ABSTRACT

Title of Document: PROLONGED ILLNESS AMONG SUBSISTENCE AGRICULTURAL HOUSEHOLDS IN RURAL MOZAMBIQUE: COPING STRATEGIES AND POLICY LEVERS

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Subsistence agriculturalists are highly economically vulnerable, and generally lack access to resources that may help strengthen their livelihoods. Health is a well-established form of human capital that is also one of the biggest assets for subsistence agricultural households. Therefore, any instance in which this form of capital is threatened has potential consequences for livelihood sustainability. This dissertation examined prolonged illness among subsistence agricultural households in rural Mozambique. Prolonged illness can diminish household labor supply, a vital input for subsistence agriculture. My research sought to: 1) identify potential agricultural and land use coping strategies used by unhealthy subsistence agricultural households, and examine whether or not changes in health status induce land cover change; 2) isolate health's effect on a known agricultural land use decision—fallowing—to more

rigorously examine the negative health-land relationship; and 3) examine how a policy lever such as access to health services could be more equitably distributed to subsistence agricultural households. I found that unhealthy households were more likely to alter household agricultural land use decisions to cope with prolonged illness, and that they were different than their healthier counterparts in key agricultural ways that may threaten their livelihoods and contribute to food insecurity. While changes in health status do spur land use and land cover change, the relationship is challenging to detect with the current offering of satellite imagery. Additionally, access to health clinics represents a policy lever aimed at supporting unhealthy citizens to maintain their livelihoods. I found that the way "need" is defined in terms of access matters and that access to a high-quality service such as antiretroviral therapy could be more equitably distributed to vulnerable segments of society. This research demonstrates the value of using mixed methods, as the combination of qualitative, econometric, and geospatial methods, to provide a more holistic understanding of the micro-level effects of prolonged illness among subsistence agricultural households in rural Mozambique.

PROLONGED ILLNESS AMONG SUBSISTENCE AGRICULTURAL HOUSEHOLDS IN RURAL MOZAMBIQUE: COPING MECHANISMS AND POLICY LEVERS

By

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Dedication

To my wife for her endless support and encouragement

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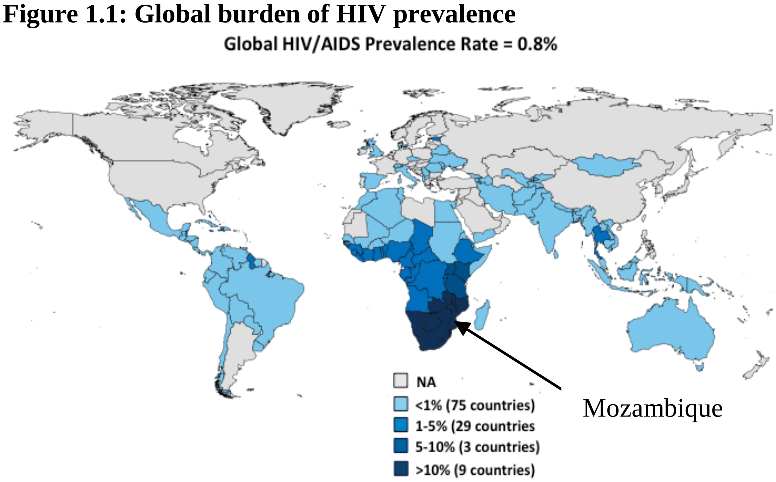
Chapter 1: Introduction

Subsistence agriculturalists in developing countries are among the most economically vulnerable people in the world (Morton 2007). Shocks, in various forms, can have especially devastating consequences for these households and may contribute to poverty traps and food insecurity (Arora 2001; Marmot 2005; Giesbert and Schindler 2012; Leichenko and Silva 2014). Shocks may be climatic (drought or flooding), economic (price fluctuations, lack of market opportunities, lack of jobs), or health-related (communicable diseases and chronic illness). Health-related shocks are of particular interest for this dissertation research, as health is regarded as a vital form of human capital (Schultz 1961; Becker 1964, 1992, 2007) and thus the depletion of this stock in unhealthy households can have far-reaching consequences (Drimie 2003; Fox et al. 2004; Yamano and Jayne 2004; Banerjee and Duflo 2005; Bukusuba et al. 2007; Masanjala 2007; Hotez et al. 2009; Chicoine 2012). The effects of health shocks have been well established in the literature, and stem from the direct effect of changes in health status on changes in labor supply (Bloom et al. 2004; Larson et al. 2004; Canning 2006; Walker et al. 2006). A pathway, then, exists by which shocks resulting in labor declines may alter agricultural land use decisions for subsistence agricultural households and could result in a reduction of livelihood capacity. This body of research investigates how subsistence agricultural households in rural Mozambique cope with prolonged illness; the potential implications for land use and land cover change (LULCC); and how access to health clinics could be more equitably distributed to mitigate any negative impacts. For the purpose of this research, prolonged illness is defined as any occurrence of illness or disease within a household that affects a member over the age of ten[1] and lasts three months or longer.

Mozambique was selected as the country of study given its heavy reliance on agriculture, persistent poverty, and significant disease burdens. Mozambique is a developing country in sub-Saharan Africa and shares borders with other countries that also have high disease burdens. Additionally, Mozambique has been experiencing rapid economic growth since the end of the civil war in 1992, though this has done very little to alleviate poverty (Cunguara and Hanlon 2012). Migration patterns to neighboring countries contributes to the spread of communicable diseases such as the human immunodeficiency virus (HIV) and acquired immunodeficiency syndrome (AIDS), tuberculosis and other sexually-transmitted diseases (Barreto et al. 2002; Barradas and Arnaldo 2003; Agadjanian and Avogo 2008; Agadjanian et al. 2011). Figure 1.1 provides a reference for the global burden of HIV/AIDS and draws attention to where Mozambique is located in relation to other high-HIV prevalence countries in sub-Saharan Africa.

Figure 1.1: Global burden of HIV prevalence



Source: Kaiser Family Foundation 2014.

[1] Note: Ten years of age was chosen as the data recognizes this as the age by which household members are considered active, working members

A consequence of rapid economic growth has been increasing inequality and poverty (Cunguara and Hanlon 2012), which prompted the government of Mozambique to prioritize poverty reduction. The official policy proposal *Action Plan for the Reduction of Absolute Poverty* (PARPA) identifies strategic pathways to assist poor households. Two key policy mechanisms supported by the PARPA declare agriculture as a pathway out of poverty and emphasize strengthening the current health infrastructure (PARPA 2007; PARPA 2011). These two policy priorities mirror the pathways of interest in the research presented in this dissertation.

Agriculture is an integral part of the Mozambican economy, where just over 85% of the population engages in this economic activity as a livelihood strategy (FAO 2015). Many rural farmers in Mozambique participate in smallholder agriculture and have very limited access to technology; thus, these households are heavily reliant on human labor (Jayne et al. 2010). Within this cohort, health may have an indirect effect on the landscape as unhealthy households may alter their agricultural land use in response to chronic poor health.

Land tenure rights may affect land use decisions within agricultural households in rural Mozambique. When Mozambique won its independence from Portugal in 1975, the country lacked any meaningful land tenure policy, and the land was used almost entirely for subsistence purposes (Negrão 1998; Nhantumbo 2000). Consequently, from 1975-1987 farmers were organized into collective production systems that were determined by the government (Nhantumbo 2000). In 1987, the government implemented the Structural Adjustment Program (SAP) that sought to provide communal rights as a means of providing greater capacity for rural livelihoods, but this system was never fully realized due to the ongoing Mozambican civil war (Nhantumbo 1997; Nhantumbo 2000). SAP remained in place through the early 1990s and into the beginning of peacetime[2].

After the civil war, the debate for a stronger land tenure process intensified. However, it still took five years after the Mozambican civil war to implement the next phase of land tenure. The Land Law of 1997 guaranteed land rights of individuals and communities to occupy, develop and transfer land use titles (Nhantumbo 2000; Lunstrum 2008). The land itself remains state-owned, but rights and access were greatly expanded under the Land Law of 1997. This expansion also signaled interest in securing foreign investment in the country. The idea was to allow communities to negotiate and work with private foreign entities as a means of local and regional development (Lunstrum 2008). This was considered a major step forward as it empowered local communities by giving them a voice in the management of local natural resources (Nhantumbo 2000). The law empowered communities to officially demarcate and title community land, thus giving them more control over how the land is to be used (Clover and Eriksen 2009). While the Land Law of 1997 was considered a major advancement in land tenure policy, there has been growing concern that it may be exploited by the economically privileged as they may be given priority access to better tracts of land. This could translate into impoverished agricultural households being forced onto marginal and smaller tracts of (Clover and Eriksen 2009).

Though considerable progress has been made in land tenure for rural Mozambican farmers, room remains for protecting access rights for poorer

[2] Two years after winning the war of independence with Portugal, Mozambique entered into a civil war lasting from 1977-1992. Thus, the civil war made land tenure progress arduous and difficult to successfully implement.

households. Taken together, the current land tenure policy suggests that unhealthy and poorer agricultural households may be further marginalized as wealthier and healthier households may be able to capitalize on community land rights. This could have direct implications for livelihood sustainability and may further complicate the hypothesized health-land relationship.

Also relevant to this research is the impact of illness and disease. Mozambique represents an appropriate case study as it has one of the highest disease burdens in the world, as do its neighboring countries (Murray et al. 2013). Therefore, Mozambique is an excellent candidate to test the hypothesized health-environment relationship given that the country is land abundant, but labor poor (Tschirley and Benfica 2001; FAO 2007), which limits the option to engage in labor substitution as a coping mechanism. As of 2010, Mozambique had one of the highest HIV prevalence rates in the world at just over 11%, with some provinces reaching rates as high as 25% (Ministry of Health 2010). Despite the rollout of antiretroviral therapy (ART) in 2004, fewer than 25% of those with advanced HIV were actually enrolled in ART as of 2007 (Audet et al. 2010). Access to health clinics and ART is of particular interest in this research as it represents a potentially key policy instrument to help unhealthy subsistence agricultural households cope with poor health, thereby mitigating the negative health-labor relationship seen throughout the literature.

Mozambique also faces other significant threats to population health. Malaria is widespread and a constant threat to the health and well-being of citizens in Mozambique (Mabunda et al. 2009). Natural disasters such as devastating floods, tropical cyclones, and drought also plague the country and thus threaten household and general economic well-being (Brouwer and Nhassengo 2006; Klinman and Reason 2008; Matyas and Silva 2013). Unhealthy landscapes are created by these natural disasters, which in turn undermine the general health of the affected population. For example, many new disease vectors form post-flood and this contributes to a dramatic increase in infections (Kondo et al. 2002). People in flood-prone areas of Mozambique are more susceptible to cholera as contaminated water infiltrates village and city water sources, limiting access to clean, safe drinking water (Mengel 2014). These are the types of health issues this research seeks to examine, specifically how they may reduce a household's ability to sustain its livelihood.

This research is particularly focused on the human-environment link between poor health and livelihood sustainability (via agriculture), and will therefore apply some of the major tenets of political ecology to examine the different strategies agricultural households use to absorb an adult prolonged illness. These tenets include a recognition of the unequal distribution of the costs and benefits associated with environmental change and how they are unequally distributed; the varying effects of this unequal distribution on different groups or individuals; and inequitable access to various resources (e.g. resources such as health clinics and hospitals, land for farming, agricultural markets to sell excess production, agricultural extension agents to assist with crop strategy, and transportation) (Blaikie and Brookfield 1987; Rocheleau 2008; Turner and Robbins 2008; Wagstaff and Lindelow 2014). Collectively, mixed method analyses are used to provide a much-needed record of *where* agricultural LULCC may be occurring as a result of adult prolonged illness and *how* access to health clinics can be more equitably distributed to vulnerable segments of the population.

1.2 Research purpose and motivation

As a mixed methods study, this research seeks to provide a more nuanced understanding of the pathway in which poor health can alter livelihood strategies, and by extension, induce LULCC for subsistence agricultural households. Given the lack of data for rates of specific diseases for Mozambique, I use prolonged illness as a measure for chronic health conditions that may jeopardize the ability of unhealthy subsistence agricultural households to maintain their livelihoods. As many of these households live well below the poverty line and exist mainly off of the crops they produce, issues that threaten food security become a major concern for their broader economic well-being (Misselhorn et al. 2012).

Focusing on rural subsistence agricultural households and villages in Mozambique, the primary goal of my research is to better understand how unhealthy households cope with prolonged illness. More specifically, what effect prolonged illness has on their livelihoods, what effect it may have on agricultural land use, and how existing health resources could be better allocated to help these households mitigate the potential for a diminished livelihood associated with the negative health-environment relationship.

In the literature, coping strategies can be categorized into three groups, and take the form of behavior-based strategies (such as consuming less), asset-based strategies (such as using savings or assets to offset poor health), or assistance-based strategies (received either through informal safety nets or public sources) (Heltberg and Lund 2009). For the purpose of this research, I focus primarily on behavior-based strategies and examine how unhealthy agricultural households may alter land use decisions to deal with poor health. As a secondary analysis, I examine how asset structure may be different between healthy and unhealthy households to identify which assets may be more beneficial for mitigating poor health.

This research integrates several data sets to address the strategies used by unhealthy subsistence agricultural households in response to prolonged illness. Chapters 2 and 3 use a nationally- and provincially-representative agricultural survey known as *Trabalho de Inquerito Agrícola* (TIA) for the years 2002, 2005 and 2008 to examine the health-environment relationship. Additionally, Chapter 2 makes use of Landsat satellite imagery in an attempt to associate land cover change with changes in health status. Chapter 4 relies on a longitudinal women's health survey and a longitudinal health clinic survey. The primary research goal is to understand how unhealthy subsistence agricultural households deal with prolonged illness. In addressing this primary goal, a series of supporting research questions are asked. These supporting research questions can be organized into three specific research objectives, each comprising a chapter of this dissertation. Specifically, Chapters 2-4 assess the following research objectives:

- Chapter 2 qualitatively examines self-reported coping strategies for households that experience a prolonged illness; investigates the relationship between prolonged illness and reported fallowing of land using logistic regression; provides a comparative household economic profile for healthy and unhealthy households; and examines potential land cover change associate with changes in health status.

- Chapter 3 builds on Chapter 2 and uses econometric modeling to rigorously examine national patterns of reported fallowing and the amount of land fallowed; and uses Kernel Density Estimation (KDE) to map agricultural land use patterns onto patterns of prolonged illness.
- Chapter 4 examines how a particular policy mechanism such as access to health care can be improved to provide more equitable access to underserved populations; and uses location-allocation and geospatial modeling to compare the current configuration of health clinics offering a high-quality health service to an optimal configuration.

The main objective of Chapter 2 is to identify self-reported coping strategies at the national level, regional differences between healthy and unhealthy households, and possible village-level changes in land cover as a function of prolonged illness. The analysis design for this chapter is hierarchical in nature and uses a nationally-representative smallholder agricultural survey to perform regression analysis (national-level), comparative household profiles for healthy and unhealthy subsistence agricultural households (regional-level), and remote sensing analysis (village-level). These are used to answer the following supporting research questions:

- Is there an association between prolonged illness and whether or not a household reports cultivating less land as a coping strategy?
- Are unhealthy households observably different from healthy households?
- Can Landsat satellite imagery detect land cover changes due to prolonged illness?

The main objective of Chapter 3 is to combine agricultural land use, health, and spatial data to examine the impact of prolonged illness on a particular land use decision (a reduction in area under cultivation as a coping strategy). Using the same nationally-representative smallholder agricultural survey used in Chapter 2, kernel density estimation (KDE) examining the association between prolonged illness and land use and a two-part regression model are used to answer the following supporting research question:

- Is health status associated with fallowing even after controlling for agricultural, economic, demographic, and climatic conditions?

The main objective of Chapter 4 is to identify how access to health clinics may be more equitably distributed among vulnerable segments of the surrounding population in Gaza province. Longitudinal data from a women's health survey and a health clinic survey are combined with spatial data to generate descriptive statistics, perform location-allocation analyses, and conduct panel data change analysis to answer the following supporting research questions:

- Does the current configuration of health clinics prioritize the economically vulnerable? Could the current configuration be better sited to address "need"?
- Can the current configuration of health clinics offering a high-quality health service such as ART be more equitably distributed?

While the TIA is a well-respected and commonly analyzed agricultural survey, there are some potential data limitations associated with it. For example, the TIA asks households to either identify the "total area in hectares under permanent crops" or the "total area in hectares under fallow"[3] and does not leave open the opportunity for other possible agricultural land uses. As a result, I associate changes in health status with changes in land reported as fallowed for this research. Typically, fallowing represents an advanced land use decision aimed at improving the overall quality of the land (Grisley and Mwesigwa 1994; Thangata et al. 2007; Sauer et al. 2012). I use this for my outcome variables to examine how prolonged illness and fallowing may be related. Therefore, I hypothesize that this land use decision has both positive and negative impacts—the practice of fallowing is beneficial to the land, but it comes at the expense of household livelihood sustainability as unhealthy households may become food insecure as a result of a reduction in cropped area. However, it is important to note that households may be cultivating less land for other reasons not captured in the TIA data (e.g. households may report land as being fallowed when in fact it may have been temporarily

[3] This is summed for all fields belonging to a household to obtain the total area under fallow. This question is used to generate a binary outcome variable that examines whether a household fallows or not, as well as an outcome variable that looks at fluctuations in the total amount of land fallowed.

abandoned due to poor health). Additionally, there is the potential endogeneity of self-reported household illness and uncertainty around the timing of the health events experienced in the household.

The TIA 2002 provides an additional qualitative component not seen in the TIA 2005 or 2008, asking health-affected households to “identify their top coping strategies” for dealing with prolonged illness or the death of a family member. The design of the survey instrument is close-ended and provides a set of twenty possible coping strategies most likely employed by unhealthy households. Therefore, these coping strategies may not fully capture how households respond to prolonged illness. Moreover, these reductions in area cultivated may represent an impact of prolonged illness rather than a coping strategy. However, this nuanced difference would not be discernable in the TIA data. For the purpose of this research, I assume that “cultivating less land” (a provided coping strategy prompt in the TIA) represents a behavior-based coping strategy.

Despite the data limitations mentioned, the TIA data are widely used in the literature and are regarded as a robust rural household survey. Additionally, the inclusion of comprehensive health-related questions is rare in agricultural surveys, and provides a unique opportunity to examine the potential negative health-environment relationship.

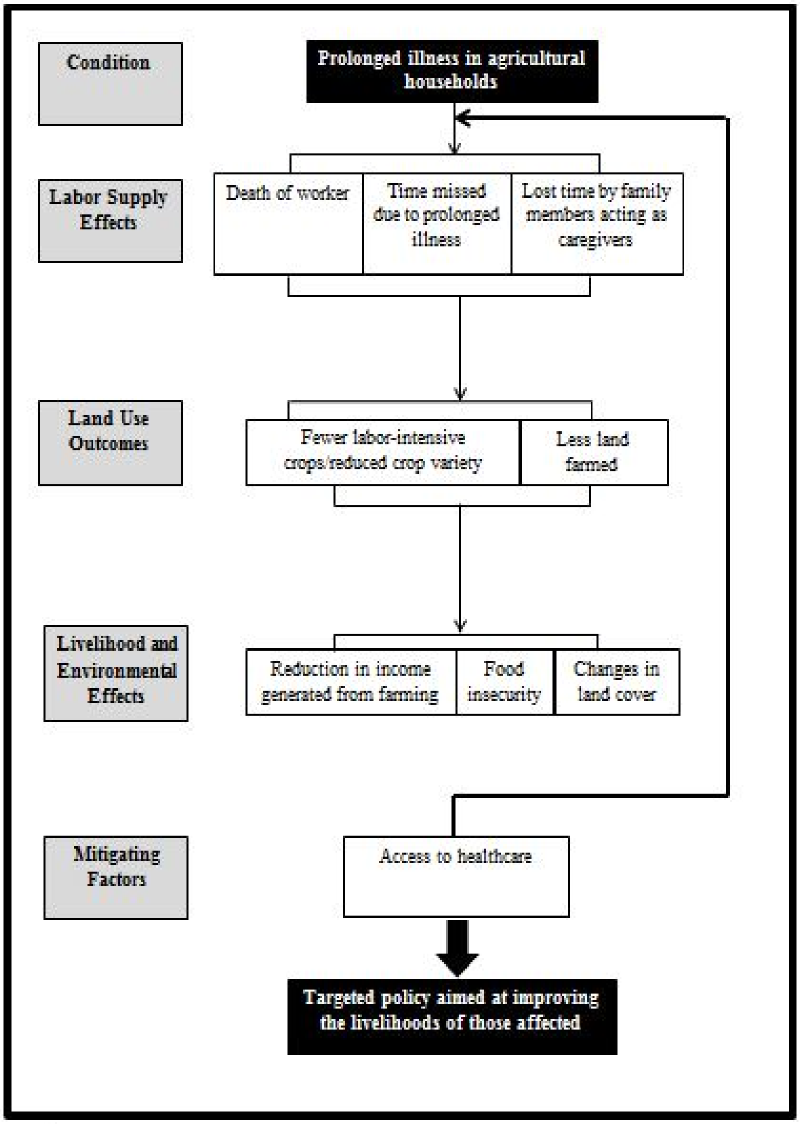
1.2 Political ecology framework

The research questions asked and answered in this dissertation are explored through the lens of the political ecology framework. Political ecology offers a logical, comprehensive framework for addressing coupled human-environment problems. This research focuses on the lesser-known broader impacts of a well-known problem—the negative impact of poor health on labor supply (Schultz and Tansel 1997; Asenso-Okyere et al. 2010; Pennap et al. 2011; Asenso-Okyere et al. 2011).

Political ecology draws attention to the uneven distribution of resources and opportunities for certain members of society (Blaikie and Brookfield 1987). This uneven distribution is not the result of any one particular factor, but rather, is a function of a series of societal constructs; these include economics, policy, and access to resources—all working in concert to set the stage for "winners and losers" (Rocheleau 2008; Turner and Robbins 2008). This disenfranchisement is a direct theme in this body of research, which is concerned with the human-environment system of land-health interactions. I am particularly focused on how prolonged illness may manipulate and reinforce vulnerability among subsistence agricultural households. The political ecology framework seeks to identify drivers that contribute to the marginalization of various groups, and in turn, how this may affect environmental change.

In this research, I hypothesize that poor health is a contributing driver that not only sets the stage for further disadvantaging marginalized members of society, but may also be a driver of environmental change. Figure 1.2 provides a conceptual framework that identifies the broader implications of poor health, including how it might contribute to a decline in economic well-being and catalyze environmental change.

Figure 1.2: Conceptual framework



Source: adapted from Negin (2005) by author

The conceptual framework starts with a given condition (prolonged illness) and then seeks to capture what effect it will have on labor supply—known effects include the death of a worker, time missed to due to prolonged illness, and time lost by another family member providing care for a sick individual. These labor supply effects could then have direct implications for land use outcomes as households adjust by altering their crop selection and the amount of area they cultivate. This, then, potentially threatens the livelihoods of unhealthy subsistence agricultural households as the combination of labor supply effects and land use changes could culminate in reduced income from crops and food insecurity. Additionally, there may be an effect on the actual landscape as agricultural land use decisions are shifted to cope with prolonged illness. However, there are mitigating factors that could disrupt this chain of events. Access to health clinics has the ability to mitigate the pathway from the given condition and labor supply effects and has the ability to disrupt the negative health-land relationship before it has a chance to fully develop.

1.3 Research importance and implications

Much research has been dedicated to the economic well-being of subsistence agriculturalists in rural Mozambique. The literature base surrounding the livelihoods of smallholder farmers in Mozambique includes:

Table 1.1: Topics of study regarding Mozambican farmers

Topic Area	**Scholarly Work (key examples)**
Health	Arndt 2006; Donovan and Massingue 2007; Mather and Donovan 2008
Agriculture	Walker et al. 2006; Cunguara and Kajisa 2009; Cunguara and Kelly 2009; Donovan and Tostão 2010; Janyne et al. 2010; Kajisa and Payongayong 2011
Poverty	Tschirley and Benfica 2001; Jayne et al. 2003; Walker et al. 2004; Boughton et al. 2007; Mather et al. 2008; Silva 2008; Cunguara and Hanlon 2010; Giesbert and Schindler 2012; Silva 2013
Climatic Shocks	Matyas and Silva 2013; Leichenko and Silva 2014; Silva and Matyas 2014

Note: Table created by author

This body of literature informs the research questions this study seeks to answer and also inform some of the methodology used for the analyses. Additionally, King (2010) noted that the effects of illness on the physical environment are under-researched at the micro-level. My research addresses this gap by identifying the various strategies used by unhealthy subsistence agricultural households to cope with poor health, what implications they may have for LULCC, and whether or not health policy (such as investments in and better access to health clinics) could be more equitably distributed so these households can better manage their health without needing to alter their livelihood strategies and land use decisions.

Results from this research have implications for academics, policy makers and elected officials, health care providers, and, most importantly—subsistence agricultural households in rural Mozambique. This research provides a much needed depiction of the ways in which these unhealthy households cope with prolonged illness. The human capital effects of poor health can have significant implications for livelihood sustainability, food security, and LULCC. Not only does this research identify how agricultural livelihoods may be threatened, it also examines how land use may be transformed by prolonged illness, and also explores alternative solutions to improving access to health clinics for the most vulnerable. By doing so, it provides policy makers with a strategy that is in keeping with the poverty reduction strategy adopted by the country of Mozambique. Investments in health infrastructure are capable of mitigating the observed negative health-land relationship by reducing the frequency and severity of disease, and therefore may help unhealthy subsistence agricultural households maintain their livelihoods (PARPA 2007; PARPA 2011). Lastly, the results from this research may also be applicable in other land-abundant, labor poor settings (e.g., Ethiopia and Zambia), as these types of households in other countries may adopt similar coping strategies that affect LULCC.

1.4 Dissertation organization

This research is organized into three major sections. Each section addresses specific research questions outlined in Section 1.1. Chapter 2 seeks to establish a general relationship between prolonged illness and adjustments in land under cultivation as a coping strategy. This is primarily executed by qualitatively examining self-reported coping strategies provided in the TIA 2002 for unhealthy agricultural households, and is then supported with a national-level regression testing the observed health-environment relationship. It also identifies the ways in which unhealthy subsistence agricultural households are different from their healthier counterparts. It then concludes with a case study that examines the potential for Landsat imagery to detect land cover changes brought about by prolonged illness. Building upon findings from Chapter 2, Chapter 3 more rigorously models changes in the amount of land cultivated by unhealthy subsistence agricultural households, controlling for agricultural, demographic, economic and climatic factors. Access to health clinics and high quality services are considered to be one way households can mitigate the effect of the condition on household labor supply. To that end, Chapter 4 examines how access to health clinics can be more equitably distributed to the most economically vulnerable groups in rural Mozambique. Chapter 5 includes a brief summary of the results from this collective body of research, identifies future directions for further research, and explores policy implications and next steps. Chapters 2 through 4 have been written such that they can stand alone for publication in different journals that correspond to their specific topic area and for this reason some information in the Introduction may be repetitive.

Chapter 2: Does prolonged illness drive land use change among subsistence agricultural households?

2.1 Introduction

Humans are inextricably coupled with their environment, where the strategic use of agriculture is critical to survival in developing countries. Health has long been recognized as a form of human capital (Shultz 1961; Becker 1964, 1992, 2007), and many studies have examined how changes in the landscape impact human health (Lindblade et al. 2000; Patz et al. 2004; Vanwambeke et al. 2007; Vasilakis et al. 2011). However, very few studies have examined the impact of health on the landscape. Many countries still rely on agriculture as a force of economic development, and this type of physically demanding livelihood closely links the health status of household members with their land, a microcosm of the human-environment interaction (Tschirley and Benfica 2001). I hypothesize that subsistence agricultural households may alter their land use decisions to cope with prolonged illness and that this may have consequences for livelihood sustainability. The primary catalyst by which this would occur is through a decline in labor productivity.

This paper examines the impact of prolonged illness on agricultural LULCC in Mozambique. It examines how possible alterations in household land use decisions may be used to cope with prolonged illness. Altered land use decisions may take multiple forms; reductions in the area cultivated or the total amount of land in possession, or the rental of land represent possible opportunities to alter the household's land use. One of the many sustainable land use techniques employed by subsistence agriculturalists is the use of reducing the area under cultivation. This reduction is usually practiced in the form of fallowing, which is typically classified as an advanced agricultural practice, and is used by households with sufficient resources to improve output efficiency (Grisley and Mwesigwa 1994; Thangata et al. 2007; Sauer et al. 2012). However, reducing the land area under cultivation may be an undesired consequence of economic shocks that leave households unable to cultivate all of their land; this may manifest itself as a temporary increase in fallowing. Health-related human capital effects of diseases such as HIV/AIDS have been linked with adjustments in livelihood strategies as unhealthy households respond to the effects of sickness; this includes changes in cropping patterns and land use decisions (Gillespie 2006).

In its most basic form, fallowing is the practice of leaving land uncultivated; this practice is traditionally adopted for economic reasons (Boserup 1985; Sauer et al. 2012). The practice of fallowing is typically used to improve some component of the land that benefits an agricultural household. Additionally, it can be used pastorally as it improves feeding for livestock. In this paper, I consider an alternative use of fallowing. Specifically, I posit that just as the practice of fallowing can be used for improving the land, for increasing agricultural production, or for improving feeding grounds for livestock, so too can it be used as a coping strategy for unhealthy households. Thus, I seek to contribute to the fallowing literature by identifying an additional use of the practice. Using a political ecology framework, this paper examines the geography of prolonged illness amongst subsistence agricultural households and villages in rural Mozambique and the potential implications for LULCC as health-affected households reduce the land area cultivated as a coping strategy for dealing with poor health.

Poor health has been linked to a decline in household resources in developing countries (Barnett and Whiteside 2002), and thus may affect how agricultural households manage their most basic resource—land. To determine what role health may play in LULCC, mixed methods are employed within a political ecology framework to address three research questions, at various scales, that focus on altering household land use decisions as a possible coping mechanism for unhealthy agricultural households:

1) National: Is there an association between prolonged illness and whether or not a household reports cultivating less land as a coping strategy?
2) Regional: Are unhealthy households observably different from healthy households?
3) Village: Can Landsat satellite imagery detect land cover changes due to prolonged illness?

At the national level, the relationship between altering land use decisions and prolonged illness is established using a regression framework with a nationally representative agricultural data set known as *Trabalho de Inquerito Agrícola* (TIA). The regression results from the national level analysis prompt further exploration into how unhealthy households are different in the way they choose to farm and the potential implications this has for LULCC. Because agricultural practices vary by region throughout Mozambique, I chose to focus on a highly agricultural province in southern Mozambique which also has one of the highest health burdens in the country. More specifically, Gaza province was chosen for a more nuanced examination of how unhealthy fallowing households differ agriculturally and economically from their healthier counterparts Then, the spatial component applies remote sensing techniques to two study villages in the Chokwe district in the Gaza Province, examining the potential for Landsat imagery to detect land cover change brought about due to prolonged illness.

This study contributes to the literature by examining: (1) how altered agricultural land use decisions such as reducing the area under cultivation may be used as a coping mechanism by subsistence agricultural households in Mozambique, and is therefore a more rudimentary land use decision; (2) what potential drivers or behaviors make unhealthy agricultural households different from their healthier counterparts with respect to fallowing; and (3), demonstrates how satellite imagery may help us understand the implications for LULCC. The primary contribution of this study provides a more nuanced understanding of the role of prolonged illness in shaping household agricultural land use decisions for unhealthy agricultural households, and the vulnerability to their livelihoods that prolonged illness creates. A secondary contribution of this study is the innovative application of remote sensing to map the potential impact of changes in agricultural land cover and its implications for the economic well-being and rural livelihoods of subsistence agriculturalists. Health studies using satellite imagery often study this relationship from how a change in land cover can alter health status; the innovation of this study is a reversal of that mechanism.

2.2 Background

2.2.1 Political ecology framework

Political ecology is well suited for contributing to this research. At its core, it offers a logical framework for addressing known problems. For this study, health is known to have an effect on labor supply (Schultz and Tansel 1997; Asenso-Okyere et al. 2010; Pennap et al. 2011; Asenso-Okyere et al. 2011). Thus, in agriculturally-reliant countries, poor health may contribute to diminished livelihoods and agricultural LULCC. Under such conditions, political ecology allows for a systematic examination the “chains of explanation” (Blaikie and Brookefield 1987, p. 27) associated with how prolonged illness amongst subsistence agricultural households may contribute to a reduction in livelihood capacity and the amount of land under cultivation.

Since its inception, political ecology has illustrated how decisions that transform the landscape are often the consequence of political and economic systems working at various scales (King 2010). King (2010) posits that political ecology of disease is needed and points out that only a handful of studies have actually applied political ecology to studying human disease (see Kalipeni and Oppong 1998; Oppong and Kalipeni 2005; Richmond et al. 2005; Sultana 2006; Cutchin 2007; Baer and Singer 2008; Hanchette 2008). Political ecology is committed to mixed methods and multi-scalar analysis, and such a commitment is useful for depicting how vulnerability to prolonged illness and health decision making are nested within social and spatial processes that contribute to places of disease (Rocheleau 2008; King 2010). Robbins and Bishop (2008) further stressed the importance of political ecology of disease, noting that very little is actually known about how unhealthy households respond to poor health and the micro-level implications remain "shrouded in mystery." Taken together, this paper contributes to understanding how unhealthy subsistence agriculturalists respond to, adapt and deal with prolonged illness, offering a more holistic understanding of the various decisions these types of households face.

2.2.2 Fallowing as an agricultural land use decision

Fallowing has long been practiced by subsistence agriculturalists throughout much of Africa to help improve agricultural output on small parcels of land (Boserup 1985). The classic practice of fallowing entails cropping lasting a few years before a household shifts their cropping to more productive land (Boserup 1985). The modern-day application of fallowing is for more sustainable reasons and seeks to use a shortened, improved fallowing cycle and intercropping to help restore nutrients to degraded soils (Sauerborn et al. 2000). Fallowing made the shift to its modern day use as population pressures and climatic shifts forced agricultural households to further shorten their fallow cycles and become more sustainable in the way it is practiced (Boserup 1985; Drechsel et al. 2001; Gaiser et al. 2011). Gaiser et al. (2011) found that population pressure will have just as much of an impact on agricultural land use and fallowing cycles as climate change, suggesting a heightened risk of increased food insecurity. Grisley and Mwesigwa (1994) found that agricultural households were moving away from longer fallowing periods as population demands increased the need for intensified land use, and intercropping began to replace the traditional fallowing system in place. Such a shift in land use practice was done to ensure a more sustainable approach to farming and thus can be viewed as an advanced agricultural land use decision. Health and gender have been shown to affect fallowing and the ability to remain food secure in Malawi. Thangata et al. (2007) found that gender plays a significant role in how HIV-affected households sustained their livelihoods, noting that the death of a male member of the household leads to a significant decline in agricultural output and an increase in fallowing. This is important when we consider Malawi neighbors Mozambique and the possibility of a similar relationship may exist within Mozambique.

Shifting cultivation and bush fallow regimes help restore nutrient properties to the soil, and are common throughout Mozambique due to vast stretches of land available for agriculture (Nhantumbo et al. 2009). In southern Mozambique, Nhantumbo et al. (2009) found inconsistent use of bush fallowing systems. Because of land abundance in Mozambique, large portions of land can be left fallow at a time. Arndt et al. (2010) found that in some areas of Mozambique, 20 hectares (ha) of land could be left fallow for every hectare cultivated. Missing from the relatively small research niche on fallowing in Mozambique is an understanding of drivers behind the decision to fallow, a gap this study addresses.

2.2.3 Health as an input

In the developing world, climatic factors such as droughts and floods have serious effects on food security — this is especially true for sub-Saharan Africa (Gillespie et al. 2007). In addition, HIV/AIDS is a significant threat to food security in this region, ushering in what has been described as a new variant famine (deWaal and Whiteside 2003). In Mozambique, many families rely heavily on agriculture, with maize, cassava, and wheat representing the core staple crops for rural households. These crops are labor-intensive, often cultivated via a hand hoe, and are rain fed, resulting in strenuous work and long hours (Donovan and Tostão 2010). Traditional knowledge plays a vital role in agriculture in Mozambique. Mather and Donovan (2008) found that the death of a prime-age adult in Mozambique can have significant effects on the livelihoods of agricultural households, with the death of a male head accounting for an average loss of 25% in crop income and an average loss of 88% in non-farm income. It has been demonstrated that HIV/AIDS erodes the transfer of traditional knowledge among women in the Limpopo Basin, reducing the sustainability of this way of life (Dominguez et al. 2005). Thus, an adult health event can affect a household's livelihood by diminishing its labor productivity and supply (Fox et al. 2004; Masanjala 2007; Chicoine 2012). The sickness or death of an adult can lead to the inability of a household to farm all of its land (du Guerny 2000). Yamano and Jayne (2004) showed that the death of an adult male household head in Kenya resulted in a 68% decrease in the net value of the household's crops. Furthermore, there is a significant lag effect associated with the death of an adult household head, suggesting long-term economic effects (Arndt 2006).

Spatial methods have been used to understand the diffusion and progression of disease and other health trends. Large data sets gathered from surveillance sites are now used to infer prevalence rates. This allows for a timelier estimation of the magnitude of infection. For example, Kalipeni and Zulu (2008) used continent-level HIV data from surveillance sites to estimate the general burden of HIV/AIDS for Africa, finding that sub-national prevalence rates can be calculated through interpolation and mapped to provide a better sense of the hardest hit regions.

Additionally, Tanser et al. (2009) used spatial analyses to detect and map clusters of HIV infection and illustrate the correlation of health with access to roads, markets, and other resources in South Africa.

2.2.4 Remote sensing and health

Remote sensing studies of how LULCC affects health status is the dominant mechanism studied in the literature, many with a focus on how changes in LULCC can drive outbreaks of infectious disease (Lindblade et al. 2001; Patz et al. 2004; Vasilakis et al. 2011). Vanwambeke et al. (2007) used Landsat Thematic Mapper (TM) data to show how changes in LULCC, most notably changes in agricultural land use, exacerbate the spread of dengue and malaria in Thailand, noting that anthropogenic changes in LULCC have a detectable impact on mosquito populations and infection. Young et al. (2013) combined vegetation indices from Moderate Resolution Imaging Spectroradiometer (MODIS) with elevation data from the Shuttle Radar Topography Mission (SRTM), and land cover data from the National Land Cover Database (NLCD) to show how agricultural land use expansion strongly correlate with increases in West Nile virus. Midekisa et al. (2012) used MODIS-derived products to account for LULCC in Ethiopia to help develop a malaria early warning system, concluding that specific attention to LULCC is needed to accurately estimate malaria potential. Estrada-Pena (2002) used Advanced Very High Resolution Radiometer (AVHRR) data coupled with temperature and rainfall data to show how changes in LULCC are contributing to more inviting environments for ticks in the eastern region of the United States, and thus driving increases in Lyme disease.

Largely missing from the literature are studies examining the impact of health on LULCC. Boutayeb et al. (2009) examined how malaria impacts agricultural productivity in developing countries, but stops short of assessing the impact on the physical environment. Zhang et al. (2011) took their assessment one step further and examined the probability of a plot of land being inhabited based on a risk assessment of malaria occurring within the area, finding that plots were less likely to be inhabited in areas where malaria risk was high but this effect was partially mediated by non-resident farming of the plot (i.e., the plot owner would occasionally have a plot under cultivation and would travel to it rather than residing at the plot). A reversal of the typical land-to-health relationship commonly studied, my research seeks to contribute to closing this current gap in the literature, demonstrating the application of established remote sensing and regression methods to help answer the village-level research question: Can Landsat satellite imagery detect land cover changes due to prolonged illness?

2.3 Study area

Mozambique is a southern African country that has struggled to contain the spread of HIV/AIDS (Audet et al. 2010). This disease is notable for this study because of its concentrated impact on prime-age adults, who are the most economically and agriculturally active subset of the population. The 2009 estimated HIV prevalence for Mozambique is 11.5%, one of the ten highest rates worldwide (DHS 2009). There is significant geographic variation, and prevalence is highest in the south. The region of focus for this study, the Gaza province, represents one of the most impacted provinces with an estimated HIV prevalence of 25.1% in 2009 (DHS 2009). The case study villages for this research, Chokwe and Conhane, are located in the Chokwe district within the Gaza province. Chokwe also serves as a provincial market center for Gaza province.

Approximately 85% of the population in Mozambique supports themselves through agriculture (FAO 2015). Land use practices in Mozambique are also important to this study; much of the area is smallholder agriculture with very limited use of technology, making households reliant on human labor (Jayne et al. 2010). In Mozambique, fallowing is typically practiced in the form of shifting cultivation (Nhantumbo et al. 2009), suggesting a less advanced use of this land use decision. Southern Mozambique has the largest irrigation network in the country and as a result, the cash cropping system is stronger in this region (Silva 2008). Sugar, cotton, tobacco, paprika and chickpeas represent popular cash crops grown in Mozambique (Walker et al. 2004; Boughton et al. 2007). There has been a growing emphasis on cash crops and the agricultural sector as a whole as the government seeks to strengthen its poverty alleviation strategy (Tschirley and Benfica 2001; PARPA 2007; PARPA 2011).

For this study, the villages of Conhane and Chokwe were chosen from the TIA data to examine the association between prolonged illness and alterations in agricultural LULCC. Both villages are located in the Chokwe irrigation scheme—the largest irrigated area in Mozambique (Charlwood et al. 2013). Conhane is located roughly 18km southeast of the provincial market center of Chokwe. The soil composition is predominantly clay and thus lends itself to rice production despite being located in a semi-arid area (receiving less than 600mm of rain a year) (Charlwood et al. 2013). The year is split into two seasons, hot and rainy (October-April) and dry and cold (May-September) (Charlwood et al. 2013). This area is a prime agricultural area and has enormous potential for providing Mozambique with needed food security, as it is capable of producing half of the country's rice need (Kajisa and Payongayong 2011). Unfortunately, damaging floods in 2000 drastically reduced the capacity of the irrigation scheme, and as a result, only roughly 4,000 ha of the 26,000 ha are currently being irrigated (Kajisa and Payongayong 2011). Figure 2.1 provides a map that situates the study villages with respect to Gaza.

Figure 2.1: Map of study area

Source: Map constructed by author using TIA data

2.4 Data and methods

This study uses a three-tier hierarchical analysis to address whether or not prolonged illness has an impact on agricultural land use, and whether this effect can be detected on the landscape. Mixed methods are employed to address the three supporting research questions. The scale of the analysis is refined with each subsequent tier and takes a top-down approach, focusing on: (1) national-level coping strategies; (2) regional differences between healthy and unhealthy households; and, (3) possible village-level changes in land cover as a function of prolonged illness.

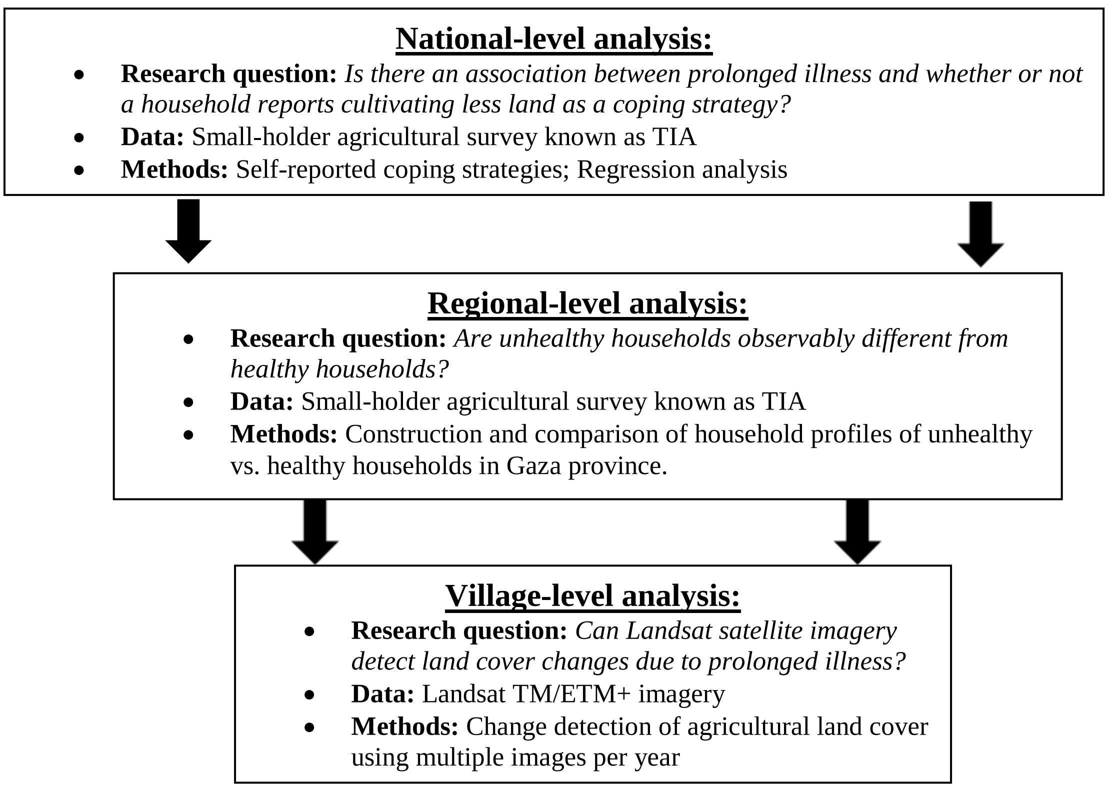
At the national level, a nationally representative smallholder agricultural survey, TIA, is used for the years 2002, 2005 and 2008[4] to help determine whether or not unhealthy subsistence agriculturalists employ different land use decisions as a coping strategy for experienced prolonged illness. Regression analysis will be used to establish whether or not a relationship exists between prolonged illness and a reduction in the amount of area cultivated exists. Additionally, qualitative reports on coping strategies are explored for top approaches used to mitigate the impact of prolonged illness.

At the regional level, the same TIA data are used for a refined geographic household analysis. Household profiles for healthy and unhealthy households in the Gaza province are constructed from the TIA and are used to help identify how unhealthy fallowing households are different from their healthier fallowing counterparts.

[4] A TIA survey for 2012 exists but was not included in this research as this survey dropped health related questions

At the village level, two villages are chosen to closely examine land cover change through time. These villages were chosen as they represent areas that are both agriculturally-reliant and have high rates of prolonged illness. Landsat TM/ETM+ imagery is used to hand digitize active agricultural fields. The objective is to determine the degree to which satellite imagery of this resolution is capable of detecting land cover change brought about by prolonged illness. Figure 2.2 summarizes the three objectives.

Figure 2.2: Overview of hierarchical analysis



2.4.1 Small-holder agriculture data

The TIA is an agricultural survey that is administered to rural small- and medium-holder agricultural households. It is a comprehensive survey that includes questions on demographics, socioeconomic indicators, agricultural land holdings, crop production, consumption and expenditures, agricultural input use, and health and well-being measures. The data are representative at both the provincial and national levels (Mather and Donovan 2008). This study makes use of TIA data from the 2002, 2005 and 2008 survey years and specifics for each year are detailed in Table 2.1.

Table 2.1: Number of households, villages, and districts covered by the TIA

TIA Year	Number of Households	Number of Villages	Number Districts
2002	4,908	559	80
2005	6,149	656	94
2008	5,968	687	128

Note: There are a total of 128 districts in Mozambique
Source: Table constructed by author using TIA data

TIA data were used for all three levels of analysis in the study. The data include measures of both agricultural land use and household health status. Households are surveyed about their total land holdings, and are also asked about how much of that land was cultivated or fallowed during the last year. This information was used to identify households that engaged in fallowing. Illness was identified at the household level and then aggregated to village-level rates for each year of the TIA data used. Specifically, the household survey asks whether any members of the household were ill for three months or more. This information is used to identify households that experienced a prolonged illness in the preceding year. The 2002 survey also asks about coping strategies used by households that experienced a prolonged illness. Additional TIA variables were incorporated into the regional-level analysis. To understand the role of agriculture, and specifically land, in the livelihoods of households in this area, demographic and agricultural characteristics from the TIA were used to construct household profiles for the province of Gaza.

While there is some overlap in households surveyed across these three waves, the TIA is not designed to be a panel and not all households and villages overlap across the three survey waves. A secondary contribution of this study is to examine LULCC at the village level over time; study villages that were captured in all three waves of the TIA data were identified and used for this component. Conhane and Chokwe are the two villages chosen for the village-level analysis. These villages are located in the Chokwe district, which is relatively advantaged agriculturally but disadvantaged from a health perspective; the Chokwe irrigation scheme positions the district as an agricultural hub for Mozambique, but it has a substantial HIV burden where it is estimated that prevalence is as high as 29.4% (Feldblum et al. 2014).

Because fields are not necessarily adjacent to households, and the geographic coordinates for fields provided in the TIA are missing or unreliable, for the change detection analysis, I used the TIA to create a buffer around each village to capture the agricultural land that may be associated with each village. Each wave of the TIA includes a self-reported measure for average distance to field; this variable was used to construct the buffer radius. I calculated this measure at the household level and then took the village mean for each of the two villages. These measurements were then used to define and create a buffer in ArcGIS 10.2. From here, I was able to import it as a vector file into ENVI 5.0 to assist with the hand-digitization of agricultural fields that correspond with the study villages.

2.4.2 Satellite imagery

The change detection analysis was performed using Landsat TM/ETM+ imagery; limited high resolution satellite imagery was used to assist with identifying seasonal trends in agriculture. Imagery collected by the Landsat TM/ETM+ sensor is of 30 meter resolution (medium-resolution) and provides a detailed record of the landscape with a 16 day repeat cycle for a given area. The twice per month record of land cover allows for a more comprehensive understanding of the potential transitory changes occurring within a particular agricultural season under optimal conditions. However, in this part of Africa, twice-per-month coverage of Landsat imagery is rarely achieved due to significant cloud cover. All available Landsat scenes for the study area (Worldwide Reference System – 2 (WRS-2) path/row 167/77) corresponding to each agricultural year of the TIA data (2002, 2005 and 2008) were downloaded from the United States Geological Survey (USGS) Earth Resources Observation and Science (EROS) Data Center as L1T data. The L1T correction is the optimal choice of processing as it provides both precision and terrain correction that incorporates ground control points and a Digital Elevation Model (DEM) to assist with topographic accuracy (USGS Landsat Missions). The satellite data were delivered in WGS 1984 UTM format and correspond with zone 36S. The study villages, Conhane and Chokwe, fall entirely within one Landsat scene, thus I did not need to worry about compositing multiple scenes. Images with cloud cover greater than 30% over the study villages were excluded from the analysis. This imagery was used to generate hand-digitized maps for each agricultural year. Scene specific information is provided in Table 2.2.

I also made use of the limited high resolution imagery (<5 meter resolution) available from Google Earth, and these data represented a combination of Quickbird, WorldView-1 and WorldView 2 data. However, the high resolution imagery was not temporally rich and prohibited me from using it to map changes in land cover. The high resolution imagery that does exist for the study area was used to assist with visual interpretation of the land cover, as well as assisting with the trend analysis. Available years included 2004, 2005 and 2010, and while this did not always temporally correspond with the TIA data, 2004 and 2010 imagery were generally used to help understand the composition of the landscape, whereas 2005 was used concurrently with 2005 Landsat TM data.

Table 2.2: Landsat Scene Information

Agricultural Year 2002 Landsat 7 ETM+	**Agricultural Year 2005 Landsat 5 TM**	**Agricultural Year 2008 Landsat 7 ETM+**
10/30/2001	03/07/2005	09/21/2007
03/07/2002	04/24/2005	02/12/2008
04/24/2002	06/11/2005	09/07/2008
05/10/2002	08/30/2005	10/09/2008
10/17/2002	10/01/2005	

Source: Table constructed by author

2.4.3 National-level analysis

To establish whether households in Mozambique employed different land use decisions in response to a prolonged illness, descriptive data on coping strategies from the 2002 TIA were analyzed and I conducted a household-level regression analysis using the TIA data for 2002, 2005 and 2008. The regression approach is a more robust validation of LULCC in response to prolonged illness as it is possible to test the significance of prolonged illness on a reduction in the amount of area cultivated. The dependent variable in this case was a binary indicator of whether a household engaged in fallowing in the previous year. Because the outcome variable is binary, a logit model was used for estimation. The model was estimated separately for each year to allow for the land-health relationship to change throughout time. The model took the following form for household *i* in province *j*:

$$Y_{ij}= \delta 1(\text{ProlongedIllness})_{ij}+\beta\ \text{TotalFieldArea}_{ij}+ \gamma 1(\text{RentsLand})_{ij}+\mu_j+\varepsilon_{ij},$$

where:

$1(\text{ProlongedIllness})_{ij}$ = an indicator of whether household *i* in province *j* experienced a prolonged illness (illness lasting greater than three months) in the prior year

$\text{TotalFieldArea}_{ij}$ = the TIA size of field area belonging to household *i* in province *j*

$1(\text{RentsLand})_{ij}$ = an indicator for whether household *i* in province *j* rents any part of its land holdings

μ_j = a province indicator

ε_{ij} = the error term for household *i* in province *j*

This model mirrors the approach taken in the remote sensing analysis by attempting to identify whether an association between prolonged illness and land use decisions among agricultural households in Mozambique exists. Variable significance was tested using the adjusted Wald test. Additionally, the variance inflation factor (VIF) was calculated for each year of the regression to test for multicollinearity.

2.4.4 Regional-level analysis

While Mozambique, and more specifically the Gaza province, is known to be agriculturally-reliant, agriculture in this case is broadly defined to include both crops and livestock, and thus further examination is needed to understand the land-reliance of these households, specifically the role of reducing the amount of land under cultivation. Household profiles were constructed for Gaza households to highlight their agricultural and economic characteristics, reflecting resources such as household members engaged in agriculture, crops grown, livestock owned, and participation in outside employment. Profiles were categorized based on whether the household had experienced a prolonged illness, and the profiles of unhealthy fallowing households were compared with the profiles of healthy fallowing households. The goal of this analysis was to understand what makes households' agricultural land use decisions vulnerable to the presence of a prolonged illness. A two-sample test of proportion was used to test for significant differences in profile indicator variables, and a two-sample test of equal variances was used to examine the remaining variables. These profiles contribute to the interpretation of the change detection results by speaking to the ability of households to cope with a prolonged illness through other means, such as substituting labor or relying more heavily on livestock.

2.4.5 Village-level analysis

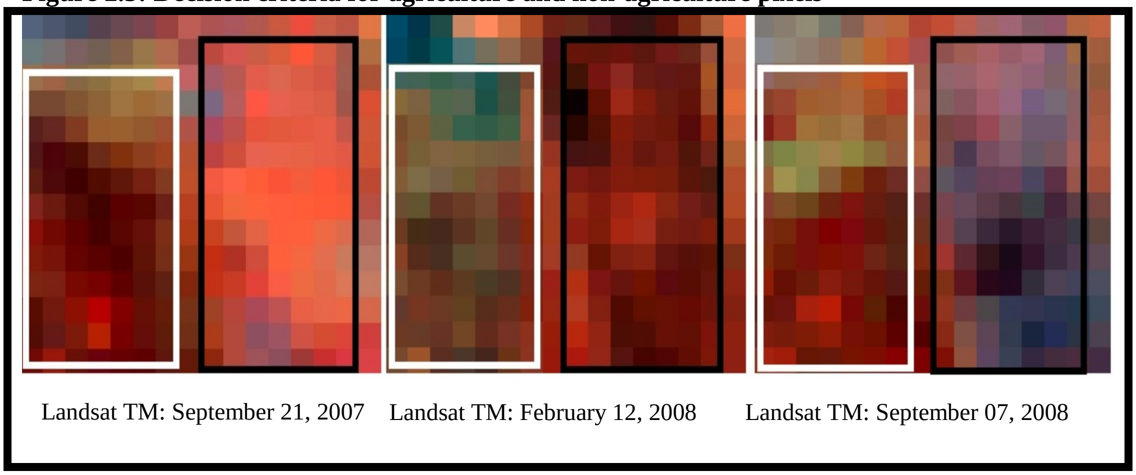
The village-level analysis analyzes the health-land use relationship in an innovative way using satellite imagery. A change detection analysis of active agricultural land was performed using Landsat TM/ETM+ data from 2002, 2005, and 2008, chosen to correspond with the years of the TIA surveys. This allowed for a comparison of village trends in agricultural land with village trends in prolonged illness. I focused on two villages in the Gaza province, Chokwe and Conhane.

This study was first attempted using a decision tree classification algorithm. I attempted to use a semi-automated algorithm that would classify the land cover into either agriculture or non-agriculture. Training areas were selected using a stack of individual scenes from different dates throughout each study year and a then supervised classification algorithm based on decision trees was implemented. For each scene, spectral reflectance for bands 2-5 and 7 were used for the analysis; band 1 was excluded due to its susceptibility to atmospheric interference. Unfortunately, the small-scale agricultural practices in this area made it problematic for this algorithm to distinguish small-scale farming from other land cover types. Because of the issues surrounding a semi-automated classification algorithm, I opted for a hand-digitization process using visual interpretation that made use of all available Landsat TM/ETM+ satellite imagery, and freely available high resolution imagery accessible via Google Earth; this assisted with the hand-digitization of each year of interest (each agricultural season corresponding to the TIA surveys).

Hand-digitization was performed using ENVI 5.0 by using bands 1-5 and 7 for each image for the given agricultural years. Agricultural pixels were interpreted using the band 4, 5, 7 red-green-blue combination. This band combination provided the best contrast while also generating an approximate “false color” rendition of the land cover and greatly assisted in the delineation of vegetation boundaries. As a result, atmospheric scattering was at a minimum, while vegetation vigor was maximized. This band combination streamlined the selection process and aided with identification of agricultural pixels. All cloud free images for a given year were used to help identify potential agricultural areas (see Table 2.2) to improve the robustness of the approach.

Because this area is well-suited for agriculture, multiple images throughout the agricultural year were examined to provide a refined estimate of the amount of land cultivated. This was especially important because change detection analysis of agriculture is more dependent on the changes that occur on the landscape throughout a growing season more than the changes that occur on a yearly scale. For example, the multiple stages of growth that corn goes through from seed to harvest. By using multiple images throughout a growing season, I was able to more accurately map active agricultural areas. In addition to the 4,5,7 band combination, additional images consisting of other band combinations were used to help select agricultural pixels using multiple criteria, including shape, greenness, and harvest patterns (e.g., high greenness in one image and then bare soil in the next). Additionally, the available Google Earth high resolution imagery were used to confirm agricultural areas and greatly assisted with the delineation of the land use classes *agriculture* and *non-agriculture*. However, the high resolution imagery did not always temporally align with the Landsat TM/ETM+ data; 2004 and 2010 high resolution imagery were used to help provide general information and examples of distinguishing agriculture from non-agriculture. Because these years do not align with the TIA or Landsat TM/ETM+ data, they were not used to help directly map the two classes; rather, they were used to help provide a better sense of the overall land cover in this area for the period from 2004-2010. 2005 satellite data align with the TIA data and was used to specifically help distinguish agricultural land from non-agricultural land. The temporal mismatch necessitated using the intra-annual signature to assist with the classification of the two classes. The intra-annual signature relies on using all available Landsat TM/ETM+ images for a given year and then examining agricultural areas according to the multiple stages of growth crops go through. As depicted in Figure 2.3, the decision criteria used for distinguishing agriculture from non-agriculture pixels shows the use of both seasonal changes in land cover, as well as the signature for active cropped areas. The series of Landsat images shows how I made the distinction and helped to refine the digitization classification.

Figure 2.3: Decision criteria for agriculture and non-agriculture pixels



Note: The black rectangular box corresponds to cropped area, whereas the white rectangular box corresponds to natural vegetation. It was important to use the intra-annual temporal trend to help distinguish agriculture from non-agriculture.
Source: Figure constructed by author using available Landsat TM/ETM+ imagery

The pixel count for agriculture was used to provide an estimate of the area of cultivated land for a given year; I opted for a hectare areal measure. A buffer was calculated for each village to identify the agricultural areas that were associated with each village. An average distance to field metric was calculated for each village for each TIA study year by standardizing the reported values for distance-to-field and converting them to kilometers. All available households in the two study villages were included in the calculation of this metric, which included 30 observations from Conhane and 31 observations from Chokwe. The buffer was imported into ENVI 5.0 to assist with the manual classification of each agricultural year's map. I was only concerned with agriculture within the defined buffer distance, and as a result, excluded farm land falling outside of the buffer. In an effort to be inclusive, agricultural pixels that intersected the defined buffer were included in the hand-digitization. The buffer layer streamlined the process of hand-digitization and allowed for expedient identification of the agricultural area of interest.

2.5 Results

2.5.1 National-level analysis

The household data on coping strategies, collected in the TIA 2002 survey, provides support for the hypothesis that health affects agricultural land use. In fact, "cultivating less land" was the primary response identified as a coping mechanism for deaths or illnesses in the household. Of the 477 survey respondents who answered the question in 2002 on coping strategies used for a reported death in the household, 43% said they had no strategy for dealing with a loss in the household and nearly 33% said they "cultivated less land." Of the 155 households that experienced an illness to a household member lasting longer than three months, 53% of respondents said they "cultivated less land." Table 2.3 expands on the self-reported coping strategies and examines the average rates for prolonged illness and use of fallowing by province.

Table 2.3: Rates of prolonged illness and fallowing by province

Province	Prolonged Illness	Use of fallowing
Niassa	5.3	9.3
Cabo Delgado	7.2	12.0
Nampula	4.7	17.4
Zambezia	5.6	15.2
Tete	4.0	11.2
Manica	4.8	20.6
Sofala	5.5	12.2
Inhambane	6.7	25.4
Gaza	7.9	26.9
Maputo	6.8	27.8

Note: Rates calculated using TIA data for 2002, 2005 and 2008 by the author

Overall, fallowing is not used as frequently as one would expect in Mozambique. In the TIA, the average rate of fallowing engagement for healthy households during 2002, 2005 and 2008 was 17%, 18% and 17%, respectively. However, the rate of fallowing for unhealthy households is much higher, 26%, 24% and 27% for 2002, 2005 and 2008 respectively.

The regression findings further establish the association between experienced prolonged illness and land use, specifically whether a household engages in fallowing. Table 2.4 reports regression results as odds ratios. Specifically, experiencing a prolonged illness was a significant predictor of fallowing ($p<0.05$) across all three study years, increasing the odds of engaging in fallowing by approximately 40-50%. This finding mirrors the results of the descriptive coping strategies reported in the TIA 2002 survey. Size of total field area belonging to a household was also a significant predictor ($p<0.01$) of participation in fallowing. This finding suggests that it may be difficult to farm all land when area increases, as households may be constrained by labor. Another possible explanation is that households with larger land holdings employ more sophisticated agricultural techniques. In the regression model I also account for another potential coping strategy for unhealthy households—the ability to rent out land. Land rental was a significant predictor of fallowing for 2005 and 2008, but not for 2002. Taken together, these findings suggest that the effect of prolonged illness is persistent throughout time and households with unhealthy members are much more likely to report fallowing than healthy households. The VIF of the covariates was calculated for each year of the regression and ranged from 1.03-1.17, indicating that multicollinearity was not an issue with the model estimation.

Table 2.4: Fallowing regression results

Variables	**2002**	**2005**	**2008**	**Change through time**
	OR (SE)	OR (SE)	OR (SE)	
Household experienced prolonged illness	1.50**	1.38**	1.54**	
	(0.30)	(0.21)	(0.32)	
Household total field area	1.39***	1.20***	1.24***	***
	(0.04)	(0.06)	(0.04)	
Household rents out land	1.33	1.87***	1.53**	
	(0.68)	(0.36)	(0.28)	
Niassa province	0.145***	0.29***	0.36***	**
	(0.04)	(0.07)	(0.08)	
Cabo Delgado province	0.07***	0.56***	0.73	***
	(0.02)	(0.10)	(0.14)	
Nampula province	0.59***	0.50***	0.86	*
	(0.10)	(0.09)	(0.14)	
Zambezia province	0.253***	0.516***	0.906	***
	(0.05)	(0.09)	(0.16)	
Tete province	0.36***	0.25***	0.46***	
	(0.07)	(0.06)	(0.09)	
Manica province	0.47***	0.93	0.56***	**
	(0.10)	(0.17)	(0.12)	
Sofala province	0.18***	0.76	0.26***	***
	(0.04)	(0.13)	(0.07)	
Inhambane province	0.45***	0.95	1.15	***
	(0.09)	(0.17)	(0.21)	
Maputo province	0.54***	1.59**	1.23	***
	(0.11)	(0.29)	(0.23)	
Observations	4849	5982	5781	

Note: Calculations from TIA by author. Significance defined as: * $p<0.10$, ** $p<0.05$, *** $p<0.01$

The reference group for the regressions is the Gaza province, a severely health-afflicted region of Mozambique where just over 1 in 4 adults have HIV (Ministry of Health 2010). Gaza also has high rates of fallowing participation, based on the TIA survey. The provincial indicators suggest significant spatial variation in the decision to fallow. For 2002, Cabo Delgado had the lowest rates of fallowing participation, followed by Niassa, Sofala, Zambezia, Tete, Inhambane, Manica, Maputo and Nampula respectively. The pattern of fallowing shifts slightly in 2005, where Tete was the least likely province to fallow land. Interestingly, Maputo's odds of engaging in fallowing were higher than Gaza in 2005. In 2008, Sofala had the lowest rate of fallowing participation, followed by Niassa, Tete and Manica respectively. Niassa consistently ranks near the top for provinces least likely to fallow when compared to Gaza. Other than 2002, households in the Inhambane province were most similar to those in Gaza in their fallowing participation.

Additionally, I examined what factors affecting fallowing may have varied significantly through time. The effect of prolonged illness did not significantly vary across the study years; the health effect remained strong and consistent throughout the study. The effect of total field area on fallowing varied across the survey years, attenuating through time. There was no significant difference in the role of renting land on fallowing engagement across the survey years. The odds of fallowing varied for most provinces through time and slightly increased for Niassa, Cabo Delgado, Nampula[5], Zambezia, Tete[6], Manica, Inhambane and Maputo provinces.

The descriptive data on coping strategies and results from the regression analysis motivate further exploration of the role of fallowing in subsistence agricultural households in Mozambique. While fallowing is broadly associated with advanced farming practices, the results thus far suggest a second identity, as a coping mechanism. To understand what might drive households experiencing a prolonged illness to fallow, more insight into the differences between healthy and unhealthy households that fallow, and the potential agricultural and economic vulnerability unhealthy households face is needed. Fallowing as a response to prolonged illness

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[5] Nampula's odds of fallowing attenuated in 2005 suggesting that may have been hit hard by drought.
[6] Tete's odds of fallowing attenuated in 2005 suggesting that they may have been hit hard by drought.

further motivates the remote sensing analysis at the village level. Higher rates of fallowing participation by households facing a prolonged illness should aggregate to imply that villages with higher rates of prolonged illness have different LULCC patterns than villages with lower rates of prolonged illness. I seek to determine whether this response can be captured by Landsat TM/ETM+ imagery, using remote sensing to map trends in cultivated land onto trends in health status for two villages in the Gaza province.

2.5.2 Regional-level analysis

Table 2.5 summarizes the profiles for subsistence agricultural households throughout the Gaza province. The profiles compare healthy and unhealthy households that fallow with the intent of identifying key differences in livelihood strategies. The profiles include agricultural inputs, as well as measures of economic potential, such as education and participation in non-agricultural activities. For many of the included variables, there is no significant difference between healthy and unhealthy households that fallow. However, the profiles do identify a few key differences. The age of the household head is greater for unhealthy households, approximately 56 years of age for unhealthy households compared to approximately 51 years for healthy households. This age difference may contribute to the ability to farm all of one's land. Interestingly, household ownership of a latrine is significantly different between the two groups, with a greater rate of ownership occurring in healthy households. Lower ownership of this item in unhealthy households point to lower socioeconomic status and thus magnifies their potential vulnerability to poor health.

Table 2.5: Comparison of fallowing households based on experienced prolonged illness

Variable	**Healthy** means / (std. deviation)	**Unhealthy** means / (std. deviation)	**Sig.**
Household total cropped area (ha)	2.20	2.43	
	(2.63)	(2.00)	
Household field fragmentation	2.98	2.71	
	(1.58)	(1.46)	
Full-time workers in household	0.12	0.25	
	(0.61)	(1.53)	
Household uses agricultural extension agent	0.20	0.27	
	(0.40)	(0.45)	
Household uses emergency seed	0.13	0.12	
	(0.34)	(0.32)	
Household uses any fertilizer	0.09	0.06	
	(0.29)	(0.24)	
Household uses any pesticides	0.08	0.06	
	(0.27)	(0.24)	
Household uses any animal traction	0.61	0.67	
	(0.49)	(0.47)	
Household uses any agro-processing equipment	0.09	0.08	
	(0.29)	(0.27)	
Household uses any mechanized traction	0.25	0.27	
	(0.43)	(0.45)	
Household engages in any outside employment	0.47	0.46	
	(0.50)	(0.50)	
Household proportion of land that is upland	0.57	0.48	
	(0.42)	(0.44)	
Household proportion of land that is irrigated	0.14	0.17	
	(0.31)	(0.35)	
Household head is male	0.70	0.77	
	(0.46)	(0.43)	
Household head average age	51.15	56.13	**
	(14.64)	(16.02)	
Household head average education	3.13	3.75	
	(4.18)	(4.54)	
Household child dependency ratio	0.44	0.40	
	(0.43)	(0.27)	
Average number of household members in agriculture	4.02	5.23	***
	(2.76)	(3.08)	
Household owns a lantern	0.63	0.65	
	(0.48)	(0.48)	
Household owns a radio	0.54	0.58	

	(0.50)	(0.50)	
Household owns a latrine	0.65	0.50	**
	(0.48)	(0.50)	
Household owns a table	0.65	0.63	
	(0.48)	(0.49)	
Household owns any cattle	0.44	0.54	
	(0.50)	(0.50)	
Household owns any goats	0.48	0.63	**
	(0.50)	(0.49)	
Household owns any sheep	0.09	0.17	*
	(0.29)	(0.38)	
Household owns any pigs	0.19	0.17	
	(0.39)	(0.38)	
Household grows corn	0.97	0.92	*
	(0.17)	(0.27)	
Household grows rice	0.10	0.08	
	(0.31)	(0.27)	
Household grows sorghum	0.06	0.08	
	(0.24)	(0.27)	
Household grows millet	0.05	0.04	
	(0.21)	(0.19)	
Household grows staples	0.84	0.67	***
	(0.37)	(0.47)	
Household grows sweet potatoes	0.69	0.62	
	(0.46)	(0.49)	
Household experienced food hardship in last year	0.48	0.64	**
	(0.50)	(0.49)	
Household production (kg)	991.18	763.00	
	1690.13	1006.37	
N	478	52	

Note: Calculations from TIA by author. Significance defined as: * p<0.10, ** p<0.05, *** p<0.01

Where some of the key differences arise between these two groups is engagement in agriculture. Unhealthy households that fallow are more reliant on intra-household labor, having more active members (approximately 5 members) participating in agriculture than healthy households (approximately 4 members). Ownership of goats and sheep are higher for unhealthier households that fallow, but there is no statistically significant difference in rates of cattle ownership.

Additionally, unhealthy households are less likely to grow corn and staples than their healthy counterparts, and also report experiencing food hardship in the last year more often than healthy households. The increased likelihood of food hardship among unhealthy households could be a direct effect from growing less corn and staples. Poor health in this sense may be contributing to heightened vulnerability to food insecurity for unhealthy households. The increase in goat and sheep ownership suggests that unhealthy households are possibly becoming less land-reliant in terms of crops they grow, but are possibly becoming more reliant on communal land for their smaller livestock as they seek alternative means of coping with prolonged illness. This would further reinforce a potential shift in land cover away from farming and back to a natural vegetative state as fallowing participation increases and land abandonment may occur. Taken together these findings suggest that prolonged illness is prompting unhealthy subsistence agriculturalists to shift agriculturally, as it appears they are making a shift from crops to livestock. This does not negate the idea that prolonged illness is a threat to livelihood sustainability, but does offer some hope that alternative coping strategies may be able to mitigate the impact of poor health.

2.5.3 Village-level analysis

The prevalence rates of prolonged illness in Conhane and Chokwe are given in Table 2.6 and Table 2.7, respectively. For Conhane, the prevalence of prolonged illness, as reflected in the TIA, increased from 2002 to 2005 and then dropped from 2005 to 2008. For Chokwe, the prevalence of prolonged illness dropped significantly through time. This analysis assumes that the sampled households in each village are an approximation of the overall prevalence of prolonged illness in the village, as the households weights are applied to the study villages. The sudden drop in prolonged illness from 2005 to 2008 is a bit unusual. While it would be viewed as a success to see health improve this much through time, studies suggest that this area in Chokwe is consistently plagued by poor health. Thus, the drop in prevalence may relate to the small number of households surveyed from each village.

Table 2.6: Conhane prevalence of prolonged illness and cropped area

Year	**N**	**Mean** (%)	**Std. Dev.**	**Cropped Area (ha)**
2002	10	14.1	0.366	228
2005	11	24.6	0.452	239
2008	9	0	0	288

Source: Calculated by author

Table 2.7: Chokwe prevalence of prolonged illness and cropped area

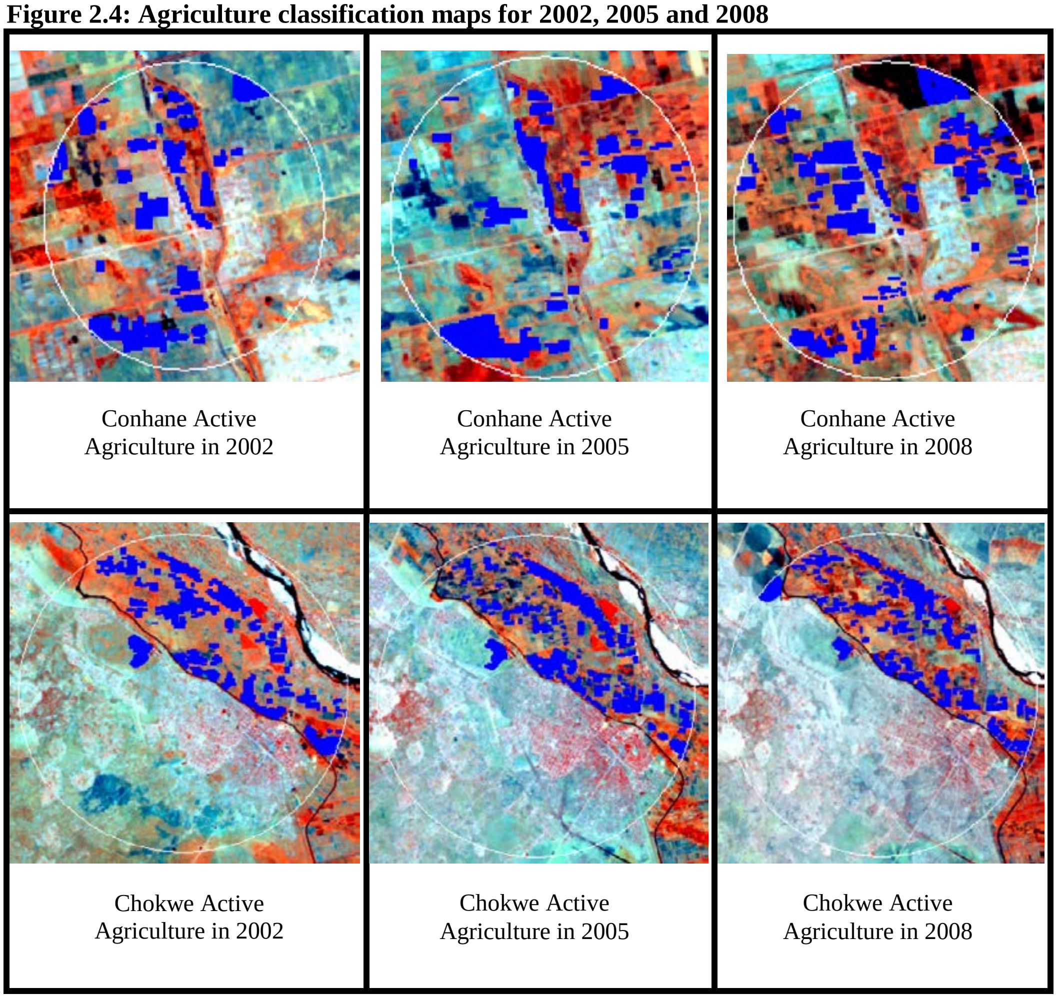
Year	**N**	**Mean** (%)	**Std. Dev.**	**Cropped Area (ha)**
2002	11	35.9	0.503	489
2005	13	11.8	0.335	470
2008	7	0	0	468

Source: Calculated by author

Based on the self-reported measure of distance to field from the TIA, the average distance was estimated to be 2.67 km for Conhane and 4.25 km for Chokwe. Tables 2.6 and 2.7 present the total cropped areas for each village at each time point. Figure 2.4 shows the classified maps for each village and survey year. Classified agriculture pixels are shown in blue. The area farmed increased consistently over time in Conhane, while a steady decrease was observed in Chokwe. In Conhane, agricultural land use mapped at 228 ha in 2002 and increased to 239 ha in 2005, and increased to 288 ha in 2008. This finding is a bit counterintuitive as I would expect to find cropped area increase as prevalence of prolonged illness decreases; however, prevalence of prolonged illness increased as cropped area increased for Conhane between 2002 and 2005. For Chokwe, agricultural land use mapped at 489 ha in

2002, decreased slightly to 470 ha in 2005 and remained fairly consistent at 468 ha in 2008. The decline in agricultural area seems counterintuitive for Chokwe as the area has been dubbed the “breadbasket of Mozambique” (Hermele 1988). However, a possible explanation for this would be the great floods of 2000 which severely devastated the irrigation network and still has not been fully restored (Kajisa and Payongayong 2011).

Figure 2.4: Agriculture classification maps for 2002, 2005 and 2008



Note: Author’s own calculation. Blue areas correspond to active agricultural areas.

As seen in Figure 2.4, the hand digitization yielded a relatively stable estimate of cultivated land through time, but also highlights the shifting agricultural system in place as the actual location of cultivated land moves around the study village area between time steps. This is most likely due to the transition between fields in the irrigated areas based on access to water and land use rights, as parcels of land in the irrigation network are in the process of being reallocated to younger farmers who are willing to farm larger plots and enter into farming contracts to grow rice (Veldwisch et al. 2013). Figure 2.4 also identifies areas that appear to be fields with crop cover, however this is a bit misleading as many fields in this area are abandoned and thus the signal is not indicative of actual crop cover. This is misleading because of the similarities in the spectral signature of land cover types. For example, active grassland can be similar to active agriculture in the way they appear in the satellite imagery. Because there is not a temporal overlap between Google Earth imagery for 2002 and 2008, the seasonal changes that occurred within the year were the primary means of distinguishing agriculture from non-agriculture in this setting. The village-level results suggest that it is difficult to detect what effect prolonged illness has on cropped areas at the Landsat scale.

2.6 Discussion

The coupled health-agriculture relationship has been well studied (Gillespie et al. 2001; Canning 2006; Dominguez et al. 2005; Mather and Donovan 2008; Shultz 1961; Becker 1964, 1992, 2007; Asenso-Okyere et al. 2011). However, studies that examine the impact of health on the physical landscape are largely missing from the literature. This analysis addresses this gap by examining the connection between experienced prolonged illness and potential implications for LULCC in Mozambique. The modern day application of fallowing is often viewed as an advanced sustainable agricultural land use decision aimed at improving the overall productivity of a parcel of land. However, in this study I recast fallowing as a rudimentary agricultural land use decision. Fallowing is a coping strategy for households that experience a prolonged illness, often because of an overall lack of resources available for dealing with chronic health issues. As a result, there are direct implications for both LULCC, as well as livelihood sustainability and food security. While the TIA data has questions specifically relating to illness and deaths due to disease, it does not provide the exact illnesses experienced. Just as in Mather and Donovan (2008), I use this health information as a proxy to estimate the potential impact of HIV on agricultural land use.

Results from the national-level analysis confirm that unhealthy subsistence agricultural households use fallowing as a coping strategy for prolonged illness. The descriptive responses from the TIA 2002 data laid the foundation by asking health-affected households to name their top coping strategies for dealing with a prolonged illness. Of those who reported a prolonged illness in 2002, 53% cited “cultivating less land” as their number one coping strategy. Somewhat surprisingly, fallowing is not practiced by a large proportion of subsistence agricultural households in Mozambique. This prompted further exploration, as this coping strategy has potential immediate implications for both land cover change and food security. Subsistence agricultural households that experienced a prolonged illness during the study years had approximately 40-50% higher odds of fallowing than their healthier counterparts.

HIV and the link to food security can be thought of as bi-directional—the disease can heighten vulnerability to food insecurity, and food insecurity can contribute to a further decline in health due to the disease (McEwan 2004). FAO (2000) estimated that between 1985-2020, Mozambique would lose roughly 20% of its agricultural labor force due to HIV/AIDS. Furthermore, in a 2005 FAO report, HIV/AIDS, poor health and inadequate access to health services were contributing factors to the regional food insecurity in the central and southern regions of Mozambique. As a result, not only do the findings from the national-level analysis suggest that unhealthy subsistence agricultural households are in the midst of losing the ability to sustain their livelihoods when dealing with a prolonged illness, but there may also be a macroeconomic effect on development for the country if the FAO estimate is realized.

Identifying fallowing as a coping strategy for prolonged illness is a first step in understanding the vulnerability unhealthy subsistence agricultural households face. However, the degree of vulnerability needs to be further explored. The regional-level analysis sought to identify some of the key differences between healthy and unhealthy agricultural households that engage in fallowing. I found that average age of the household head in unhealthy households was approximately five years older (56.13 years old) than heads of healthy households. Furthermore, unhealthy households were more reliant on agriculture and employed more household members in the activity than healthy households. However, they were less likely to grow corn and staples than their healthier counterparts, and thus reported greater food hardship in the previous year. As a result, the decrease in the main crops grown in the house (corn and staples) coupled with the increased report of food hardship suggests that these households remain agriculturally and economically suppressed.

Of the few assets that appeared to be significantly different was the ownership of a latrine, of which healthy households had a much higher ownership rate than unhealthy households. Mather et al. (2008) found that ownership rates of a latrine were much higher for households in the highest income quintile (61%), where households in the lowest income quintile had a much lower rate (31%). Taken together, these findings suggest that healthy fallowing households may be economically better off than unhealthy fallowing households, supporting the notion that fallowing in Mozambique takes two distinct forms: as a long-term strategy adopted by well-resourced subsistence agricultural households, and as a coping strategy made under duress by less-resourced unhealthy agricultural households..

In terms of livestock ownership, there was no statistical difference in rates of ownership for cattle between healthy and unhealthy households. However, unhealthy households were more likely to own goats and sheep than healthy households. One possibility for this could be that unhealthy households may be holding onto cattle as long as possible to use as a potential asset that could be sold to mitigate the impact of a prolonged illness, while ownership of goats and sheep is used as an imperfect substitute for the potential loss of cattle down the line. The increase in likelihood of owning goats and sheep suggest that unhealthy househods are investing in these smaller livestock rather than cattle, as cattle are more expensive and more difficult to maintain. Mutenje et al. (2008) found that HIV/AIDS-afflicted households in Zimbabwe owned more goats and poultry than non-afflicted households, namely due to the lower labor required for raising small livestock, and used sales of these stock as a coping strategy to smooth consumption when dealing with health related negative income shocks. Additionally, increased ownership of small livestock for unhealthy households in Mozambique suggests that this coping strategy may further reinforce land cover change as it makes them less land-reliant. Low ownership rate of latrines, the increased likelihod of owning goats and sheep, and the increased odds of fallowing for unhealthy households suggest that these are key coping strategies for households of lower socioeconomic status and are ways in which unhealthy households are attempting to maintain a sustainable livelihood. However, the results from the analyses suggest that this coping strategy may not be enough to help mitigate the associated food insecurity that comes from growing less corn and staples, and as a result, unhealthy households remain quite dependent on agriculture. The differences between healthy and unhealthy households that fallow suggest a potential for long-term food insecurity for subsistence agricultural households that experience a prolonged illness. Donovan and Massingue (2007) found that the nutritional effects of illness and death varied by gender in Mozambique, and substantially reduced the daily recommendations for calories, proteins, and fats consumed using data from the TIA 2002 and 2005. Additionally, because unhealthy households in the TIA survey are more reliant on agriculture, they may have limited economic growth potential as they are not able to transition away from subsistence agricultural to off-farm employment.

Results from the TIA analysis confirm that these particular villages have been affected by prolonged illness. The prevalence of prolonged illness rises then falls for Conhane, whereas, it falls precipitously in Chokwe. This decrease in prevalence may be a function of the increased effort Mozambique has invested in its health infrastructure, such as increasing the number of health clinics and bolstering services provided. Mozambique began introducting ART in 2004 (Audet et al. 2010). While this is at most a partial contributor to the decrease in prolonged illness prevalence observed in Conhane and Chokwe between 2002 and 2008, it does speak to the availability of health clinics in the area to have such diseases diagnosed and treated. By 2008, ARTs were readily available throughout the region, and the overall health infrastructure expanded greatly in this district (Yao and Murray 2014). The rollout of ART coincided with the need for more health clinics, and thus this could have been a contributing factor in the decline of prolonged illness prevalence during the study period. One possible reason cropped area for Conhane may have increased as the prevalence of prolonged illness also increased may be due to the close proximity of a health clinic in the area. However, it may also be that Landsat imagery is not fully capable of estimating small scale land cover changes and the estimate for cropped area may be skewed. Another, more practical possibility is that the small sample size affected the estimates through time.

The trend in hectares farmed based on the hand digitization for Conhane showed a slight increase in the total agricultural area between 2002 and 2008 as prolonged illness prevalence decreased. However, I see a different pattern occuring in Chokwe. Here, the prevalence of prolonged illness decreased through time, but area farmed also decreased slightly between 2002 and 2005 before leveling off between 2005 and 2008. This may also be a function of reallocating land to a younger generation that is interested in farming larger plots and engaging in farming contracts (Veldwisch et al. 2013). While there is a chance that some areas were misclassified as a result of producer error, I minimized this error by making use of the intra-annual variation in agriculture, as well as all available Google Earth high resolution imagery to assist with the digitization process.

One consideration in reconciling the national-, regional- and village-level analyses is that households may farm less land themselves, and may instead rent that land out to others. While Mozambique is generally considered to be land-abundant, irrigated land, such as can be found in these villages, is a relatively scarce commodity. Therefore, I also examined what effect renting land had on fallowing, and it too increased the likelihood of leaving land fallow. As a secondary outcome, the impact of prolonged illness on renting of agricultural land was also examined (results not shown). I found that, just as with fallowing, prolonged illness is a statistically significant predictor ($p<0.05$) of renting out land, where experienced prolonged illness increases your chance of renting out land by 2%. This suggests that households may pursue alternative coping strategies that would reduce the amount of land cultivated directly but not be detectable through a change detection analysis.

2.7 Conclusion

Other studies have established an economic link between health and agriculture and how the landscape influences health, but very little is understood about how health may impact the landscape. This study contributes to the literature by providing a more nuanced understanding of how prolonged illness contributes to changes in LULCC. Mixed methods were used to understand how a sustainable agricultural land use decision such as fallowing is transformed into a more rudimentary one when used as a coping strategy for subsistence agriculturalists that experience a prolonged illness. My analyses took a top-down approach where I sought to better understand how the hypothesized relationship plays out on the landscape. The main findings at each level are as follows:

- National: Subsistence agricultural households that experience a prolonged illness have approximately 40-50% higher odds of fallowing than their healthier counterparts.
- Regional: Unhealthy subsistence agricultural households grow fewer corn and staples than healthy agriculturalists, and are more likely to report food hardship.
- Village: The small-scale land cover changes brought about by prolonged illness cannot be adequately mapped using Landsat TM/ETM+ imagery. Satellite imagery of higher resolution, and increases in its temporal coverage, are needed to detect land cover changes due to poor health.

The primary contribution lies in the mixed methods approach to analyzing the implications of prolonged illness on LULCC. The results revealed that a traditionally sustainable land use decision such as fallowing may become an unsustainable one, in that it contributes to food insecurity and inferior crops grown, when used as a coping strategy by unhealthy subsistence agriculturalists. In doing so, I established both the general vulnerability these households face and the potential for becoming food insecure. The regional-level analysis provides a better understanding of the key differences between healthy and unhealthy subsistence agriculturalists that fallow. A secondary contribution comes from the innovative application of remote sensing to map changes in land cover brought about by prolonged illness.

Studies such as this shed light on the vulnerability unhealthy subsistence agricultural households face. Because the health-environment link is so strong—especially in subsistence-reliant societies—there is the need to better understand how health impacts the surrounding environment and identify the possible implications for sustainability moving forward. Additional mixed methods studies are needed to better understand which policies would best serve unhealthy subsistence agriculturalists, as well as understanding the degree of vulnerability they face due to poor health. Future work will rely on an improved temporal record produced by high resolution sensors capable of being tasked for a consistent repeat-cycle to map changes in land cover due to poor health. However, we are not quite at the point where a sufficient record exists. Health and agricultural policies need to be designed such that those who rely on agriculture for their livelihoods will continue to have the means to sustain their way of life in the presence of an adverse health event.

Chapter 3: Are fallowing decisions affected by prolonged illness in subsistence agricultural households?

3.1 Introduction

The pervasive societal effects of disease are broadly recognized but still incompletely understood. The economic consequences of poor health have been well-documented, from micro-level examinations of household labor supply effects of disease to macro-level estimates of the stunting effect of specific illnesses on national GDP and growth (Bloom et al. 2004; Larson et al. 2004; Canning 2006; Walker et al. 2006). Illness and death have been linked to reduced economic well-being among households in Africa and contribute significantly to the poverty trap dynamic that inhibits economically disadvantaged households from advancing (Arora 2001; Marmot 2005). At the macro-level, diseases such as HIV/AIDS and malaria have been shown to halt, or even temporarily reverse, economic development (Bonnel 2000; von Schirnding 2002). Less evident are the indirect effects of the health-wealth relationship, such as the environmental impact. This impact may manifest itself in various forms, including regenerative vegetation growth as households abandon land, a reduction in the amount of land under cultivation, or an intensification (such as clearing more land) of the landscape as households employ outside labor or abandon more sustainable agricultural practices to temporarily increase agricultural income.

In many developing countries, agriculture is still viewed as an integral component of economic development (Owens et al. 2003; Ragasa et al. 2013; Van der Ploeg 2014). This pathway involves a transition from subsistence smallholder agriculture to more formalized agricultural markets, either through exports or selling excess produce at the local market (Van der Ploeg 2014). Subsistence agriculturalists represent a vulnerable segment of society, largely unprotected from the risks associated with farming and with limited access to capital and other economic opportunities, making them vulnerable to poverty traps (Tschirley and Benfica 2001; FAO 2005). Health is a vital form of human capital for agricultural households, given the physically demanding nature of agricultural work (Banerjee and Duflo 2005). Taken together, poverty and poor health tend to go hand in hand and reinforce each other; such a process creates a "poverty-health" trap and prevents affected households from improving their socioeconomic standing (Whitehead et al. 2001; Khan et al. 2006). Agricultural households that experience a health shock or death of a prime-age adult often need to divert financial, labor and land resources away from agricultural production (Yamano and Jayne 2004; Arndt 2006; Mather and Donovan 2008). Thus, the well-studied economic impacts of disease may be associated with reduced or varied land use among subsistence agricultural households due to changes in resource allocations. Health, then, potentially affects the environment indirectly by altering the economic choices and constraints of these agricultural households.

The effects of illness on the physical environment are under-researched at the micro-level (King 2010). Much of the literature thus far has focused on the environment's effects on health, seeking to understand how changes in LULCC bring about changes in health status (Lupo et al. 2001; Patz et al. 2004; Foley et al. 2005; Vasilakis et al. 2011). I hypothesize that prolonged illness may contribute to changes in LULCC. This relationship is mediated by reductions in labor supply, a well-documented consequence of illness (Schultz and Tansel 1997; Asenso-Okyere et al. 2010; Pennap et al. 2011; Asenso-Okeyere et al. 2011). For example, HIV/AIDS currently represents one of the largest global health challenges, and is especially economically devastating for agriculturalists in that it typically affects working-age individuals (Drimie 2003).

Mozambique is a prime setting to test this possible reversal in directionality, as its agricultural system is dominated by subsistence agriculture (Tschirley and Benfica 2001; IFDC 2011; FAO 2012). It also has one of the highest HIV/AIDS burdens in the world, characterized by marked spatial variation (UNAIDS 2012; Feldblum et al. 2014). In addition, Mozambique is land abundant and labor poor. According to the FAO (2007), Mozambique has roughly thirty-six million hectares of arable land, but only ten percent is actually under cultivation, where expansion of agriculture is constrained by labor. This potentially increases the impact of illness on subsistence agricultural households by limiting substitution of labor, allowing for a starker examination of the environmental effects of illness. In exploring the impacts of health on land use decisions by subsistence agricultural households, I am specifically interested in how a particular land use decision (fallowing) is affected by prolonged illness. This relationship is explored through both an econometric analysis, as well as the application of KDE to capture spatial variation, and draws on a comprehensive household agricultural survey for Mozambique.

I ground my approach in the political ecology framework. Political ecology suggests that the impact of illness on agricultural households will be unequally distributed through space and time, a function of access to additional resources. This uneven distribution may bring about a series of land use decisions that may have varying consequences for land cover change (Thangata et al. 2007; Wagstaff and Lindelow 2014). Factors that may moderate this impact include the ability to employ outside labor, benefit from agricultural extension, as well as access to other agricultural inputs. Understanding the agricultural land use impact of illness in this setting potentially speaks to broader societal implications as well, including food security, livelihood sustainability, and economic equality (King 2010).

The rest of the paper is organized as follows: section two discusses the guiding theoretical framework for the analysis; section three provides a review of the literature on health, agriculture, and their interrelatedness; section four describes the study area; section five discusses the research design for the analysis; I present my findings in section six; section seven is used to provide context for these results in an active discussion of the potential implications of fallowing land; section eight offers a brief overview of possible extensions and future work using the data; and section nine provides a brief conclusion.

3.2 Theoretical framework

This study is concerned with the human-environment system of health-land interactions, and I am particularly concerned with how health impacts agricultural households. Because this relationship may transition households to a more vulnerable state, I frame the analysis and supporting research questions using the political ecology framework. Pioneered by Blaikie and Brookfield (1987), political ecology predicts that the costs and benefits of environmental change are unequally distributed, and that this unequal distribution has varying effects on different groups or individuals (Rocheleau 2008; Turner and Robbins 2008). Nested within this framework are potential drivers of environmental change, and I more rigorously examine the role of health as a potential driver in this analysis. Political ecology predicts that marginalized groups are most likely to be affected; in this study, these would most likely include rural subsistence agricultural households that experience a prolonged illness and are without adequate access to resources. This uneven impact is a manifestation of economic, ecological, and political marginalization.

Taking Blaikie and Brookfield's (1987) key analytical focus one step further, this paper argues that health is another factor that marginalizes subsistence agricultural households in Mozambique. In turn, this may contribute to a vulnerable state in which health-affected households may become food insecure. Additionally, female headed households may be more vulnerable to becoming food insecure without the help of male labor—this would also be true for households where the male head becomes ill (Thangata et al. 2007). Furthermore, poverty has also been shown to be a contributing factor, and thus those that are below the poverty line may be more susceptible to the broader household impacts of illness (Weiser et al. 2011).

Intricately entwined in the health-environment relationship is spatial proximity to various resources. These resources include health clinics and hospitals, land for farming, agricultural markets to sell excess production, agricultural extension agents to assist with crop strategy, and transportation. These resources may affect the degree to which households are marginalized under the political ecology framework. If so, I would expect to see the impact of health on the landscape vary throughout space as a function of distance to these various resources (Wagstaff and Lindelow 2014). For example, wealthier households may be able to respond to an illness without it affecting their overall well-being. However, female-headed households, rural households with poor access to resources, or impoverished subsistence agricultural households may be especially more vulnerable to an illness and less capable to respond.

Robbins and Bishop (2008) identify the political ecology framework as an efficient "blueprint" for examining health and agriculture, emphasizing:

> …the political and ecological characteristics of the disease [HIV] seem increasingly important, including the land and labor systems in which it is enmeshed, the livelihoods to which it is tied…Land, labor, and ecological knowledge lie at the heart of what is arguably the world's largest crisis. (Robbins and Bishop 2008, p.751).

This framework is particularly useful for studying how the hypothesized human-environment relationship will manifest, especially within the context of impoverished and marginalized communities that derive much of their livelihoods from natural resources. As previously mentioned, regenerative vegetation growth as households abandon land, a reduction in the amount of land under cultivation, or the intensification of the landscape may be consequences of the impact of health on the surrounding environment. Earlier harvests and farming less land have been demonstrated as top coping mechanisms for these types of households (Barnett et al. 1995; Thangata et al. 2007; Wagstaff and Lindelow 2014).

Political ecology provides a comprehensive theoretical platform to investigate how health events impact the capacity of agricultural households to sustain their livelihoods in a developing-country setting. The integration of methodologies used in this study is in keeping with the new direction that the field of political ecology is taking—one which calls for "inveterate weavers of analysis that… bridges the social and biogeophysical sciences" (Zimmerer and Bassett 2003, p.276; Walker 2005). The application of KDE facilitates consideration of the spatial variation in vulnerability to this hypothesized relationship, allowing for a visual comparison of how village rates of prolonged illness map onto village rates of agricultural land use. The ensuing regression analysis more robustly isolates the role of health in land use from other demographic, economic, and climatic factors.

3.3 Health, environment, and its bi-directionality

Much research has been done in the areas of the economic effects of disease, agriculture and health, land cover change as a driver of health, spatial effects of health, and to a much lesser extent, impacts of health on land use decisions among subsistence agricultural households. Here, I focus only on the most relevant literature from the aforementioned fields.

Many economic studies have examined the impact of health on macroeconomic measures such as productivity, GDP, and economic growth, finding that illness contributes to declines in these measures at the macroeconomic scale (Barnett and Blaikie 1994; Bloom and Canning 2000; Bloom et al. 2004; Canning 2006; Walker et al. 2006). However, these studies do not disaggregate and examine the micro-scale drivers of these phenomena (King 2010; King 2012). The impacts of health on agricultural production are well documented in the literature, where health is often a contributor to declines in agricultural production and income (deWaal and Whiteside 2003; Drimie 2003; Bukusuba et al. 2007). Illness can diminish labor productivity and supply, and thus can erode a household's ability to secure its livelihood (Fox et al. 2004; Masanjala 2007; Chicoine 2012). Health is often linked to economic development at the household level, and thus disease has the ability to erode livelihoods and constrain both micro- and macro-level economic growth in developing nations (Hotez et al. 2009). Masanjala (2007) used data from multiple countries in Africa to examine the impact of HIV/AIDS on poverty and found that households without a good social network often remained trapped in poverty when dealing with the disease. Other studies have demonstrated the important role gender plays in terms of household production, livelihood sustainability, income and poverty, citing that the death or illness of a household head male contributes significantly to a decline in the household's ability to remain food secure, and that poorer households are even more vulnerable to becoming food insecure (Larson et al. 2004; Yamano and Jayne 2004; Chapoto and Jayne 2008, Jayne et al. 2010).

In the presence of an illness, agricultural households may have difficulty maintaining previous levels of agricultural production and cultivation (duGuerny 2000). This land use decision has consequences not only for household livelihood, but also sets up a secondary flow that has possible environmental implications. In terms of livelihood sustainability, this can contribute to a decline in the crops produced for the household. For example, it has been shown that the death of an adult male head of household in Kenya results in a 68% decline in the net value of the household's crops (Yamano and Jayne 2004). Furthermore, prior work has found that recovery from the death of a household head is lagged, suggesting that there are potentially long-run economic implications of illness for agriculturally-reliant households (Arndt 2006).

Few studies have extended their analyses of the agricultural implications of illness to changes in LULCC. Boutayeb et al. (2009) examined how malaria impacts agricultural productivity in developing countries, and briefly describes implications for agricultural land use, but stops short of assessing the impact on the physical environment. Zhang et al. (2011) took their assessment one step further and examined the probability of a plot of land being inhabited based on a risk assessment of malaria occurring within the area, finding that plots were less likely to be inhabited in areas where malaria risk was high but this effect was partially mediated by non-resident farming of the plot (i.e., the plot owner would occasionally have a plot under cultivation and would travel to it rather than residing at plot). My analysis seeks to contribute to this apparent gap in the literature and focuses on how health itself can physically alter the surrounding environment by influencing the land use decisions of subsistence agricultural households.

In terms of impacts of health on the environment, land use decisions that employ land abandonment or fallowing as a coping strategy have impacts on the surrounding environment. Barnett et al. (1995) found that HIV-affected households in a Ugandan village may abandon as much as one-third of their land because of the disease. Orphans left behind from parents who died from AIDS were found to let large farms rapidly degenerate into bush in Tanzania because they either were too young to tend to the land and/or lacked farming experience (UNAIDS 1999). An ethnographic study in rural Malawi found that gender of the disease-affected household member was a contributing factor to land fallowing, citing that female-affected households were able to remain food secure in the presence of an illness, but male-affected households became food poor and fallowed more land (Thangata et al. 2007). While these studies examined this relationship at the micro-level scale, they did not have the ability to fully assess an entire country. Additionally, a gap still exists in our understanding of the decision process undertaken by subsistence agricultural households that experience a prolonged illness, and whether or not fallowing is systematically employed throughout a region as an illness coping strategy.

Research on the reverse mechanism of health-to-environment focuses on how changes in LULCC can be a driver of infectious disease. Lindblade et al. (2000) found that changes in land use patterns, such as cultivating near swamps, and increases in urban density lead to increased rates of malaria in Uganda. A similar effect was found by Vanwambeke et al. (2007) in northern Thailand. Anthropogenic changes in land use related to agricultural encroachment, deforestation, mining, and irrigation have also been shown to lead to increases in many different types of diseases such as Lyme disease, malaria, mercury contamination, and many zoonotic diseases (Patz et al. 2004). Vasilakis et al. (2011) found that patterns of deforestation significantly contribute to increases in dengue viral spread.

Natural disasters, coupled with LULCC, create dire situations and exacerbate health issues. Cockburn et al. (1999) found that areas in Central America with extensive deforestation and households located either in these areas, or in floodplains, suffered higher morbidity and mortality during Hurricane Mitch. Furthermore, Foley et al. (2005) noted that widespread water- and vector-borne diseases ensued, and more than one million people were left homeless. Lupo et al. (2001) found that households located in low-lying areas—primarily for farming—in a large region of Africa (covering parts of Ghana, Togo, Burkina Faso, Benin, and Niger) were ravaged by heavy flooding that displaced more than 290,000 people, destroyed 117,000 acres of farmland, and caused widespread cholera outbreaks.

Spatial methods, such as exploratory spatial data analysis (ESDA), hot-spot analysis, inverse distance weighted (IDW), kriging, and KDE have been used to document the diffusion and progression of disease and other health trends through space and time. Kalipeni and Zulu (2008) demonstrated that data gathered from surveillance sites in Africa can be used to infer prevalence rates at both a country- and continent-wide scale through the use of spatial interpolation methods such as IDW and kriging, thus allowing for rapid appraisal of disease progression. Tanser et al. (2009) used estimated prevalence rates to detect and map disease hot spots, while demonstrating the correlation of HIV trends with access to roads, markets and other resources. Feldacker et al. (2010) examined both regional characteristics and individual level factors to understand how HIV prevalence decreases with distance from health clinics in Malawi, while Gabrysch et al. (2008) found the opposite effect occurring in Zambia. Additionally, spatial methods such as ESDA and KDE are used to better depict underlying spatial processes (Diggle 1985; Waller and Gotway 2004). Yao et al. (2012) used ESDA to provide a clear spatial visualization to support their hypothesis that sexual-reproductive health (SRH) service use varied spatially, and then used regression to confirm their ESDA results, citing that distance to a health clinic mattered in use of SRH services. Yao et al. (2013) used Poisson regression and KDE to better understand how women in rural Mozambique accessed SRH services to assist with household family planning decisions and found that distance to a health clinic was a significant factor in family planning utilization. Taken together, these studies suggest the spatial methods are quite powerful in both visualizing an underlying spatial process, as well as estimating potential disease diffusion. Additionally, these studies highlight the importance of location, where distance, or access, to a health resource is a defining factor in its use.

Much work has been done in Mozambique on the micro-level role of agriculture and its importance for development, income, and poverty (Mather et al. 2008; Cunguara and Hanlon 2010; Giesbert and Schindler 2012; Silva 2013). These studies often cite poor health as a possible contributing factor. Tschirley and Benfica (2001) demonstrate the importance of agriculture in Mozambique, coupled with wage labor, as an important means of reducing poverty and enhancing the livelihoods of subsistence agricultural households, but that a mixture of wage labor and commercial agriculture will not be enough to sustain the development strategy without a strong focus on increasing productivity and profitability for smallholder agricultural households.

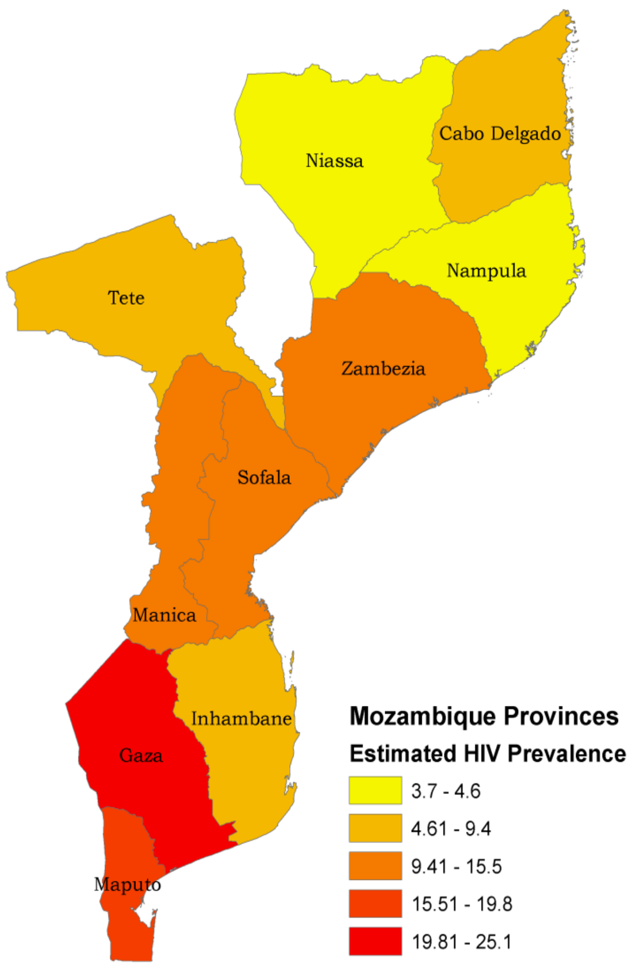
The effects of morbidity and mortality on agriculturally-reliant households in Mozambique have been documented. The loss of a prime-age adult accounts for an average loss of 25% in crop income and 88% in non-farm income (Mather and

Donovan 2008). Donovan and Massingue (2007) found that households in both southern- and northern-Mozambique experiencing a male illness or death in 2002 produced significantly fewer macronutrients from crops in 2005 compared to non-affected households, and that HIV/AIDS related cases impaired the ability of subsistence agricultural households to produce enough food. Dominguez et al. (2005) found that HIV/AIDS erodes the direct transfer of traditional knowledge between generations in the Limpopo Basin, suggesting that health incapacitates a household's ability to sustain its livelihood. Taken together, these studies suggest that health has a role in shaping agricultural output, but both the impact on agricultural land use (i.e. area farmed versus area fallowed), and possible coping strategies remains under-researched.

3.4 Study area

This research focuses on Mozambique, a southern-African country that has aggressively worked to contain diseases such as malaria, cholera and HIV/AIDS (Agadjanian and Menjivar 2011). These diseases are of particular interest when thinking about the effect of health on agricultural land use because it predominantly affects prime age adults, the most economically productive age group, and thus is particularly likely to impact labor supply in agricultural households. This analysis uses a general measure of prolonged illness as a proxy for chronic diseases such as HIV/AIDS among subsistence agricultural households due to its known high prevalence rates throughout the country. Mozambique's first HIV/AIDS case was identified in 1986 and prevalence accelerated quickly through the early 2000s before leveling off (UNICEF 2004). Mozambique has one of the highest HIV burdens in the world (Feldblum et al. 2014). The current estimated HIV prevalence for Mozambique is 11.5%, one of the ten highest rates worldwide (DHS 2009). However, there is significant geographic variation throughout the country, and prevalence follows a spatial gradient, with the lowest rates in the north and the highest rates in the south. Figure 3.1 provides an estimate of HIV prevalence in Mozambique by province.

Figure 3.1: Map of HIV prevalence by province in Mozambique



Source: Map created using DHS estimated HIV prevalence rates for 2009.

The Gaza province represents one of the hardest hit areas, with an estimated HIV prevalence of 25.1% (DHS 2009). ART became available nationwide in 2004, but less than 25% of the population with advanced HIV were actually enrolled in ART as of 2007 (Audet et al. 2010).

Mozambique's health system faces other health challenges. Malaria is endemic in many portions of the country, often afflicting children under the age of ten (Mabunda et al. 2009). Additionally, unscheduled deliveries and poor antenatal care were significant contributors to maternal deaths in Mozambique, where simple prevention could have help reduced the risk of malaria related mortality in pregnant women (Granja et al. 1998). Mozambique is also prone to many natural disasters; the country has experienced many devastating floods over the past thirty years, in addition to damaging tropical cyclones and drought (Brouwer and Nhassengo 2006; Klinman and Reason 2008; Matyas and Silva 2013). Post-flood infections increase dramatically as drinking conditions deteriorate and new disease-vectors appear; malaria, respiratory infectious disease, and diarrhea have all been shown to increase dramatically after flooding (Kondo et al. 2002). These unhealthy landscapes work to erode health, as many individuals are not only stunned by the natural disaster, but also have to cope with adverse health conditions. Poor access to clean, safe drinking water is also a major concern for citizens of Mozambique—a resource problem that is associated with cholera. Mozambique's case fatality ratio for cholera from 1970-2012 is roughly twice as high as the acceptable threshold set by the World Health Organization (WHO) (Mengel 2014). These are the types of health issues I am seeking to capture, specifically how they may reduce a household's ability to sustain its livelihood.

Agriculture is an integral part of the Mozambican economy, where roughly 85% of the population in Mozambique supports themselves through agriculture (FAO 2015). The average farm size in Mozambique is roughly 1.66ha (Walker et al. 2004). Disasters such as drought and flood often are enough to cripple a struggling agricultural system, and the added threat of disease epidemics compounds the risks facing subsistence farmers (Lewis and Mayer 1988). Because of the heavy reliance on agriculture, health events such as HIV/AIDS have the ability to erode human capital by diminishing labor supply and productivity, a consequence that is potentially more acutely felt in a land-abundant, labor-poor setting such as Mozambique.

Land use practices in Mozambique are also important to this study; much of the area is smallholder agriculture with very limited use of technology, thus households are reliant on human labor (Jayne et al. 2010). Irrigated land is more common in southern Mozambique and as a result, the cash cropping system is stronger in this region (Silva 2008). Popular cash crops within Mozambique include sugar, cotton, tobacco, paprika and chickpeas (Walker et al. 2004; Boughton et al. 2007). As part of the government's poverty alleviation strategy, there has been a growing emphasis on cash crops and the agricultural sector as a whole (Tschirley and Benfica 2001; PARPA 2007; PARPA 2011).

3.5 Study design

In this study information on agricultural land use and health are combined with spatial data to examine the impact of health on the landscape. This information is derived from three years of a nationally representative survey of smallholder agricultural households in Mozambique. First, coping strategies identified in the survey are descriptively explored, as well as the rates of fallowing engagement by year, to understand the extent to which households identify changing land use as a response to prolonged illness or death. Since this is likely a conscious household decision, as opposed to an unexpected consequence, this component of the analysis will identify whether this is viewed as a practical response, rather than one merely predicted by theory. Then, KDE was used to examine the spatial nature of prolonged illness and land use. Finally, regression analysis using a two-part model was conducted to more rigorously isolate the effect of household health status on household agricultural land use and to identify whether or not illness-afflicted households use fallowing as a coping strategy. The two-part model separately modeled whether households engage in fallowing and, for those households who did fallow, the amount of land fallowed.

3.5.1 Data

This study uses data from a series of rural smallholder household surveys known as *Trabalho de Inquerito Agrícola* (TIA) for the years 2002, 2005 and 2008[7]. The survey data represent a joint effort between Mozambique's Ministry of Agriculture

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[7] Note: A TIA survey exists for 2012, but was excluded from this analysis due to questions regarding illness being removed from the survey

and Michigan State University. The TIA 2002 and 2005 surveys employed the same sampling frame used for the 2000 agriculture census: a stratified, clustered sample design that is representative at the provincial and national levels of rural small- and medium-holder agriculture. The TIA 2008 employed the same sample design, but modeled itself after the 2007 population census sample frame. Each year of the TIA includes a weights file that adjusts the household data to be representative at both the national and provincial levels. Table 3.1 demonstrates the number of households and districts (areas within provinces) covered for each year of the TIA used in this study.

Table 3.1: Number of households and districts covered by the TIA

TIA Year	Number of Households	Number of Districts
2002	4,908	80
2005	6,149	94
2008	5,968	128

Note: There are a total of 128 districts in Mozambique
Source: Calculated by author using available TIA data

The TIA was designed to provide a more nuanced understanding of agriculture, economic and poverty dynamics for small- and medium holder farmers in Mozambique. Thus, the TIA surveys capture agricultural practices and output, demographics, well-being, and food security, as well as health status. Because this study seeks to understand the relationship between agricultural land use and health, questions relating directly to land holdings, agricultural output, well-being, and health are of particular importance.

This study makes direct use of key agricultural variables to help frame the household's reliance on this sectorial activity. The TIA includes questions on crop varieties grown, total size of land holdings belonging to the household and how this land is allocated (cropped vs. fallow), production generated from crop campaigns, location (upland vs. lowland), access to agricultural extension, access to credit, use of various inputs (chemical, traction, and irrigation), use of agro-processing equipment, labor dedicated to farming, and whether or not the household employs outside labor to assist with farming.

The second set of variables that are critical for examining the health-agricultural dynamic relates to questions in the survey that deal with illnesses experienced by household members. In the 2002 survey, households are asked to identify members who were affected by an illness for longer than three months. However, the way in which the question was asked in the 2005 and 2008 waves changed slightly from 2002 and first ask about any illnesses experienced in the household, and then ask how long these individuals were unable to work. I excluded individuals affected less than three months in the 2005 and 2008 waves in an effort to match the TIA 2002. Questions relating to illnesses experienced are general in nature (i.e., the specific illness was not always identified, though the survey left room for individuals to explicitly state their illness or disease). Questions relating to illnesses suffered include time spent not working, ages of those who experienced the illness and those responsible for caring for those who were ill. The TIA 2002 survey also asked households about their coping strategies when dealing with health shocks. For my illness measure, I identify households in 2002, 2005, and 2008 who reported a member 10 years or older that was ill for three months or longer.

As mentioned, the TIA 2002 survey also asked households about their coping strategies. These questions identify the extent to which households consciously adapt their land use in the face of an adverse health event. Households were asked to identify coping strategies used to mitigate the impact of the death of a PA adult and the impact of an illness lasting three or more months. This allows me to qualitatively examine the top strategies used by unhealthy households to mitigate the impact of prolonged illness. Additionally, villages surveyed in each TIA year were geo-referenced. These coordinates ae used to help understand the underlying nuance and distribution of prolonged illness and fallowing through space and time by mapping health onto land use.

3.5.2 Potential data limitations

One limitation of this analysis is the potential endogeneity of self-reported household illness, and uncertainty surrounding the nature and timing of the health events experienced in the household. Endogeneity could exist if households that report illnesses are unobservably different from those that do not report illnesses, and this unobservable difference is associated with fallowing. In addition, more specific timing data around the health events would have been particularly useful for establishing a stronger causal link between health events and agricultural land use change.

3.5.3 GIS and kernel density smoothing

Kernel density smoothing is used to provide a better representation of the rates of health events and land use changes at the village level[8]. This improves upon scattered village-level point estimates, using a kernel function to fit those estimates to the

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[8] Note: Some village coordinates for 2008 were corrupt and unsalvageable, and were thus excluded from the KDE analysis. However, I was able to rectify a total of 434 villages out of the original 576 villages and still had a sufficient number of villages for the KDE analysis.

continuous space. This surface allows for a continuous estimate of the prevalence of prolonged illness, as well as the proportion of land fallowed. This means that at any given point, even in unmapped areas, the burden of prolonged illness and the proportion of fallow land can be inferred. While these portrayals look at unadjusted rates of prolonged illness and fallow land, this mapping provides a spatial depiction of how health may impact land use through space and time. This approach is commonly used to spatially identify variation in trends, and in this case this visual representation identifies areas that are vulnerable to both prolonged illness and engage in fallowing.

3.5.4 Regression model and variables

For the regression analysis, the outcome of interest is fallowing, and it is measured in two ways: whether the household engages in any fallowing in the survey year, and the amount of land that is fallow in the survey year. The independent variable of interest is household health, and the health measure used is whether anyone in the household 10 years or older experienced a prolonged illness in the survey year, defined as lasting three months or longer. As mentioned earlier, this approach is similar to that used by Mather and Donovan (2008), and serves as a proxy for the potential impact of HIV/AIDS. Regression covariates reflect those used in other models of agricultural output from the literature (Udry 1996; Owens et al. 2003; Mather and Donovan 2008; Ragasa et al. 2013). The model takes the following form:

$$Y_{ijt}=\alpha+\delta 1(\text{ProlongedIllness})_{ijt}+X_{ijt}\beta+\mu_j+\varepsilon_{ijt},\ i=1,2,\ldots,N$$

In the model, Y_i represents a measure of fallow land for household *i* in district *j* in year *t*, $1(\text{ProlongedIllness})_{ijt}$ is an indicator for a prolonged illness in the household lasting three months or longer, X_{ijt} is a vector of household covariates, and μ_j represents province indicator variables.

The vector of household covariates X_{ijt} includes demographic and agricultural characteristics. Table 3.2 provides a detailed breakdown of the variables that were included in the model. Demographic variables were constructed to capture characteristics about the household and its members that may affect the household's agricultural productivity. Variables capturing characteristics of the household head include age, education level, and gender, as well as family size measures such as the child dependency ratio and total household size, have been used in similar studies to represent potential contributors to the modeled relationship (Grisley and Mwesigwa 1994; Owens et al. 2003; Sauer et al. 2012). The dependency ratio in this analysis is calculated as young children (less than ten years old) [9] and those over sixty-five; this ratio was chosen because there were instances of household members greater than sixty-five raising young children.

Use of agricultural inputs such as fertilizer, pesticides, improved seeds, irrigation, and land location should theoretically affect participation and the amount of fallowing by increasing the likelihood of both, as these represent sophisticated agricultural land use decisions that are likely to be associated with more advanced, sustainable practices such as fallowing. Additionally, gender has been shown to matter in this regard, whereby males typically find it easier to find outside

[9] I chose 10 years of age as the cutoff because the TIA uses this to make the distinction between working members of the household and those who are too young.

employment, and thus this would potentially contribute to increases in participation and amount of fallowing (Walker et al. 2006; Boughton et al. 2007; Cunguara and Kajisa 2009). Furthermore, the child dependency ratio may be a potential indicator for increases in fallowing, as more attention has to be focused at home to care for young children and the elderly.

I also sought to capture economic well-being in the model, and opted for an asset score rather than income measure. Self-reported income is a challenging variable to cleanly collect due to factors such as measurement error and accounting for seasonality, subsistence livelihoods, and in-kind compensation (Vyas and Kumaranayake 2006; Filmer and Kinnon 2012). Asset ownership is regarded as a viable alternative for representing economic status and in many settings is more straightforward to capture. The asset score was constructed using principal components analysis (PCA), a standard technique in the social sciences to summarize asset ownership in a single measure (Filmer and Pritchett 2001; Sastry 2004; Vyas and Kumaranayake 2006; Fernald 2007; Paxson and Schady 2007; Chuma and Molyneux 2009). Essentially, an asset score attempts to reduce a lot of information about asset ownership (many variables) into one single measure. This is an appealing option to capturing economic status, especially in settings that are not predominantly income-driven. However, one challenge with asset scores is how to weight the different assets. One option is to weight them all equally and then sum them up, but this is problematic because it treats a chair the same as a car. PCA is one common option for systematically assigning weights. It is a statistical approach that converts a set of correlated variables into a set of uncorrelated components. The first component is the one that explains the most variation. Thus, for assets, the first component describes the most variation in asset ownership. The major assumption, then, is that the first component represents economic status. By making this assumption, it is implied that economic status is the primary driver of asset ownership. This means that the coefficients from the first component (with each component being a vector) are used as weights in the asset score.

PCA as a method for variable construction has been used in several other applied geography studies that seek to understand livelihood diversification, vulnerability indices, poverty mapping and other development issues, and I mirror their approach (Erenstein et al. 2010; Godar et al. 2012; Johnson et al. 2012; Jakobsen 2013; Frazier et al. 2014; Li et al. 2014). The subsistence nature of many households in the TIA sample makes the asset score a particularly appealing representation of economic status for this study, and I use TIA questions about ownership of a lantern, table, latrine and a radio, questions about housing quality, livestock ownership, and indicators for whether or not the household grew tobacco or cotton.[10] The constructed asset score in this study is an estimated version of that used by Giesbert and Schindler (2012).

Table 3.2: Construction of dependent and independent variables for regression analysis

Variable	Definition
Dependents	
Household reports fallowing	Dummy variable that indicates whether an agricultural household fallows any of its land. This is used to examine the impact of negative health events on agricultural land use.
Amount of land fallowed	Total land fallowed by a household, in hectares.
Independents	

[10] A list of the loadings for the primary component is included in Appendix A.

Prolonged illness dummy	Dummy variable that takes a value of 1 if the household has one or more members (age 10 or older) that were ill for at least 3 of the preceding 12 months, and 0 otherwise
Asset score[11]	Generated using weights from first component of PCA applied to assets and housing variables in TIA surveys. This variable is used to measure economic well-being.
Household total cropped area[12]	The total cropped area, in hectares, belonging to a household.
Household number of fields	This variable captures the fragmentation of agricultural fields owned by counting the number of separate fields belonging to the household.
Household employs any full-time workers	Dummy variable capturing the use of any outside help for farming activities for the household.
Household uses agricultural inputs	Split into basic and advanced agricultural inputs. Basic inputs include: fertilizer, pesticides, emergency seed, and access to agricultural extension. Advanced inputs include: animal traction, mechanized traction, and use of agro-processing equipment.
Household engages in outside employment	Dummy variable that take a value of 1 if any member of the household engages in outside (off-farm) employment, and takes a 0 otherwise.
Household proportion of land that is upland	The proportion of a household's total cropped land that is located in upland areas. This variable captures geographical differences in growing location (upland vs. lowland).
Household proportion of land that is irrigated	The proportion of a household's total cropped land that is irrigated.
Household head is male	Dummy variable that takes the value of 1 if head of household is male, and 0 if female.
Household head age	Variable for the age of the household head in years.
Household head education[13]	Variable that measures the education level of the household head in years of schooling.
Household child dependency ratio	The number of children under the age of 10 years divided by the number of people in the household aged 10 years and over. The inclusion of elderly adults in the denominator reflects the fact that the elderly may take care of the very young when there are no working adults in the household.

[11] A squared version of this variable also exists as identified by the Box-Tidwell test
[12] A squared version of this variable also exists as identified by the Box-Tidwell test
[13] A squared version of this variable also exists as identified by the Box-Tidwell test

Household members engaged in agriculture[14]	Captures the available household labor pool for agriculture, counting those who identify agriculture as a primary or secondary activity.
Village experienced a drought in prior year	Dummy variable that takes a value of 1 if the village has experienced a drought in the last 12 months and 0 otherwise. Meant to capture the possible climatic effect on land cover/land use.
Village experienced a flood in the prior year	Dummy variable that takes a value of 1 if the village has experienced a flood in the last 12 months and 0 otherwise. Meant to capture the possible climatic effect on LULCC
Village has any electricity	Dummy variable that takes a value of 1 if the village has any access to electricity, and 0 otherwise. Meant to capture potential development of the village and possible enhanced well-being of households in the village.
Province dummy variables	Dummy takes the value of 1 if a household is located within the province, and 0 otherwise. Dummies for all 10 provinces are constructed. The survey waves of the TIA include geographic coordinates of the village location of households.

Note: these variables were constructed by the author for each year of the TIA for 2002, 2005 and 2008

Regional indicators were employed to control for spatial variation. Specifically, province dummy variables account for systematic spatial differences in land use decisions, and thus control for known differences in land practices across regions.

3.5.5 Model estimation

A separate model is estimated for each TIA survey year. This allows for the nature of fallowing to vary over time, whether due to systemic changes such as climactic factors or due to the way an independent variable affects fallowing, such as how a household absorbs a prolonged illness.

The effect of household health on land fallowing was modeled using a two-part model. This approach, also referred to as a double-hurdle model, models

[14] A squared version of this variable also exists as identified by the Box-Tidwell test

fallowing in two ways: first, it examines factors associated with any fallowing, and then it attempts to explain how much land is fallowed conditional on some fallowing having occurred. This approach is commonly used for outcomes in which observed zeroes are substantively different from observed non-zero values, and has been used to estimate outcomes as varied as wages, health care utilization, and adoption of agricultural inputs (Duan et al, 1983; Gebremedhin and Swinton 2003; Ricker-Gilbert et al. 2010). A classic application of the two-part model is estimating expenditures, where the difference between spending $0 and $1 (not spending vs. spending) is dramatically different from spending $1 versus $2 (merely a difference in levels) (Cameron and Trivedi 2005). Observed land fallowing behaves similarly, in that fallowing zero hectares is very different from fallowing one or more hectares; I wanted to allow the decision to participate in fallowing to be distinct from the decision around intensity of fallowing. The two-part model captures this distinction by modeling participation (binary measure of whether household engages in any fallowing) using a logit model, and then modeling intensity (positive, continuous measure of amount of land fallowed) using ordinary least squares (OLS) for only those households that reported fallowing in a given survey year.

The functional form specification of the included covariates was checked using the Box-Tidwell model, which uses maximum likelihood to identify the powers of covariates that maximize model fit. Robust standard errors are calculated to account for possible misspecification of the distribution. For the logit component, goodness of fit can be evaluated using the Pearson chi-squared goodness-of-fit test with groups; this test groups observations based on the distribution of predicted values, and then compares observed and expected outcomes. For the OLS model, the R-squared was used to evaluate the overall model. The model specification was checked using the link test, which regresses the outcome on the fitted value and the square of the fitted value. Model misspecification is suggested if the square of the fitted value is statistically significant. The VIF was used to identify if multicollinearity is an issue.

3.6 Results

3.6.1 Descriptive statistics

Information about coping strategies used by households who faced an illness lasting three months or longer in the 2002 survey are reported in Table 3.3. Of the 155 respondents who answered the question on coping strategies used for a prolonged illness, 53% stated that they "cultivated less land." The second most commonly cited strategy was "hiring additional labor", named by 7.8% of households. In this sample, "cultivating less land" appears to be the dominant coping strategy employed when faced with a prolonged illness, confirming that health is perceived to have an impact on agricultural land use.

Table 3.3: Coping strategies used by TIA 2002 households experiencing prolonged illness

Strategies employed by households experiencing an illness lasting longer than 3 months (n=155)		
Strategy	Frequency	Percentage
Cultivated less land	82	52.9
Hired more labor	12	7.8
Increased the practice of mutual aid with other families	9	5.8

Source: Calculated by author using available TIA data

Fallowing is a recognized agricultural land use decision that many subsistence agricultural households employ to help improve overall crop production through time (Grisley and Mwesigwa 1994; Thangata et al. 2007; Sauer et al. 2012). The TIA 2002 survey provides some support that health-affected households are also using this type of land use decision as a coping strategy for prolonged illness, which in turn may impact LULCC (i.e., changes to the physical landscape). Table 3.4 presents descriptive statistics on participation in fallowing based on health status for the years of the study. Overall, while fallowing is a practiced agricultural land use decision by healthy and unhealthy households, rates of fallowing participation among households experiencing a prolonged illness are roughly 6-10% higher than rates for households without a prolonged illness. This additional evidence motivates the examination of the health-fallowing relationship for all three years of the TIA survey.

Table 3.4: Prevalence of prolonged illness and fallowing participation

Year	Overall prevalence of prolonged illness	Fallowing participation		Sig.
		No prolonged illness	Prolonged illness	
2002	5.14%	16.78%	26.51%	***
2005	7.24%	17.81%	23.56%	***
2008	4.15%	17.33%	26.67%	***

Note: *** significant at $p < 0.01$
Source: Calculate by author using available TIA data

Examining households across all three survey waves, roughly 6% of the households report experiencing an illness lasting three months or more. Households let roughly 6% of their land lie fallow in any given agricultural season, and the average land holding is roughly 2.3 hectares. Many households make use of some means of traction, whether it is animal driven or mechanized. Very few households (roughly 4%) have the ability to make use of irrigation. The mean household size is roughly 5.73 members, with just over 75% being male-headed households and roughly 3 members engaged in some form of agricultural activity. These figures suggest that fallowing in general is not widely practiced in Mozambique, few households have access to irrigation but do rely on some means of traction, and over half of the household is engaged in some form of agriculture. Descriptive statistics for the demographic, agricultural and health variables are presented in Table 3.5.

Table 3.5: Descriptive Statistics: Standard deviation in parentheses

Variable		**Year**	
	2002	***2005***	***2008***
Household participates in fallowing (%)	17.3%	18.2%	17.5%
	0.35	0.22	0.12
Amount fallowed by household engaging in fallowing	(5.74)	(1.38)	(0.54)
Household experienced health event (%)	5.1	7.2	4.1
Asset score	-0.01	-0.01	-0.06
	(1.87)	(1.87)	(1.87)
Household total cropped area	2.13	2.30	1.80
	(2.88)	(2.56)	(1.63)
Household number of fields	2.51	2.06	1.94
	(1.37)	(1.17)	(1.07)
Household employs full-time workers	0.10	0.21	0.08
	(1.53)	(1.78)	(0.68)
Household uses any basic agricultural inputs	0.30	0.26	0.17
	(0.46)	(0.44)	(0.38)
Household uses any advanced agricultural inputs	0.74	0.77	0.81
	(0.44)	(0.42)	(0.39)
Household engages in outside employment	0.22	0.36	0.36
	(0.42)	(0.48)	(0.48)
Household proportion of land that is upland	0.69	0.63	0.67
	(0.38)	(0.42)	(0.42)
Household proportion of land that is irrigated	0.058	0.050	0.023
	(0.19)	(0.19)	(0.13)
Household head is male (%)	76.2	76.0	76.9
Household head age	43.94	45.95	44.11
	(15.07)	(14.98)	(14.82)
Household head education	2.80	2.85	2.81
	(3.99)	(3.58)	(3.02)
Household child dependency ratio	0.56	0.53	0.63
	(0.56)	(0.54)	(0.62)

Household members employed in agriculture	3.29	3.59	3.11
	(2.10)	(2.31)	(1.80)
Village has any electricity (%)	8.5	13.0	16.1
Village experienced drought in past year (%)	24.9	94.4	64.0
Village experienced flood in past year (%)	16.7	4.9	2.4
N	4818	5919	5712

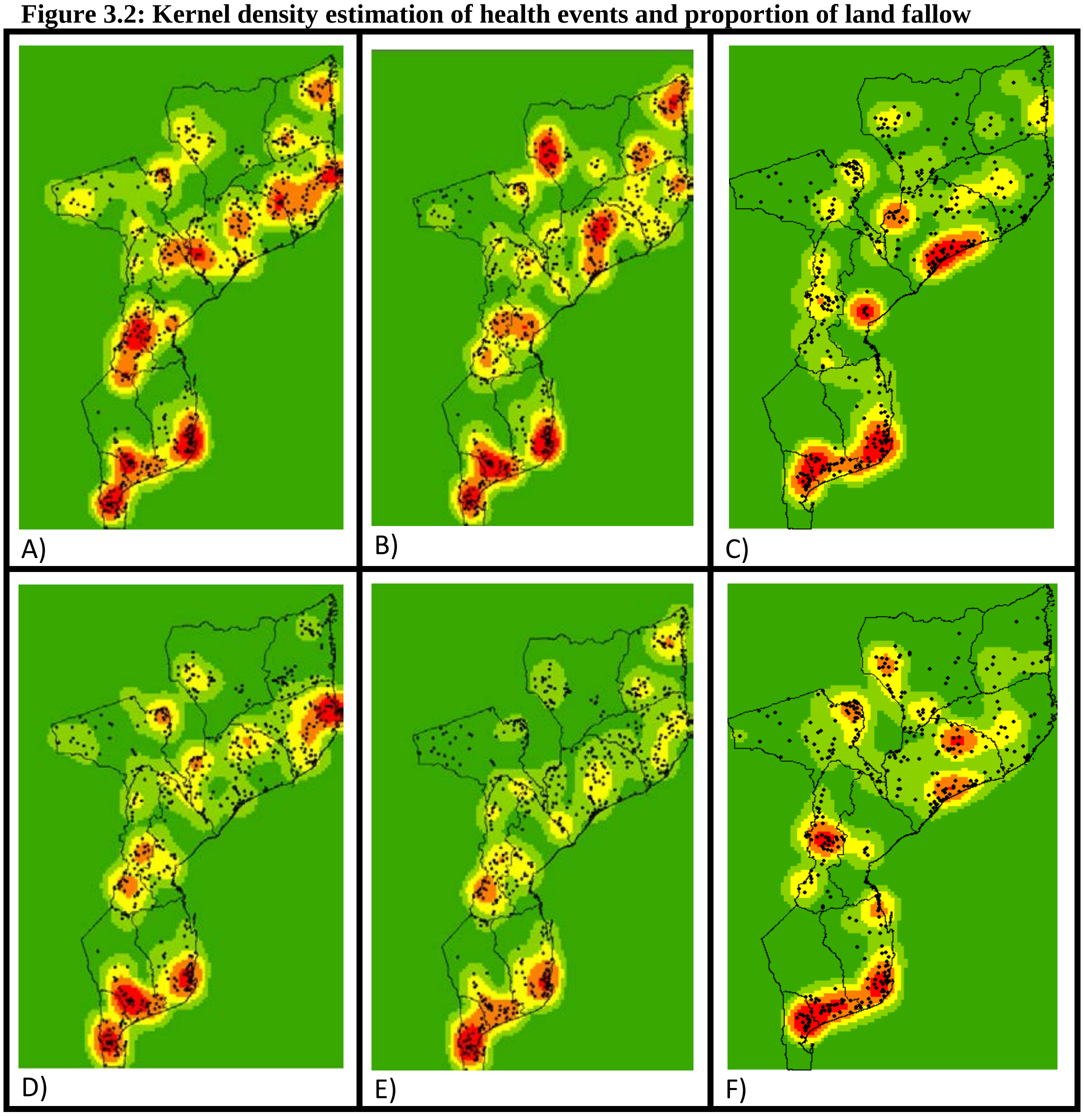
Source: Calculated by author using available TIA data.

3.6.2 GIS and kernel density smoothing results

Spatial patterns of prolonged illness and fallowing can be observed in Figure 3.2. First, prevalence of prolonged illness is shown in five classes using different rendering, with orange and red representing high rates of prolonged illness. Interesting trends emerge geographically, as increases in reported illness appear to occur along country borders (with Malawi, Zimbabwe and South Africa), along the coast and moving north to south. Additionally, there is a consistent temporal trend for some areas of the country. For example, the southernmost provinces of Gaza, Inhambane and Maputo exhibit a persistently high prevalence of prolonged illness through time, but there appears to be some decrease in the southernmost part of Maputo province. These provinces also represent some of the areas hardest hit by HIV/AIDS. Furthermore, increasing prevalence of prolonged illness through time is observed in Sofala province, more specifically in and around Beira. And, a decrease in prolonged illness is seen in Manica province.

I then use the same approach for mapping the proportion of fallow land throughout the country. Figure 3.2 suggests that a correlation between prolonged illness and increases in participation in fallowing exists spatially in the southernmost provinces and this appears to remain consistent through time. This is not surprising, as this area is consistently the hardest hit in terms of prolonged illness. In the central and northern provinces, this association appears to be dampened a bit in some areas, but these factors still appear to generally move together—mostly along the eastern coast and borders with neighboring countries. Taken together, the visual results of the KDE analysis suggest that fallowing and health do exhibit some overlap, albeit at varying levels.

Figure 3.2: Kernel density estimation of health events and proportion of land fallow



Note: Villages are overlaid for reference. A) 2002 prolonged illness; B) 2005 prolonged illness; C) 2008 prolonged illness; D) 2002 agricultural fallowing; E) 2005 agricultural fallowing; F) 2008 agricultural fallowing. Calculated by author using available TIA and GIS data.

3.6.3 Regression results

The regression analysis of household agricultural land use and health is presented in Table 3.6. Because a two-part model was used, the results are reported as follows for each year of the TIA that was analyzed: marginal effects for the logit model; standard coefficients for the OLS component; and then finally marginal effects that represent the combined processes. Because I am interested in the separate decision processes of fallowing land, I focus my discussion of the results on the individual logit and OLS estimations.

Table 3.6: Regression results of fallow land analysis

Dependent Variables:
Logit: Reports fallowing (binary)
OLS: Total amount of land reported as fallow

	Year								
	2002			***2005***			***2008***		
Independent Variables	*Logit*	*OLS*	*Avg. Marginal Effect*	*Logit*	*OLS*	*Avg. Marginal Effect*	*Logit*	*OLS*	*Avg. Marginal Effect*
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
Household experienced a prolonged illness	0.057**	0.329	0.138*	0.038**	0.047	0.049*	0.067**	0.038	0.047**
	(0.022)	(0.339)	(0.072)	(0.019)	(0.091)	(0.025)	(0.029)	(0.087)	(0.023)
Household total cropped area	0.007	-0.138	-0.017	-0.026***	0.099	-0.009	-0.022**	0.263***	0.032***
	(0.007)	(0.327)	(0.058)	(0.006)	(0.106)	(0.019)	(0.009)	(0.049)	(0.010)
Household total cropped area (sq.)	0.000	0.068	0.011	0.000***	0.018	0.003	0.001	-0.023***	-0.004***
	(0.000)	(0.049)	(0.009)	(0.000)	(0.015)	(0.003)	(0.001)	(0.008)	(0.001)
Household number of fields	0.024***	0.035	0.035***	0.036***	-0.016	0.021***	0.034***	-0.090***	0.005
	(0.005)	(0.048)	(0.013)	(0.006)	(0.032)	(0.008)	(0.007)	(0.023)	(0.006)
Household employs full-time workers	0.004	0.581*	0.100*	0.013**	0.028	0.017	0.022**	0.208**	0.049***
	(0.003)	(0.338)	(0.059)	(0.006)	(0.097)	(0.018)	(0.010)	(0.083)	(0.022)
Household uses any basic agricultural inputs	-0.005	-0.020	-0.018	-0.003	0.127**	0.022	0.018	-0.193***	-0.022
	(0.012)	(0.196)	(0.040)	(0.014)	(0.062)	(0.017)	(0.018)	(0.055)	(0.014)
Household uses any advanced agricultural inputs	0.016	0.197	0.060*	0.022	0.091	0.032*	0.004	0.144***	0.027**
	(0.014)	(0.129)	(0.034)	(0.014)	(0.051)	(0.017)	(0.018)	(0.045)	(0.013)
Household engages in outside employment	0.004	-0.198*	-0.024	0.011	-0.015	0.009	0.030**	0.065	0.029**
	(0.014)	(0.118)	(0.030)	(0.012)	(0.044)	(0.014)	(0.014)	(0.054)	(0.013)
Household proportion of land that is upland	-0.028*	-0.117	-0.095**	-0.006	0.160***	-0.005	-0.019	0.051	-0.003
	(0.017)	(0.189)	(0.041)	(0.014)	(0.052)	(0.016)	(0.017)	(0.057)	(0.014)
Household proportion of land that is irrigated	0.003	1.428*	0.215	0.038	0.562***	0.090**	0.045	0.131	0.050

	(0.032)	(0.832)	(0.152)	(0.032)	(0.180)	(0.043)	(0.0456	(0.161)	(0.039)
Household members employed in agriculture	-0.004	-0.062	-0.031	0.000	0.050	0.003	-0.001	0.004	0.000
	(0.007)	(0.078)	(0.019)	(0.006)	(0.032)	(0.008)	(0.011)	(0.034)	(0.009)
Household members employed in agriculture (sq.)	0.000	0.003	0.002	0.000	-0.003	0.000	0.000	0.000	0.000
	(0.001)	(0.007)	(0.002)	0.000	(0.004)	(0.001)	(0.001)	(0.003)	(0.001)
Asset score	0.013**	-0.042	0.014	-0.010**	-0.034*	-0.013**	-0.003	0.007	-0.001
	(0.006)	(0.053)	(0.011)	(0.005)	(0.020)	(0.006)	(0.006)	(0.021)	(0.005)
Asset score (sq.)	-0.003*	0.039*	0.002	0.001	0.015*	0.004	0.001	0.009	0.002
	(0.002)	(0.023)	(0.005)	(0.002)	(0.008)	(0.002)	(0.003)	(0.009)	(0.002)
Household head is male	0.021	0.208	0.079**	-0.004	-0.012	-0.004	-0.020	0.054	-0.002
	(0.014)	(0.133)	(0.036)	(0.014)	(0.050)	(0.017)	(0.017)	(0.050)	(0.013)
Household head age	0.001**	0.005	0.002**	0.001**	0.001	0.001**	0.001	0.001	0.001
	0.000	(0.004)	(0.001)	0.000	(0.001)	(0.001)	(0.001)	(0.002)	0.000
Household head education	0.002	-0.006	0.002	0.003	0.022	0.008	-0.004	-0.018	-0.006
	(0.004)	(0.040)	(0.010)	(0.004)	(0.020)	(0.005)	(0.006)	(0.029)	(0.006)
Household head education (sq.)	0.000	0.002	0.000	0.000	-0.001	0.000	0.001	0.003	0.001
	0.000	(0.003)	(0.001)	0.000	(0.001)	0.000	(0.001)	(0.004)	(0.001)
Household child dependency ratio	0.005	0.021	0.004	-0.002	-0.035	-0.011	-0.011	0.031	-0.001
	(0.011)	(0.074)	(0.021)	(0.011)	(0.033)	(0.012)	(0.011)	(0.047)	(0.010)
Village experienced drought in prior year	0.011	-0.325***	-0.047*	-0.039*	-0.039	-0.052**	0.003	-0.027	-0.003
	(0.013)	(0.108)	(0.028)	(0.023)	(0.072)	(0.027)	(0.017)	(0.058)	(0.015)
Village experienced flood in prior year	0.001	0.367	0.071	-0.012	-0.068	-0.012	0.015	-0.033	0.003
	(0.016)	(0.279)	(0.057)	(0.027)	(0.08)	(0.031)	(0.018)	(0.05)	(0.014)
Village has any electricity	-0.054**	-0.359	-0.140*	0.006	-0.051	0.009	-0.027	0.025	-0.012
	(0.024)	(0.260)	(0.077)	(0.018)	(0.064)	(0.021)	(0.020)	(0.063)	(0.016)
Cabo Delgado	-0.140***	-0.543	-0.302***	0.046	-0.086	0.044	0.063*	0.067	0.050*
	(0.041)	(0.358)	(0.098)	(0.029)	(0.139)	(0.038)	(0.034)	(0.111)	(0.028)

Nampula	0.118***	-0.254	0.129	0.026	-0.161	0.015	0.082***	0.209*	0.086***
	(0.031)	(0.354)	(0.090)	(0.029)	(0.139)	(0.038)	(0.032)	(0.116)	(0.028)
Zambezia	0.014	-0.286	-0.044	0.023	-0.185	-0.001	0.075**	0.127	0.067**
	(0.032)	(0.346)	(0.079)	(0.029)	(0.144)	(0.038)	(0.033)	(0.123)	(0.029)
Tete	0.082***	-0.393	0.039	-0.018	-0.295	-0.063	0.014	0.015	0.011
	(0.031)	(0.356)	(0.083)	(0.034)	(0.208)	(0.049)	(0.033)	(0.105)	(0.027)
Manica	0.135***	-0.508	0.103	0.156***	0.223	0.188***	0.055	0.196	0.067*
	(0.032)	(0.365)	(0.084)	(0.031)	(0.174)	(0.045)	(0.037)	(0.158)	(0.036)
Sofala	-0.007	-0.496	-0.106	0.082***	-0.195	0.048	-0.073*	0.279*	0.004
	(0.036)	(0.363)	(0.087)	(0.030)	(0.145)	(0.040)	(0.042)	(0.164)	(0.038)
Inhambane	0.101***	-0.474	0.068	0.132***	0.033	0.134***	0.133***	-0.100	0.064**
	(0.034)	(0.405)	(0.092)	(0.030)	(0.157)	(0.042)	(0.036)	(0.123)	(0.030)
Gaza	0.163***	0.100	0.266**	0.122***	0.041	0.134***	0.083**	0.071	0.062**
	(0.034)	(0.406)	(0.108)	(0.031)	(0.150)	(0.043)	(0.037)	(0.122)	(0.031)
Maputo	0.111***	0.268	0.223*	0.167***	0.079	0.179***	0.129***	0.239	0.120***
	(0.037)	(0.557)	(0.134)	(0.033)	(0.164)	(0.047)	(0.038)	(0.159)	(0.036)
N	4818	895		5919	1242		5712	996	
R-squared/Pseudo R-squared	0.092	0.177		0.046	0.326		0.034	0.207	
Link test (p-value associated with squared predicted value)	0.805	0.435		0.110	0.591		0.800	0.700	
Mean VIF	4.18	3.22		4.41	2.98		5.16	3.36	

* p<0.10, ** p<0.05, *** p<0.01

Across time, I find significant results of the impact of a prolonged illness on participation in fallowing, with some variation in the magnitude of the effect. The occurrence of a prolonged illness is associated with increased participation in fallowing, increasing participation by 5.7% ($p<0.05$) in 2002, 3.8% ($p<0.05$) in 2005, and 6.7% ($p<0.05$) in 2008. While the magnitude may seem small, these increases in fallowing may nonetheless have a substantial micro-level impact when we consider that subsistence agricultural households are economically vulnerable and the marginal value of cultivated land is potentially much higher for them, based on the assumption of diminishing marginal returns (Tschirley and Benfica 2001). These results comport with the coping strategy findings from Tables 3.3 and 3.4 and suggest that agricultural households are adopting fallowing as a means of mitigating the impact of a prolonged illness. The second part of the model explores whether prolonged illness affects the amount that is fallowed for those households that engage in fallowing. The results indicate that there is no systematic way in which these households change the amount they fallow in the presence of a prolonged illness.

There is significant variation in the effect of agricultural characteristics on fallowing, including variation in the role of different variables through time. Cropped area appears to have no significant impact on any aspect of household fallowing in 2002. In 2005, more cultivated land decreases the likelihood that a household engages in fallowing, but this effect is attenuated as households cultivate more land. In 2008, the effect is more pervasive, affecting not only participation but also the intensity of fallowing. For those households that engage in fallowing, there is a positive, but diminishing, relationship between cultivated land and fallowed land. The number of fields belonging to a household has a significant impact on the decision to fallow land across all survey years in the analysis, implying that as the number of fields increase for a household, they are more likely to engage in fallowing some of those plots. However, the impact of the number of fields on the amount of land fallowed increases though time, with no significant impact in 2002 or 2005, a marginal and a significant impact in 2008, where fragmentation leads to fallowing less land. Previous studies in other settings have found a similar effect from field fragmentation (Grisley and Mwesigwa 1994; Pender and Gebremedhin 2008; Sauer et al. 2012). Full-time workers employed by the household also show a varying effect on the amount of land fallowed. In 2002, there is no significant impact on the decision to fallow and only a marginal effect on the amount fallowed. However, this input does have a significant impact on the decision to fallow for 2005 and 2008, with no effect on the amount of land fallowed in 2005, but with a significant impact on the amount for 2008. This increase may be due to the ability of households to more easily reallocate resources to plots deemed to be more productive (Collier and Dercon 2013). The use of basic agricultural inputs has no impact on the decision to fallow, but does affect the amount fallowed in 2005 (increases amount) and 2008 (decreases amount) or the amount of land, though the magnitude is quite small. The use of advanced agricultural inputs has no apparent effect on the decision to fallow or the amount of land fallowed in 2002 and 2005. However, in 2008, use of advanced agricultural inputs does lead to an increase in the amount of land fallowed. This suggests that agricultural inputs may still be inadequate or absent for subsistence agricultural households to use on a regular basis. Whether the household's field(s) are upland appears to have a marginal effect on the decision to fallow, but not on the amount fallowed for 2002, and appears to increase the amount of land fallowed for 2005. Additionally, access to irrigation does not appear to have an effect on the decision to fallow through time, with a weak effect on the amount fallowed in 2002 and a strong effect on the amount fallowed in 2005, though the magnitude is small. Interestingly, total agricultural labor in the household appears to have no effect on either the decision or the amount of land fallowed in any of the TIA survey years.

Asset holdings appear to also affect the fallowing participation decision in 2002 and 2005, but not in 2008. For 2002, higher asset holdings appear to increase the likelihood to participate in fallowing. Whereas, higher asset holding has the opposite effect in 2008; additionally, higher asset holdings decreases the amount of land fallowed in 2008. It is worth noting that only a marginally significant association between the amount of land fallowed and the gender of the household head for 2002 but not for 2005 or 2008 is observed, suggesting that gender is not really a decisive factor in the decision making processes of fallowing land or the amount of land fallowed. The age of the household head is a significant predictor of the decision to fallow land in 2002 and 2005 only, but in terms of practical significance this is a rather small effect. Age may reflect the accumulation of agricultural knowledge increases with more years of experience; this experience may allow seasoned farmers to more efficiently use fallowing as a land use decision. Interestingly, education and the child dependency ratio appears to have no impact on either the decision to fallow or on the amount fallowed in any of the study years.

The model also captured community level characteristics and sought to understand how climatic events may impact fallowing. Interestingly, drought experienced in the prior year appeared to reduce the amount of land fallowed in 2002 and decreased the likelihood of engaging in fallowing for 2005; I do not see any other effect of drought on fallowing throughout our study years. Flooding, appears to have no effect on either the decision to fallow or the amount of land fallowed throughout time. Presence of electricity in the village appears to decrease participation in fallowing for 2002, but not for the other years. This suggests that as electricity became more available through time, it may have less of an effect on fallowing.

While the demographic and agricultural input variables capture the general association of these variables with fallowing for the entire survey area, the estimated model also allows for spatial flexibility through the use of province indicators. Because the outcome variable of interest is focused on fallowing, Niassa province is chosen as the reference group as this province consistently has the lowest level of fallowing participation, and thus serves as a baseline for comparison with the other provinces. There is significant spatial variation in the participation decision to fallow land at the provincial level, and more interestingly, strong variation in the spatial distribution through time is observed. However, there does not appear to be any significant variation in the amount of land fallowed across the provinces, with a marginal impact occurring in Nampula and Sofala provinces in 2008. Some areas, such as Cabo Delgado province, see a complete change in fallowing participation over time relative to Niassa; households in Cabo Delgado exhibited less fallowing participation than households in Niassa in 2002, no significant difference in 2005, and more fallowing participation in 2008. While some spatial and temporal variation occurred in the northern provinces, in which some provinces show significant differences from Niassa (also a northern province) for some years and then not others, consistently higher participation in fallowing occurred in the southern provinces of the country. Relative to Niassa province, Manica, Inhambane, Gaza, and Maputo provinces all had statistically significant greater participation in fallowing over the course of the survey years. Notably, this may align with the aforementioned observed spatial gradient in HIV/AIDS prevalence, where prevalence increases from the northern-most province of Niassa to the south-west.

The fallowing participation models pass the Pearson chi-squared goodness of fit test. The R-squared values for the OLS component of the two-part model were significantly higher. For the purpose of this study, the overall strength of the model is less of a concern than whether the model correctly isolates the effect of health from other confounders—I am not attempting to generate a predictive model of fallowing, but rather understand this specific health-land relationship. Thus, it is notable that the model specification passed the link test for all years for both the logit and OLS estimations. Also, the mean variance inflation factor is under 5.15 for all years across the covariates, suggesting that multicollinearity is not a major concern in this model.

3.7 Discussion

This analysis gives a more nuanced view of the implications of illness for subsistence agricultural households in Mozambique. The findings reflect a human capital view of health, emphasizing the role of health as a driver of economic activity. The results suggest that households are more likely to engage in fallowing as a way of coping with illness. However, there is no systematic way in which unhealthy subsistence agricultural households are choosing the amount of land to fallow. This suggests that increases in fallowing may be unequally distributed through space and time as households have access to varying levels of resources, and is in keeping with the theoretical predictions of political ecology. This increase in fallowing in response to a prolonged illness could potentially heighten the vulnerability of smallholder agricultural households to food insecurity as they farm less land. Responses from the TIA 2002 agricultural survey and descriptive results of fallowing participation for all years of the survey identified fallowing as a coping strategy, and a statistically significant association between prolonged illness and the decision to fallow land prevailed in the regression analysis.

Additionally, results from the KDE analysis for each year revealed spatial and temporal trends for both prolonged illness and land fallowing. In terms of a spatial trend, the southernmost provinces (Gaza, Inhambane and Maputo) exhibit consistently high rates of prolonged illness and fallowing. These provinces have also had the highest HIV/AIDS prevalence rates for Mozambique throughout time. It is also worth noting that there was a growing trend in prolonged illness occurring in and around Beira in the Sofala province. This growing trend is not surprising since Beira is the second largest city in Mozambique and also has a significant urban problem with HIV/AIDS. The prolonged illness-fallowing relationship is a bit dampened in the northern and central provinces, and this is may be due to the lower rates of prolonged illness and the more favorable climatic conditions for agriculture. However, pockets of this relationship still exist in these provinces and these occur along the eastern coast of Mozambique, as well as along borders shared with Malawi, Zimbabwe, and South Africa. The surrounding countries also have relatively high HIV/AIDS prevalence rates and could contribute to the trends observed in Mozambique. Overall, the individual and joint variation in prolonged illness and fallowing align with the political ecology tenet around variation in marginalization and the role of other factors in determining the extent to which households become marginalized in the face of an adverse event.

The regression results suggest that the health-fallowing relationship weakened slightly in 2005, though the prevalence of prolonged illness was highest in this survey year. The climatic and policy context of 2005 possibly contributed to the change in this health-fallowing relationship. Flooding in 2001, followed by very poor rainfall and drought between years 2002-2004 may have contributed to the weakened effect on the health-land relationship (FAO 2005; Cunguara and Kelly 2009). By 2005, many households had experienced 3-4 subpar agricultural seasons, and may have faced dire consequences from letting land fallow (FAO 2005). Additionally, an expansion in economic diversification occurred between 2002 and 2005, where households that were better off were able to transition from being solely agriculturally-reliant and supplemented their livelihoods through outside employment (Mather et al. 2008; Cunguara and Kajisa 2009). However, this may have further contributed to a potential poverty trap, whereby the poorest subsistence agricultural households could not diversify economically. As a result, they were most likely forced to revert to the only livelihood means they know—agriculture. Thus, this may have set up a potential situation whereby these households were forced to farm more land because they had been food insecure for multiple, consecutive years despite experiencing a prolonged illness. Furthermore, this may also help explain the attenuation on the prolonged illness-fallowing relationship observed in the KDE results. Taken together, the persistently bad climatic events, may have overcome the impact of prolonged illness on the environment for 2005 despite the observed high rates of prolonged illness. This suggests that households with unhealthy members were forced to farm as much as possible to make up for the impact of poor growing seasons in previous years.

The vulnerability of smallholder agricultural households in Mozambique to marginalization is well-established, and this analysis suggests that these households may not be adequately protected from an additional force of marginalization: illness. This suggests a need for targeted policy that takes a balanced approach to helping subsistence agricultural households diversify their livelihood strategies. This type of policy approach is vital to reducing the vulnerability these households face and can help transition them into more sustainable livelihoods (Tschirley and Benfica 2001; PARPA 2007; PARPA 2011). Within this balanced policy approach is the need for stronger social safety nets, as too many households rely on informal safety nets comprised of family and remittances, and these are not always predictably available (FAO 2005). Such an effort would mean establishing better access to healthcare, agricultural resources, and outside employment opportunities.

Land and labor constraints vary spatially; some countries are labor rich and land poor (e.g. Tanzania and Malawi), while others such as Mozambique are land abundant and labor poor. This variation in resource constraints is likely to lead to different responses to illness. Households in labor-rich countries may more easily substitute labor in the face of a household member's illness, while this kind of substitution is likely more challenging in settings that are relatively labor-scarce. Current agricultural policy in Mozambique does little to help protect subsistence and smallholder agricultural households, as there is a lack of a meaningful land tenure policy in place. Typically, this is not an issue for smallholder agricultural households in the country, as there is usually enough land to farm. While Mozambique is regarded as land-abundant due to the low proportion of total arable land that is actually cultivated, it can also be regarded as land-scarce in terms of irrigated land. Irrigated land is the most productive land type for agriculture, and in Mozambique, is often in high demand. In Mozambique, this land is generally allocated to households for cultivation based on allocation by the village chief or head. This risk of land loss is considerably lower in non-irrigated areas where allocation among households is less competitive. However, there are implications for vulnerable smallholder households to be pushed to more marginal lands moving forward—especially in the presence of a health event. Large agribusinesses from Brazil, China, and India are finding an abundance of land to farm in Mozambique and this may increase the vulnerability of subsistence agricultural households to illness, even those not in the irrigated area.

On a broader level, health events that diminish a household's ability to farm all of its land have the possibility to introduce food security issues. For a country that relies heavily on agriculture as a mode of economic development, poor population health may contribute to a state of economic stagnation and prevent subsistence agricultural households from making the transition to more advanced farming practices. Mozambique's health care system has been slow to advance and this is one possible reason that health still plays such a major role in household resource allocation decisions. For example, Audet et al. (2010) note that while ART became available in 2004, less than a quarter of the population with advanced HIV were actually enrolled as of 2007. Improving access to health care may naturally weaken the importance of the health-fallowing link by reducing the number of households facing a prolonged illness.

3.8 Future work

One possible extension to this analysis involves examining the impact of prolonged illness on overall crop production. While this analysis examined the quantity of land cultivated, the quality of that cultivation is another potential way that households are affected by illness. This includes changes in the crops grown, or the crop yield, and more directly addresses the broader issues of food security and livelihood sustainability. Households experiencing prolonged illness may be more nutritionally vulnerable, and may resort to less labor intensive or less risky crop varieties as a means of coping. Additionally, another extension of this work could examine the impact of health on non-agricultural employment throughout Mozambique. Poor health status may act as a barrier from transitioning away from subsistence agriculture to off-farm income generating activities; this could potentially have profound implications for poverty eradication, economic equality, and overall development.

These analyses are natural extensions now that the effect of household illnesses on agricultural land use has been established.

3.9 Conclusion

This research improves our understanding of how health affects subsistence agricultural households and agricultural land use decisions in areas characterized by endemic poverty and high disease burdens. The identified association of household prolonged illness with an increase in participation of fallowing land, using robust regression methods, is a critical piece of evidence around the impact of health on the environment, and extends our understanding of the economic implications of health among subsistence agricultural households that are already economically vulnerable. My findings suggest that unhealthy subsistence agricultural households engage in fallowing more than healthier households and use this as one of their coping strategies. However, I do not find evidence of a systematic way in which households allocate a certain proportion of their cropped area to fallow in the event of prolonged illness. This suggests that households absorb prolonged illness differently through both space and time. These findings provide a more nuanced understanding of the household-level effects of illness by incorporating the experiences of traditionally marginalized and economically disadvantaged groups in examining health and agricultural land use and indicate that targeted policy is needed to help mitigate the impact of prolonged illness on their livelihoods.

Some households have been able to make the transition to off-farm employment and economically diversify. However, many subsistence agricultural households still struggle to make this transition. A balanced policy is needed to provide these households the necessary resources to economically diversify. Tschirley and Benfica (2001) noted that the government of Mozambique has made some strides in assisting subsistence agricultural households and smallholder farmers, but the policy is not effective in reaching everyone. Instead, Tschirley and Benfica (2001) argued that a balanced approach is needed, with policy specifically targeted for sub-divisions of subsistence agricultural households and smallholder farmers that focuses on better access to agricultural markets, access to credit, and access to improved agricultural technology. I build on this call, and suggest that policy needs to be even more targeted than this. Because many of these subsistence agriculturalists live below the poverty line, policy needs to begin with investments in human capital. It has already been demonstrated that higher levels of education and better health contribute significantly to the upward mobility of the poor and enable them to weather illness and other household shocks (Baulch and Hoddinott 2000). This paper elucidates the health-land use relationship by drawing attention to the possible unsustainability of agricultural livelihoods for health-affected households, in that fallowing more land as a coping strategy may lead to increased vulnerability and food insecurity. This seems a bit counterintuitive given that fallowing is typically meant to increase yields, but when unhealthy households engage in this practice, they use it as a stop-gap solution that may contribute to year-on-year reductions in crops grown, and thus this may contribute to food insecurity. Policy that not only invests in better access to agricultural markets, access to credit and access to improved agricultural technology, but *also* the school system, roads infrastructure, and access to health care is vital to helping transition subsistence agricultural households into a more advanced agricultural system, and helping these households economically diversify by engaging in off-farm employment. These types of policy levers may serve to mitigate the marginalizing economic impacts of illness, which would in turn also reduce the effect of health on the natural environment.

Chapter 4: Does the current configuration of health clinics and services prioritize vulnerable subsistence agriculturalists in rural Mozambique?

4.1 Introduction

Health as human capital implies that investments in health will generate broader returns, and this link between health and economic performance has been established at both the micro and macro levels. This relationship can also work in reverse, as poor health can inhibit labor force participation and stunt economic growth. The negative economic implications of poor health in agriculturally-reliant areas have been documented (Bloom et al. 2004; Larson et al. 2004; Canning 2006; Walker et al. 2006), and illness can deepen and perpetuate poverty traps by stifling economic mobility among economically constrained households. A variety of policy levers have been applied to attempt to disrupt this negative health-wealth relationship in low-income countries (LICs). In LICs, health clinics are commonly used to improve health care access and reduce the frequency and severity of adverse health events. Governments and donors are increasingly concerned with maximizing the return on health investments for LICs. For clinics, factors such as location and services offered can both affect a clinic's efficacy, as they can a regional clinic system's efficacy, which can affect the value of this policy instrument.

Subsistence agricultural households are by definition highly vulnerable to economic and agricultural shocks. They are also highly vulnerable to health shocks and, in turn, highly dependent on the clinical services that, if accessible and adequate, may help cushion these shocks. Largely unprotected from the risks associated with farming and with limited access to capital and other economic opportunities, subsistence agricultural households are also particularly vulnerable to poverty traps (Tschirley and Benfica 2001; FAO 2005). For example, chronic illnesses such as diabetes, cancer, and hypertension plague older generation subsistence agriculturalists, while communicable diseases such as HIV/AIDS, sexually transmitted diseases (STDs), and cholera, to name a few, typically affect the younger generations (Negin 2005; Hawkes and Ruel 2006). Additionally, subsistence agricultural households have limited economic mobility and are thus limited in livelihood diversification (Ulrich et al. 2012).

Agricultural households often rely on intra-household labor and have very little access to advanced agricultural inputs that would help facilitate greater productivity while minimizing the physical demands of this laborious livelihood strategy (Banerjee and Duflo 2005). Poor health and disease are capable of diminishing household stocks of human capital, have far-reaching consequences for those reliant on physical labor, and are felt more acutely in households that are subsistence-reliant (Obrist et al. 2007). Thus, an inferior configuration of health clinics may limit the ability of subsistence agricultural households to maintain their livelihoods in the face of disease or injury; this may be further complicated in countries where health services are not subsidized or given freely.

This analysis examines the distribution of clinics and services in four rural districts in Gaza, Mozambique, using several metrics to define need. It focuses on subsistence agricultural and other economically vulnerable households and their access to health clinics providing a specific high-quality service—ART. It then focuses on how changes in health status affects livelihood sustainability and whether or not improved access to health clinics mitigates the possible negative impacts associated with poor health. Gaza, Mozambique, is an excellent site for this analysis as its economy is highly agricultural, is characterized by considerable inequality, and has a worrisomely high HIV prevalence rate where just over 1 in 4 are infected; this has led to targeted government efforts to alleviate poverty, which efforts include improving health care access (PARPA 2007; Ministry of Health 2010; PARPA 2011).

As part of the government's poverty alleviation strategy, investments in health infrastructure are cited as a top priority. The government of Mozambique uses health clinics as platforms to roll out high-quality services such as ART, prevention of mother-to-child transmission of HIV (PMTCT), maternal and child health (MCH) services, and immunizations (PARPA 2007; WHO 2007; PARPA 2011). Additionally, in an effort to support its poverty alleviation strategy, while making serious strides in investments in health, the government provides certain high-quality services to the general public for free; these services include ART, HIV testing, services for pregnant women (e.g., prenatal, delivery and counseling services), immunizations, and care to children under five (WHO 2007).

Using health clinic data from 2009, I evaluate village access to health clinics and correlate that access with population, economic status, and agricultural intensity. I consider multiple measures of access for this analysis, using distance to nearest clinic, distance to nearest clinic offering ART, and average quality of surrounding clinics. Cost is not considered a barrier to access in this study because of the commitment made by the Mozambican government to provide ART (a high-quality service) for free (WHO 2007; Yao et al. 2014). Barnighausen et al. (2007) established that the major limitation for providing additional ART in sub-Saharan Africa is not money, but human resources. To examine the potential implications of limited resources, I also construct a quality score comprised of available resources for each clinic (both physical and human). I hypothesize that the current configuration of clinics offering ART is not well situated to best serve surrounding communities. To test this hypothesis, I perform a location-allocation analysis to understand how the current configuration of clinics offering ART may be underperforming and test alternative configurations. To do this, I construct multiple metrics for "need" and then model how access to ART varies as a function of need for both the current and alternative configurations. I ask if a redeployment of health services such as ART might improve access for the need-based groups.

Additionally, I use a survey on women's health to examine how changes in access and health status may affect the livelihoods for respondents. For this analysis, I make use of household panel data from 2009 and 2011 and construct a variety of economic-based indicators for subsistence agriculturalists. I also use health clinic panel data from 2009 and 2011 to track changes in health services offered. I correlate changes in access (as measured by reduced distance and an improvement in quality of services offered) with economic-based indicators to understand how improvements in health may impact the livelihoods of subsistence agriculturalists.

This study contributes to the literature on access to care in spatially innovative ways. First, I take advantage of precise spatial information about both villages and clinics; this type of spatial analysis is challenging with other household data sets, such as the Demographic Health Surveys, which often scramble geographic coordinates. Second, I integrate a comprehensive quality measure into the optimality analysis, considering all clinics within a predefined radius of each village rather than just the closest one. And third, I examine how improvements in access may correlate with changes in livelihood sustainability. Ultimately, this paper seeks to compare how clinic services are currently and optimally distributed in terms of providing access to the vulnerable segments of society, and whether or not this policy lever is helping subsistence agriculturalists to mitigate the negative livelihood effects of poor health.

4.2 Background

A high priority in establishing health clinics and allocating services is to provide resources close to those who need them most. Physical accessibility is a major concern for siting these facilities as there is a need to establish a link between the providers and consumers of health care. Not only do geographic features act as barriers in these settings, but physical distance can also inhibit utilization. Access, then, can be defined in multiple ways. The most common approach in the literature is to define access in terms of equity and equality. I limit the review to supporting literature that frames access in this manner, as my analysis, which is most concerned with reaching the more vulnerable pockets of society, is equity-oriented.

Common measures of equity in health care include: equality of utilization, distribution according to need, equality of access, and equality of health (Culyer and Wagstaff 1993). These definitions often clash with each other, where certain ones are prioritized by different groups. For example, policy makers typically prefer measures such as distribution according to need and equality of access, while economists more commonly gauge equality of utilization and equality of health (Culyer and Wagstaff 1993). A more modern approach of striving for equity in health care seeks to combine these various measures into an all-encompassing one, with the main objective being to provide health care in a manner that does not systematically favor one group over another. Braveman and Gruskin (2003) define equity in health as “the absence of systematic disparities in health between groups with different levels of underlying social advantage/disadvantage—that is wealth, power or prestige.” Framing equity in this manner allows health care to be allocated in a way that supports social justice; assessing this approach to health equity entails comparing health and its social determinants between those that are more advantaged with those that are not (Braveman and Gruskin 2003).

Braveman (2006) refines this definition of health equity, noting that in order to establish health equity, health inequality needs to be eliminated; this is done by helping place disadvantaged social groups (e.g., poor, racial/ethnic minorities, women, or other groups who persistently face social disadvantage) on the same level as socially advantaged groups. Health equity can then be framed in terms of access to the opportunity to achieve good health (Sen 2002). In the case of this study, equal opportunity is interpreted as equal access to high-quality services provided by the surrounding health clinics. While poor individuals have high levels of illness and suffer from premature death, poor health is not clustered below the poverty threshold; rather, health status is somewhat linearly correlated with socioeconomic status (Marmot et al. 2008). This suggests that reducing or eliminating poverty could decrease inequity regarding access to health services. Therefore, closing the gap on health inequity requires policy makers to understand what determinants affect population health and how this health-economic gradient operates (Marmot et al. 2008).

In order to mitigate health inequality, policy mechanisms need to account for observed socioeconomic inequality, as this is a social determinant of health. One such mechanism is providing high-quality care through health clinics. Thus, improving access to these facilities enables socially disadvantaged members of society to obtain the "capability" to achieve good health (Sen 2002; Obrist et al. 2007; Peters et al. 2008). Studies that examine access to health facilities in developing countries often confirm that access is unequally distributed, with the poorest members of society typically having less access to health care (Peters et al. 2008).

Access to high-quality health care is a broader societal issue, with economic implications due to the impact of poor health on livelihood sustainability. This relationship, commonly referred to as the "health-wealth" link, is self-reinforcing. Poorer individuals typically have less means to support their livelihoods and have a lower asset base to draw from; adverse health events can exacerbate this economic fragility, and thus may deepen a poverty trap (Arora 2001; Marmot 2005.)

The relationship between health care access and utilization has been confirmed empirically in a variety of contexts. For example, Gabrysch et al. (2008) found that in Zambia's third largest city, Ndola, HIV prevalence increased with distance from existing health clinics. Yao et al. (2012) found that use of sexual-reproductive health (SRH) services varied spatially and used regression analysis to confirm that distance to a health clinic mattered for SRH service utilization in rural Mozambique. Also in rural Mozambique, Yao et al. (2013) used Poisson regression and kernel density estimation to demonstrate that distance to a clinic offering family planning services was a significant factor in the use of those services. In their systematic literature review, Posse et al. (2008) found that long distance from home to the closest health facility offering ART was the top barrier cited in the literature.

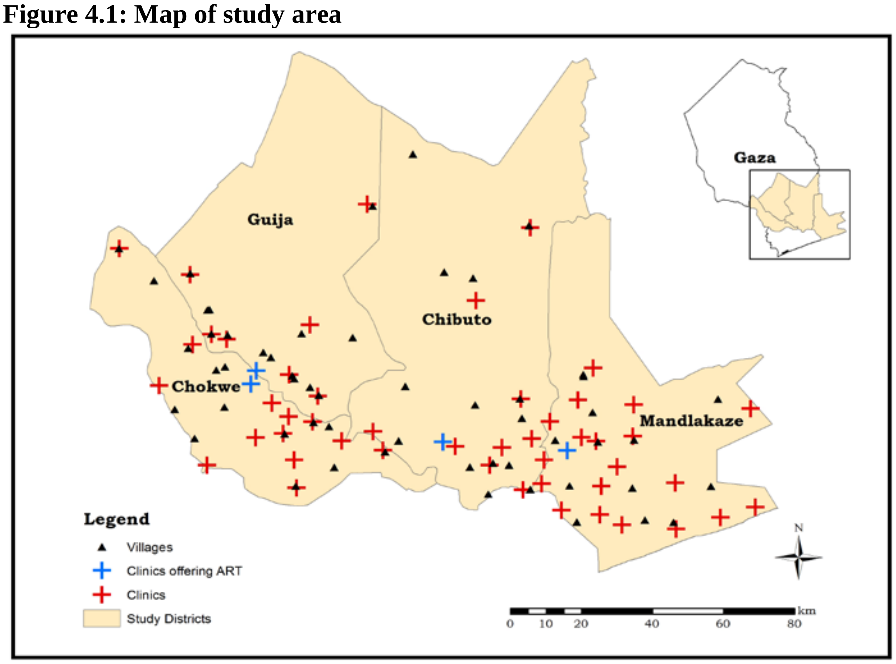
Spatial analytical methods are commonly used to evaluate access to health care (Cromley and McLafferty 2011). This is especially important because access to health care and utilization are tightly bound (Higgs 2009). Using spatial methods, the evaluation and configuration of health clinics can be used to identify vulnerable segments of society and project where future resources should be allocated (Yao and Murray 2014). Spatial analytical methods thus allow for comparison between the current and optimal configurations of health services offered, and can be designed to reflect social determinants of health. Many facility-location models have been developed to assess a wide range of health-access issues (Osleeb and McLafferty 1992; Daskin and Dean 2004; Ratick et al. 2009; Rais and Viana 2011; Wang 2012; Yao et al. 2014). Facility-location models assume that clinics are fixed spatially and then seek to assign demand to the clinics. The most popular type of this model—location-allocation—is the p-median problem model; this model seeks to locate *p* clinic locations among a given set of candidates such that the total distance travelled is minimized for the demand (typically, the surrounding population) (Hakimi 1964, 1965). Wang (2006) noted that this is the same as maximizing geographic access to health services. Additionally, the p-median problem model can be extended to choose optimal locations for additional clinics to improve access, and that this is beneficial for siting services for disadvantaged segments of society (Bennett 1981; Mehretu 1985; Oppong and Hodgson 1994).

For this analysis, I incorporate multiple social determinants of health to better understand how underserved populations can be better served. In doing so, I present an alternative to the current configuration of health clinics offering a much needed service—ART. Where most location-allocation analyses have focused on siting additional health clinics based on population, I seek to contribute to the literature by incorporating quality into the model. Thus, I offer potential optimal solutions for the extension of ART to clinics drawing from all possible current locations as well as their respective level of quality of services offered. The incorporation of this quality measure helps identify which clinics are better equipped with human resources and prioritizes extending ART to these first.

4.3 Study area and data

The data used in this analysis come from a longitudinal rural survey of women's health conducted in 2009 and 2011 in four districts (Chibuto, Chokwe, Guija, and Mandlakaze) of Gaza province in southern Mozambique. In 2009, 1,868 women were interviewed. In 2011, diligent effort to re-interview the same women was made; the women who died or could not be interviewed were replaced with additional women in the sample. For this analysis, I make use of data on women (1,272) who were interviewed in each year of the survey. Women in the survey were between the ages of 18-40 years living in 56 villages. Fourteen villages per district were selected with probabilities proportional to their population size based on census data. Within each village, at least 30 households were chosen; these were split between those with women married to migrants and those who were not, and were selected through probability sampling. The survey included standard demographic and economic questions such as age, assets, education levels, religion, agricultural engagement, husband's migration status, and household activities, as well as extensive questions about health status, health-care utilization, and health knowledge. As part of this data collection effort, all health clinics in the four districts were surveyed in 2009 and 2011 about the MCH services offered. The number of clinics increased from 53 to 57 by the end of 2011. This analysis uses questions about clinic services, infrastructure, and staffing to assess quality. The geographic location of each respondent, village and health clinic was recorded via longitude and latitude. Figure 4.1 depicts the spatial organization of the health clinics and villages in the study area.

Figure 4.1: Map of study area



Source: Map constructed by author

Mozambique is a sub-Saharan country that has been striving to contain such diseases as malaria, cholera, tuberculosis, and HIV/AIDS (Agadjanian and Menjivar 2011). These diseases are of interest because of the effect they have on household labor and human capital for subsistence agricultural households. Gaza province is located in southern Mozambique and has been plagued by high HIV prevalence for years, with the most recent estimate suggesting that just over 25% are infected with HIV (Ministry of Health, 2010). In 2004, ART was rolled out nationwide but through a very limited number of health clinics; less than 25% of the population with advanced HIV were actually enrolled in ART as of 2007 (Audet et al. 2010).

The country's health care system also faces other challenges, as malaria is endemic in many portions of the country (Mabunda et al. 2009). Additionally, unscheduled deliveries and poor antenatal care were significant contributors to maternal deaths in Mozambique, where simple prevention could have helped reduce the risk of malaria-related mortality in pregnant women (Granja et al. 1998). This particular region is prone to many natural disasters; it has experienced devastating floods and severe drought (Brouwer and Nhassengo 2006; Klinman and Reason 2008; Matyas and Silva 2013). Post-flood infections increase dramatically as drinking conditions deteriorate and new disease-vectors appear; malaria, respiratory infectious disease, and diarrhea have all been shown to increase dramatically after flooding (Kondo et al. 2002). Furthermore, households in this region may be disadvantaged by the occurrence of a natural disaster, forcing them to deal with the creation and expansion of many disease vectors, thereby eroding household human capital by creating unhealthy landscapes.

Agriculture is a vital part of the Mozambican economy, where just over 85% of the population engages in this livelihood strategy (FAO 2015). Many of those engaged are subsistence farmers and are more vulnerable to poor health as they often have a small or no social safety net to rely on. The particular region for this study boasts some of the better soil and growing conditions in the country; households in the survey are heavily reliant on agriculture. Households located in this region are situated within, or sit just outside the largest irrigated network in the country, and, as a result, cash cropping is emphasized in this area (Silva 2008). Sugar, cotton, tobacco, paprika, and chickpeas are common cash crops grown within this area (Walker et al. 2004; Boughton et al. 2007). The government of Mozambique has identified cash cropping as a poverty alleviation strategy and has placed a growing emphasis on these types of crops (PARPA 2007; PARPA 2011).

4.4 Methods

The analyses make use of descriptive statistics, principle component analysis (PCA), location-allocation analysis, GIS, and panel data change analysis. Descriptive statistics are used to explore the level of reliance on agriculture for households in the survey, to frame the motivation for my primary research question, and explore the relationship between livelihood vulnerability (measured in multiple ways) and access to healthcare. PCA is used to generate an asset score and is used as the measure of economic well-being for the households, as well as the health services quality (HSQ) index. Location-allocation analysis is used to examine how clinic placement may affect households that are potentially more vulnerable. Spatial methods are applied to examine optimal clinic placement and explore potential improvements in locating health clinics more effectively. Additionally, change through time is measured for healthy and unhealthy households using panel data, as I examine how health status may affect livelihood sustainability and whether or not access to health clinics prioritizes one group over another.

I use descriptive statistics to contextually understand the division of household labor dedicated to agriculture, as well as the potential vulnerability households face when access to health care varies spatially. It has been observed that distance has an effect on health service utilization, where those living in rural areas are most likely to use their nearest clinic (Haynes 2003). I assume that households residing in the same village will have roughly the same level of distance to overcome, as well as access opportunities such as access to high-quality services. I generate two measures of access: one based on network connectivity of the current road system in the study districts (geographic access), and the other measured through a comprehensive HSQ index (quality measure of access). While other studies have demonstrated that Euclidian distance can be a sufficient measure of spatial access in sub-Saharan Africa (Tanser et al. 2006; Yao et al. 2012), it is not useful for understanding distance and access barriers as they occur in reality. The surrounding physical geography needs to be considered in such analyses that focus on access to healthcare and vital resources. Euclidean distance fails to accommodate for geographic barriers, and this is illustrated in Appendix B as there are multiple water features that need to be accounted for as individuals travel around these impediments. Additionally, the current road network is comprised of primary and secondary routes, as well as trails.

Each has a different travel cost associated with it, and thus I take a hierarchical approach in weighting the roads by their respective speed limits; this is to help minimize travel impedance for the surrounding population.

4.4.1 Defining and measuring livelihood vulnerability

I generated several measures of potential livelihood vulnerability. The first measure is an asset score; this is calculated using PCA and is to be a measure of potential economic status at the household level. Many studies have demonstrated the value of using wealth-based indicators to rank households based on asset or wealth (Filmer and Pritchett 1999; Montgomery et al. 2000; Filmer and Pritchett 2001; Khan et al. 2006; Flimer and Kinnon 2012; Giesbert and Schindler 2012; Yao et al. 2014). Since the survey collected detailed information on dwelling conditions, access to electricity and water, access to a latrine, and asset ownership, all of these variables were used to generate a composite measure of economic well-being (or wealth) using PCA. An asset score creates a single measure by reducing a lot of information about assets. This is preferred means of estimating economic status, especially in settings that are not predominantly income-driven. However, how to weight the different assets represents a challenge. One option is to weight them all equally and then sum them up, but this is problematic because it treats a chair the same as a car. PCA is a statistical approach for systematically assigning weights. It converts a set of correlated variables into a set of uncorrelated components, where the first component is the one that explains the most variation. It is assumed that the first component represents economic status. Therefore, economic status is the primary driver of asset ownership. The coefficients generate from the first component are then used to weight the assets and can be used to derive an asset score.

Livestock are assets for subsistence agricultural households in developing countries and these were included in the composite index (Thornton et al. 2007; Giesbert and Schindler 2012). Livestock were converted to tropical livestock units (TLUs) using the Food and Agriculture Organization (FAO) conversion formula; I did this to facilitate the estimation of livestock in household assets. Full details on the assets included in the construction of the wealth score index are provided in Appendix C.

Because I am concerned about the health of subsistence agriculturalists, and how poor health negatively impacts household livelihoods and well-being, I construct an index that measures reliance on agriculture. Other studies have demonstrated that reliance on agriculture is a function of the number of household members engaged in the activity (Maxwell 1995; de Sherbinin et al. 2008). Additionally, livestock ownership is often a proxy for wealth, as it represents not only social status but wealth as well (Thornton et al. 2007; Giesbert and Schindler 2012). The data for this analysis also focuses on migration and how this impacts the household; often, the husband or male household head migrates out of the region for work and sends remittances back home. However, it has been established that remittances (and the anticipation thereof) from migrant husbands, while supporting food and household security, discourage women from seeking non-agricultural employment (Amuedo-Dorantes and Pozo 2006; Lokshin and Glinskaya 2009). Given that these relationships have been established in the literature, I make two assumptions when creating the land-reliance index. First, I assume that a household is less reliant on the land when the male head is able to diversify economically when migrating for work, and is thus able to provide more for the household (when compared to male heads that do not migrate). This is not to mean that households with migrant husbands are not still reliant on the land; rather, I seek to capture households that are the *most* reliant on the land. Second, I assume that the lack of ownership of livestock correlates with less wealth and a possible lower social status, and that these types of households may represent the lower bound of subsistence agriculturalists. To that end, land-reliance was captured through a simple index that identified households that have both spouses engaged in agriculture and report no ownership of livestock. I use this not only to get a better sense of how important agriculture is as a livelihood strategy for the households in the study but also estimate the impact that access to health care may have on helping land-reliant unhealthy households. Additionally, I seek to understand how access to healthcare may help households that report food hardship during the study period. For the food hardship measure, I identify households that reported having fewer than two meals a day in the past week.

For all of the livelihood vulnerability measures—asset score, land-reliance and food hardship—I group households based on terciles. Terciles are preferable for developing countries because dividing samples into quartiles or quintiles (for developing countries) often results in arbitrary cutoff values in which a large proportion of households would be allocated to an adjacent category due to a clumping of wealth scores at the lower end of the distribution (Khan et al. 2006). For population, tercile 1 is equal to the least populated villages while tercile 3 represents the most populated. For asset score, tercile 1 is equal to those with the least number of assets (worst economic status) while tercile 3 represents those with the greatest number of assets. For both land reliance and food hardship, tercile 1 is equal to the least amount of land reliance and food hardship while tercile 3 represents the greatest land reliance and food hardship. Table 4.1 shows the ranges used for each tercile when defining the livelihood vulnerability measures.

Table 4.1: Tercile ranges for village population and livelihood vulnerability measures

Access measure	***Mean***	***Std. Dev.***	***Tercile 1***	***Tercile 2***	***Tercile 3***
Population	1750	1524.61	86-1000	1001-1502	1503-7069
N			(21)	(17)	(17)
Asset score	-0.02	0.89	-1.87 - -0.40	-0.39 - 0.29	0.30 - 4.08
N			(19)	(19)	(17)
Land reliance (%)	8	5	0 - 6	6.1 - 12	12.1 - 27
N			(22)	(19)	(14)
Food hardship (%)	8	7	0 - 3	3.1 - 12	12.1 - 31
N			(18)	(18)	(19)

Source: Calculated by author.

Table 4.2 illustrates that each need-based metric is generally independent from each other, as there is very little to no correlation between the metrics. This suggests that each one provides a different viewpoint for vulnerable segments of society.

Table 4.2: Correlation matrix for livelihood vulnerability metrics

	Population	Asset score	Land reliance	Food hardship
Population	1.0000			
Asset score	0.1503	1.0000		
Land reliance	-0.1560	0.3942	1.0000	
Food hardship	-0.0472	-0.0670	0.2106	1.0000

Source: Calculated by author

4.4.2 Minimizing distance to health clinics through optimal placement

Measuring optimal placement of health clinics in this study is modeled through location-allocation analysis. The purpose is to assess the current spatial organization of health clinics and determine if these clinics are sited so as to provide best access for the study region. The measure of access used for this analysis is average distance and can be obtained using an optimization model. Additionally, I develop a health clinic quality index that will be used to weight health clinics by the level of resources and services they provide.

4.4.2.1 Defining access to high-quality health clinics

Measuring access to high-quality health care is a multi-step process that involves a two-step derivation. First, I constructed the HSQ index for each health clinic in the study area. I modelled the HSQ index after that of Yao et al. (2013) and have expanded it to include additional measures of quality pertaining to health clinics. Rather than focusing on the effect of available resources in a health clinic for one specific health service (family planning), I sought to derive a comprehensive index that would be a predictor of the overall quality of services provided by a given health clinic. This modification allowed me to capture the overall attractiveness of a health clinic and may help in understanding the role this has in shaping access. The HSQ index is the weighted sum of health clinic attributes:

$$a_j = \sum_{i=1}^{15} w_i v_i$$

where i is the index of variable i = 15 j is the index of the health clinic, j = 1,2,…N; v_i is the ith variable; w_i is the weight for the ith variable; and, a_j is the HSQ index of the jth clinic. The attributes pertaining to a specific health clinic are listed in Table 4.3 and provide the basis of my measure of geographic access.

Table 4.3: Health clinic attributes

Resources available	**2009 (N=53)**		**2011 (N=56)**	
	Mean	***Std. Dev.***	***Mean***	***Std. Dev.***
Number or rooms in clinic[15]	2.17	1.30	1.68	0.96
Clinic has access to piped water*	0.26	0.45	0.20	0.40
Clinic has access to electricity*	0.57	0.50	0.20	0.40
Clinic receives NGO assistance*	0.47	0.50	0.38	0.49
Services offered				
Prenatal consultations*	0.98	0.14	0.98	0.13
Counseling and testing*	0.55	0.50	0.89	0.31
PMTCT*	0.49	0.50	0.84	0.37
ART for general public*	0.07	0.26	0.07	0.26
ART for pregnant women*	0.19	0.39	0.16	0.37
Delivery assistance*	0.68	0.47	0.77	0.42
Postpartum consultations*	0.98	0.14	0.98	0.13
Child consultations*	0.96	0.19	0.96	0.19
Child at risk care*	0.51	0.50	0.84	0.37
Family planning*	0.98	0.14	1.0	0.0
Child vaccinations*	0.92	0.27	0.93	0.26

Note: * these attributes are binary
Source: Calculated by author using available data

To estimate the importance of the various health clinic attributes, a hedonic model was used to understand the contributory value of each specific attribute. Because many of the health clinic attributes are binary in nature, the first two variables were standardized to take a value between 0 and 1, whereby higher values of the HSQ index are indicative of better health services. For this analysis, the weights for health clinic attributes were estimated using PCA.

The second step was to use the HSQ for each clinic to create an access metric for each village that includes distance and quality of health clinics. This metric is the weighted sum of the HSQs for all clinics within a ten kilometer radius of a village, with weights corresponding to distance of the clinic from the specific village.

[15] While the average number of rooms in the clinic seems low, anecdotal evidence on waiting times suggest that most patients are seen the same day and waiting overnight to be seen at these clinics does not happen (Victor Agadjanian, personal communication, February 15, 2015).

Given that the data are based on a survey of women's health and health services utilization, the services included in the HSQ are primarily MCH-related, and thus they do not reflect the broader array of services available to the population. While the analysis focuses on ART offered to the general public (not just pregnant women), I use these MCH services as a proxy for the capacity of a facility to offer high-quality services in general. This use of these services as a proxy is justified by the high fertility rates observed across villages in the study (Yao et al. 2012). The similarity of these rates suggests that the quality of services offered is most likely to be fairly distributed based upon maternal need. Additionally, the degree to which a facility provides a wide array of MCH services potentially creates heightened awareness of the clinic's quality because ostensibly more women and children will seek care at the clinic. This awareness then could have immediate spillover effects to the general public (male and female alike). It is important to note that while the majority of services examined in my quality measure are MCH-specific, the health clinics do have the ability to offer general services to the public (i.e., males may also be seen at these clinics). Indeed, these health clinics represent the only type of health facility immediately available to rural residents (Yao et al. 2014).

4.4.2.2 Location-allocation analysis

The location-allocation analysis uses the current health clinics in the study area and the total population for the study villages as a proxy for demand. The shortest distance along the existing road network, from the villages to the health clinics, is calculated and used to measure access. Location-allocation is modeled using the p-median model which seeks to minimize the average total distance between demand points and their closest facilities. In 2009, there were 53 established health clinics. Essentially, the p-median model is used to select the best configuration of health clinics offering ART to the general public. This is done by choosing where a defined number of clinics offering ART should be sited given the current configuration of 53 clinics. Formally stated, the p-median model takes the following form:

$$\text{Minimize } Z = \sum_{i=I} \sum_{j=J} a_i d_{ij} x_{ij}$$

Facing the following restraints:

A clinic has to be allotted with a separate demand site (village): $x_{ij} \leq x_{ij}$ for all (i,j)

An open clinic must be allotted a demand:

$$\sum_{j=J} x_{ij} = 1 \text{ for all } i$$

Only the p clinics are to be located:

$$\sum_{j=J} x_{ij} = p \; for \; all \; j$$

All villages assigned to them equal the number of clinics to be located.

Total demand from a separate village: x_{ij} = (0,1) for all (I,j) is allotted to only one facility)

When:

Z = the objective function.

I = all of the villages where the nodes on network along the subscript i are an index signifying a specific demand area.

J = the collection of candidate clinics when the nodes on the network along the subscript j are an index which signifies a particular clinic location.

a_i = the number of people who are present at village i.

d_{ij} = denotes the distance or time in terms of the travel cost and separates place i from candidate clinic j.

x_{ij} = equal to 1 when demand at place i is allotted to a facility opened at site j, or equal to 0 when demand at place i is not allotted to the location.

p = the number of clinics to be located.

Because the p-median problem is a combinatorial problem of type “N choose P”, the solution frontier can grow extremely large. These types of problems involve finding the optimal grouping of a discrete, finite set of objects that satisfy a given set of conditions; in my case, I seek to choose the optimal configuration of clinics offering ART from the total possible set of clinics, while minimizing overall distance and maximizing clinic resources. Commercial software uses advanced programming and structured models to solve this, but it can efficiently be solved in a GIS through the use of heuristics. The program uses Tietz and Bart vertex substitution heuristics to refine solutions through multiple iterations. When no further improvement can be found, the metaheuristic returns the best solution found. The use of the edited cost matrix, semirandomized initial solutions, Tietz and Bart vertex substitution heuristic, and the refining metaheuristic generates near-optimal results.

The analysis weights the villages by population for the first iteration, then based on asset score for the second, and a final iteration by food hardship. For the asset score-weighted version, I take the inverse of the asset score to give more priority to those with the lowest economic status. The clinics are weighted by two versions of the HSQ; one version of the HSQ assumed no clinics offered ART and the other version did. I use these to generate a scenario where no clinics exist—whereby new ones need to be located—and baseline comparisons respectively. For the population, asset score, and food security weighted versions, I establish: the baseline assessment (the current configuration of clinics offering ART), new, previously un-sited clinics (assumes optimal configuration chosen from all possible health clinic locations), the current configuration plus one additional clinic, the current configuration plus five additional clinics, and the current configuration plus ten additional clinics. With each new location scenario, I choose the optimal configuration of clinics that minimizes overall impedance, and this is done according to the associated weights for each variable of interest (i.e., population, asset score, and food hardship).

4.4.3 Measuring the impact of changes in health status on livelihoods

The panel nature of the data allows me to examine how health status, health-care access, and economic well-being are linked. These relationships speak to the role of health clinics in mediating the health-wealth relationship. A strong relationship emphasizes the importance of improving access to primary clinics for poverty alleviation. I use the 2009 and 2011 surveys to examine whether changes in health status are associated with changes in health-care access and economic status. To identify changes in health status, I use a question from the 2011 survey about whether the respondent's health status has improved, worsened, or stayed the same in the past three years. Based on this question, I generate an indicator to identify those with declining health status over time.

Changes in health-care access are represented by the difference in the household's HSQ and distance to nearest clinic in 2009 and 2011. To understand how economic well-being has changed over time, I examine differences in a variety of agricultural and economic indicators. These include: field area cultivated, agricultural reliance, type of crop grown, food hardship, coping strategies such as employing additional labor or rental of land, livestock ownership, sale or exchange of livestock, asset score, and decline of living conditions over the previous three years. I then use two-sample *t*-tests to test for significant changes in health-care access and economic well-being between the healthy and unhealthy cohorts.

4.5 Results

Because agriculture is such a dominant livelihood strategy for residents in this region of Mozambique, I descriptively explored the role it plays for households in the study area. Migration is also quite common in this region given the close proximity to South Africa and neighboring countries, as male members of the household typically seek work elsewhere; this often leaves majority of agricultural responsibility to women within the household (Jiggins 1989; O'laughlin 1998; Bryceson 2002; Agadjanian et al. 2011). This is confirmed in Table 4.4, as stark difference between the percentage of women and men engaging in agriculture for the study sites emerge. Just fewer than 30% of male heads engage in agriculture, whereas nearly 100% of women do. Additionally, women are highly engaged in all aspects of farming, from clearing the land to harvesting the crops.

Table 4.4: Reliance on agriculture and division of labor

Household member engages in agriculture		Women's effort in agricultural tasks			
			A lot	A little	Not at all
Wife	98.75%				
Husband	29.59%	Field preparation	86.63%	11.46%	1.91%
Children	11.25%	Planting	92.41%	6.60%	0.98%
Relatives	43.67%	Weeding	86.79%	11.24%	1.97%
Non-relatives	16.73%	Harvesting	86.52%	12.39%	1.09%

Source: Calculated by author using available data

4.5.1 Livelihood vulnerability

I generated descriptive statistics for the livelihood vulnerability metrics. These were used in an exploratory manner to better understand how the current distribution of health clinics may impact different groups within the population. I examined both physical distance and access to high-quality clinics by tercile for population, asset score, land-reliance, and food hardship.

I tested to see if distance and access were significantly different between terciles. Table 4.5 reports the results from the descriptive statistics. The table shows how distance to the nearest health clinic, nearest health clinic providing ART, and the overall quality of services offered varies by village population and the livelihood vulnerability metrics for the defined terciles. Distance to the nearest clinic is not significantly different for the terciles based on any of the metrics. This suggests that these villages have fairly even access to the nearest health clinic. However, there are significant differences between terciles for the food hardship metric when examining distance to the nearest clinic offering ART to the general public. While there was not a significant difference between terciles for the other metrics, there is considerable variation. For that reason, I chose to examine the role of clinic placement further with respect to population, asset score, and food hardship.

Table 4.5: Distance and access to health clinics by village population and livelihood vulnerability

Measures	Population concentration				Asset Score				Land reliance				Food hardship			
Tercile	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.
Distance to nearest clinic (km)	4.71	5.91	5.64		4.44	6.41	5.13		5.97	4.42	5.69		4.99	4.68	6.37	
Distance to nearest clinic offering ART treatment (km)	24.77	23.56	23.61		29.73	23.09	18.73		26.77	23.50	20.47		28.72	16.30	26.93	**
Mean HSQ	0.53	0.47	-0.53		-1.09	0.80	0.76		0.04	0.78	-0.41		0.02	0.73	-0.18	
Number of villages	21	17	17		19	19	17		22	19	14		18	18	19	

Note: Calculated by author using available data. Significance defined as: ** $p<0.05$

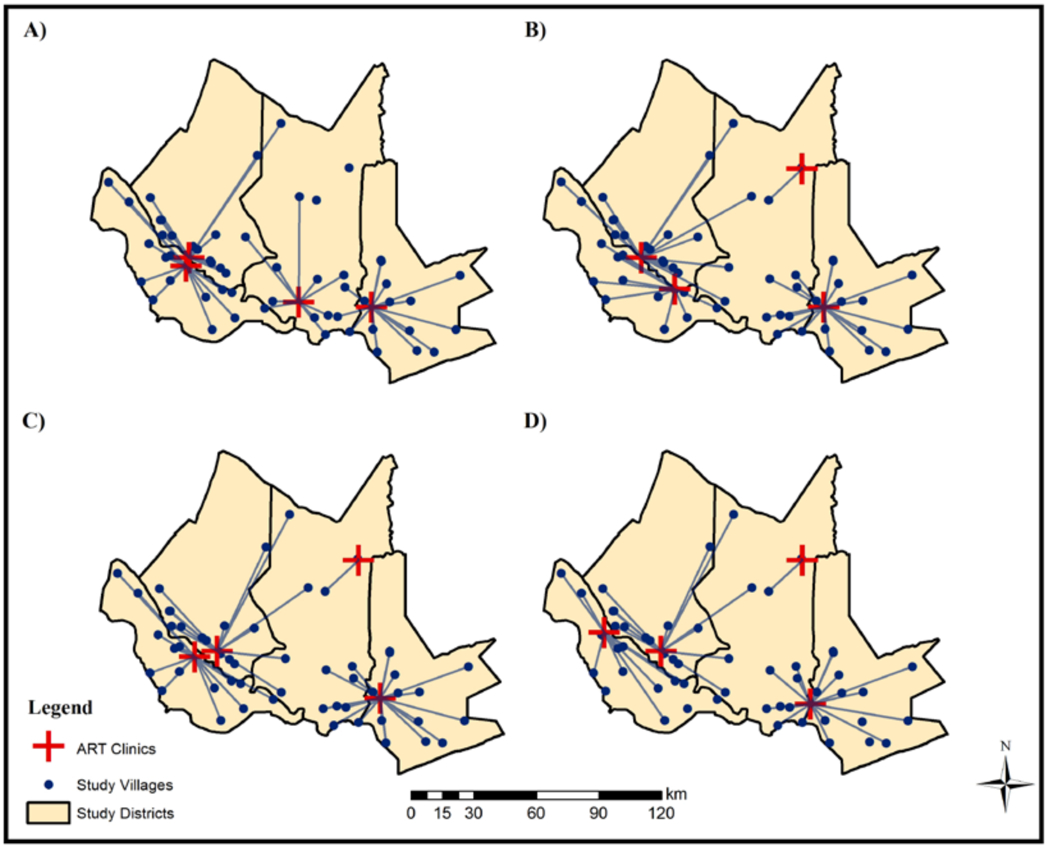
4.5.2 Optimal solutions for the placement of health clinics

The results from the livelihood vulnerability metrics suggest that clinics are not placed efficiently, no matter which metric is used. As mentioned earlier, ART is vital both to extending the lives and preserving the livelihoods of HIV-affected subsistence agriculturalists. As of 2009, only 4 clinics in the study area were providing ARTs. I compared the current configuration of clinics providing ARTs with the optimal configuration; this was analyzed by population, asset score, and food hardship. Figure 4.2 shows the current configuration of clinics offering ARTs. For each scenario depicting the current configuration of clinics offering ART, where villages are weighted by the defined livelihood vulnerability metrics, some villages have to travel disproportionately further to access this service than others. Additionally, two villages in the Chibuto district are surrounded by lakes and thus are not able to easily access health clinics offering ART[16]; this suggests that the current configuration of clinics offering ART is a sub-optimal. To find the optimal solution for 4 clinics offering ART, I assumed that none of the 53 clinics offered ART and modeled clinic configuration by choosing the optimal location for 4 clinics to offer ART from the current set of clinic locations; I did this for all metrics analyzed. When searching for the optimal solution, I consider quality of services offered by the 53 health clinics. Each clinic is weighted by its HSQ and identifies those clinics with the best potential for offering ART. Therefore, the optimal solution reallocated clinics offering ART such that all villages have better access. Table 4.6 facilitates identifying the overlap between clinics under the current and optimal configurations for each defined metric.

[16] Note: Appendix B identifies the geographic limitations for these villages.

There is variation in the optimal solutions based on the need-based metrics, suggesting that the way in which need is defined matters.

Figure 4.2: Current versus optimal configurations for clinics offering ART when weighted by total population, asset score, and food hardship



Note: Map constructed by author. A) Current configuration of clinics offering ART. B) Optimal configuration when weighted by total population. C) Optimal configuration when weighted by asset score. D) Optimal configuration when weighted by food hardship.

Table 4.6: Overlap in ART clinics under current and optimal configurations for generated metrics

Current ART clinics	Population optimal clinics	Asset score optimal clinics	Food hardship optimal clinics
ASMI02	ASMI03	ASMI02	ASMI09
BSMI01	BSMI10	BSMI10	BSMI10
CSMI08	CSMI08	CSMI04	CSMI04
DSMI20	DSMI20	DSMI20	DSMI14

Source: Calculated by author.

Note: The alpaha-numeric combination represents a unique identifier for the health clinics and does not bear any significant meaning other than distinguishing the clinics from one another.

When villages are weighted by population, only 2 of the 4 clinics overlap between the current configuration and the optimal solution, suggesting that there is room for improvement. However, the optimal solution accounts for geographic barriers and allows for all villages to be served.

I also performed the analysis for villages weighted by asset score. This allowed me to examine how clinics should be spatially organized based on economic need. Figure 4.2 compares the current configuration with the optimal configuration for clinics offering ART. The solution set for optimal clinics suggest that only half of the current clinics best serve villages based on asset score, suggesting there is need for improvement. The optimal solution results in a decline of average distance travelled by roughly 1.78km when I compare the current and optimal configurations.

Because agriculture is the dominant livelihood strategy for individuals in the study area, I sought to understand how access to ART varied for villages that were more vulnerable to food hardship. This particular metric is important for exploring potential vulnerability for subsistence agricultural households in the region. Figure 4.2 compares the current configuration with the optimal configuration for clinics offering ART for this metric. The solution set for optimal clinics suggest that a complete reconfiguration of the current clinics is needed to serve villages best according to their food-hardship status. The optimal solution results in a decline of average distance travelled by roughly 3km when I compare the current and optimal configurations.

Not only did I compare the current and optimal configurations for clinics offering ART, but I also examined the potential benefits from offering ART in additional clinics. I examined what effect 1, 5, and 10 additional clinics offering ART would have on access and how such clinics would impact the surrounding villages. Table 4.7 shows the overall improvement in access as ART is extended to additional clinics for all of the metrics. For example, the optimal solution reduces the average travel distance by just over 3.2km. Siting 1 additional clinic reduces the trip to the nearest clinic offering ART by 3km. Furthermore, Table 4.7 illustrates that prioritizing by population disproportionately affects villages experiencing greater food hardship.

Assuming the current configuration of clinics offering ART, Figure 4.3 illustrates the optimal spatial solution for clinics next to provide ART. This configuration minimizes overall impedance and results in a savings of roughly 12.3km when 10 additional clinics are added to the current configuration of ART clinics, bringing the average distance travelled to just over 11.5km. Figure 4.3 also depicts the optimal spatial solution for which clinics should be the next to provide ART to villages when weighted by economic status. Table 4.8 highlights that when minimizing overall impedance, adding an additional 10 clinics to the current configuration would result in a 12.78km average reduction. However, what is more telling is that when prioritizing villages with low economic status, adding 10 clinics offering ART would result in an average distance travelled below 10km for nearly a 20km savings. Table 4.8 also shows that households experiencing greater food hardship are disproportionately affected when ART clinics are sited by economic status. Figure 4.3 additionally illustrates the optimal spatial solution for which clinics should be the next to provide ART to villages when weighted by food hardship. Table

4.9 highlights that when minimizing overall impedance, adding an additional 10 clinics to the current configuration would result in an average reduction of nearly 12km.

Table 4.7: Recalculation of access to health clinics when villages are weighted by population

Measures	Population concentration				Asset score				Land reliance				Food hardship			
Terciles	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.
Current (km)	24.77	23.56	23.61		29.73	23.09	18.73		26.77	23.50	20.47		28.72	16.30	26.93	**
Optimal (km)	19.20	19.12	23.94		19.40	23.65	18.66		22.76	17.40	21.72		22.11	15.69	23.94	*
Current + 1 (km)	20.48	18.85	23.61		20.78	23.09	18.73		23.14	18.76	20.47		24.28	16.30	22.18	*
Current + 5 (km)	20.01	13.87	15.02		16.99	17.25	15.33		18.02	16.60	14.24		18.69	15.83	15.26	
Current + 10 (km)	12.55	12.90	9.51		14.30	12.00	8.53	*	11.90	11.42	11.84		11.80	9.93	13.34	

Note: Calculated by author using available data. Significance defined as: * p<0.10, ** p<0.05, *** p<0.01

Table 4.8: Recalculation of access to health clinics when villages are weighted by asset score

Measures	Population concentration				Asset score				Land reliance				Food hardship			
Terciles	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.
Current (km)	24.77	23.56	23.61		29.73	23.09	18.73		26.77	23.50	20.47		28.72	16.30	26.93	**
Optimal (km)	20.07	20.15	26.36		19.00	24.34	22.87		25.41	17.91	22.34		24.81	15.72	25.40	**
Current + 1 (km)	20.48	18.85	23.61		20.78	23.09	18.73		23.14	18.76	20.47		24.28	16.30	22.18	*
Current + 5 (km)	17.78	13.45	15.60		14.53	16.82	15.97		17.17	14.89	14.75		17.42	15.21	14.73	
Current + 10 (km)	9.72	11.01	13.10		9.88	12.45	11.16		11.65	10.50	11.30		12.35	9.76	11.37	

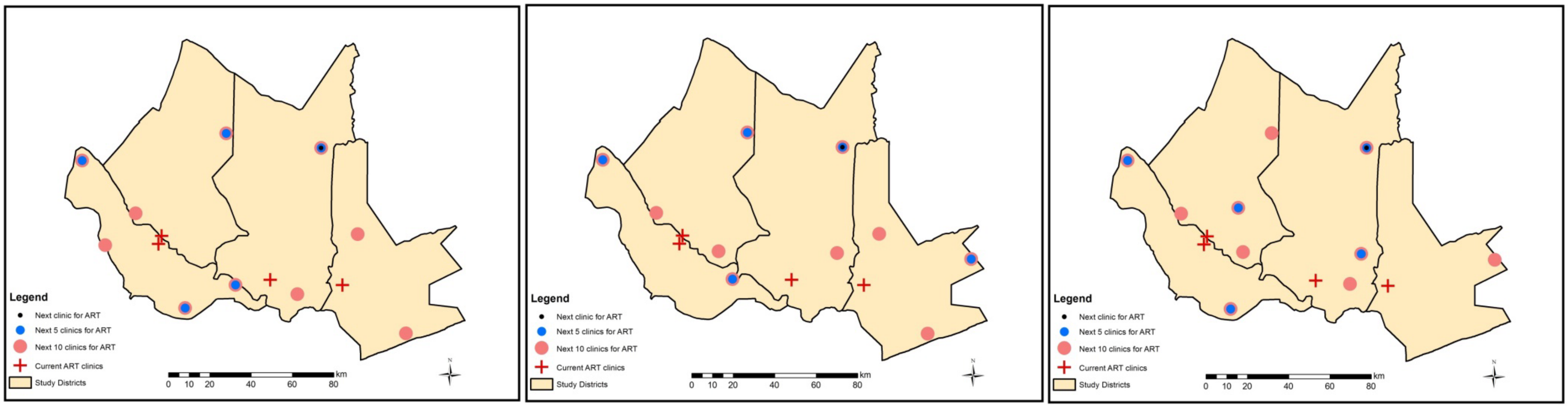
Note: Calculated by author using available data. Significance defined as: * p<0.10, ** p<0.05, *** p<0.01

Table 4.9: Recalculation of access to health clinics when villages are weighted by food hardship

Measures	Population concentration				Asset score				Land reliance				Food hardship			
Terciles	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.	1	2	3	Sig.
Current (km)	24.77	23.56	23.61		29.73	23.09	18.73		26.77	23.50	20.47		28.72	16.30	26.93	**
Optimal (km)	17.57	19.47	24.89		20.00	22.30	18.79		24.83	17.24	17.80	*	25.92	13.66	21.62	***
Current + 1 (km)	20.48	18.85	23.61		20.78	23.09	18.73		23.14	18.76	20.47		24.28	16.30	22.18	*
Current + 5 (km)	18.41	16.07	15.70		17.52	16.33	16.70		21.15	15.52	11.92	**	22.34	15.29	13.14	**
Current + 10 (km)	12.08	9.98	13.91		11.21	14.33	10.27		15.86	9.75	8.97	**	15.83	10.87	9.43	**

Note: Calculated by author using available data. Significance defined as: * p<0.10, ** p<0.05, *** p<0.01

Figure 4.3: Optimal placement of the next 1, 5, and 10 clinics to offer ART for the defined livelihood vulnerability metrics



Population | Asset score | Food hardship

Source: Maps constructed by author

Interestingly, when prioritizing villages with a low asset score, 10 additional clinics offering ART would result in an average distance travelled below 10km and a savings of just over 17km traveled. However, Table 4.9 also shows that households that are more land-reliant are also positively affected when ART is extended to clinics that take into consideration high levels of food hardship. This suggests that this solution has the potential to benefit both of these vulnerable segments of society.

4.5.3 Panel data change analysis

The results from the panel data change analysis shed light on the broader implications of adverse health for households in this survey, suggesting that poor health has a negative effect on livelihood sustainability. Table 4.10 shows the results from tracking healthy and unhealthy households throughout the two periods of the survey. I did not find a significant difference between healthy and unhealthy households in terms of changes in access to health care. While healthier households saw bigger improvements in their access to higher quality care (HSQ) and unhealthy households saw larger reductions in distance to the nearest clinic, these differences were not statistically significant. In terms of the agricultural and economic indicators, unhealthy households reduced their land cultivation relative to their healthier counterparts ($p<0.05$). They may have become more reliant on agriculture when compared with healthy households ($p<0.10$), suggesting that good health may more easily allow households to diversify economically. Corn is the main crop grown in the study region, but I see unhealthy households more likely to shift towards growing manioc (cassava) as their primary crop than were healthy households ($p<0.05$). This crop is considered an inferior substitute for corn, does not carry much value (in terms of selling) and is often used more for subsistence; it also suggests an erosion of livelihood sustainability as unhealthy households resort to growing a diminished crop to cope with poor health (Jayne et al. 2003). Additionally, unhealthy households varied significantly from healthy households in the use of employing outside labor ($p<0.05$), suggesting an additional coping strategy for dealing with poor health. There were not statistically significant differences between healthy and unhealthy households in terms of changes in livestock ownership, whether households sell or exchange livestock, or household asset score.

Table 4.10: Association of changes in health status with changes in health care access and economic well-being

Variables	**Healthy households (N=1166)**		**Unhealthy households (N=442)**		**Significance**
	Mean	**S.E.**	**Mean**	**S.E.**	
HSQ	1.15	0.07	0.98	0.11	
Clinic distance	-0.04	0.04	-0.13	0.06	
Field area cultivated	0.02	0.05	-0.16	0.07	**
Agricultural reliance	-0.04	0.01	0.01	0.02	*
Grows corn as primary crop	0.04	0.01	0.03	0.02	
Grows manioc as primary crop	-0.04	0.01	0.01	0.02	**
Experienced food hardship	0.89	0.01	0.90	0.01	
Employs labor	-0.04	0.02	0.02	0.03	**
Rents land	0.00	0.00	0.01	0.01	
Livestock ownership^	0.35	0.17	0.27	0.13	
Sell or exchange livestock	0.02	0.01	0.04	0.02	
Asset score^	0.19	0.05	0.20	0.07	
Worsening living conditions	-0.01	0.01	0.00	0.02	

Note: Calculated by author using available data; * $p<0.10$, ** $p<0.05$
^ Livestock were converted to TLUs for common measurement; livestock (in TLUs) included in asset score composition.

4.6 Discussion

As part of its poverty alleviation strategy, the government of Mozambique has identified investments in human capital as one of its three main pillars for its development strategy; the need to invest in health and health care is nested within the human capital pillar (PARPA 2007; PARPA 2011). This identification of the role of health is an important step for the country—especially since health has such an effect on labor supply. Therefore, access to health care becomes an important goal for investing in human capital. However, defining access to care and establishing health care equality is not an easy task. Extension of vital health services such as ART then represents a policy mechanism by which the government can come closer to achieving its overarching goal of poverty eradication. This analysis demonstrates that there are multiple ways to define need and while each metric is a valid measure for some vulnerable segment of society, the way need is defined affects how health clinics should be located. This study contributes to the literature by incorporating quality of services provided into the location-allocation analyses. This inclusion identifies clinics that have the potential capacity for extending ART (a recognized high-quality service). The lack of resources has been identified as a limiting factor when extending ART, and thus considering quality is necessary for providing policy makers with a solution for the future rollout of additional ART. Additionally, results from the panel data-change analysis confirm that the negative health-wealth relationship is present and further motivates the need for access to high-quality health care.

I generated multiple measures of livelihood vulnerability and examined distance and access effects for these villages based on their respective tercile. In addition to examining a population effect, I constructed metrics for asset score, land reliance, and food hardship. Testing for possible correlation between the metrics revealed that they are relatively uncorrelated and that each need-based metric is a valid representation of a potentially vulnerable group within society. Results from the descriptive statistics revealed that households in this study are highly agricultural, where women are responsible for the majority of farming. Additionally, results from the descriptive statistics revealed that, across terciles, most villages were located less than 6.5km from the nearest health clinic. While the average distances were not significantly different between terciles for each need-based metric, some interesting patterns emerged. It appears that rural populations are slightly closer to health clinics than larger populations. Villages with the highest asset score were closer to health clinics than those with the lowest asset score. Villages that had the least (tercile 1) and greatest (tercile 3) reliance on land traveled farther for health care than those with an average reliance on land; this suggests that villages with an average reliance on the land were located closer to health clinics, and by proxy, were most likely located closer to town. This result may indicate that households in these types of villages may be able to diversify in their livelihood strategy, whereby they are not solely reliant on agriculture as a way of life. Furthermore, villages that experienced the greatest food hardship were located significantly furthest from health clinics. In addition to examining distance to the nearest health clinic, I also examined distance to the nearest clinic offering ART, finding that there was no significant difference between terciles for the population, asset score, and land reliance measures. However, there was a significant difference between terciles for the food hardship measure with villages that experienced low and high food hardship and they were much further from clinics offering ART than the middle tercile.

Because ART is still quite limited for individuals in Mozambique (Audet et al. 2010), I extended the analysis to examine the current configuration of health clinics offering ART and compared that with the optimal solution. As of 2009, only 4 clinics in the study area were offering ART. Additionally, I examined how an additional 1, 5, and 10 clinics offering ART could provide better access for society. I then re-estimate the improvements in distance and access for all of the livelihood vulnerability measures. The location-allocation analyses focused on population, asset score, and food hardship. Population was chosen because I was interested in how the clinics could serve the surrounding community as a whole and how both the optimal solution and roll out of additional clinics could offer improved access. The descriptive statistics revealed that distance and access to these health clinics varied significantly between terciles based on food hardship.

The population weighted location-allocation analysis first compared the current configuration of clinics offering ART (4 clinics) with what an optimal solution would be. Across terciles for population, the average distance travelled was 23.98km to the nearest clinic providing ART. Additionally, some villages are not serviced by the nearest clinic offering ART as significant geographic barriers are present. The optimal solution chose 4 clinics from all 53 possibilities and resulted in just over a 3km improvement in distance needed to travel. Because a complete reorganization is highly unlikely, I examined what the optimal locations for adding additional clinics would be given the current configuration of those offering ART. Adding one more clinic improved access by 3km. An additional 10 clinics in the study region would provide access to the surrounding villages and result in an average distance of roughly 10km. It has been established that most individuals are not willing to travel beyond 10km, one way, for health care (Yao et al. 2013). Thus, providing access by which individuals can travel less than 10km is a key step in providing equitable access to all.

Providing access to the surrounding population is a good goal, however, this does not necessarily mean the most vulnerable groups are being reached. The descriptive results indicated that those with the least number of assets are more disadvantaged in terms of access to ART than those who have more assets. The most interesting results come from siting clinics offering ART when weighted by food hardship. Because much of the population of Mozambique are subsistence agriculturalists, changes in the ability to secure daily meals are of great importance for the overall well-being of the population. The current configuration of clinics offering ART is not at all set up to help villages experiencing high levels of food hardship, and a complete reconfiguration is needed to help. However, because a complete reconfiguration is not a likely scenario, the analysis identified the next best options for extending ART to these villages. An additional 5 clinics would help villages with the highest levels of food hardship and bring the average travel distance closer to 10km (13.14km), and an additional 10 clinics would bring the average travel distance below 10. What is also interesting about siting clinics that prioritize villages with high levels of food hardship is that it also greatly benefits villages where households are heavily reliant on the land (a measure of the importance of agriculture as a livelihood strategy).

The change analysis that used the panel data confirmed the well documented negative health-wealth relationship that has been observed in numerous other studies. This was ascertained by the negative effects that changes in health status have on how households sustain their livelihood—subsistence agriculture. As such, unhealthy households cultivated less land, were more reliant on agriculture, shifted away from growing corn to growing manioc (cassava) as their main crop, and employed labor more often than their healthier counterparts. Thus, poor health is potentially reinforcing and may further entrench households in a subsistence way of life. While I did not observe a significant difference between healthy and unhealthy households for more traditional economic measures, such as livestock sales and asset ownership, this could be due to the small time frame and that the impact of asset loss has not yet been realized as households have not fully depleted these more traditional means for mitigating the negative effects of poor health.

Health clinics are one policy lever that can be used to help disrupt the negative health-wealth relationship. In this study, unhealthy households saw a larger reduction in the distance to nearest clinic, while healthier households gained in terms of access to high-quality care. However, these differences were not statistically significant. There are number of possible explanations for this to be the case. First, clinic placement may be based on factors other than health status, and may be located to deal directly with specific diseases or priority conditions. Second, the health measure is subjective and relies on perceived changes in health status. Finally, the lack of significance also underscores the fact that access is only one issue, and once access is improved, improvements in awareness and confidence in the health system itself need to be fostered.

4.7 Concluding Remarks

This research improves our understanding of how distance and access to high-quality health care varies depending on how need is defined. The goal is to provide informed decisions of how health care, and more specifically, how ART should be allocated to vulnerable groups within society. Few studies consider the inherent geography, and most solely rely on Euclidean distance when considering how vital resources should be allocated. However, this does not provide an optimal solution as it does not accurately represent reality. This analysis made use of the existing road network by analyzing how people travel to their nearest health clinic for care. I identified a critical high-quality service that is in dire need of being extended more broadly—ART.

Health clinics are a primary policy mechanism that are supposed to provide valuable resources and care to those who need it most. Therefore, access to these facilities is vital for health-affected households to mitigate the potential negative effects of illness and disease. Because agriculture is such a laborious endeavor, and untreated HIV ravages one's health, access to ART is vital for allowing affected individuals to maintain their livelihoods and provide for their household. Despite Mozambique's commitment to rapid expansion of vital HIV testing and treatment, access to ART is extremely limited and thus individuals affected by this disease have little to no social safety net in place. Therefore, access to high-quality health care and services such as ART is vital for helping these individuals break free from poverty.

While ART is a vital service that needs to be expanded, issues surrounding drug stock-outs (a drug stock-out occurs when medication is currently unavailable and can persist for days, weeks, or even months at a time) cannot be fully determined with the current data, as this issue has persisted in other countries in sub-Saharan Africa (Muhamadi et al. 2010; Schouten et al. 2011). Additionally, I do not have the ability to measure the flow statistics for ART patients visiting the clinics currently offering this service. Therefore, future work would include a more comprehensive health clinic survey that captures the frequency and duration of ART stock-outs, as well as the number of patients receiving ART. It would also be interesting to examine whether or not health clinics and high-quality services are being prioritized for the ruling political party. An expanded analysis, for example would examine voting records by villages to see if siting of health resources is a function of politics.

While the overarching goal is to provide equality in health care, equality is rarely achieved. This is often a function of how need is defined; the process can be murky at times. Disadvantaged populations should be a focus when striving for equity in health, and thus any improvements in the current health-care system that can be made to provide these individuals with the opportunity to invest in their health should be a high priority for policymakers. By emphasizing the surrounding geography, accounting for the level of quality, and identifying vulnerable groups within society, this analysis can aid policymakers in deciding how to expand health services, while providing a more nuanced blueprint for future planning.

Chapter 5: Conclusions, future research, and policy implications

Health is arguably the most important form of human capital for subsistence agricultural households. Therefore, prolonged illness may pose a direct threat to the ability of these households to maintain their livelihood. The hypothesized mechanism by which this occurs is through diminished labor supply. Once affected by prolonged illness, subsistence agricultural households face a series of choices to cope with poor health. These decisions have consequences for both household economic well-being and the surrounding landscape. Therefore, not only is it important to identify the set of coping strategies used by unhealthy subsistence agricultural households, it is equally important to identify mechanisms that might disrupt the negative health-land relationship.

This dissertation examined the common strategies used by unhealthy subsistence agricultural households in rural Mozambique to mitigate the negative effects of prolonged illness. Access to health clinics and high-quality services (such as ART) are mitigating factors that may disrupt the pathway between prolonged illness and labor supply effects. To that end, I also examined how access to health clinics and ART could be more equitably distributed among the most economically vulnerable subsistence agricultural households in a particularly hard-hit HIV province in rural Mozambique (Gaza province).

In this dissertation, I used mixed methods to offer a more holistic understanding of how prolonged illness affects the livelihoods of subsistence agricultural households, the potential implications for LULCC, and how access to health clinics may be more equitably distributed to disrupt the negative health-land relationship. More specifically, I combined econometric modeling, remote sensing, and GIS across seemingly disparate data sets to help answer my overarching research question. My analyses were shaped by the political ecology framework; this was helpful for identifying the multiple pathways that connected labor supply and land use outcomes with the various coping strategies used by unhealthy subsistence agricultural households. By doing so, I established a logical sequence of supporting research questions that would speak to my overarching research objective. To answer the research questions outlined in Section 1, I undertook three main tasks in this dissertation.

First, I descriptively examined self-reported coping strategies in unhealthy agricultural households. I then used a basic model to establish a general relationship between prolonged illness and alterations in land use as a coping strategy for unhealthy households. Next, I sought to identify how unhealthy households that fallow were structurally different from their heathier counterparts; this was done to identify possible ways in which health-affected subsistence agriculturalists could be better helped. After establishing the general relationship between prolonged illness and changes in land use, I explored the capability of using Landsat TM/ETM+ (medium-resolution) imagery to see if the health-land relationship could be detected.

Second, I used a more rigorous econometric model to control for agricultural, demographic, economic, and climatic confounders in an attempt to further isolate the effect of prolonged illness on a specific agricultural land use decision—fallowing. Not only did I explore the effect of prolonged illness on fallowing, I also identified variation in how fallowing is used throughout the country. This was done to gain a better understanding of how this land use decision varied from province to province, as well as to understand the potential significance of using fallowing as a coping strategy for prolonged illness. Kernel density estimation was used as an exploratory spatial analysis by mapping the prevalence of prolonged illness onto the rate of fallowing for each province. This was done to help visualize how prolonged illness and fallowing move together through time and space.

Third, I examined how access to health clinics (a known mitigating factor) could be more equitably distributed among subsistence agricultural households in the Gaza province. To carry this out, I generated a series of metrics that defined village need in multiple ways: population, asset score, land-reliance, and food insecurity. For each metric, villages were assigned to terciles and access to health clinics and ART was evaluated by tercile. I then used location-allocation analysis to compare the current configuration to an optimal configuration of clinics offering ART, exploring how the optimal configurations differed based on the need metric used. I also identified where ART should be extended if additional clinics were to offer this service. Lastly, I used the panel nature of the data to confirm that health status negatively affected agricultural land use and the livelihoods for those who were sick.

The main findings and contributions of the dissertation are summarized in Section 5.1. Section 5.2 discusses direction for future research and Section 5.3 concludes with policy implications.

5.1 Main findings and contributions

Section 2 of this dissertation entitled "Does prolonged illness drive land use change among subsistence agricultural households?" found that the top reported coping strategy for unhealthy households was to "cultivate less land". This was used as a means of broadly confirming that a negative health-land relationship existed. Additionally, using logistic regression, I established that a general relationship between prolonged illness and changes in agricultural land use does exist. I found that the odds of engaging in fallowing were significantly higher for subsistence agricultural households that experienced a prolonged illness. A profile comparing unhealthy subsistence agricultural households that fallow with their healthier counterparts was also constructed. The profile consisted of extensive agricultural, demographic, and economic factors—many of which were not statistically different. However, there were some interesting areas in which the two groups diverged. Unhealthy households typically had more household members engaged in own-farm agriculture (by more than 1 additional member), were less likely to own or have access to a latrine than their healthier counterparts, were more likely to own smaller livestock, grew less corn and fewer staple crops, and more frequently reported experiencing food hardship in the previous year. An interesting finding from this particular analysis was that unhealthy households were increasing ownership of smaller livestock. This suggests that as unhealthy agricultural households become less reliant on their own land, they become more land-reliant on communal land for grazing their small livestock. Taken together, these findings suggest that unhealthy households may not be able to sustain their livelihoods as they report greater food insecurity, which is not surprising given that they also report growing fewer staple crops.

Once I established a general relationship between prolonged illness and changes in land use, I chose two study villages in the Chokwe district (located in Gaza) to examine whether or not the effect of poor health on the landscape could be detected using Landsat TM/ETM+ imagery. Given the small-scale nature of the farms, and the spatial resolution of the Landsat TM/ETM+ data, I hand digitized the scenes for each year to distinguish active from inactive agriculture. Conhane saw an increase in the prevalence of prolonged illness from 2002 to 2005 before dropping of sharply in 2008, whereas, Chokwe saw a significant decline in poor health through time. The case of Conhane goes against what we would predict—that as prolonged illness decreases, the total cropped area should increase. This relationship did not hold true for either study village. These mixed results suggest that the health-land relationship is not easily detected with medium-resolution satellite imagery.

The main contributions from Section 2 include the identification of fallowing as a possible coping strategy for unhealthy subsistence agricultural households in rural Mozambique. It also identified key areas of concern for the livelihoods of these unhealthy households. Taken together, these finding suggest a direct threat to food security and livelihood sustainability exists. It is a response to the call from King (2010) which noted that the micro-level effects of disease on the environment are not fully understood. Additionally, the remote sensing analysis established a novel application of change detection of health's effect on the environment, and that future gains made in high resolution imagery will only improve our ability to study health's effect on the environment. The literature up until this point has focused on how changes in land cover can affect health status, and this application is a reversal of that studied mechanism—how changes in health status may affect land cover change.

Section 3 of this dissertation, entitled “Are fallowing decisions affected by prolonged illness in subsistence agricultural households?,” built upon results from Section 2. While Section 2 established the general relationship between prolonged illness and changes in land use, this section more rigorously modeled the relationship by examining a specific land use choice—fallowing. In the TIA 2002 data, unhealthy households were asked to identify their primary coping strategies for dealing with poor health—“cultivating less land” was the top strategy reported. This motivated further exploration of the use of fallowing by healthy and unhealthy subsistence agricultural households. Between 2002 and 2008, unhealthy households were fallowing anywhere from 6% to 10% more often than healthy households. I used KDE to estimate a continuous surface for the prevalence of prolonged illness and the rate of fallowing; maps were constructed for the years of study to better visualize how the two measures move together. An econometric, two-part model was used to control for agricultural, demographic, economic, and climatic variables in an effort to further isolate the effect of prolonged illness on fallowing. The first part of the model examined participation in fallowing—simply whether or not a household engaged in fallowing. The second part of the model examined how much land was being set aside for fallowing. This was done to determine if there was a systematic way in which subsistence agriculturalists allocated land to fallow. I found that, when controlling for other factors, prolonged illness is a significant predictor of engaging in fallowing, but there was not a systematic way in which households allocated land to fallow.

The main contributions from Section 3 come from a more rigorous isolation of the effect of prolonged illness on fallowing. After controlling for an extensive list of additional factors, the effect still remained significant. Fallowing is typically regarded as an advanced land use decision aimed at improving agricultural output. However, these findings expand the possible reasons for fallowing, in this case as a coping strategy to mitigate poor health. These results help shape the way academics and policymakers view the role of fallowing. When used as a coping strategy, it no longer represents a means for increasing agricultural productivity, but rather a way to deal with reductions in household labor supply.

Section 4 of this dissertation, entitled "Does the current configuration of health clinics prioritize vulnerable subsistence agricultural households in rural Mozambique?," examined how a mitigating mechanism, access to health clinics, could be more equitably distributed to improve access to the most economically vulnerable. It uses a panel data set that surveys women in the Gaza province and catalogues the health clinics in the region. I found that equity of access to ART, a high-quality health service, varied based on how "need" was defined. The current configuration of clinics offering ART is not well situated to serve the surrounding villages when they are weighted by each defined need metric. Using various definitions of "need", the optimal solution identified allocations of ART which generated more equitable access and improved travel distances for my defined vulnerable groups. Additionally, Section 4 provided suggested optimal placement for additional clinics to offer ART; this was done for three different scenarios—one additional clinic, five additional clinics, and ten additional clinics. I found that adding an additional ten clinics offering ART drastically improved travel distances, often reducing total distance travelled by half or more. To understand the potential value of improving health care access, I made use of the panel nature of the data to examine the association of changes in health status with changes in health care access and economic well-being. I found that unhealthy households cultivated less land, were more reliant on agriculture, were more likely to grow manioc as the primary crop, and were more likely to employ additional labor.

The main contributions from Section 4 include contributing to the literature on access to health care, as well as identifying viable solutions for extending ART to additional clinics. The results from this section shed light on the importance of how 'need' is defined. This is important if equitable access is to be provided to the most vulnerable. ART represents a high-quality service that has the ability to help HIV-affected subsistence agriculturalists return to more normal[17] working conditions. This research provided optimal solutions for where ART can be extended to additional health clinics. Such a finding can immediately enable policymakers to respond accordingly, and has the ability to help achieve the investment in health goals outlined in Mozambique's PARPA (PARPA 2007; PARPA 2011).

[17] "more normal" in the sense that ART has the ability to reverse HIV-associated effects on health and energy

5.2 Future research

While this collective body of research brought the struggles of unhealthy subsistence agricultural households to the forefront, there is still room for improving our knowledge of the intricate ways these households adapt to prolonged illness. This dissertation primarily focused on how fallowing may be used as a coping strategy and how access to health clinics may be more equitably distributed to disrupt the negative health-land relationship. However, there are other ways in which these households could adapt and mitigate the negative impacts of poor health on their ability to maintain their livelihoods.

Section 2 modeled a general relationship between prolonged illness and fallowing, compared unhealthy subsistence agricultural households that fallow with their healthier counterparts, and explored the use of satellite imagery for detecting land cover change due to changes in health status. While the remote sensing analysis demonstrated a novel application, the results were mixed. Future research would take advantage of high-resolution satellite imagery to examine the impact of health on land cover. While the current resolution of Landsat data is not quite sensitive enough to capture small-scale land cover changes associated with unhealthy subsistence agriculturalists, it does offer the current best option for studying the health-land relationship as high resolution imagery lacks the temporal record and commercial imagery is still quite prohibitively expensive.

Section 3 more rigorously examined the effect of prolonged illness on fallowing. There are a few different extensions of this research that would yield important results. One possibility involves examining the impact of prolonged illness on overall crop production. Another extension of this work could examine the impact of health on non-agricultural employment throughout Mozambique. Poor health status may act as a barrier to transitioning away from subsistence agriculture to off-farm income generating activities; this could potentially have profound implications for poverty eradication, economic equality, and overall development.

Section 4 examined a current mechanism meant to mitigate the impact of prolonged illness on household labor supply. Future research would involve a more comprehensive survey (as the data for this analysis was women's health-centric). Additional information regarding specific disease prevalence for the area would also help inform the location-allocation analysis, as health services could be targeted towards populations most in need. Furthermore, an expansion of data collected from the health clinics would be useful in providing further insight into the capacity and limitations health clinics face. These data would refine the current estimates and would further strengthen the ability of policymakers to enact policy targeted for vulnerable groups.

5.3 Policy implications

Sections 2 and 3 shed light on the fact that unhealthy subsistence agricultural households are implementing coping strategies that reduce livelihood sustainability. Mozambique's PARPA has identified strengthening agriculture and investments in health care as top priorities to mitigate poverty (PARPA 2007; PARPA 2011). The PARPA recognizes that existing in a subsistence capacity threatens the well-being of citizens and identifies cash crops as a way of transitioning subsistence agriculturalists out of poverty and into a more economically lucrative livelihood. However, as seen in Sections 2 and 3, there is still a lack of a social safety net in place as unhealthy subsistence agricultural households are driven to partially surrender their livelihoods to deal with prolonged illness.

Sections 2 and 3 laid the foundation for the importance of reaching an identified vulnerable group—unhealthy subsistence agricultural households. In Section 4, I examined a current policy mechanism (access to health clinics and high-quality services) that has the ability to disrupt prolonged illness' effect on labor supply and, by extension, livelihoods. However, I show that the way in which "need" is defined matters. Currently, clinics are not placed in such a way that prioritizes the most economically vulnerable. Section 4 offered a solution to how the current offering of ART could be reallocated among the current set of clinics in the area to provide more equitable access to the identified vulnerable groups. Section 4 also identified the next set of clinics where ART should be extended to further target vulnerable households. Such information is useful to elected government officials and policymakers as it provides them with a viable option for redistributing services and planning future rollouts of services. However, improved availability of health care services does not necessarily translate to an instant impact. Time is needed to establish a reputation with surrounding communities, disseminate information regarding additional services provided by the clinics, and clinic capacity may need to be expanded.

While the PARPA recognizes the importance of agriculture and health, more can be done to provide a stronger social safety net. The PARPA already includes goals for strengthening education, job training, and providing better access to agricultural extension agents, not to mention building capacity in the health care system and expanding high-quality services. However, further investments could be made in these areas as they have the potential to directly benefit unhealthy subsistence agricultural households by bolstering human capital. Investments in health represent a unique opportunity for policymakers as they can attain multiple goals by strengthening the current health care system, as this investment in human capital also directly translates into their goal for investments in agriculture. If the PARPA seeks to accomplish its goal in transitioning farmers from subsistence agriculture to cash crops, policies that further promote access to capital, seeds, and fertilizers for unhealthy subsistence agricultural households are needed as these policies can help buoy health-affected households while they are coping with, and adapting to, prolonged illness. Investments in human capital have the ability to help these households diversify economically so they are not so reliant on physical labor. Simultaneous improvements in agriculture and health have the ability to improve the overall development of Mozambique. These improvements would repair the health-land relationship and allow the country to capitalize on its abundance of prime agricultural land while improving the livelihoods of its vulnerable citizens.

Appendices

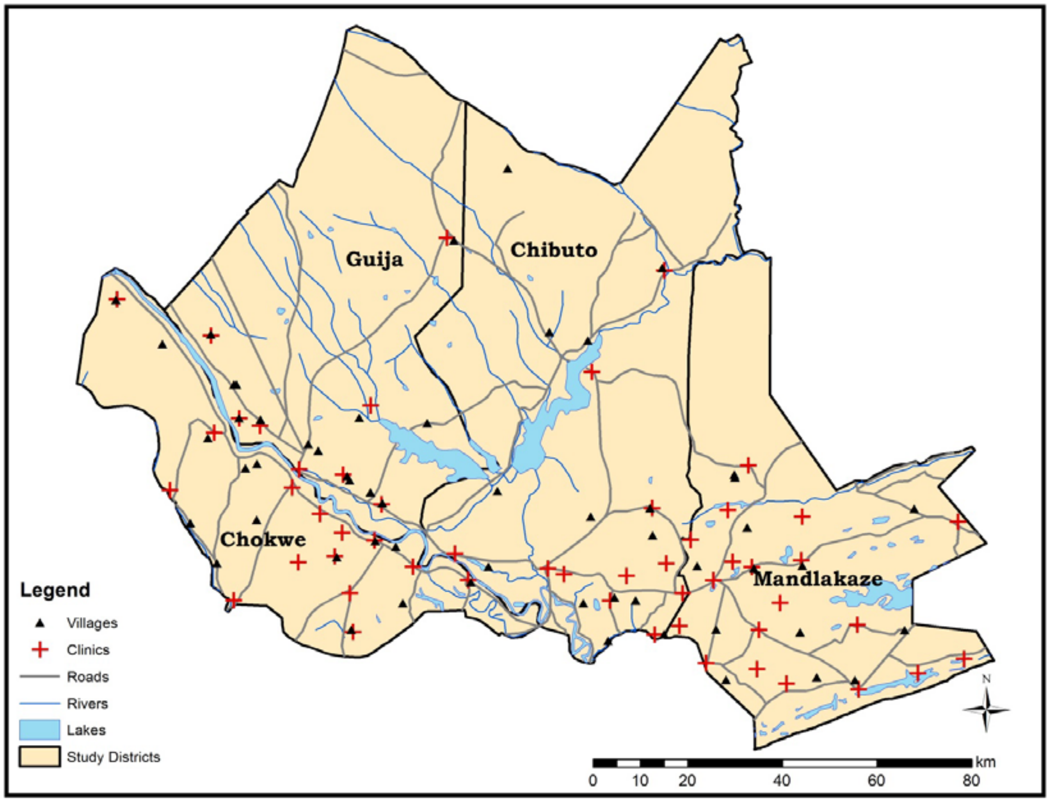
Appendix A: PCA loadings by year for TIA variables

Variable	**Year**		
	2002	***2005***	***2008***
Lantern	0.2425	0.2650	0.2186
Radio	0.2286	0.2161	0.2062
Latrine	0.2832	0.2890	0.2779
Table	0.3212	0.3583	0.3602
Roof: Grass/cane/palm tree leaves	-0.4740	-0.4683	-0.4708
Roof: Zinc	0.4164	0.4292	0.4586
Roof: Luzalite	0.1888	0.1549	0.0782
Roof: Aluminum Sheets	0.0656	0.0218	0.0188
Walls: Sticks	-0.2646	-0.2253	-0.2353
Walls: Clay blocks	-0.0251	-0.0539	-0.1013
Walls: Concrete blocks or brick	0.3535	0.3581	0.3677
Walls: Grass/cane/palm tree leaves	0.1376	0.1024	0.1040
Walls: Aluminum sheets	0.0621	0.0303	0.0349
Walls: Other	0.0148	-0.0242	0.0126
Household grows cotton	-0.0750	-0.0777	-0.0784
Household grows tobacco	-0.0185	0.0336	-0.0127
Livestock*	0.2072	0.2051	0.2139
% Variation explained by 1st component	19.36%	19.86%	20.32%

* Livestock are converted to tropical livestock units (TLUs) using FAO coefficients. Livestock included in the calculation: cattle, goats, sheep, hogs, donkeys, and chickens

The first component of PCA has been established as a good predictor of economic well-being. PCA generates weights associated with each asset or item that explain the variation in ownership within the sample; these weights are used to generate a single asset score for each household (Filmer and Pritchett 2001). By examining the loading and sign of the first component for each asset, we are able to understand the role and importance each asset has on predicting economic well-being. Unsurprisingly, assets such as a radio, lantern, latrine and table are all good predictors of increased economic well-being. Low quality housing materials such as grass/cane/palm tree leaves for roofs and either sticks or clay blocks for wall materials were good indicators of decreased economic well-being. On the other hand, housing materials such as zinc roofs and concrete blocks/bricks were strongly associated with increased economic well-being. Contextually, these signs and magnitudes make sense, reinforcing that applying PCA to these assets and household characteristics reflects a measure of household economic status. This component explained roughly 20% of the variation in these variables in all years, which is not surprising given that other factors such as resource availability are likely to affect aspects such as housing quality.

Appendix B: Map of geographic features in study districts



Source: Map constructed by author

Appendix C: PCA loadings by asset type for women's health survey

It has been established that the first component of PCA is a good predictor of economic well-being. PCA generates weights associated with each asset or item that explain the variation in ownership within the sample; these weights are used to generate a single asset score for each household (Filmer and Pritchett 2001). By examining the loading and sign of the first component for each asset, we are able to understand the role and importance each asset has on predicting economic well-being.

Variable	Component loading
Cell phone	0.2312
Electricity from grid	0.1902
Electricity from generator	0.1253
Electricity from battery	0.0755
Electricity from solar panel	0.1452
No electricity	-0.3128
Piped water in house/yard	0.1486
Water from well in yard	0.0490
Water from public well/fountain	-0.0647
Water from river/lake/rain	0.0064
Water from other source	-0.0079
Cooking fuel from wood	-0.1298
Cooking fuel from charcoal	0.1401
Cooking fuel from petrol/kerosene	0.0028
Cooking fuel from other	0.0546
Flush toilet	0.1019
Improved pit latrine	0.1862
Non-improved pit latrine	0.0036
No toilet in residence	-0.1330
Cement walls	0.2517
Wood and zinc walls	0.0179
Wood sticks and mud walls	-0.0971
Reed/palm branches/bamboo walls	-0.0909
Other wall material	-0.0118
Cement ceiling	0.1169
Lusalite ceiling	0.0421
Zinc-covered sheets ceiling	0.1846
Grass or palm branches ceiling	0.2160
Radio	0.2545

TV set	0.3010
Refrigerator	0.2578
Metal or wood bed with mattress	0.2386
Land or cell phone	0.2542
Bicycle	0.1683
Motorcycle	0.1459
Automobile	0.1983
Plow	0.1123
Water tank	0.1256
Livestock*	0.0260
% variation explained	12.76

Unsurprisingly, assets such as a radio, TV, refrigerator, bed, land/cell phone, and the combination of a flush toilet or improved pit latrine are all good predictors of increased economic well-being. Low quality housing materials such as wood sticks and mud walls, and reed/palm branches/bamboo for wall materials were good indicators of decreased economic well-being. On the other hand, housing materials such as cement walls, and either zinc-covered sheets or grass covered palm branch ceilings were strongly associated with increased economic well-being. Somewhat surprisingly, livestock does not have much weight in predicting economic well-being. Livestock were converted to tropical livestock units (TLUs) prior to calculation. Contextually, these signs and magnitudes make sense, reinforcing that applying PCA to these assets and household characteristics reflects a measure of household economic status. This component explained roughly 13% of the variation in these variables in all years, which is not surprising given that other factors such as resource availability are likely to affect aspects such as housing quality.

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