Crops (May - Sept.)																	2
Summer Crops (Oct. - April)																	4
Charcoal Production																	4
Homestead Location																	4
Beekeeping																	5
Harvest:																	
Thatching/Cane																	5
Firewood																	8
Timber (homes, handicrafts, art)																	9
Wild Plant Foods																	13
Medicinal Plants																	14
Herding:																	
Cattle																	7
Goats																	9
Hunting																	9
Ecotourism/REM																	16
Total Activities/Habitat	13	13	12	11	11	7	7	7	7	6	5	5	5	4	4	2	

forest mosaic. A previous study showed that 90% of plant species preferred for wild food, construction materials, and firewood were trees, and that residents harvest medicines from many of these same species (Shaffer 2005). Summer horticultural activities and wild food harvests, both of which underpin household economies in this district, rely heavily on habitats that contain both trees and grassland. Winter horticultural fields are located in floodplains and along swamp forest edges.

Resident responses to the question asking about homestead location support the hypothesis that access to landscape heterogeneity is key to local adaptive strategies (Figure 3.3A). "Access to resources" was the primary reason for homestead location in both Madjadjane and Gala, followed by "quality of life" in Madjadjane and my "family has always lived here" for Gala. When explaining the access to resources, informants specifically mentioned shorter distances to water, presence of trees to provide fruit, shade and cooler temperatures, proximity to good locations for agricultural fields, protection from wind during cyclones, and a lake or river nearby for fishing. Table 3.2 supports this idea, as residents build homesteads in four of the five most heavily utilized habitats. The ability to construct a homestead in a location with the desired traits mentioned above would improve a household's quality of life. Additionally, their comments about homestead locations being places where their family has always lived indicate that constructing homes in areas central to livelihood activities likely reflect historic landscape use strategies. A 71 year old Gala farmer stated that he built his home on the site where his grandparents had lived, while another native Gala elder in her early 90s said that her current homestead location was very close to where she was born and raised. Landscape Heterogeneity was also important in access to infrastructure, as people were interested in proximity to schools, roads for selling locally made or harvested products, and electrical lines for future use.

A



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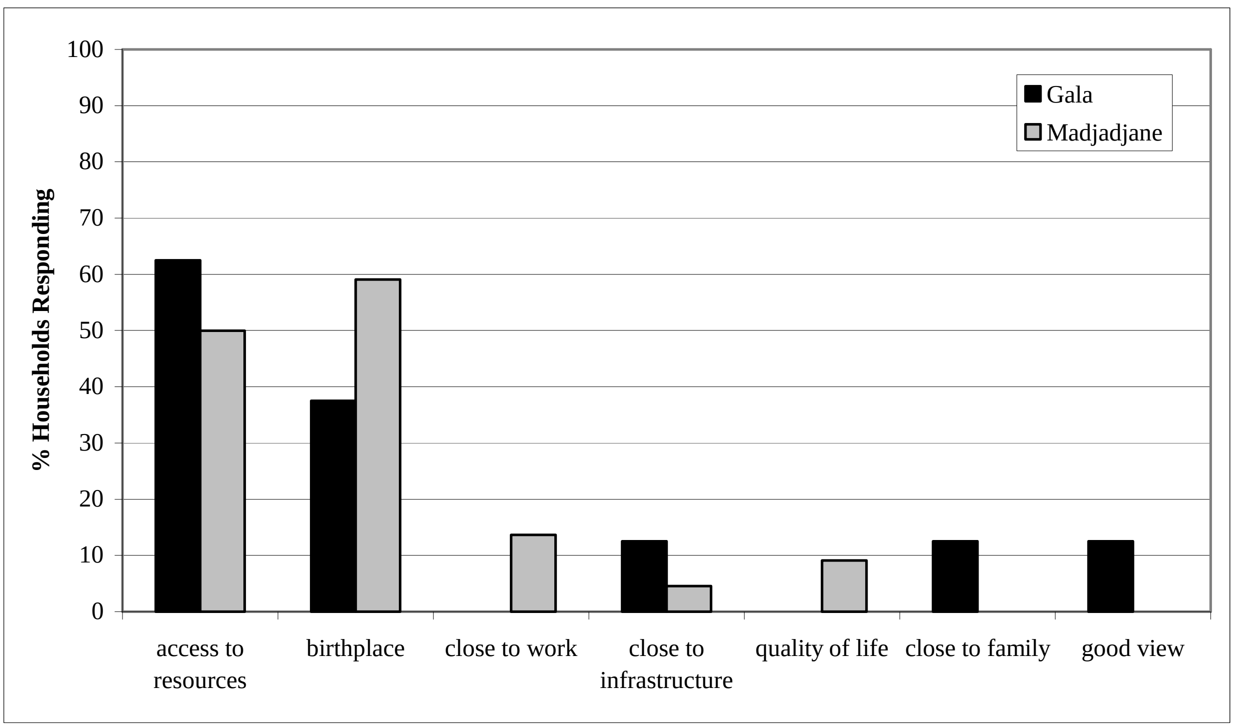

Figure 3.3 Importance of location to residents of Madjadjane and Gala. The results presented here are based on two questions asked during an exit interview: (A) Why did you build your homestead in this location? (B) Why do you like living in this region?

In general, Matutúine District's highly diverse landscape is appreciated by residents and seen as a birthright. When asked why they liked living in Matutúine District residents responded primarily that this place was their home and that they had access to all the resources they needed to live a good life (See Figure 3.3B). Birthplace is important because those born into a community retain primary rights to access resources in communal areas and can make claims on resources associated with family homesteads. Outsiders may join the community and gain access to local resources in the landscape, but those born in the community have a distinct advantage. As one Gala resident summarized, "It is my birthplace. The environment is favorable. I have many things available to me – resources, plants, lakes, forests. Gala has everything a person needs to live." Others mentioned that these resources are free. "My parents were born in Madjadjane, as was I. Here the fields provide many things and we don't need to buy food. Madjadjane, this place, provides many things" [farmer, Madjadjane]. Some recognized that the cost of living is lower in rural areas compared to urban areas although they may not have access to large markets for their products. "Life in the country is easy compared to life in the city. Here, I do not pay for water or food" [artisan, Madjadjane]. Elderly respondents also mentioned the close proximity of family who share food and are available to help with agricultural work.

Environmental and Social Factors Contributing to Vulnerability

The top ten self-reported problems, i.e. factors contributing to vulnerability, households experience fall into five categories: health, local food supply, income, non-local food supply, and education (See Table 3.3). Minor differences exist between communities both in ranking of problems and the types of problems reported. Gala residents ranked crop destruction by elephants (*Loxodonta africana*) and bush pigs (*Potamochoerus larvatus*) as the worst problem, followed by concerns for healthcare access and potable water. The lack of a local health clinic followed by no crops and no money to purchase food were seen as major factors contributing to household vulnerability in Madjadjane.

Figure 3.4 groups all 37 self-reported factors contributing to household vulnerability for Gala and Madjadjane into general categories. Health and local food supply issues remain dominant, however income stresses increase for Gala households while education and other miscellaneous problems increase for Madjadjane. Gala's greater distance from the main road and bigger towns in Matutúine District means residents pay more for transportation and non-local food supplies. Madjadjane's parents believe a poorly constructed primary school building, and upper-level schooling options far from home impair their children's access to a good education. Children attending middle school currently walk 16km daily and older teens board at a high school more than 20km distant. The social support category reflects single parent concerns about a lack of childcare while working in the fields and no spouse to share the responsibilities of raising children well. The other category includes environmental and social factors like a lack of electricity, reduced access to natural resources, concerns with wildfires, no grandchildren, and alcoholism that contribute to individual household vulnerability.

The economic surveys revealed that women head almost half the households in Madjadjane and one-quarter of the households in Gala (See Table 3.4). Many of these women are widows and single mothers supporting grandchildren or young children. Some of the single mothers are unmarried, while others have husbands working in South Africa as migrant laborers. Savings are negligible and households spend money as soon as it is earned on food and school costs. When I conducted the survey, residents were buying food to make up for agricultural shortfalls due to the 2007-08 droughts. Residents receive very little food assistance or other

Table 3.3 Top 10 self-reported problems for Madjadjane and Gala. HH rank is the importance of this problem for individual households. Overall rank is the importance of this problem for all households within a community.

	Gala:			Madjadjane:		
Problem	**Overall Rank**	**HH Rank**	**% HH Reporting**	**Overall Rank**	**HH Rank**	**% HH Reporting**
Health						
No transportation (primarily to health clinic)	2	2.7	45.8	9	3.5	17.2
No local health clinic	3	2.1	45.8	1	2.7	39.1
Limited or no access to potable water	4	3.3	41.7	7	3.0	21.9
Transportation expensive (primarily to health clinic)	10	5.7	12.5			
Distance to water increased				8	2.3	17.2
Local Food Supply						
Wildlife destroys crops (elephants, wild pigs)	1	2.2	75.0	3	2.5	37.5
No food grown (not including wildlife problems)	6	1.5	16.7	2	2.5	37.5
No rain/drought	7	2.8	16.7	5	2.7	26.6
Don't own livestock	9	1.7	12.5			
Income						
No work (paid labor)	5	2.0	25.0	6	2.4	25.0
No money				4	1.6	34.4
Non-local Food Supply						
No local stores	8	7.3	12.5			
Education						
No local secondary school				10	3.8	12.5

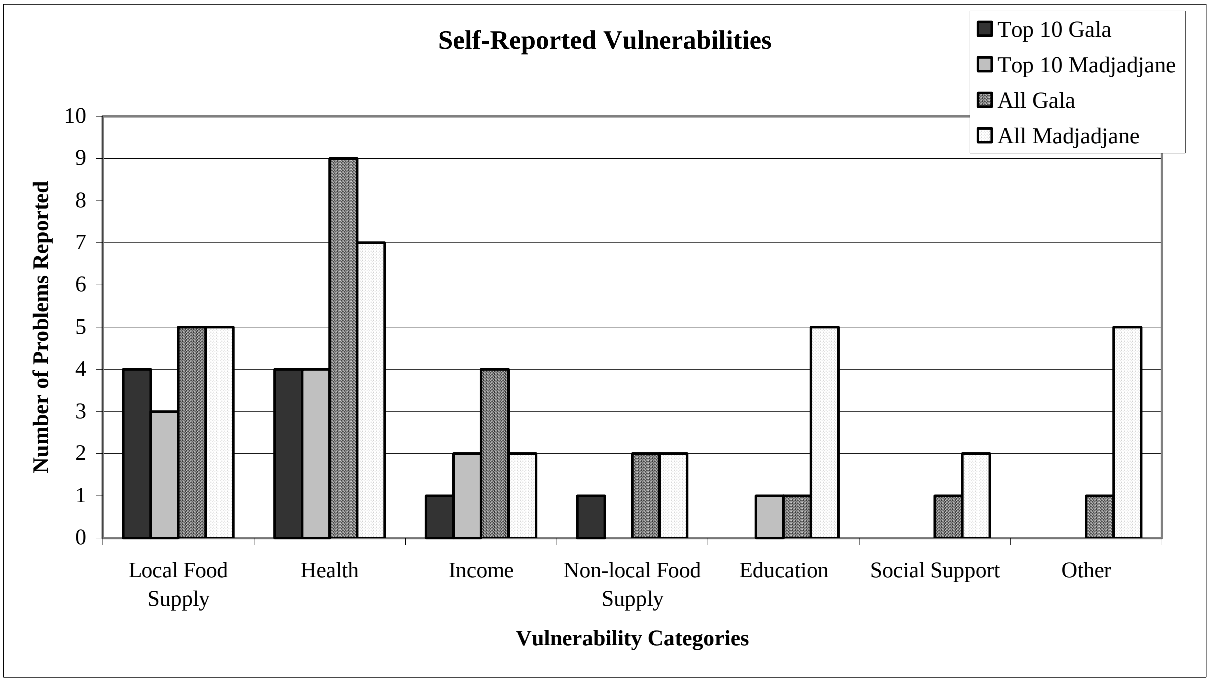

Figure 3.4 All self-reported problems for Madjadjane and Gala. All in the legend refers to the top 10 problems plus additional problems reported by households.

charitable aid from outside organizations. Adult literacy rates are at or below the total national rate of 47% (UNICEF 2009). Many of these literate adults are young people born around the end of Civil War and not the head of household. Residents know that reading and writing skills allow participation in Mozambique's modernization process and improve household adaptive capacity. Therefore, all eligible primary school-aged children in both communities attend school.

My conversations with local residents often turned to the lingering effects of Mozambique's Civil War (1975-1992), the rapid modernization that has followed, and changes to REM. During the war, district population declined, and cattle, tools, and other household resources were lost. Heavy wildlife poaching during the war reduced future tourist revenues and made remaining elephant herds more aggressive towards humans. The current reluctance of Mozambique's government to remove or cull problematic animals that destroy crops is

Table 3.4 Summary of household economic survey results for Madjadjane and Gala. Household is abbreviated HH. Calculations of average monthly earnings (+) includes only those households providing actual earning amounts. The Gala value (*) was calculated without inclusion of a single resident commercial farmer who earns 27,000 Mtn per month, or $1150.63 USD at the 2007 conversion rate.

	Gala	Madjadjane
Demographics		
Population Total	114	331
Number Households	24	64
Males	63	163
Females	51	168
Children (0 - 15 years)	46	124
Adults (16 - 70 years)	61	193
Elders (70+ years)	7	14
Children per HH	1.9	1.9
Adults per HH	2.5	3
Elders per HH	0.3	0.2
Education		
Literate Adult Men	22 (34.9%)	76 (46.6%)
Literate Adult Women	10 (19.6%)	58 (34.5%)
Boys in School	19	37
Girls in School	12	30
Household Economics		
Male Head of HH	17	34
Female Head of HH	6	26
Shared Decision-making	1	4
Average Monthly Earnings^{+}	886.36 Mtn*	1704 Mtn
USD at 2007 conversion rates	$37.09	$71.30
HHs With No Earnings	3	5
HHs Not Reporting Earnings	12	29
HHs Receiving Food Assistance 2006	2	5

connected to the wartime poaching, since certain types of economic aid are tied to conservation of remaining wildlife populations. Tensions created by rapid modernization at the national level, and the lack of infrastructure and financial capital at the local level, further exacerbate vulnerability to climate change and poverty. Residents spoke of corruption, infrastructural problems getting surplus crops and small-scale home production to market, access to financial capital, and reduced educational opportunities in Mozambique. One farmer related that he stopped going to Maputo where he could obtain the best prices for surplus crops because local police at stops along the route demanded his entire profit margin. Travel in Matutúine District requires 4WD and public transport is expensive and infrequent. Small micro-financing organizations have recently started projects in the district to fill the gap left by non-existant, formal financial institutions. However, youth continue to leave Matutúine for South Africa and Maputo because of better educational and employment opportunities.

Wildlife conservation in Matutúine District brings employment opportunities for local residents as well as increased vulnerability. Several international corporations have applied for permits to build visitor facilities within REM boundaries now that plans for the LTCA are moving forward. Staffing facilities with locals will increase opportunities for paid labor in the district. However, a lack of language and business skills within the local population ensures that residents will not be able to participate at more than the most basic level. International groups, like the IUCN, have been working with communities to build these needed skills. Designation of a corridor along the Futí River within the LTCA will allow free migration of species like elephants, rhinoceros, impala, and lions between South Africa and Mozambique. Fencing off the corridor began in 2007 to protect local human populations from migrating animals. During this process some district residents lost access to fertile land adjacent to the river. LTCA agreements, backed by Mozambican national law, also require the five communities located within REM boundaries to move out. Relocated households are likely to settle with kin, in communities like Madjadjane and Gala, as close as possible to their old homes and ancestral lands inside REM boundaries. Lost access to land and other resources, combined with rising pressures on remaining resources, serves to increase vulnerability to future environmental risks for both human and wild populations.

<u>Building on Local Adaptive Strategies to Reduce Vulnerability to Future Climate Change</u>

Many of the adaptive strategies developed by indigenous and other traditional rural communities in response to anticipated climate conditions and less predictable events historically required permanent cultural changes that continue to shape how community members interact with each other and the larger world. The magnitude and frequency of predicted future climate changes, combined with new sources of vulnerability, require greater innovation and ingenuity than before. Technological and large-scale solutions offer some relief, but site-specific adaptive strategies will be more successful and sustainable because they respond directly to variation in local conditions, and use locally available resources. Local scale analysis highlights the important role individuals, communities, and cultures have in developing adaptive, site-specific strategies.

My analysis of how Madjadjane and Gala residents reduce vulnerability to climate variability shows that their adaptive strategies depend on access to local resources varying spatially and temporally in the landscape. Climate risks from drought and flood, historically accompanied by widespread famine, likely drove adaptive strategy development in Madjadjane, Gala, and other Ronga communities in Matutúine District in the past (Coelho and Littlejohn 2000, Junod 1927). Later, during Mozambique's Civil War, residents drew upon historic climate strategies to reduce vulnerabilities stemming from a politically unstable environment. Some left the district and stayed with kin in South Africa or Maputo, while others fled to the bush and used their TEK to find wild food resources scattered throughout the landscape. Now Madjadjane and Gala residents are applying these previously successful adaptive strategies to counter the combined threat of climate change and poverty. This time, however, their adaptive strategies may be overwhelmed.

Environmental and social factors in Madjadjane and Gala compromise the efficacy of adaptive strategies, and ultimately affect adaptive capacity by limiting resource access directly and the ability to access resources. Poor health and limited healthcare access, food insecurity, income, and education top the lists of self-reported problems for residents in this study. Workable solutions could be found for each problem taken individually, but households generally experience combinations of three or more problems. In the absence of good health, households lose food security because people lack the ability to cultivate crops, forage wild foods, or hire out for paid labor. Reduced access to education limits future adaptive strategy options when responding to changing environmental conditions. Adults who read and write beyond a basic level can find stable, better paying jobs in urban areas and send remittances home to help out in times of scarcity. Additional economic setbacks generated by the lingering effects of Civil War hinder local efforts to access resources and participate in Mozambique’s rapidly growing economy. Households lack tools, finances, and labor capacity, while communities lack the infrastructure.

LTCA development requires strict enforcement of national laws preventing communities from existing within protected area boundaries like those of REM and the Futí River Corridor. While enforcement protects residents from dangerous wildlife, tightening conservation regulations to meet international standards threatens resource accessibility for residents of Matutúine District. In Matutúine District, resource access rights have traditionally come from ancestral ties to the landscape and special permissions granted by the entire community to newcomers. When people are removed from their ancestral lands, many move to communities like Madjadjane and Gala that are adjacent to protected area boundaries to stay close to their old homes and in a familiar landscape. The intensified resource demands on land, water sources and wild plants in boundary communities increase the vulnerability of long-time residents, newcomers, and biodiversity to future climate and other environmental changes. Mozambican law currently grants rights to rural residents to harvest wild plants for personal consumption within protected areas. Potential extinction risks associated with climate change may trigger alterations to usufruct rights to protect the district's rare and endemic flora and fauna.

Strengthening individual and community adaptive capacity remains important because government and international aid agencies cannot provide sustained aid over the long-term. Participation in programs developing new industries like ecotourism and market honey production in Madjadjane and Gala indicate that residents recognize the significance of changes to conservation policy and actively seek to improve their adaptive capacity. These programs, introduced by international aid agencies, help residents build the necessary skills to sustainably access new economic resources and well-known resources across the landscape in new ways. Conservation also contributes towards building adaptive capacity. As the LTCA planning progresses, significant efforts are being made to incorporate game farms and ecotourism operations that offer employment to residents, as well as develop a core-buffer system (Smith et al. 2008). District residents will continue to live, work, and harvest resources for livelihood activities in the buffer zones. Core areas will exclude all resource harvest to protect rare species and habitats, and provide a source pool for the species residents use. Risks from climate change and population increases make establishing core areas high priority if residents plan to continue their use of locally available wild resources.

The complex mix of existing adaptive strategies, vulnerability factors, and socio-ecological conditions that vary spatially and temporally means that simple, blanket solutions to reduce vulnerability to future environmental and social change will not work. Although the issues presented here are site specific, some of the policy implications drawn from my analysis have wider application. The environmental and social factors many indigenous and other traditional rural communities currently face act synergistically and residents do not manage each separately. The adaptive strategies residents of communities like Madjadjane and Gala practice work best in their home territory because they are based on personal experiences, knowledge, and cultural practices developed through long-term, human-environment interaction. As a result, people's preferences for remaining on ancestral lands are strongly tied to adaptive strategies that maintain food security under uncertain environmental conditions by accessing known resources that vary spatially and temporally across the landscape. Aid programs that build on local knowledge and experience help reduce vulnerability and increase adaptive capacity. Additionally, indigenous and traditional rural communities, like those in Matutúine District, are often "vital and active parts of many ecosystems and may help to enhance the resilience of these ecosystems" (Salick and Byg 2007: 4). Thus accommodating locally specific needs, national law, and international protection, while remaining sensitive to cultural and ecological diversity, requires understanding how local communities currently reduce their vulnerability to climate variability and asking for their assistance in planning for future climate change.

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CHAPTER 4

WHY ANALYZE LOCAL CLIMATE CHANGE MODELS?: A CASE FROM SOUTHERN MOZAMBIQUE[5]

[5] Shaffer, L.J. and L. Naiene. To be submitted to *Weather, Climate, & Society*.

Abstract

Local climate change models incorporate human perspectives and experiences of past climate events and changes. As a result, these models offer critical insight into locally important factors that trigger responses to new climate conditions and can be used to ground-truth regional climate models. In this paper, we explore perceptions and experiences of changes to local climate patterns and climate-associated environmental changes over the past 45 years (1963-2008) in two rural communities in Matutúine District, Mozambique. Measurable climate change in this region includes increasing temperatures and more erratic rainfall leading to drought and altered season timing. Residents discuss both short-term and long-term precipitation changes, as well as temperature increases and altered seasonal timing. The climate-associated environmental changes they have observed draw attention to links between local livelihood practices and climate. Such changes include reduced crop and wild fruit production, fewer cattle, variable forest size, increased wildfires and elephant raiding of crops, drying up of water sources, poor health, and cultural change. Differences between adjacent communities highlight the role of landscape variability in perceptions and experiences of climate change, and demonstrate how local climate change models can provide insight into local ecological patterns and processes.

Introduction

Faced with overwhelming evidence for global climate change, the focus of research and policy has shifted towards understanding the mechanisms driving climate change, the effects of climate change at regional scales, and how human communities must adapt in order to survive. However, the coarse resolution of current modeling efforts is frequently inappropriate for policy and intervention efforts. Global and regional scales fail to capture how local climate may vary over complex terrain. Some interactions between climate, environment, and human communities are not readily observed in the data sets used for regional climate models (Magistro and Roncoli 2001), and influential parameters affecting the reactions of individuals and communities as they encounter new conditions may be ignored, misunderstood, or remain unknown (Rayner 2003). As people interact with changing conditions, they construct models of climate change that reflect their perceptions and experiences. These models contain locally relevant climate and climate-associated environmental change parameters (Berkes 1999, Salick and Byg 2007). We suggest that analysis of such local climate change models can be used to ground-truth regional climate change models, as well as provide crucial insight into locally important parameters of change and human-environment interactions.

In this paper, we investigate local climate change models developed from observations made by swidden farmer-foragers living on the coastal forest-savanna mosaic of Matutúine District in southern Mozambique. These models are based on interviews with residents of two rural communities concerning their perceptions of climate change and experiences of its effects on their community and the local environment. We first compare the local model to climate data collected at a regional weather station from 1963-2008, and then explore the changes residents have observed and connections between these changes that residents make. Climate, particularly rainfall, plays a key role in regulating vegetation production and distribution in southern Mozambique (Rutherford and Westfall 1994). Subsistence dependency on domestic and wild vegetation suggests that residents of Matutúine District would therefore be keenly aware of any climate and climate-associated environmental changes that affect their survival. In light of projected impacts to food security and disaster risk for this region, specific details about how populations have been, and expect to be, affected by climate change are important for planning and policy.

Modeling Climate Change

Southern Africa's vulnerability to climate variability has promoted a strong research agenda investigating the effects of potential change, particularly on food security, the agricultural sector, and disaster management. Anticipated changes to regional climate patterns include average temperature increases of $1^{o}C$, greater drought frequency, a 10% decline in the total amount of rainfall, and changes to rainfall timing (Boko et al. 2007, Lobell et al. 2008). The resulting decreases in agricultural production threaten food security for rural and urban poor. By 2030 overall production of maize, a regional staple, is expected to decline roughly 30% (Lobell et al. 2008). During El Niño droughts, maize production could drop 20-50% - a loss equivalent to the amount needed to feed 15 million people for one year (Stige et al. 2006).

Narrowing the focus to southern Mozambique, predictions for increasing El Niño-Southern Oscillation (ENSO) strength and frequency, and thus bigger, more frequent, droughts emerge. ENSO strongly affects annual and interannual rainfall variation. Historic climate record analyses link ENSO to two-thirds of droughts in this region, and climate scientists suspect ENSO as the likely cause of increasingly erratic precipitation timing and amounts since 1984 (Coelho and Littlejohn 2000). The ENSO-related droughts affect food supply and water supplies. ENSO-related droughts and changed climate patterns are part of a suite of risks including cyclones, flooding, and disease outbreaks expected to severely degrade living conditions in southern Mozambique over the next 20 years (IRIN 2009).

Regional models identify key aspects of climate and environmental change that governments and aid agencies must address while preparing populations for change impacts. However, the resolution of these models treats regions as physically, ecologically, and culturally homogeneous (Magistro and Roncoli 2001). Casciarri's research in southeastern Morocco shows that nomadic herders and sedentary farmers living in the same valley perceive drought differently and use disparate, but interrelated, strategies to cope with this environmental stress (2008). Sometimes the needs of policymakers and resource managers to achieve intervention goals may further bias model parameters, data input, and analysis. For example, Raynor (2003) found that U.S. water managers are reluctant to include new climate forecast data, despite improvements to decision-making ability, if it meant accepting increased responsibility and blame for water supply failure. These model and user biases contribute to misunderstandings of significant climate and environmental changes at a human scale. Research with indigenous, and other traditional communities, indicates that local climate change models can be used to ground-truth regional models, provide crucial insight into locally important environmental processes not readily observed in data sets or at larger scales, and give commonly under-represented communities a voice in the greater climate change discussion (Nichols et al. 2004, Salick and Byg 2007). Differences in focus between regional and local climate change models suggests that their integration offers a more valuable, holistic view of past, present, and future human-environment relations.

The study of traditional ecological knowledge, or TEK, opens a door to perceptions and experiences that can speak to living conditions under changing climate conditions. Following Berkes, we define TEK as

> "a cumulative body of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment" (1999: 8).

This cumulative body is a site-specific model derived from long-term, human-environment interaction. The elements chosen for local analysis are those of primary importance to the production and survival of the community and its culture. Relationships between various physical, ecological, and social elements of the system as they interact with each other under changing climate conditions are also of interest for local modelers (Berkes 1999, Nichols et al. 2004, Salick and Byg 2007). Expectations of normal climate and environmental conditions may be explicitly stated or implied in the comparisons, generalizations, and conclusions people make about their experiences. Local climate change models, then, are a summative conception of all a community's traditional ecological knowledge (TEK) of climate based on their perceptions and experiences of past and ongoing climate variability.

Remote sensing studies use field-collected data to ground-truth, i.e. validate and calibrate, the content of images prior to analysis. In this sense, local models ground-truth regional models by verifying the presence and extent of climate changes. Residents of communities record trends and major events, often within the context of their livelihood activities. Climate change observations by farmers in China and Burkina Faso correlate closely to actual data trends despite extensive interannual rainfall variability which was predicted to cause confusion in their observations (Hageback et al 2005, West et al. 2008). Significant household-level economic diversification, migration, and long-term changes to agricultural practices by these farming communities demonstrate the extent and duration of climate change that analysis of regional models could not capture. In some cases, non-climate variables are the primary signals of change. Vedwan and Rhoades (2001) found that apple growers in northern India recognize changes in onset, duration, and intensity of snowfall relative to the affects on crop growth and production. Furthermore, local climate change models incorporate social stability, livelihood, and other social elements that are very difficult to capture in the homogeneity of regional models. Bharara documented the perception of Indian villagers that "[d]rought is not simply the dearth of rain (though everyone knows that rain would remove it) – it is the total quality of life, including, besides weather, animal behavior and social relations" (1982: 352). The inclusion of social relations, including loss of life from famine, labor migration to cities, conflict over remaining resources, and collapse of local economic activity, recognizes the far-reaching effects climate events and changes can have in tearing communities apart.

Human-Environmental Interaction in Matutúine District

Matutúine District, our study location, is part of Maputo Province and the southernmost district in Mozambique (See Figure 4.1). The 5,403 km^2 district begins south of Maputo Bay and is bordered by the Indian Ocean to the east, Swaziland to the west, and KwaZulu-Natal, South Africa to the south. We worked with residents of Madjadjane and Gala, two rural communities in this district. Residents of these small communities belong primarily to the Mazingiri Ronga ethnic group – 85% and 95% of Madjadjane and Gala respectively. Ronga occupation of Matutúine District dates back at least 500 years based on evidence from oral histories, archived documents, and archaeological materials (Bruton et al. 1980, Felgate 1982, Junod 1927). The local economy is based on a combination of swidden agriculture and foraging. Livelihood

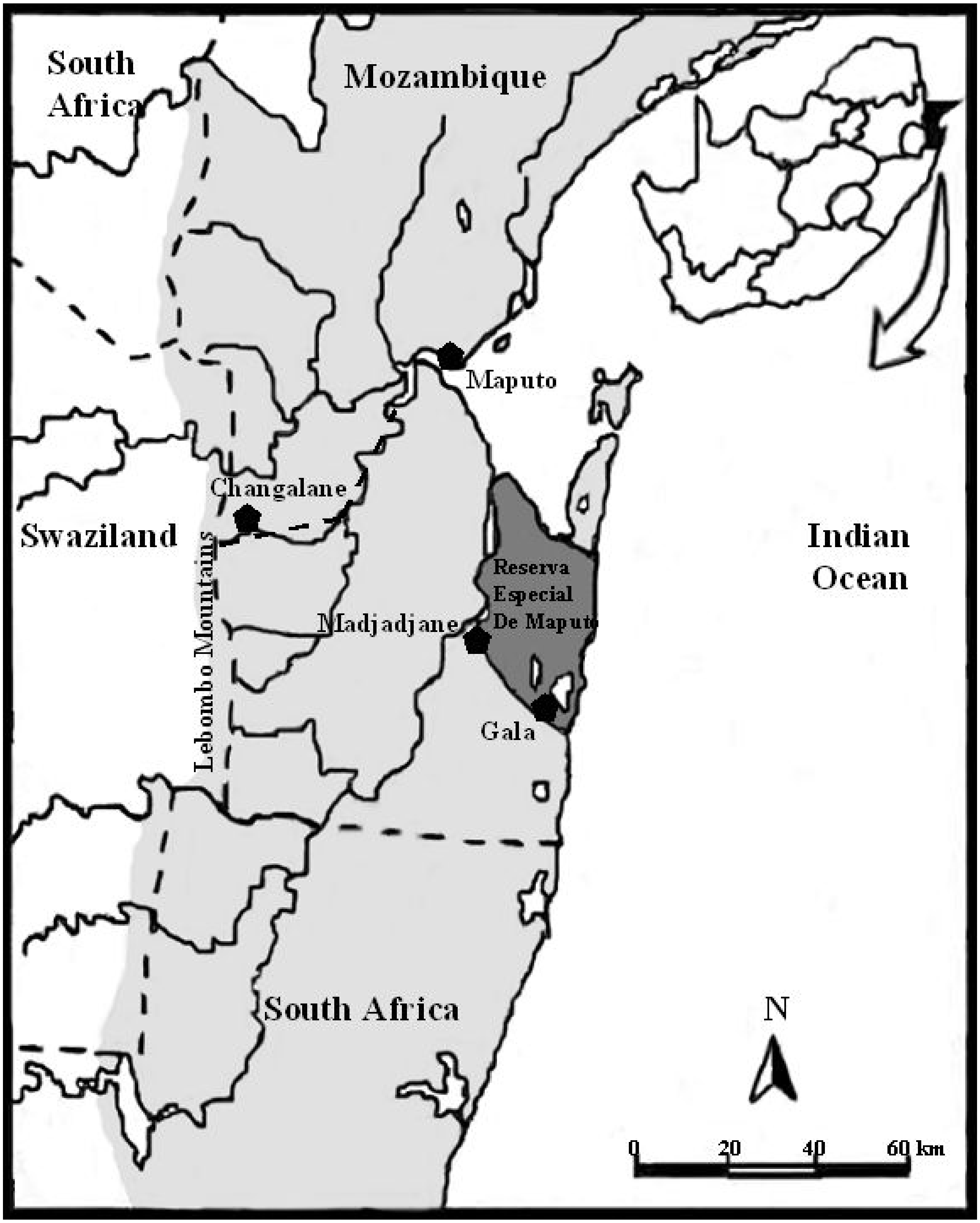


Figure 4.1 Map of Matutúine District, Mozambique. Dashed black line indicates district boundary within Mozambique. Light grey signifies the Maputaland Centre of Endemism and the dark grey is the Reserva Especial de Maputo. Madjadjane, Gala, and Changalane Weather Station are indicated with black pentagons.

activities like fishing, goat and cattle herding, mat and charcoal production, beekeeping, reserve work, and tourism supplement household resources and generate income. Intergenerational transmission of ecological and cultural knowledge remains strong, despite large population losses in these communities during the Civil War (1986-1992), because survival depends upon accessing a wide range of wild and domesticated resources through their mixed subsistence-based economy. New environmental knowledge enters Madjadjane and Gala through interactions with conservation organizations like the IUCN, primary schools, visiting scientists, and the Reserva Especial de Maputo, a protected area adjacent to both communities.

A mosaic of grassland, wetland, woodland and thicket, swamp forest, and rare sand forest covers the sand dunes comprising Matutúine District's landscape. Freshwater and brackish lakes, along with the Maputo and Futí Rivers, also contribute to ecosystem diversity and provide permanent water sources for human and non-human communities alike. Pans between the dunes hold water during wetter periods. This wide range of habitats contributes to the high diversity of flora and fauna found in the district. In fact, Matutúine District sits at the heart of the Maputaland Centre of Endemism, a 17,000 km^2 region containing 2500+ plant species including 225 endemic or near-endemic species and three endemic plant genera, 100 species of mammals, and 470 bird species including four species and 43 subspecies that are endemic or near endemic (Smith et al. 2008, van Wyk 1994). While only 19 km separate Madjadjane and Gala, the communities encompass a range of habitats available to residents for resource exploitation. Riverine woodlands, open woodland, and sand thicket and forest give Madjadjane, stretched along the Futí River, a predominantly woodland landscape. The predominantly grassland landscape of Gala incorporates open and wooded savanna, hygrophilous grassland, sand forest-woodland mosaic, patches of swamp forest, and the shores of Lakes Piti and Ntiti (DEIBI 2000).

Figure 3.2 shows average monthly precipitation and temperature for Matutúine District. Hot, rainy summers prevail from October to April when the Intertropical Convergence Zone (ICTZ), an equatorial low-pressure system, moves south of the equator, releases latent heat, and interacts with sea surface temperatures. The movement of the ITCZ north of the equator from May to September coincides with Matutúine District's cooler, drier winter conditions. An ~18 year oscillation, producing nine relatively dry years followed by nine relatively wet years, overlays the annual precipitation cycle. Tree ring analysis confirms the presence of this oscillation in rainfall variability over the past 600 years (Tyson et al. 2002). Rain generally falls heaviest along the coast (~1000 mm/yr) and on the eastern slopes of the Lebombo Mountains (~800 mm/yr). Madjadjane and Gala, located on the plains midway between the mountains and the coast, receive an average of 600mm annually (Tello 1972). Temperature and relative humidity remain roughly constant across the district. Temperatures average 25.3^{o}C during summer and 20.5^{o}C during winter. Annual relative humidity averages 68.7%.

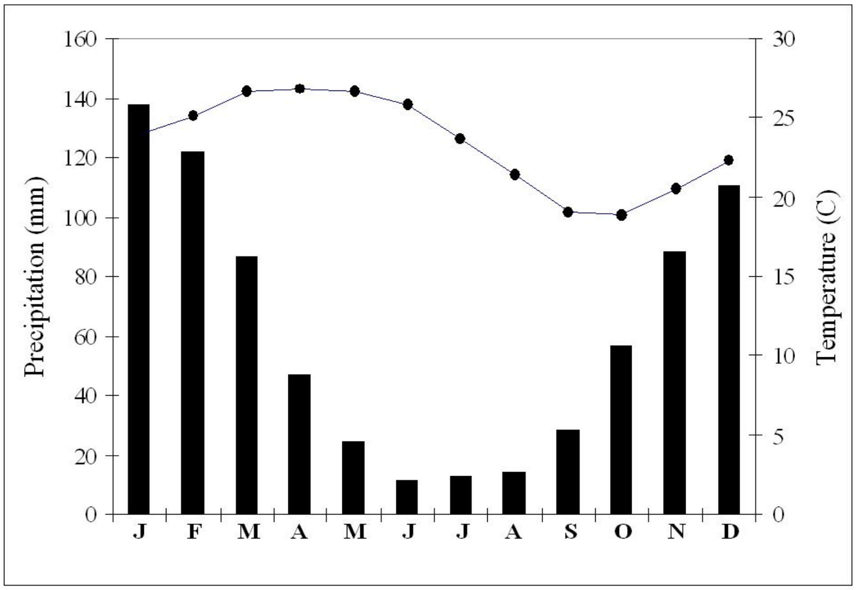


Figure 4.2 Climate data for Changalane Weather Station, Mozambique. Monthly means are based on measurements taken from 1963-2008. The total annual average precipitation at Changalane is 739.04 mm. Black bars indicate mean monthly precipitation in millimeters, measured along the left y-axis. The dotted line indicates mean monthly temperature, measured along the right y-axis.

Climate significantly affects both the ecological and human communities of Matutúine District. Average precipitation levels, particularly on the plains, hover around the transition from moist to arid savanna[6]. This precipitation ecotone likely contributes to high biodiversity, and gives district residents access to diverse subsistence options. However, the timing and amount of rainfall also regulates vegetation production. Rainfall at the beginning of summer in October stimulates the annual growth of wild plants and signals people to clear fields and plant crops like maize, cassava, peanut, and pumpkin. Additional rain over the months that follow determines actual production quality and quantity (Shorrocks 2007, Stige et al. 2006). Risks from interannual variation in precipitation to wild and domestic production ensure that most residents practice both swidden agriculture and foraging, but all local livelihood activities are climate

[6] The savanna transition zone is roughly 530mm to 650mm of precipitation annually. Arid, base-rich savannas receive less than 650mm of rain while moist, nutrient-poor savannas receive more than 530mm of rain (Rutherford and Westfall 2003).

sensitive in that they depend on vegetative production. Dry years are hard on rainfed production, and drought wipes out crops completely. People use wild plants and purchase what food they can afford to make up the difference. However, during very bad drought or flood years both domestic and wild plant sources can fail placing all livelihood activities at risk. At these times residents may also ask for help from family in South Africa and Maputo or migrate to these places for paid labor in the agricultural, mining, and service sectors.

Methods

Climate Data Analysis

Due to the coarse resolution of regional models and the need to gauge the possible range of informant responses, we first investigated specific climate changes in Matutúine District. Monthly temperature and precipitation data for 1963-2008 at Changalane Weather Station were obtained from the Instituto Nacional de Meterologia in Maputo, Mozambique. Changalane Weather Station provides information for climate forecasting of inland areas in Matutúine District. Changalane receives slightly greater rainfall than Madjadjane and Gala because it lies in the foothills of the Lebombo Mountains rather than the midst of the savanna plains. This also means that some of our calculations, like T/P ratio, cannot account for microclimate heterogeneity at the field site. While actual instrumental measurements likely differ between the weather station and the study site, our analysis compares data trends and informant perceptions of climate trends.

Prior to analysis, monthly data were reorganized to better reflect local conceptions of annual cycles so that comparisons could be made with interview data. The year for local farmers begins in October, the traditional start of the growing season when the rains arrive, rather than January, the middle of the growing season. In our analysis, year 1963/64 begins October 1963 and ends September 1964. For analysis purposes, summer lasts from October to April, winter lasts from May to September, and the early growing season months are October, November, and December.

We calculated average annual temperatures for summer and winter, generated a scatterplot of the values, and ran a simple linear regression to determine if significant changes in temperature had occurred. A similar analysis was conducted for temperatures in the early growing season months. Overall temperature changes for 1963-2008 are based on the line that best fits the temperature scatterplots.

The Standard Precipitation Index (SPI) provides a simple assessment of precipitation by comparing monthly, seasonal, or annual precipitation to the long-term average for that same time period (McKee et al. 1993). A minimum of 30 years of data is needed to provide a solid comparison. Index values of –1 to 1 signify normal climate conditions, values less than –1 indicate dry to drought conditions, and values greater than 1 indicate wet to flooded conditions. SPI comparisons correlate indirectly to livelihood needs in that minimal local water requirements are met under normal to wet conditions. The SPI is useful because it can be assessed and compared at different time scales, requires only one input variable thereby reducing error, is spatially consistent, and provides information on precipitation deficit and expected drought frequency (Guttman 1998, McKee et al. 1993). We calculated annual, seasonal, and early growing season SPI values and plotted the values as a smooth line.

Lacking access to daily precipitation data and dates for the start of the annual rains, we used T/P ratios as a coarse season proxy. The T/P ratio, an index of potential water availability to plants, is a measure of the environmental conditions to which plants must adapt over the long-term. Higher ratio values signify lower potential availability of water. This ratio is not as precise as the ratio of potential evapotranspiration to precipitation, however no assumptions concerning local biotemperature and vegetation adaptations are required in this straightforward calculation (Brown and Lugo 1982). We computed seasonal and early growing season T/P ratios, generated a scatterplot of the values, and ran a simple linear regression to look for significant changes. Months receiving no rainfall were given precipitation values of 0.001mm so that the analysis could be made. Finally, a Pearson's correlation test was run on temperature and precipitation data for October, November, and December to determine if any significant relationship existed between the two variables.

Building and Analyzing Local Climate Change Models

Semi-structured interviews with 28 residents of Madjadjane and Gala were conducted in Ronga, the local language, and translated into Portuguese for analysis. Men and women – aged 30 to 100 – answered open-ended questions about local climate and climate-associated environmental changes, as well as the causes and consequences of climate change. Each type of change mentioned by respondents was coded as a variable for quantitative and qualitative analyses. We also recorded informant age, gender, birthplace, and the time a person had lived in the community where they were interviewed. Initially we chose to interview community elders because of their long interaction with the environment in this region. Later, some of the elders suggested interview candidates they felt had relevant expertise and knowledge. Our use of an open-ended question structure likely led to more conservative results. No informant was directed to comment on specific aspects of change, so more informants could have observed a change than were recorded as having observed a change.

To construct the local climate change models, we ran a two-step cluster analysis on all change-related and demographic variables. Two-step cluster analysis is a useful tool for finding optimal groupings of variables that best explain collected data, particularly when one has both continuous and categorical variables and is interested in exploring the relationships between them (Kaufman and Rousseeuw 2005). Each cluster produced by the two-step analysis represents a local climate change model. An Akaike Information Criterion (AIC), AIC change (ΔAIC) and Akaike weight (w_i) were calculated for each set of clusters the two-step analysis produced. AIC is a rigorous, statistically solid method that focuses on the strength of the evidence to assess which of the cluster sets contains the simplest and most informative groupings of variables. Because it is not hypothesis driven, AIC conserves as much information as possible and intuitively chooses the optimal number of clusters (Burnham and Anderson 2001, Wagenmakers and Farrell 2004). Lower AIC values signify better variable clustering, while ΔAIC measures each cluster set relative to the best cluster set. The w_i indicates the probability that the cluster set chosen is the best among all possible candidates.

We employed a grounded theory approach to analyze interview text and flesh out the local climate change models that our two-step cluster analysis produced (Corbin and Strauss 1990). As mentioned above, we based our thematic codes on the types of climate and environmental change residents mentioned. We then used further interview text analysis to assess how people connected climate changes and climate-associated environmental changes. Additional text analysis concerning the causes and consequences of climate change looked at the interaction between local beliefs and climate-associated environmental change.

<u>Analyzing Local Climate Change Models</u>

By using two-step cluster analysis we determined that the optimal number of clusters for informant change variables was three (See Table 4.1). This grouping of clusters has an AIC value of 552.597 (ΔAIC = 0, w_i = 0.96). Each cluster of variables represents a local climate change model and the community variable was the only significant factor separating two of the clusters. Figure 4.3 shows the local climate change models represented by each cluster of variables that sorted along community lines. The third model is not depicted because it contains all the variables, in effect combining Models 1 and 2. Model 1 represents all 16 informants from Madjadjane and one informant from Gala, and Model 2 represents the remaining 11 informants from Gala.

Table 4.1 Two-step clustering results with Akaike Information Criterion (AIC) values.

Number of Clusters	**AIC**	**ΔAIC**	**w_i**
1	634.125	81.528	1.91×10^{18}
2	560.432	7.835	0.02
3	552.597	0	0.96
4	560.336	7.739	0.02
5	572.186	19.589	5.36×10^{5}

Model 1: Madjadjane

Climate Changes:
- Short-term drought
- Over the long-term, the timing of the rains is erratic and there is less rain overall
- Temperatures are increasing

Environmental Changes:
- Crop production has declined
- Total way of life has changed
- Increased elephant raiding of crops
- Forests are smaller
- Wild fruit production has declined
- Less water in nearby rivers and wells
- Health problems/disease has increased
- Forests are bigger
- Population has increased
- New plants have appeared
- Agricultural pest appeared after 2000 floods

Demographic Characteristics:
- Madjadjane resident
- Lived in community on average 52.2 years
- Average age is 62.9 years
- Predominantly female (70.6%)
- Born in Madjadjane (58.8%), Gala (17.6%), Matutúine District (100%)

Model 2: Gala

Climate Changes:
- Short-term drought
- Over the long-term, the timing of the rains is erratic and there is less rain overall
- Temperatures are increasing
- Seasonal timing has changed

Environmental Changes:
- Crop production has declined
- Total way of life has changed
- Increased elephant raiding of crops
- Forests are smaller
- Wild fruit production has declined
- Fewer cattle
- Wildfires more common
- Population has decreased
- Fewer wild animals present

Demographic Characteristics:
- Gala resident
- Lived in community on average 32.8 years
- Average age is 58.7 years
- Predominantly male (72.7%)
- Born in Gala (27.3%), Madjadjane (9.1%), Matutúine District (81.8%)

Figure 4.3 Local climate change models for Matutúine District, Mozambique.

Ground-Truthing Climate Change

We used analysis of local weather data and informant responses to a question about observed climate changes to ground-truth regional climate change models and explore community experiences of change. Everyone interviewed recognized that they are in the midst of a shorter-term drought/dry period. The annual SPI plot, Figure 4.4A, shows drier years beginning with a drought in 2003/04 and ending with the beginning of a drought in 2007/08. As expected, most annual SPI values fall within the normal range of -1 to 1 for 1963-2008. However, beginning in 1983/84 the oscillation extremes get larger and the dry periods longer. The plot of seasonal SPI, Figure 4.4B, also demonstrates this change in the long-term precipitation cycle. Figure 4.4C, depicting early growing season SPI, displays a weaker signature for long-term change. Since 2000/01 October rainfall has been low in comparison to November's rain. Roughly 71% of all residents in both communities mentioned that over the long-term, the timing of the rains has become more erratic and that precipitation has declined. A Madjadjane farmer, born and raised in Gala, said people generally expect big floods every 10-15 years, but that the rains have become less predictable since 1980. A 100-year-old respondent believed the current drought to be just a part of the regular cycle of wet and dry periods. Although the older farmer from Madjadjane did not mention the change to the expected long-term rainfall pattern, her observation highlighted the local recognition of a long-term rainfall oscillation.

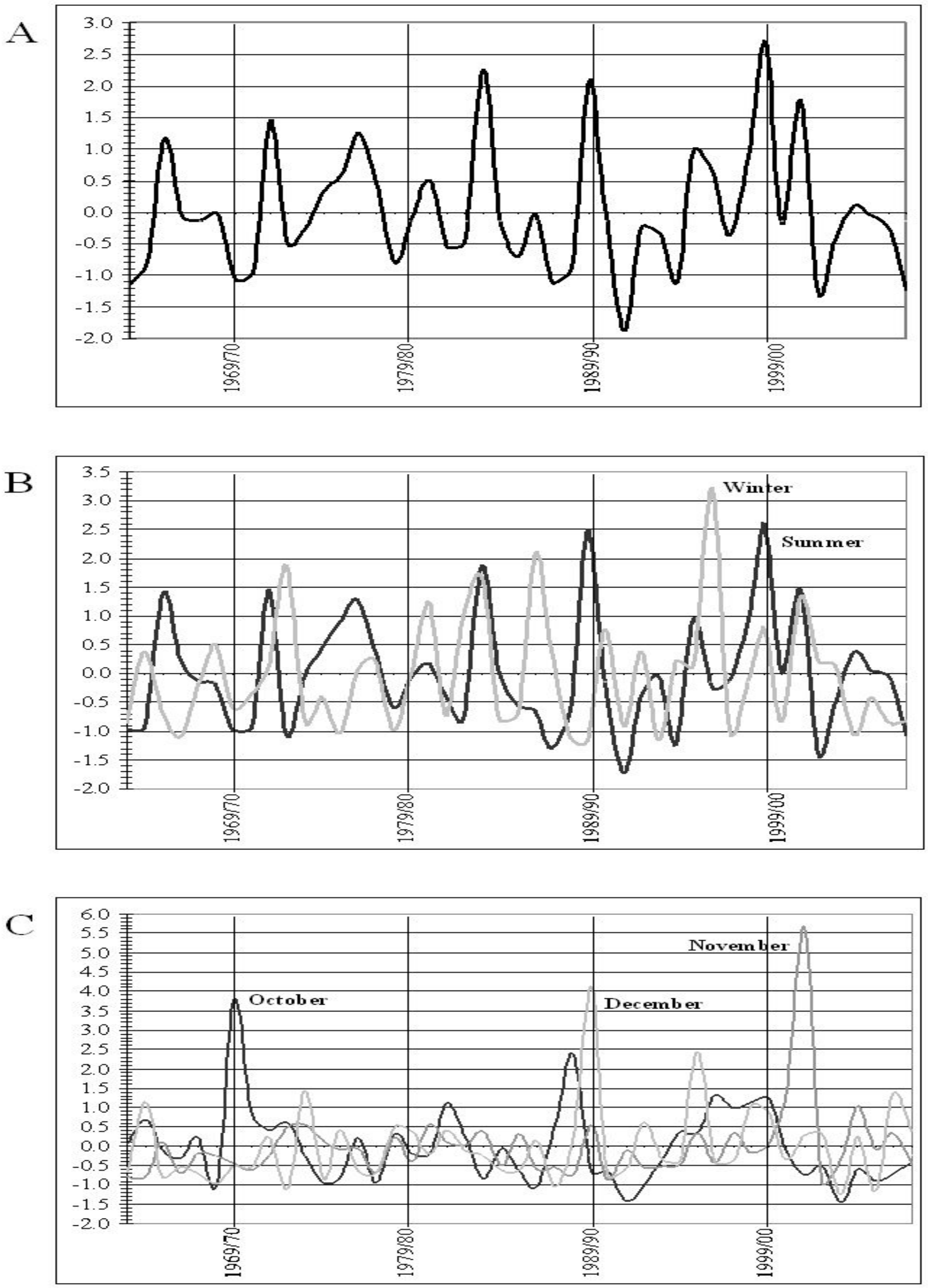
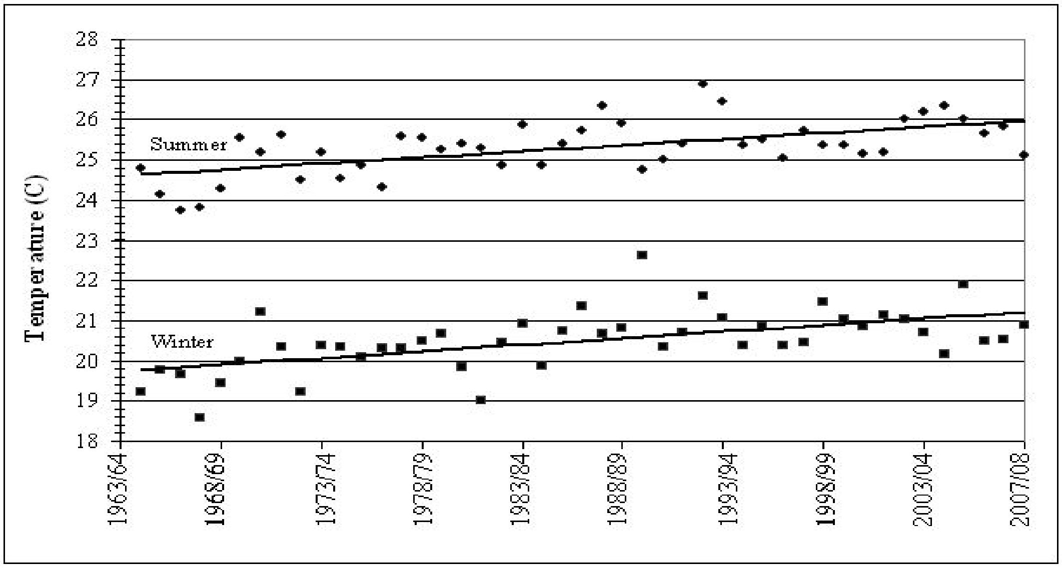


Figure 4.4 Standard Precipitation Index (SPI) data for Changalane Weather Station, Mozambique 1963-2008. SPI values are found on the y-axis and years on the x-axis. Values –1 to 1 are considered normal, above 1 indicate wet to flooded conditions, and below –1 indicate dry to drought conditions. (A) shows the annual SPI values. (B) shows seasonal SPI where winter is a grey line and summer a black line. (C) shows SPI values for the early growing season months where October is a black line, November a grey line and December a light grey line.

All informants noticed rising temperatures. Figure 4.5 shows significant temperature increases at Changalane Station between 1963 and 2008. Summer temperatures have warmed an average 1.4^{o}C, while winter temperatures have warmed an average 1^{o}C (Figure 4.5A). Temperatures in the early growing season months have also risen significantly over this 45-year period (Figure 4.5B). The average temperature rose 1.7^{o}C, 2.1^{o}C, and 1.1^{o}C in October, November, and December respectively. People observed that the heat killed crops, grass, trees, and other plants through desiccation. Some link the temperature increases to precipitation declines and believe that higher temperatures cause droughts. "Now it does not rain. It is all dry. In the past it rained a lot. The heat is not the same, now it gets very hot. A lot of heat causes drought" [farmer, Gala].

A



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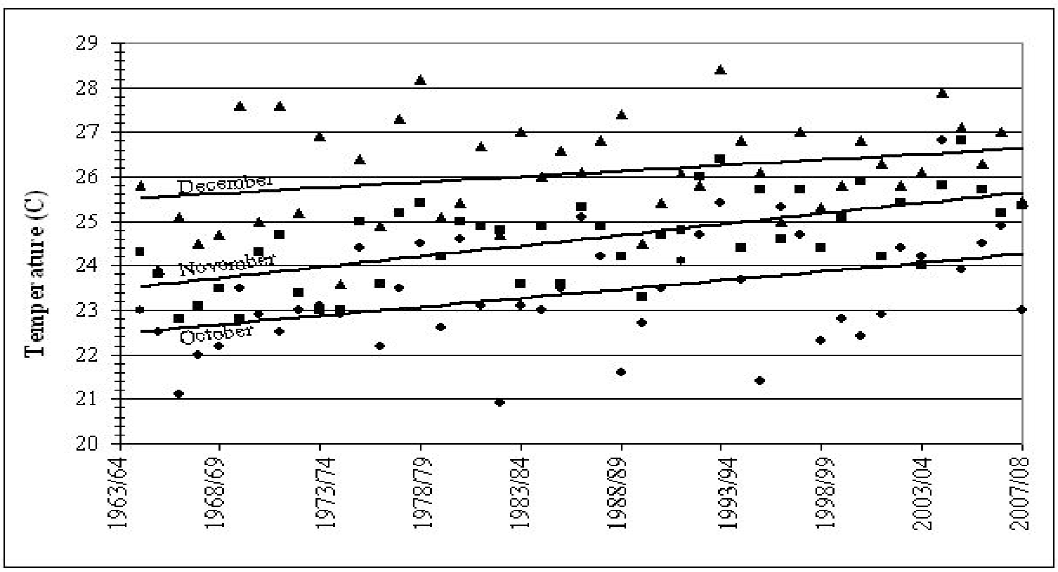

Figure 4.5 Average temperatures for Changalane Weather Station, Mozambique 1964-2008. Years are found on the x-axis. (A) Mean seasonal temperatures show a 1.4°C increase for summer (circles/top, $y = 0.0305x + 24.6$, $R^2 = 0.351$, $p < 0.000$) and 1°C increase for winter (squares/bottom, $y = 0.0323x + 19.8$, $R^2 = 0.322$, $p < 0.000$). (B) Mean temperatures for the early growing season show a 1.7°C increase for October (circles, $y = 0.0397x + 22.5$, $R^2 = 0.18$, $p < 0.004$), a 2.1°C increase for November (squares, $y = 0.0482x + 24.6$, $R^2 = 0.403$, $p < 0.000$), and a 1.1°C increase for December (triangles, $y = 0.0252x + 25.5$, $R^2 = 0.086$, $p < 0.051$).

As Model 2 shows, only Gala residents talked specifically about altered timing of seasons, particularly focusing on when the rains are supposed to arrive versus when they actually arrive. “Now we don’t always know when the rains will start. The rains should start in October. And if it rains well, people will begin planting their fields” [chief, Gala]. Analysis of the T/P ratio showed no significant seasonal differences (See Figure 4.6A). October’s trendline in the T/P ratio plot for the early growing season increased, but not significantly (See Figure 4.6B). The October trendline reflects a rising average temperature with concurrent decrease in precipitation for this month. Furthermore, bivariate correlation analysis of temperature and precipitation produced a Pearson’s value of –0.481 ($p < 0.01$) for October and –0.361 ($p < 0.05$) for December. No significant correlation was found for these variables in the November data. The combined temperature and precipitation results for the early growing season suggest a weak, but not significant, trend towards a shift in the beginning of summer from October to November. The best evidence for changes to the timing of seasons comes from local rainfall observations of drier Octobers and wetter Novembers compared to growing season SPI values (Figure 4.4C). This suggests that for locals, precipitation timing is more important than temperature in signaling season timing.

Differences Between Local Climate Change Models

Residents attribute a wide range of environmental changes to climate change, and significant differences exist between models. Of the cases included in Model 1, 41.1% observed no climate-associated environmental change and instead attributed local environmental changes to the Civil War or its repercussions. Remaining differences between the models stem from observations mentioned by only one or two individuals in each community.

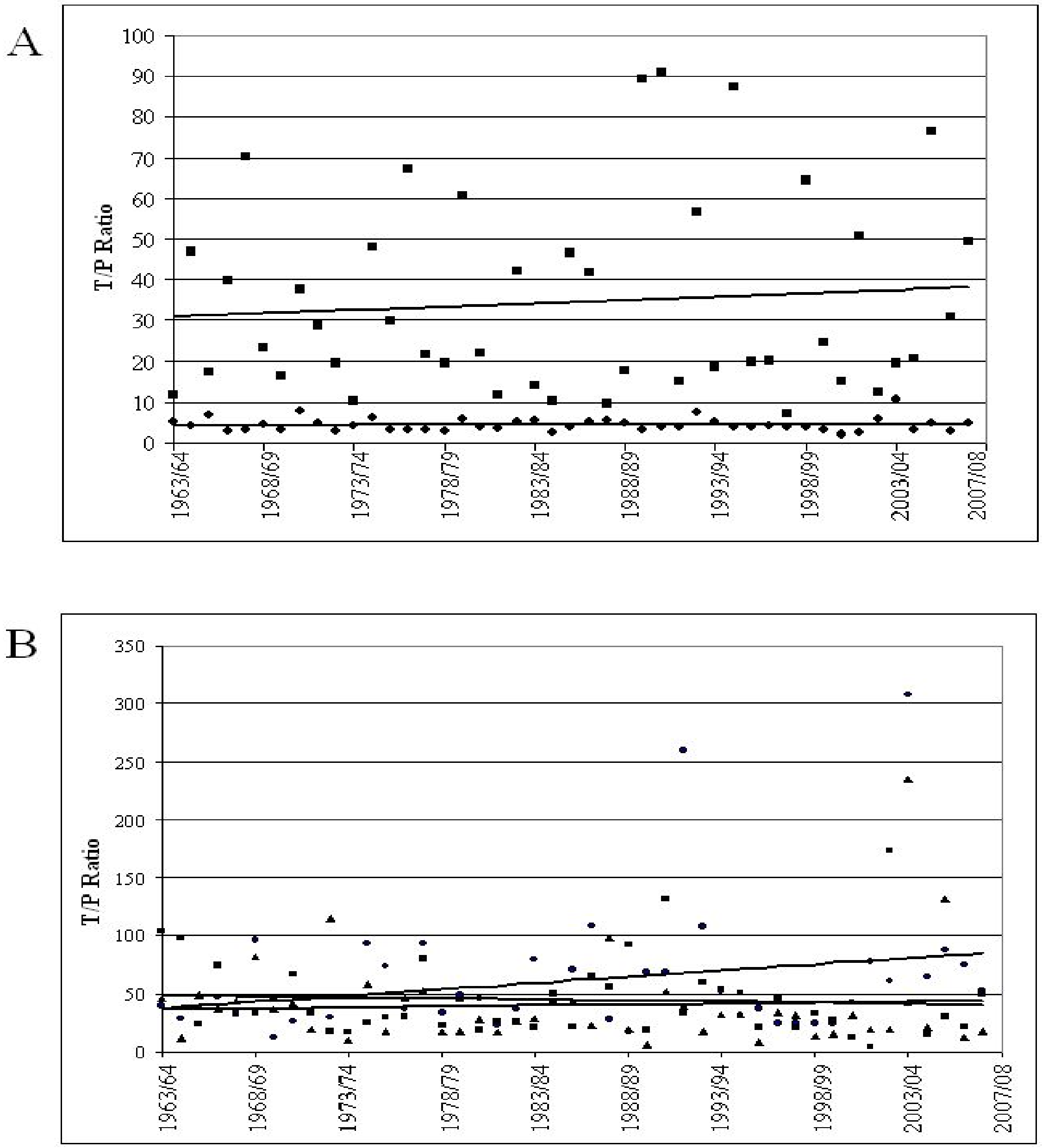

Figure 4.6 Index of potential water availability (T/P) for Changalane Weather Station, Mozambique 1963-2008. The greater the ratio value, the less water available to plants. Years are found on the x-axis. (A) The seasonal T/P Index show no significant changes for summer (circles/bottom, $y = 0.006x + 4.2$, $R^2 = 0.003$, $p < 0.725$)) or winter (squares/top, $y = 0.1397x + 32.3$, $R^2 = 0.006$, $p < 0.61$). (B) The early growing season T/P index shows no significant changes for October (circles, $y = 1.0789x + 37.5$, $R^2 = 0.066$, $p < 0.087$), November (squares, $y = -0.1834x + 48.5$, $R^2 = 0.005$, $p < 0.638$), or December (triangles, $y = 0.1574x + 36.4$, $R^2 = 0.003$, $p < 0.735$).

Changes specific to Model 1, and observed by 58.9% of residents, include observations of decreased river flow and groundwater, increased health problems, growing forested areas, more people in the community, the presence of new plants, and an invasive agricultural pest. Water availability is tied to both agriculture and health. “Now it does not rain. Before people did not buy food. They ate vegetables grown at home, but now they do not” [farmer, Madjadjane]. The chief of Madjadjane, in consultation with the community elders, told people to move their homes and fields closer to the Futí River in 2002/03 because of the drought. He explained that normally people do not cultivate directly adjacent to the river due to wildlife conflict and flooding issues, but during the drought and drier periods water for crops can be found adjacent to the river. People spend less time collecting water when they live closer to a reliable water supply. Many of the wells dug by the government and aid agencies are dry during the dry winter and remain dry during summer droughts. At the same time, river water consumption contributes to increased rates of diarrhea, dysentery, and water-borne parasites (T. Mutombene, personal communication, 17 March 2009). However, the elder Gala resident and Madjadjane’s chief who mentioned poor health tied it to hunger from lower food production. Two residents reporting forest growth in Madjadjane believe the increases are due to fewer people clearing fields for agriculture. The combination of drought and wildlife conflict has made many hesitant to invest the time and effort needed to clear large areas for cultivation. The one person mentioning population increases did not explain why she believed they were connected to climate. A single farmer in Madjadjane observed the presence of new plants and an insect. She stated that flooding in 2000, associated with Cyclone Eline, made different plants grow and brought in a type of ant that destroyed maize and cassava plants by eating the leaves.

Environmental changes specific to Model 2 included smaller forested areas, fewer cattle, increased wildfire frequency, fewer people, and fewer wild animals. Gala residents attribute reduction in forest size to flood destruction and increased wildfires. "At the height of the floods [2000], some trees died. The floods destroyed a lot of trees" [farmer/builder, Gala]. "The forest is devastated by uncontrolled burns" [farmer, Gala]. Drought and dry periods increase wildfire risk due to a drying out of fuel and Gala's predominantly grassland habitat provides prime fuel for wildfires. The current drought makes cattle replacement at this time extremely difficult, even if residents were financially able to replace lost herds. "The cattle did not go hungry in the past as there was rain – no problems with drought" [farmer/herder, Gala]. Herders move cattle regularly to take advantage of good forage. Without rain, the grasses cannot regrow quickly or extensively following grazing. Another herder explained, "During droughts, many things die for lack of water including the grasses. It is a very dangerous time for cattle. They become thin." This lack of forage also affects wild animal populations. Finally, Gala's chief connected population some declines to the 2000 floods following Cyclone Eline. Thirty families returned to Gala between the end of the Civil War in 1992 and Cyclone Eline. After the floods, five families moved to South Africa.

Locally Important Environmental Changes Shared by Communities

While importance varies, people in both communities spoke of declining crop and wild fruit production, and increased crop raiding by elephants. "In the past it rained. They cultivated and ate. But now fields are not cultivated because of the animals and the lack of rain" [farmer, Gala]. Historically, all the food consumed within the household was harvested from family swidden plots or the bush. Drier Octobers affect the quality and quantity of crop and wild fruit production by delaying planting and blossoming. The decline in crop production can be tied to decreased crop diversity as well. “People grew more maize and timbaweni (*Vigna unguiculata*) because there was more rain. There are certain crops people don’t grow because there isn’t enough rain. We have the seeds, but we don’t grow them” [farmer, Madjadjane]. Another farmer mentioned that long-term drought weakens fruit trees leaving them open to insect infestation and eventually death.

Residents face further risk from crop raiding and sharing of wild resources during dry and drought periods. Drought-induced declines in wild grass quality have been shown to trigger crop raiding by elephants (Osborn 2004). Additionally, elephants and humans eat many of the same wild fruits found in Matutúine District (Shaffer 2005). Wildlife conflict is a perennial problem in these communities. While many animal species raid fields and consume wild fruits, residents consider elephants to be the worst offenders. Elephants eat the crops and wild fruits, and destroy wild fruit trees by breaking branches or pulling the tree up. Local farmers may hunt the bush pigs (*Potamochoerus larvatus*) that raid their fields. However, residents rely on the adjacent reserve to chase the animals back behind electrified fences as it is illegal to hunt elephants. Only when particular animals repeatedly bypass the fence to raid crops and harass farmers are they destroyed and the meat shared out with the community. Interestingly, three of the four farmers observing increased elephant activity perceived only short-term drought - corroborating Osborn’s observations in Zimbabwe (2004).

Changes to the traditional way of life are highlighted in both models. Our fieldwork revealed that changes to food production and rain ceremonies are likely sources of this view. Swidden agriculture and foraging of wild foods are not the only livelihood activities at risk from climate change. Further conversations revealed that drought and drier periods increase risks for other livelihood activities such as herding, mat and charcoal production, construction, and honey harvests by desiccating and killing the plants that these practices depend upon. Fishing livelihoods may be disrupted, as competition with crocodiles (*Crocodylus niloticus)* for fish increases when rivers and lakes dry up during drought. In some cases, family members migrated to South Africa to earn money and buy food to send home.

Our last question about the consequences and causes of climate change revisited the discussion concerning the transformation of local culture and disruption of residents' way of life by climate change. Residents (89%) believe they face famine and eventually death because of the long-term changes to expected precipitation patterns. The remaining three respondents stated that only God knows what will happen. Residents received government and international food assistance during the 1992 droughts and the occasional gift from religious organizations, but locals state they cannot depend on outside aid. As several different individuals explained, much of the aid is used by urban populations in the capital and what little makes it out to rural areas goes to residents of bigger towns first because the big trucks do not travel out into the bush. Therefore, local residents continue to rely on their traditional livelihood practices, migratory labor, and accumulation of new knowledge and skills to survive. Yet if climate conditions alter to the point where these practices can no longer continue famine, cultural disintegration, and death is possible.

Two residents cited global climate change as the reason for rising temperatures and unpredictable rainfall. These residents interact frequently with aid agency staff and government workers both in the district and the capital, thereby giving them access to outside educational resources. Three respondents blamed God, conflict between neighbors, or stated they did not know why. The majority of respondents (81%) blamed local climate changes on a lack of rain ceremonies or improper rain ceremonies. Their response revealed the integration of local climate TEK with a traditional Ronga worldview of climate, culture, and community management.

Rain ceremonies are held at the end of winter in August or September, and in mid-summer, early to mid February, at the same time as the canhu (*Schlerocarya birrea*) festival. The purpose of these ceremonies is to ask the chiefly ancestors to intercede with God for rain and to thank the ancestors for the help that they have already given. Events surrounding Mozambique's Civil War (1975-1992) and subsequent nation building altered four key aspects of rain ceremonies in Matutúine District during the timespan of our climate data set. During Mozambique's Civil War, no ceremonies were held. The national government forbade all traditional religious practices as part of their modernization efforts, and in many cases it was too dangerous for the community to gather anyway. When the war was over, people returned to Matutúine District and re-established the rain and canhu ceremonies. However, in some places the old chief had been killed and the chief's sons were killed, too young, or did not wish to return to rural Mozambique. As a result, the new chief was not of the right lineage and therefore did not have the right to call on the ancestors for help. During the war, both FRELIMO and RENAMO commandeered local cattle herds to feed troops while they were stationed in the district. Poverty and reduced fodder quality due to drought and dry conditions limited herd replacement after the war. Ronga rain ceremonies require the ritual sacrifice of a bull, so proper ceremonies could not be conducted following the war. Lastly, opportunities and culture outside Matutúine District continue to influence the outlooks of younger community members. As one older resident explained, the ancestors were first angered by a lack of ceremonies and now are angered by the lack of chief of the correct lineage, a proper sacrifice, and the attitudes of the younger generation that do not take the ceremonies seriously. Therefore, the ancestors will no longer help their children to survive and prosper.

Why analyze local climate change models?

The use of local perceptions and observations to ground-truth regional models allows the verification of the extent of climate change, identifies locally important factors of change, and offers insight into the experience of living under changing conditions. In our study, we found that local residents recognize the long-term precipitation oscillation described by Tyson et al. (2002), and that some noted this expected pattern became unpredictable in the 1980s as Coelho and Littlejohn (2000) report. Residents also verified a trend of temperature increases, and suggested that first summer rains, initiating the growing season, are beginning later. These observations were made in the context of livelihood activities where residents use their knowledge of expected climate patterns to make decisions about household production. Their experience of increasingly erratic rainfall patterns reinforces the idea that climate change severely compromises the abilities of individuals and communities to sustain themselves as they have traditionally and historically.

Residents generally describe change with an emphasis on the social part of the socio-ecological system in which they live. However, their observations and perceptions also touch on local ecological patterns and processes and can reveal connections between parameters of change that are not obvious in regional models. As our analysis shows, local models show that the reductions in household food production predicted by regional models result from a combination of delayed clearing and planting of fields, delayed blooming of wild fruit trees, groundwater and river flow losses, low quality forage for livestock and wildlife, increased crop raiding by elephants, invasive species, and lost labor capacity stemming from out-migration, hunger, and disease. Ripple effects in household production can be seen in reduced honey harvests from delayed and reduced blossoming, in the destruction of useful trees and livestock forage by increasingly frequent wildfires, and in growing competition with crocodiles for fish as the rivers and lakes dry up. Discussions surrounding community rain ceremonies revealed the importance of historical context and the indirect effects of war on traditional cultural practices, local economic activity, and long-term vulnerability to climate change. The range of ecological and social disruptions engendered by climate change supports the belief of local residents that their entire way of life has changed.

Differences between community models arose during our analysis, and research on cross-cultural coping strategies proposes a possible source of these differences. When solutions to an environmental problem are beyond the scope of individuals or communities to solve, people may manage their distress over a loss of control through wishful thinking or optimism bias (Nerb et al. 2008). People exhibiting an optimism bias tend to perceive that positive events are more likely to happen to them and negative events more likely to happen to others. Those employing a wishful thinking strategy will underestimate or ignore the problem. While we cannot rule out the possibility entirely, we find the fact that only Madjadjane residents reported no climate-induced environmental changes suspicious. We would expect Gala residents, who share family, history and cultural ties with Madjadjane, to also report no changes if they were exhibiting an optimism bias or practicing wishful thinking. Additionally, the climate and environmental changes residents in both communities reported were having negative effects on livelihood activities and traditional cultural practices. Therefore, we put forward a more environmental explanation.

We suggest that differences between communities in the perception of altered season timing and climate-induced environmental changes may be the result of differences in residents' day-to-day experience with predominant surroundings. Madjadjane's woodland habitats stretched along the Futí River are very different from the predominantly grassland environs surrounding Gala and the nearby lakes of Piti and Ntiti. Residents are observing the changes during daily interaction with their surroundings to harvest foods and materials necessary to the survival of their families and themselves. Furthermore, tree cover, access to water, and the spatial distribution of resources likely affect perceptions of change. Changes in tree-dominated vegetation along permanent waterways may be subtler and require large changes to become apparent. However, grass cover dieback and drying up of scratch wells or water holes in a drier grassland area might reinforce faster recognition of environmental changes driven by climate.

It is possible that Madjadjane's model represents a woodland climate change model and that Gala's model represents a grassland model for this district. Given that Matutúine District occupies almost 32% of the land area at the heart of the Maputaland Centre of Endemism, it would be worthwhile to compare climate change models produced in other woodland and grassland communities in the Centre with Madjadjane's and Gala's models to determine their relevancy at a larger scale. Southern African flora and fauna will be affected by predicted climate changes. Climate models suggest significant range shifting by terrestrial animals from west to east throughout the entire region (Erasmus et al. 2002). In KwaZulu-Natal, South Africa, a combination of climate change and current land use threatens dune, sand, swamp, riverine, and lowland forests with significant area reduction and extinction (Eeley et al. 1999). These same forest types are found just north of KwaZulu-Natal in Matutúine District. Although land use practices and human population density differs on the Mozambican side of the border, local climate change models from Matutúine District could improve the models used for regional conservation planning purposes.

Analysis of local climate change models offers insight into changes and connections that global and regional models cannot capture. None of the climate changes residents of this region have experienced between 1963 and 2008 may seem exceptionally large or significant when read as numbers in a report. Yet when the rains fail, the successful practice of local livelihood activities and the functioning of ecological processes in Matutúine District deteriorate quickly. As one fisherman in Gala stated, "Nothing can be done without rain." In this paper, we examined local climate change models to explore the predictions of regional models and improve understandings of how climate and environmental parameters interact to generate change at the local level. In the process of our analysis, we discovered locally important changes that would likely not have appeared in regional models.

Decision-making under uncertain environmental circumstances requires knowledge of past and present conditions to make the predictions of expected conditions needed for planning considerations. The predictions generated by regional climate change models provide useful information to start thinking about intervention and adaptation. However, the models' coarse resolution averages effects across the landscape regardless of existing physical, ecological, and cultural diversity. We propose complementary analysis of local climate change models as a way to access the more specific data required for the production of focused policy and decision-making. Site-specificity of the detailed observations used to generate a local model cancels the averaging effect seen in regional models and establishes what locally important changes will need to be addressed for successful intervention and adaptation.

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CHAPTER 5

INDIGENOUS LANDSCAPE MANAGEMENT AND ANTRHOPOGENIC FIRE DISTURBANCE OF COASTAL SAVANNA IN SOUTHERN MOZAMBIQUE[7]

[7] Shaffer, L. J. To be submitted to *Fire Ecology*.

Abstract

Prescribed burn regimes for protected areas in Southern Africa are often based solely on modeling of historic data and onsite experimentation. Most rural communities in this region continue to rely on fire to manage natural resources for subsistence needs, yet relatively few detailed studies of local fire knowledge and practices exist. The long history of anthropogenic fire disturbance in Southern Africa suggests that traditional ecological knowledge of fire could provide further insight into location-specific anthropogenic contributions to fire-savanna interactions. This study used an ethnographic approach to investigate how local people think about and manage fire as part of their daily activities in two rural communities in Southern Mozambique. Residents use fire for a range of livelihood activities and identify both controlled and uncontrolled anthropogenic fire sources. Disturbance regimes are presented for five common livelihood activities including frequency, seasonality, area, and type of habitat burned. Comparisons between historic and contemporary fires revealed decreases in the number controlled burns and consequent increases to the size and number of wildfires; but no changes to why or how people conduct controlled burns. Community fire regulations aim to reduce personal and communal property destruction, as well as protect locally valuable biodiversity. The results highlight the importance in accessing indigenous fire TEK for understanding anthropogenic contributions to fire regimes. Furthermore, they demonstrate that despite different worldviews, indigenous and western fire experts share a common goal in maintaining regional biodiversity.

Introduction

Fire originating from lightning strikes and anthropogenic sources is a driving disturbance force maintaining savanna ecosystems worldwide (Bond et al. 2005, Shorrocks 2007). Anthropogenic fires were critical in shaping the vegetation diversity, abundance, and distribution of Southern African savannas over the last 1.5 million years hominids and these ecosystems have been associated (Brain and Sillen 1988, Bond et al. 2005, Hall 1984). Today, most rural Southern African communities continue to use fire to manage natural resources necessary for their daily livelihood (Kepe 2005, Kepe and Scoones 1999, Kull 2002, Sheuyange et al. 2005). Nevertheless, fire regimes developed to conserve and manage Southern African savannas are primarily based on natural, experimental, or archaeological evidence (Govander et al. 2006, Hall 1984, Roques et al. 2001, Van Wilgen et al. 2003, 2004) largely ignoring traditional ecological knowledge of fire use and management (fire TEK) in contemporary rural communities. Incorporating fire TEK would improve our knowledge of savanna fire ecology and landscape management practices, and support current community economies and conservation efforts.

Problems of ideological translation between worldviews have long generated resistance to incorporating local fire TEK into western scientific management of savannas in Africa and elsewhere. In this study, I use an ethnographic approach to analyze fire TEK in two rural communities located on the coastal savanna of southern Mozambique to clarify how, when, and why they use fire in their daily livelihood activities and how these activities contribute to the fire disturbance processes in this region. I address three issues particular to the development of appropriate fire regimes and management policies for the coastal savanna of southern Mozambique and northern KwaZulu-Natal, South Africa: anthropogenic fire intentionality, community fire knowledge-practice, and fire regulation at local and national levels. My results highlight the knowledge that can be gained by working with local communities for improving landscape management, and demonstrate that residents use fire in a purposeful, controlled manner.

Integrating Knowledge and Improving Practice

Fire policies during the 20th century enacted by protected area managers and national legislators throughout Southern Africa varied spatially and temporally. Strict “no burn” policies were actively promoted in Bantustans and other areas settled by indigenous and impoverished peoples, while policy for commercial agricultural and timber operations and protected areas paralleled developments in ecological knowledge – ranging from “no burn” policies in the first half of the century to prescribed burns and lightning strike regimes in the latter half (Kepe 2005, Van Wilgen et al. 2000). The curtailing of anthropogenic fire because of misunderstandings surrounding pattern and process in the savanna landscape, a need to protect more economically important timber supplies, and a desire to control indigenous activity changed the fire disturbance regime (Eriksen 2007, Kepe 2005, Kull 2002). Over time, the last century’s policies led to a loss of habitat patchiness and species diversity, a build up of fuel, and a proliferation of invasive species (Bruton et al. 1980, Roques et al. 2007, Taylor 2007). To address problems created in protected areas, scientists and managers working in places like Kruger National Park, Greater St. Lucia Wetlands National Park, and Reserva Especial de Maputo (REM) want to establish fire regimes that mimic those used historically by people occupying those areas (Bond and Archibald 2003, Govender et al. 2006, Taylor 2007, Van Wilgen et al. 2004).

Determining appropriate fire disturbance regimes for Southern African savannas is difficult. Each savanna region has slightly different climate and vegetation parameters and a history of use, thus the optimal timing, frequency, intensity, and extent of fire needed to maintain the preferred environmental conditions varies (Whelan 1995). Fire helps native species thrive by opening up thickets and forest, maintaining open savanna, and reducing or removing invasive species. Both protected area managers and indigenous subsistence livelihood practitioners desire the increased biodiversity accompanying the habitat patchiness created by fires. Experimental burn regimes, archival data analysis, and computer modeling provides details about biological and physical factors influencing fire ecology, but fire in Southern Africa has a social component too. Humans use fire as part of household economic activities. Ethnographic information about how, when, and why people have used fire in a particular place, as well as their observations and memories surrounding historic fire events, can reveal specifics about climate, vegetation, and historic parameters for a particular savanna region. However, available records of human fire use may be fragmentary or biased against indigenous groups (Bowman 1998, Taylor 2007).

TEK studies of fire in other parts of Africa and the world suggest a promising approach that would allow ecological researchers to access historic data and develop location specific understandings of human contributions to fire-savanna interactions. Researchers working with Namibian herders combined herder knowledge and western scientific data about vegetation-fire interactions to produce a better model of the effects of anthropogenic fire on vegetation associations and responses at multiple scales (Sheuyange et al. 2005). Laris' (2002) interviews with Malian farmers about fire practices yielded a description of an annual burning regime wherein different habitats were seasonally targeted to manage the savanna landscape for hunting and agricultural production. This description of an annual burning regime elegantly explained the patchy mosaic of regional vegetation patterns observed in current and historic satellite imagery (Laris 2002). Historic ethnographic materials suggest that Aborigines skillfully manipulated the Australian landscape seasonally with fire to maximize their foraging efforts, and used their TEK to predict fire behavior and control the spatial extent of burns (Bowman 1998). More recent research in northern Australia found that continuous occupation and use of traditional fire practices by Aboriginal residents maintained the ecological integrity of their estate. Within Aboriginal managed lands, regular burns reduced wildfire risks, maintained flora and fauna diversity, removed invasive plants, and produced a patchy mosaic of habitat (Yibarbuk et al. 2001). Similarly, Krahô fire management practices within protected areas of Brazil's cerrado savanna create a patchy mosaic of diverse vegetation and reduce and prevent the spread of wildfire (Mistry et al. 2005).

Many livelihood activities practiced in Southern Africa involve fire. The effects of these fires on the savanna landscape range from minimal to extensive, and target specific habitats depending on the season. Small fires used to cook, smelt iron, harden pottery, and gather honey have minimal effects on the landscape unless they get out of control. Controlled burns are used to hunt, clear land for crops, deter wildlife from eating crops or livestock, and encourage the growth of new livestock forage or preferred wild foods. These practices target specific habitats and generally burn a few hectares or less (Bruton et al. 1980, Hall 1984, Kepe and Scoones 1999, Kull 2002, Laris 2002, Little 1996, Sheuyange et al. 2005). However, if such controlled burns are left unmanaged, they can disturb tens to hundreds of hectares and destroy the natural resources a community depends upon for food, medicine, and construction materials. In order to minimize undesirable effects of fire in the landscape, communities have developed knowledge, practices and beliefs for regulating fire size, timing, and frequency. This knowledge-practice-belief complex, or TEK, is based on long-term, cumulative observations and interactions with the surrounding landscape through the course of daily activities (Berkes 1999, Berkes et al. 2000). Consequently, community fire TEK should provide insight into a region's fire disturbance regime even if local practices altered slightly over time in response to larger political and environmental events.

Critics of using TEK for conservation often point to issues with validity and translation into a western scientific format accessible by scientists and protected area managers. As Kaschula et al. (2005) observed in their research on rural fuelwood harvest, TEK and community-based resource management practices do not easily fit into categories designated and deemed important by western science. Validity assessments based on a western science rubric may gloss over important subtleties in local knowledge and practice or completely miss other aspects such as intentionality. Misconceptions about local TEK and practice intentionality feed into conflicts over TEK use stemming from power struggles between western science and traditional science practitioners. "Western experts and aboriginal experts… have different political agendas and… relate in different ways to the resource in question" (Berkes 1999:11). Berkes references an ongoing argument between those who want to preserve nature apart from human use in protected parks and reserves, and those who restrict personal use of a natural resource in order to ensure its future use in their home territories. Unfortunately, this division influences how government and non-governmental organizations interact with local communities and results in policies that prevent residents from accessing necessary resources.

Landscape and Culture in Matutúine District

Matutúine District, the study location, is part of Maputo Province and the southernmost district in Mozambique (See Figure 5.1). The 5,403 km^2 district begins south of Maputo Bay and is bordered by the Indian Ocean to the east, Swaziland to the west, and KwaZulu-Natal, South Africa to the south. A mosaic of grassland, wetland, woodland and thicket, swamp forest, and rare sand forest covers the sand dunes comprising Matutúine District's landscape.

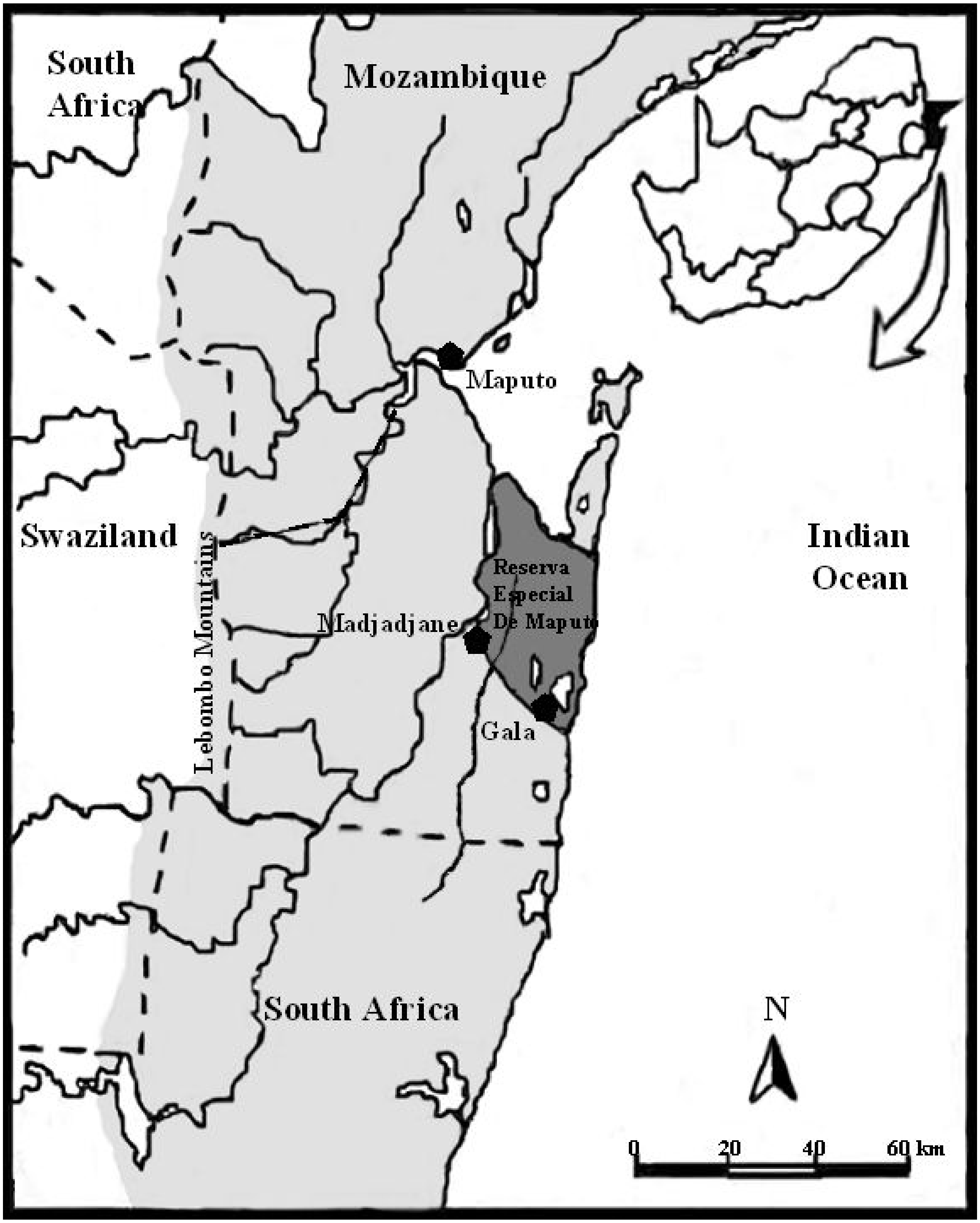

Figure 5.1 Map of Matutúine District, Mozambique. Dashed black line indicates district boundary within Mozambique. Light grey signifies the Maputaland Centre of Endemism and the dark grey is the Reserva Especial de Maputo. Madjadjane and Gala are indicated with black pentagons.

Freshwater and brackish lakes, along with the Maputo and Futí Rivers, also contribute to ecosystem diversity and provide permanent water sources for human and non-human communities alike. This wide range of habitats contributes to the high diversity of flora and fauna found in the district. In fact, Matutúine District sits at the heart of the Maputaland Centre of Endemism, a 17,000 km^2 region containing 2500+ plant species including 225 endemic or near-endemic species and three endemic plant genera, 100 species of mammals, and 470 bird species including four species and 43 subspecies that are endemic or near endemic (Smith et al. 2008, van Wyk 1994). Several Mozambican and South African parks and reserves exist in this region to protect biodiversity in the Maputaland Centre, including the 800 km^2 Reserva Especial de Maputo (REM) in Matutúine District (Tello 1972).

I worked with residents of Madjadjane and Gala, two rural communities adjacent to REM. Madjadjane's 331 residents reside in an area approximately 9 km^2, while Gala's 114 residents live over an area of 26 km^2. Approximately 90% of residents consider themselves to be Mazingiri Ronga. Ronga occupation of Matutúine District, and northern KwaZulu-Natal, dates back at least 500 years based on evidence from oral histories, archived documents, and archaeological materials (Bruton et al. 1980, Junod 1927). In order of descending percentages, smaller numbers of people identify themselves as Changaan, Zulu, Matsua, Makua, Portuguese, and Ndau. With the exception of the Portuguese who lived in this region prior to the 1960s, most non-Mazingiri arrived during the 1960s and 1970s for work, married local women, and adopted local customs.

Only 19 km separate Madjadjane and Gala, but the communities encompass a range of habitats available to district residents for resource exploitation. Riverine woodlands, open woodland, and sand thicket and forest give Madjadjane, stretched along the Futí River, a predominantly woodland landscape. The predominantly grassland landscape of Gala incorporates open and wooded savanna, hygrophilous grassland, sand forest-woodland mosaic, patches of swamp forest, and the shores of Lakes Piti and Ntiti (DEIBI 2000). A combination of swidden agriculture and foraging form the basis of the local economy. Livelihood activities like fishing, goat and cattle herding, mat and charcoal production, beekeeping, reserve work, and tourism supplement household resources and generate income. Intergenerational transmission of ecological and cultural knowledge remains strong, despite large population losses in these communities during the Civil War (1986-1992), because survival depends upon accessing a wide range of wild and domesticated resources through their mixed subsistence-based economy.

Controlled burns are a part of many local livelihood activities. Historic descriptions indicate that many of the activities residents currently practice have not changed significantly in the past century (Junod 1927). Furthermore, a 1575 map identifying a region encompassing Matutúine District and northern KwaZulu-Natal as *Terra dos Fumos*, the land of smokes provides possible support for historic use of fire by Ronga in daily activities in this area. It is postulated that Portuguese explorer Manuel de Mesquita Perestrello named it so because of the endless grass fires lit by locals (Bruton et al. 1980). The evidence for long-term residence, maintenance of local TEK, comparative descriptions of subsistence activities, and the required use of fire for such activities suggests that current Ronga fire TEK can provide information about anthropogenic contributions to fire regimes in this region.

Climate and weather significantly affect when and where when local communities burn areas as part of their regular livelihood activities. General climate patterns divide the year into a hot, rainy summer lasting from October to April, and a cooler, drier winter from May to September. Seasonal conditions depend primarily on the start and end of the rains, so timing of seasons may vary slightly year to year. In general, rain falls heaviest along the coast (~1000mm) and on the eastern slopes of the Lebombo Mountains (~800mm). Precipitation decreases on the savanna plains, located midway between the coast and the mountains, to a minimum of approximately 600mm annually (Tello 1972). Despite the variation in precipitation, temperature and relative humidity remain roughly constant. Temperatures average 24^{o}C during summer and 20^{o}C during winter. Mean relative humidity ranges in the middle to low 70s year round (Tello 1972). Lightning strikes reach a maximum at the onset of summer rains and a minimum during the winter (Lopes 1973). Most winds blow roughly parallel (N-S) to the coast. Southerly winds predominate and carry high humidity. In some years, a prevailing southeastern wind brings greater than expected rain and humidity. Northerlies, while rare, generate and precede very dry conditions. Tello (1973) reports that they can lower relative humidity 10-15%.

Research Methodology

This research was part of a dissertation project investigating how local culture and livelihood practices in Southern Mozambique contribute to the region's coastal savanna landscape pattern and process. Observations made during two field seasons – May to July 2004 and July 2007 to April 2008 – initiated a series of fire interviews and later deepened the understanding of informant explanations. I first held extensive conversations about local fire TEK with three male informants in Gala and Madjadjane. Women also have fire knowledge and conduct burns, particularly when clearing agricultural fields. However, since several male and female residents told me that traditionally fires are lit and managed by men, I conducted these initial conversations solely with men. My youngest informant, aged 21, was my field assistant who had grown up in Madjadjane. We frequently talked about community practices and he directed me to speak with two more knowledgeable men – a reserve guard and Madjadjane resident (45 years old) and an elder from Gala (71 years old) – when my questions went beyond the scope of his knowledge. My conversations with these men centered on timing and location of controlled burns, local practices for controlling burns, the frequency of uncontrolled burns, changes to burn practices over time, and local regulation.

The topic of fire came up during semi-structured interviews with livelihood activity specialists that I conducted as part of my larger dissertation project. Men and women, ages 18 to 79, were interviewed about their work as farmers, fishers, cattle herders, homebuilders, thatchers, beekeepers, wild plant harvesters, wine makers, charcoal producers, artisans, and reserve guards. I chose these activity specialists based on recommendations made by residents during an initial community-wide household economic survey and chain referral by other specialists. Of the 33 specialists interviewed, 18 mentioned that they used fire as part of their practice. I asked these men and women additional questions concerning how, when and why they used fire.

Semi-structured oral histories with 13 community elders, including two interviews with the *regulos* (chiefs) of Madjadjane and Gala, also provided fire practice information. I specifically asked male and female informants, ages 55-100, about why, when, and how people burned areas in the past, community fire regulations, and changes to fire disturbances in the region over the course of their lifetime.

Throughout this study, I employed a grounded theory approach (Corbin and Strauss 1990). The topical themes and information about local fire TEK drawn from the initial conversations generated codes to guide my text analysis of the semi-structured interviews with livelihood activity specialists and oral historians. I used interview responses, combined with field observations, to identify intentionality and the five most common livelihood activities involving fire. Informants implied intentionality linguistically during interviews because certain activities require the use of controlled burns and community members all know this. For example, “cleaning a field” includes removing brush with fire as well as turning soil, while “preparing pasture” requires burning off moribund grass to improve cattle forage. Common is defined here as widely practiced in communities in this region either currently or historically. Explanations in the results section focus on knowledge and practices associated with these five common activities, as well as local fire regulations. Text analysis of field observation notes helped triangulate controlled burn seasonality, fire management practices, and location.

Fire Sources and Intentionality

The debate surrounding fire use and control centers on intentionality, therefore I first asked local residents to identify fire sources, whether a fire is considered controlled or uncontrolled, and intentionality (see Table 5.1). Informants used the terms fire and uncontrolled burn to describe wildfires or uncontrolled burns that can occur anywhere at any time. Uncontrolled burns are unintentional or deliberately set. Unintentional, uncontrolled fire sources listed by informants include cigarettes, children, and lightning. Locals and visitors to REM start such fires by tossing burning cigarette butts into dry grass and brush. Children also accidentally start fires when playing with matches. One elder specifically mentioned that ready access to matches today makes it easier for children to play with fire. Lastly, residents noted that lightning strikes are a rare source of wildfire in this region. Archived records and personal observations support their remarks (Lopes 1973).

Table 5.1 Fire sources in Madjadjane and Gala.

Fire Source	Controlled	Uncontrolled	Intentional
Anthropogenic:			
Cigarette Butts		X	
Children Playing With Matches		X	
Children Mimicking Charcoal Production		X	yes
Arson		X	yes
Reducing Wildlife Conflict in Agricultural Fields	X		yes
Snake Removal	X		yes
Clearing Area for Homestead	X		yes
Removal of Thatching Trash	X		yes
Charcoal Production	X		yes
Cooking	X	X (poaching)	yes
Cleaning Agricultural Fields	X		yes
Preparing/Improving Pasture	X		yes
Apiculture	X (mod/trad)	X (trad)	yes
Hunting/Poaching	X	X (poaching)	yes
Sura Production	X		yes
Natural:			
Lightning		X	

Deliberately set, uncontrolled fires are rare. Children sometimes mimic parents and build small charcoal mounds to practice charcoal production. Without adult supervision, the children's charcoal mounds may be placed in inappropriate locations containing lots of dry vegetation that could catch fire and spread out of control. Rarely, individuals who are "not right in the head" burn down neighbors' homes deliberately. While the arsonist targets a specific home, they make no effort to control the fire otherwise.

Intentionally set, controlled burns, used for many food production and construction activities, can cause wildfires if not carefully tended. Fire plays a role in reducing wildlife conflict. Fires are used to drive off animals like hippos (*Hippopotamus amphibious*) and bush pigs (*Potamochoerus larvatus*) that eat sprouting crops. Later, as crops near harvest, farmers light bonfires along field perimeters to scare off the elephants (*Loxodonta africana*), monkeys (*Cercopithicus aethiops, C. mitis*), and bush pigs that raid these fields at night.

> "The elephants come during the canhu season to eat the canhu (*Sclerocarya birrea*) growing in my field. They also eat all the other crops – sugar cane, maize… all. The elephants come at night. During the day they stay in Magale Forest [a sacred forest inside REM]. To get rid of the elephants, I make big fires and keep dogs. Elephants don't like the barking or the bonfires." [Farmer, Gala]

Bonfires require tending throughout the night, so this practice is primarily observed in places with high elephant traffic, cash crop fields, and where fields surround homes. During June 2004, I observed Gala residents burning grassy areas near their homes and fields to drive off and kill poisonous snakes such as the black mamba (*Dendroaspis polylepis*). At construction sites, builders use controlled burns to clear spaces for new homesteads and community buildings like churches and schools. Thatchers build smaller bonfires in these clearings to get rid of the seeds and stems combed out of grass as it is prepared for thatching. Charcoal makers normally place their mounds in open areas with no tree canopy and where the grass has been removed. This reduces the possibility of fires inside the mound from getting out of control or the high temperatures generated inside the mound from causing spontaneous combustion. Households in Madjadjane and Gala still cook in shallow firepits hollowed into the sandy soil and sheltered from strong breezes.

Table 5.2 Five common types of controlled anthropogenic burns. Summers, October through April, are hot and rainy, while winter, May through September, is cooler and drier.

Reason for Burn	Habitat Burned	Frequency	Seasonality	Patch Size Burned
Cleaning Winter Fields	wetland along river and lake shores	when cleared originally	Apr./May	> 0.5 - 5.0 ha
Cleaning Summer Fields	open woodland, woodland	1x every 4-5 years	Oct./Nov. Feb. for fallows	> 0.5 - 5.0 ha
Preparing/Improving Pasture	open savanna (Gala) wooded savanna (Madjadjane)	every other year every 2-3 years	Feb.	> 5.0 ha
Apiculture	closed forest, woodland, open woodland Eucalyptus stands (plantation)	annual annual	Nov./Dec. June/July	Individual Colony Individual Colony
Hunting	open savanna, wooded savanna, open woodland	varies	any time during the year	Depends on Purpose
Sura Production	wooded savanna, open woodland	annual	any time during the year	Individual stands of *Phoenix reclinata*

Informants spoke of fire primarily in conjunction with common livelihood activities that field observations demonstrated as central to Ronga culture and community survival (see Table 5.2). Residents gave cleaning agricultural fields for crop production as the primary reason for lighting controlled burns currently and historically. Farmers burn fields twice a year in order to remove grass and shrubs. At the start of summer, in October and November, farmers burn areas in woodland and open woodland near their homes to clear plots for crops like maize, peanut, squash, beans, and manioc. The timing of the burn depends on previous rains. Farmers burn and plant in October if there have been “good rains.” Otherwise, they wait until November. A second burning occurs towards the end of the hot, rainy season (February/March) to keep down the growth of woody plants in fallowed fields, if an individual plans to use that area in the following year for crop production. April and May burns, also at the end of the hot, rainy season, prepare wet fields at swamp forest edges and along the river and lakeshores for sugar cane, banana, sweet potato, and vegetables grown during the drier winter season. Generally, these areas are cleared once and then used continuously. People rarely burn agricultural fields smaller than 0.5 hectares, and instead clean these fields by hand.

Madjadjane and Gala residents grazed cattle communally in open savanna, wooded savanna, and open woodland areas prior to Mozambique's Civil War. "In the past, we burned to grow new grass in the pasture" [REM Guard A, Madjadjane]. Burning pasture removes moribund grass and encourages the growth of new forage. A Gala man, who herded cattle as a boy, spoke of burning half the pasture area one year, and burning the other half the next year to make the grass grow better. After the burn, grazing was banned for a year to let the area rest. He said that these burns occurred at mid-summer, in February, when the "grass was not big, so the fire could not spread far." Another former herder from Madjadjane described burning wooded savanna patches every 2-3 years to improve forage, when she was a girl more than 70 years ago. Burn practices to improve pasture changed following the Civil War. Many people lost their herds, current impoverishment makes replacing cattle difficult, and national law forbids burning. At present, cattle owners rely on frequent herd movement and wildfires to provide good forage. The few cattle owners I spoke to emphasized that burning was illegal, and I did not observe any intentional pasture burns.

Many residents mentioned using fire in conjunction with biannual honey and comb harvests. In the wet, early summer months of November and December, apiculturists visit hives in closed forest, woodland, and open woodland to harvest wild hives and bee boxes. Non-native eucalyptus trees produce a lot of pollen during the dry months of June and July when many native plants are not flowering. Wild honey is collected at this time in eucalyptus plantation stands and from boxed colonies located within 1km of these stands. Traditional honey and comb collectors light a dry branch or bundle of grass, direct the smoke and fire at the hive to calm and kill bees, and usually take care to put out the fire before leaving the area. However, the combination of drought, dry vegetation, and tree resin makes eucalyptus stands particularly vulnerable to fire.

> “Wild bees can be very aggressive. The smoke may calm the bees but then as the person collects the honey the bees become aggressive again. The collector tosses the smoker [burning branch or bundled grass], grabs as much honey as possible, and runs. If the smoker hits a dry patch of grass or brush, this may ignite and start a wildfire.” [REM Warden, Madjadjane]

One traditional collector uses a cigar to smoke bees because he is unlikely to drop the cigar from his mouth and accidentally ignite vegetation. Use of modern apicultural equipment, like fumigators and bee boxes, has significantly reduced the potential for wildfires in Madjadjane. Gala residents planned a group honey collection outing using traditional methods to a sacred forest area in late November 2007. The residents went as a group to watch out for the elephants that live within the forest. However, both the timing and group collection reduce the chances of wildfire ignition. The summer rains had already started, and more people were around to watch for sparks and help put out fires when a smoker was dropped.

Controlled fires are used for hunting and poaching in open savanna, wooded savanna, and open woodland habitats. However, few residents will admit to hunting, and even fewer to using fire to hunt. Several elders explained that historically hunters used fire to drive game towards snare lines and to create grazing lawns. Good forage on a grazing lawn draws wildlife and the removal of tall grass makes it easier for hunters to spot prey. REM staff says that poachers continue to use these techniques. Most poachers in this area are young men from larger towns in Matutúine District and Maputo who have few or no ties to the local community where poaching occurs. As a result, they have little incentive to control the spread of fires into nearby communities like Madjadjane and Gala or to habitats that act as reservoirs for wildlife populations. Poachers may also start wildfires when cooking game in the bush. If reserve guards show up to arrest poachers and the men flee before dousing their cookfire, a wind might cause the fire to ignite surrounding dry brush and grass. As hunting and poaching occur year round, fires associated with these activities can be set at various times throughout the year.

Sura, or palm wine, makers harvest and ferment sap from kindu (*Phoenix reclinata*) to make wine year round. The plant's spiny lower branches and dead material are burned off to make tapping the main stem easier. Plant material could be cut and removed by hand, but the large spines on the lower branches make this process difficult. Field observations demonstrated that burning does not kill the plant and actually stimulates new growth. Kindu grows in stands in open woodland near water and on slightly elevated sites in wooded savanna. After three to four months of use, the palms are left to regrow before the burn and harvest cycle begins again. Lala palm (*Hyphaene coriacea*) is harvested extensively for sura further south, but not in Madjadjane or Gala.

<u>Ronga Fire Knowledge and Practice</u>

Temperature and precipitation are regionally important for determining the timing of controlled burns. Residents of Madjadjane and Gala consider daily and seasonal variation in these climatic factors when planning burns, and personal preferences reflect different experiences and habitats where burns take place. "Hot days are good for burning and also help dry out the grass so that it is ready to burn" [Farmer, Madjadjane]. A Gala elder said "it is better to burn in the early morning or very late afternoon as the cooler temperatures make the fire less intense." High temperatures dry out grass, which increases fuel load. Burn intensity, defined as the amount of heat released, increases as fuel loads grow larger (Whelan 1995). With cooler temperatures, grasses and woody vegetation retain moisture, fires release less heat, and flame heights stay low, thereby giving people greater control over the burn.

The timing of fires also depends on precipitation. When it rains residents say starting fires is impossible because the "grass is green." Rain increases fuel moisture content, which decreases the likelihood of ignition, the combustion rate, and how fast the fire will spread (Whelan 1995). To increase controllability, local residents prefer to burn agricultural fields just prior to the start of the summer rains and again at the very end of that season. Historic burns of pastures in February, in the middle of the rainy season, would also have allowed for greater control of burns on large areas.

Residents harvest large woody vegetation for cooking fuel and, in Madjadjane, for charcoal production prior to burns. Smaller woody plants, and sometimes grass, are cut and piled on the future burn site. These practices contribute to greater fire control. People then create a firebreak around the area to be burned by either excavating a ring ditch 2–2.5 meters deep by 1-2 meters wide or cutting grass down to the soil in a band 0.5–3.0 meters. Field observations and interview comments indicate that creating a firebreak by cutting grass is the most common method used. The cleared band "keeps the fire from jumping and getting out of control" [REM Guard B, Madjadjane]. The grass is cut down to bare soil using a machete or hoe, and roots are removed if they are at the surface. In addition to ringing the burn area, people make firebreaks around important medicinal and fruit trees growing in the middle of the burn site. Lower branches may brown from the heat and flames, but the trees survive (See Figure 5.2).

Figure 5.2 Firebreak in Madjadjane. A 1 m band of grass (indicated with the arrow) is cut around the edges of the field and around important medicinal and fruit trees, like this mango, to create a firebreak. The burned agricultural field will be planted with maize and peanut.

On the day of the burn the community member, or members, managing the fire checks wind strength and direction to determine ignition point placement. Personal preference and experience play a role in this placement. Some said they prefer building controlled fires on days with light breezes, as stronger winds can blow the fire out of control. These farmers rely on the breezes to spread their headfire ignitions. More cautious and experienced fire managers "start their fires against the wind so that the fire doesn't have much force and can be controlled" [REM Guard B, Madjadjane]. This backfire ignition practice allows people to use controlled burns in periods of stronger winds such as during winter. Burn site size determines the use of a single ignition point or a series of ignition points.

The number of people conducting a controlled burn depends on the fire's size, the purpose of the burn, and the experience of those involved. Most respondents indicated that they burned agricultural fields alone or with the help of a family member. Children frequently assist their parents to learn proper burn practices and help tend the fire to prevent it from spreading outside the designated area. One Madjadjane woman said that friends with adjacent fields often burn the entire area together to save on effort and reduce the risk of wildfire. Community groups will form when very large areas need to be burnt. During October 2007**,** a group of five men burned a site of approximately ten hectares of thicket and open woodland that would later be used by the entire Madjadjane community for summer crops. These men live adjacent to the site and thus had a vested interest in controlling the fire. Cattle pastures are communal areas, and historically herders worked together to burn them. The nature and questionable legality of hunting in Matutúine District makes obtaining specific answers about hunting practices difficult. However, it is likely that groups of hunters burned areas together to drive wildlife into snare barriers. A single man could create a small grazing lawn for wildlife on his own, given that individuals burn fields regularly. Sura makers and honey collectors work alone and only very small areas are exposed to fire.

Community elders say that people have not changed why they burn in Madjadjane and Gala. Additionally, the techniques used to manage fire are the same as those used by their parents and grandparents. One elderly woman (~100 years) informed me that she learned proper fire management by helping her parents and grandparents during their daily activities in the fields and around the homestead. In October 2007, her 16 year old great-grandson prepared the firebreak and then helped her burn a field in preparation for planting. The woman proudly stated that her great-grandson learned the proper way to do things by assisting his mother, grandmother, and great-grandmother.

Elders and older residents have observed an increase in the numbers and strength of wildfires, with a simultaneous reduction in controlled fires. They believe these changes began during the Civil War.

> "When the Civil War began, the community started to think differently. Many things changed. There has been a mobilization of the community not to make fires. Now it is also dry and because people don't make many fires they are bigger and stronger." [REM Guard B, Madjadjane]

During the war, fuel accumulated because residents stopped burning areas for livelihood practices. The fires drew military patrols to investigate and endangered personal safety. When the war ended in 1992, people resumed their use of controlled burns but the combination of a smaller population, fewer cattle, and new policies meant fewer controlled burns of fields and pasture. National censuses in 1980 and 1997, a time period covering the Civil War, show that in Matutúine District the population decreased 38.9% from an initial count of 57,509 people (Gaspar 2002), so fewer people now burn for livelihood activities. Non-governmental organizations entering the region after the war to provide economic and development aid pushed "no-burn" policies as part of their assistance packages. Community rules changed to accommodate these new requirements and certain areas in Madjadjane and Gala became off limits to controlled burns. The simultaneous reduction in controlled burns and resulting increased fuel accumulation during the war and afterward, as well as drought, has likely contributed to the observed increase in numbers and strength of wildfires observed by residents.

<u>Local and Regional Fire Regulation</u>

Article 40, of the Mozambican National Forest and Wildlife Law, criminalizes fires that destroy all or part of forests, bush, thicket, or savanna, and requires offenders to serve one year in prison and pay corresponding fines (Serra and Chicue 2005). This "no burn" policy does not distinguish between wildfires and controlled burns. Limited manpower and transport make it difficult for Matutúine District administration and REM staff to enforce this law. As a result, residents of Matutúine District communities are not punished for using controlled burns to clear agricultural fields. Non-governmental organizations, like the IUCN and Swiss development group Helvetas, have been more successful in encouraging a "no burn" policy as part of their assistance packages. In Madjadjane and Gala, the IUCN and Helvetas are working with residents to build ecotourism lodges and develop a cottage industry for local products such as honey and woodcarvings. "People have been told burning is very bad. It destroys nature, the animals suffer" [REM guard B, Madjadjane]. Ironically, the economic success of such projects depends on maintaining local biodiversity, which ultimately requires frequent burning of the landscape (Bond et al. 2005, Roques et al. 2001, Van Wilgen et al. 2003).

The traditional authority of local regulos and the *induna* (council of male and female community members ages 55-70) remains the strongest form of community fire regulation. As explained by the regulos, controlled burning is prohibited in Gala and residents of Madjadjane may only use controlled burns to clear fields. Moreover, community rules in Madjadjane and Gala have always prohibited uncontrolled burns and all burns in sacred forests. Residents recognize that wildfires can quickly raze traditionally built homes of wood, cane, and thatch. They may also wipe out crops, kill livestock, and destroy trees and plants that provide medicines, fruits, and construction materials. Sacred forests contain the graves of the chiefly ancestors and rare medicinal plants, and are where the regulo and community elders go to enact community rituals such as rain ceremonies. Residents spoke of the destruction wrought by uncontrolled burns on par with poaching animals and trees inside community boundaries. Junod's discussion of Thonga [Ronga] law highlights that theft "is universally condemned, not so much for its immoral character as for the fact that it renders a normal social life impossible" (1927:446). That residents speak of a wildfire's effects in similar terms underscores the ability of an uncontrolled burn to destroy a person's livelihood and community institutions.

All research informants acknowledged community prohibitions on controlled and uncontrolled fires. The regulos of Madjadjane and Gala stated that residents respect these local laws and the authority of the regulo and induna to punish offenders if the need arises. A system exists to resolve conflicts when problems arise. Occasionally a firebreak fails during a controlled field burn and neighbors find themselves at odds over the accidental destruction of property. In this case, the neighbors attempt to resolve the issue together. If they cannot come to an agreement over payment to replace the lost property, they ask the regulo to mediate.

Legal action for offenders starting uncontrolled burns, which destroy large areas of savanna, woodland, and communal property, depends on whether the individual is a local resident or an outsider. Locals are formally arrested and brought before the regulo and induna for trial to determine their guilt. Gala's regulo stated that arresting the offender lets both the individual and community know that uncontrolled fires are dangerous, and that starting one is a serious offense against the entire community. *Namzadores*, community police elected from the induna membership, collect evidence for the trial and present the case to the regulo and induna. If the offender is found guilty, they are required to beg for forgiveness from the entire community, as well as pay a fine to all whose property was damaged. This fine may be more than 1000 metacais ($1 USD = 23.9 Mtn based on conversion rates for 9/3/08) – a steep fine for those earning on average 30-57 metacais per day. Outsiders caught starting wildfires receive different treatment. Non-local offenders are arrested and brought to district police stations in Bela Vista or Zitundo, as the community has no jurisdiction.

Combining Knowledges to Manage Matutúine's Landscape

The scientific conflict over fire knowledge and practice between western and indigenous experts plays out in the landscape of Matutúine District. Intentions behind fire use are very different for local communities and protected area management. In Madjadjane and Gala, residents carefully manipulate the landscape with fire for immediate food production and to ensure a sustainable resource base for future harvest. Their environmental knowledge and beliefs about climate, vegetation, and fire behavior assist their decision-making in where, when, and how to build controlled fires for the various livelihood activities that they practice. Community institutions and fire regulations resolve disputes that arise when the resources that people depend upon are destroyed by wildfires ignited by people ignoring commonsense fire practices or the rare case of arson. In contrast, REM managers have discussed using controlled fire to manipulate the savanna landscape to maintain and generate biological diversity for its own sake. However, no formal plans had been made and present policies at REM are geared towards protecting biodiversity via wildfire prevention.

Population contraction following the Civil War, pressures to move people out of current and planned protected areas, and policies regulating fire use have altered the relationship between Ronga and their ancestral lands in Mozambique over the past 25 years. Many areas that were once regularly burned during the course of livelihood activities now experience less frequent fire disturbance in the form of more extensive and damaging wildfires. Madjadjane and Gala are small communities, both in population and land area, but residents share a common history, culture, and environment with other communities in Matutúine District and the greater Maputaland Centre region. This shared history and culture includes development of an appropriate fire regime, based on local environmental knowledge, to burn the savanna landscape regularly for livelihood purposes. My research with Madjadjane and Gala residents accesses this Ronga fire TEK and contributions to the region's fire regime. The information about anthropogenic fire frequency, seasonality, and size and type of area burned can be used by protected area managers in this region to develop burn regimes and set the burn targets needed to create a patchy mosaic of vegetation within protected areas.

Current "no burn" policies promoted by the national government of Mozambique and non-governmental agencies fail to incorporate recent scientific findings about the importance of fire disturbance for savanna diversity maintenance and reflect historic ideologies that viewed all native burn practices negatively. As a result, these policies stand in direct opposition to rural livelihood practices in Matutúine District. Rather than impose blanket "no burn" legislation without examination of local conditions and practices, this study highlights areas where Mozambique's Department of Natural Area Conservation and REM staff can work with communities in Matutúine District to incorporate local adaptive management practices. Knowledgeable fire users in the community could also be hired to assist with controlled burns inside protected area boundaries. Drawing on TEK would also aid local economies in communities like Madjadjane and Gala by supporting the continuation of livelihood activities, as well as recognizing and building on local conservation initiatives.

Examining anthropogenic contributions to the Maputaland fire regime in Matutúine District, Mozambique deepens scientific understandings of the connections between humans and the ecological processes and patterns of this region. The ethnographic description of Mazingiri Ronga fire TEK presented here demonstrates the extensive range of information that can be gained from asking local communities how, why, and where they use fire. This sort of information cannot be gained quickly through experimentation, historic records, and computer modeling. At a broad level, the data offers another example of the intentionality of fire use by rural African communities for food production. It also highlights the beliefs, practices and regulations many communities have to protect species and habitats, as well as personal and communal property, from destruction. Despite different worldviews, indigenous and western fire experts share a common goal in maintaining regional biodiversity. Finally, the detailed and holistic nature of Mazingiri Ronga fire TEK provides insight into Maputaland Centre ecology and suggests specific ways to improve national-level resource management plans. Over the long term, incorporation of this fire TEK into conservation planning will contribute to protection of Maputaland Centre biodiversity by maintaining, and re-establishing where necessary, locally appropriate fire regimes both inside and outside protected area boundaries.

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CHAPTER 6

CONCLUSIONS

In this final chapter, I summarize the main findings from each chapter describing original research and their broader significance. I also address some of the potential limitations of my research. Finally, I finish this chapter with a brief discussion of the broader significance of my work and discuss future research.

Adaptive Strategies, Vulnerability, and Landscape Heterogeneity

Adaptive strategies used by Ronga swidden farmer-foragers exploit the spatial and temporal heterogeneity of the landscape to respond to stressful environmental and social factors such as climate instability and poverty. Household and community risk management strategies use resources in the immediate rural landscape of Matutúine District as well as that of rural Northern KwaZulu-Natal and urban areas like Maputo, Mozambique, and Johannesburg, South Africa. Vulnerability sources in Madjadjane and Gala limit the efficacy of adaptive strategies, and affect adaptive capacity. Poor health and limited healthcare access, food insecurity, income, and education top the lists of self-reported vulnerabilities for residents in this study. Additional economic setbacks generated by the lingering effects of Civil War hinder local efforts to access resources and participate in Mozambique's rapidly growing economy. Households lack tools, finances, and labor capacity, while communities lack the infrastructure.

Changing conservation policies for this region increase vulnerability for local residents, but also offer them opportunities to strengthen their adaptive capacity. Development of the Lebombo Transfrontier Conservation Area includes fencing off the Futí Corridor and enforcing state policies that forbid human communities within National Parks and wildlife reserves. Participation in programs developing new industries like ecotourism and market honey production in Madjadjane and Gala indicate that residents recognize the importance of changes to conservation policy and actively seek to improve their adaptive capacity. These programs, introduced by international aid agencies, help residents build the necessary skills to sustainably access new economic resources, and well-known resources in the landscape in new ways.

Local Climate Change Models

Analysis of climate data for the past 45 years (1963-2008) shows average temperature increases of 1.4^{o}C for summer (October – April) and 1^{o}C for winter (May – September). Early growing season (October – December) temperatures rose 1.6^{o}C in this period. Rainfall has become more erratic since 1980, and the region experienced drought in the 2007/2008 growing year. Residents verified this trend of temperature increases, current drought and increasing unpredictability of rainfall, and suggested that the first summer rains, initiating the growing season, are beginning later. These observations were made in the context of livelihood activities where residents use their knowledge of expected climate patterns to make decisions about household production.

Three local climate change models were generated based on interview analysis. One model incorporated all observations of change, while the other two models grouped observed changes along community lines. Residents attribute a wide range of environmental changes to climate change, and significant differences exist between community models. Observations and perceptions touch on local ecological patterns and processes, as well as social changes, and reveal connections between parameters of change that are not obvious in regional models. Observed environmental changes include reduced crop and wild fruit production, fewer cattle, variable forest size, increased wildfire and elephant raiding of crops, drying up of water sources, poor health, and cultural change. Differences between communities in the perception of altered season timing and climate-induced environmental changes may be the result of differences in residents' day-to-day experience with predominant surroundings. It is possible that Madjadjane's model represents a woodland climate change model and that Gala's model represents a grassland model for Matutúine District.

Traditional Ecological Knowledge of Fire and Indigenous Landscape Management

Research with Ronga fire managers in Madjadjane and Gala demonstrates that residents carefully manipulate the landscape with fire for immediate food production and to ensure a sustainable resource base for future harvest. Fire is most commonly used in association with agricultural field clearing, pasture improvement, honey production, hunting, and palm wine production. Environmental knowledge and beliefs about climate, vegetation, and fire behavior assist decision-making about where, when, and how to build controlled fires for the various livelihood activities practiced locally. Traditional community institutions and fire regulations resolve disputes that arise when the resources that people depend upon are destroyed by wildfires, people ignoring commonsense fire practices, or the rare case of arson. Population contraction following the Civil War, pressures to move people out of current and planned protected areas, and policies regulating fire use have altered the relationship between Ronga and their ancestral lands in Mozambique over the past 25 years. Many areas that were once regularly burned during the course of livelihood activities now experience less frequent fire disturbance in the form of more extensive and damaging wildfires.

Despite different worldviews, indigenous and western fire experts share a common goal in maintaining regional biodiversity. REM managers have discussed using controlled fire to manipulate the savanna landscape to maintain and generate biological diversity like their counterparts do in other protected areas. The detailed and holistic nature of Ronga fire TEK provides insight into Maputaland Centre ecology and suggests specific ways that national-level resource management plans for this region could be improved. Over the long term, incorporation of this fire TEK into conservation planning will contribute to protection of Maputaland Centre biodiversity by maintaining, and re-establishing were necessary, locally appropriate fire regimes both inside and outside protected area boundaries.

Possible Limitations of This Study

One possible drawback of this research stems from the size of my field site in relation to the processes and patterns I am attempting to shed light upon. The Maputaland Centre of Endemism covers approximately 17,000 km^2 of forest-savanna mosaic in eastern Swaziland, northern KwaZulu-Natal, South Africa, and southern Maputo Province, Mozambique (Smith et al. 2008). Madjadjane's 331 residents reside in an area approximately 9 km^2, while Gala's 114 residents are spread out over an area of 26 km^2. The 5,403 km^2 of Matutúine District sit near the heart of this Centre, and I believe that the analysis of TEK, adaptive strategies, livelihood practices, and local history and economics in two small, rural villages can speak to the larger region. Madjadjane and Gala were chosen in part because of their ecological representativeness. Residents have easy access to practically all of the habitats available for resource harvest throughout the district. Furthermore, many of those interviewed had been born elsewhere within Matutúine District and moved to Madjadjane and Gala following marriage. Their oral histories and interviews demonstrate that traditional livelihood practices and household activities do not vary significantly from one community to another. Finally, approximately 90% of residents consider themselves to be Mazingiri Ronga. Ronga occupation of Matutúine District, and northern KwaZulu-Natal, dates back at least 500 years based on evidence from oral histories, archived documents, and archaeological materials (Bruton et al. 1980, Junod 1927). Given the shared culture, history, and environment, the experiences and practices of Madjadjane's and Gala's residents provide insight into human-environment interactions in Matutúine District.

The focused nature of my dissertation also limited my efforts at this time to analysis of anthropogenic fire disturbance and human responses to climate change. This was only a small part of the study I had originally proposed. A logical next step would compare the results of my vegetation surveys with land uses, livelihood practices, and fire regimes to explore how human activity shapes specific patterns of vegetation diversity, abundance, and distribution across the landscape. I would also like to further explore the role of rain rituals and traditional institutions in perceptions of climate change. Lastly, analysis of oral histories and archived documents I collected would deepen understandings of how regional conservation policies and Mozambique's Civil War have impacted livelihoods, communities, and landscape in Matutúine District.

Research Significance

My results contribute to a growing body of interdisciplinary research demonstrating that Southern African savannas and the contemporary African communities that consider these landscapes their home are the outcome of long-term, human-environment interaction. The work presented in this dissertation draws on multiple ecological and social theories including landscape ecology, disturbance, livelihood analysis, risk and decision-making, human adaptation, vulnerability and adaptive capacity, ethnoecology, historical ecology, and political ecology. I use the perspective of ecological anthropology to bridge disciplinary boundaries and produce a richer picture of what it means to live in and be a part of an African savanna landscape. Both qualitative (semi-structured interviews, oral history collection, archival records, participant observation) and quantitative (vegetation quadrats, climate data analysis) were employed. This use of mixed methods highlights the value of combining different disciplinary perspectives to gain deeper insight into a complex situation such as that of human-environment interactions on African savanna landscapes.

For many years, scientists working in savanna landscapes throughout Southern Africa have pursued separate research agendas, often along disciplinary lines, in livelihood-related studies and wildlife conservation. As mentioned above, livelihood activities and cultural institutions throughout Africa are intricately linked to the African ecological systems where they are practiced – distinctions between what is human and what is natural create a false dichotomy. Thus, the disciplinary research divide has the potential to generate conflict that negatively impacts savanna biodiversity, including human communities. This conflict stems from a failure to communicate with colleagues across disciplinary boundaries and to explicitly address the interactive nexus of social institutions and environmental processes that shapes savanna landscape. The interdisciplinary nature of my research exploring human-environment interactions that contribute to savanna landscape generation helps resolve this conflict and can be used in the development and maintenance of sustainable practices that support both human livelihoods and conservation.

The results of this research also document Ronga existence, use and rights to natural resources found in the forest-savanna mosaic where they live. Madjadjane and Gala are small communities, both in population and land area, but residents share a common history, culture, and environment with other communities in Matutúine District and the greater Maputaland Centre region. This shared history and culture includes traditional ecological knowledge of the landscape and the resources found there, adaptive strategies, locally-adapted livelihood activities, and participation in landscape processes like fire disturbance. Long-term interaction with the biodiversity of this region has shaped both Ronga culture and the Maputaland landscape. Recommendations that incorporate this information will be better able to accommodate locally specific needs, national law, and international protection, while remaining sensitive to cultural and ecological diversity.

Future Research

Further study on similar topics with communities in northern KwaZulu-Natal, South Africa, and areas closer to Maputo could address the limitations of applying results from Madjadjane and Gala to the greater Maputaland Centre of Endemism region. For example, I could test the hypothesis that the local climate change models produced in this study represented observations specific to grassland and woodland habitats.

Another avenue of inquiry might look at the effects of different government histories on landscape pattern and process in the Maputaland region. An international treaty finalized in 1891 created the Mozambican-South African border and divided the landscape and Ronga communities that occupied this region. Many of the local people I worked with during my field study maintain ties to family on the South African side of the border and travel regularly across the border to visit, sell materials harvested or produced in Mozambique, and access resources unique to South Africa. So, while ethnically and ecologically similar communities may exist on both sides of the border, there are potentially some major differences in terms of resource access, use, and management generated by contemporary and colonial government policies.

Additional analysis of oral histories and archived documents questioning how and why people moved through this landscape historically would also expand the spatial and temporal scale under consideration and allow for greater comparison between current and historic human populations.

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