Is it *who you are* or *where you live*? A mixed-method exploration of associations between people and place in the context of HIV in rural Malawi

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ABSTRACT

Caryl B. Feldacker: Is it who you are or where you live? A mixed-method exploration of associations between people and place in the context of HIV in rural Malawi
(Under the direction of Susan Ennett)

In Malawi, approximately 1 million people are infected with Human Immunodeficiency Virus (HIV). Infection rates are decreasing in urban areas; the opposite is true for rural populations. Individual-level risk factors influence patterns of HIV in Malawi. However, area-level socio-economic and access factors may play critical roles in driving HIV, and these factors are rarely investigated. To address this gap, this research uses a nationally-representative probability sample of rural Malawians linked to spatially-oriented, area-level socio-economic and access data to address two specific aims: 1) to reveal relationships between area-level factors and individual HIV status and determine whether individual risk behaviors mediate these associations using logistic regression; and, 2) to explore how relationships between area- and individual-level risks and individual HIV status vary in space using geographically weighted regression. Analysis is stratified to examine the role of gender. Area-level factors include income inequality and absolute poverty as well as proximity to roads, cities, and health clinics. Mediators include condom use, sexually transmitted infections, multiple partnerships, and, for men, paid sex. Results indicate that both people and place matter in the context of HIV in rural Malawi. Among women, high income inequality and proximity to a major road are associated with increased odds of HIV while the negative association between distance to healthcare and HIV status is mediated by individual behavior. For men, living further from a health clinic decreases the odds of HIV infection. Spatial models provide additional detail, illustrating local-level variation in these associations. Women further from health clinics, major roads, and major cities are less likely to be infected in specific geographic areas. HIV status among men is closely associated with migration patterns in distinct locations. As informed by the Political Economy of Health theory, this study confirms that area-level socio-economic and access factors influence HIV in rural Malawi. Associations vary by gender and in space and are largely not mediated by individual behavior. The findings suggest that inequality has deleterious effects on women, and that spatial isolation may lead to social isolation for both genders, decreasing HIV risk. These results could inform tailored HIV prevention efforts in rural Malawi.

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"The demand for a healthier society is, in itself, the demand for a radically different socio-economic order"

(Doyal and Pennell 1979) (p. 297)

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CHAPTER 1

INTRODUCTION

Between 30 and 36 million people are infected with Human Immunodeficiency Virus (HIV) (UNAIDS/WHO 2007). In 2007, 2.5 million people were newly infected, and 2.1 million people died of Acquired Immune Deficiency Syndrome (AIDS) (UNAIDS/WHO 2007). Of all infections in 2007, 67% percent are in Sub-Saharan Africa, and 60% of people living with HIV in sub-Saharan Africa are women (UNAIDS/WHO 2008). In sub-Saharan Africa, higher income countries generally have higher prevalence of HIV (Mishra, Assche et al. 2007); yet, lower income countries face an increasing burden of disease as the epidemic spreads through the general public, the majority of whom are poor (Piot, Greener et al. 2007). Although prevalence rates in sub-Saharan Africa are higher in urban areas, the absolute number of people infected may be greater in rural areas (FAO 2008; UNAIDS 2008). In Malawi, approximately one million people are infected with HIV (USAID 2008), and the prevalence rate varies from 6-20% throughout the country (UNAIDS 2007). The majority of Malawians live in rural areas where HIV rates are increasing (Bryceson and Fonseca 2006). Individual-level risk factors such as low condom use (Munthali, Zulu et al. 2006) and multiple partnerships (Kaler 2004) play critical roles in the patterns and presence of HIV in Malawi. Macro-level processes receive less empirical investigation. However, area-level influences such as socio-economic factors and access to resources may drive these individual behaviors (Armour 2006; Mtika 2007) and, in turn, individual HIV status. Greater understanding of macro-level influences may be critical to ameliorating the HIV epidemic.

To fill this gap, this research aims to 1) reveal whether there is a relationship between area-level factors and individual HIV status and whether these relationships are mediated by individual behaviors using contextual models that adjust for individual demographic factors; and, 2) determine how the relationship between area- and individual-level risk behaviors and individual HIV status vary geographically using spatial regression methods. Area-level factors include socio-economic factors (Gini coefficient of income inequality, poverty headcount of absolute poverty) and access factors (access to roads, access to healthcare, and access to a major urban center). Mediators include behaviors and indicators relevant to HIV transmission including condom use, multiple partnerships, previous sexually transmitted infection (STI), and paid sex. Demographic controls include age, religion, marital status, ethnicity, and education. For the purposes of this study, *area* is defined as an aggregate of census enumeration areas in rural Malawi comprised of approximately 500 households.

This project incorporates two separate papers that use two distinct approaches to assess how area-level factors influence individual behavior and, in turn, individual HIV status among rural Malawians. The first paper uses logistic regression to examine whether area-level factors have a significant influence on individual HIV status and whether individual-level risk behaviors mediate this association. Gender (Quinn and Overbaugh 2005) is also a key factor in HIV transmission; women may be more at risk than their male counterparts. Therefore, this first paper stratifies analysis to reveal the role of gender on these relationships. This paper aims to answer: 1a) Are area-level factors associated with individual HIV status in Malawi?; 1b) Are these associations mediated by individual behavioral factors?; and, 1c) Do these relationships vary by gender?

The second paper explores the associations between these area-level influences, individual behaviors, and individual HIV status using geographically-weighted regression. In comparison to the static contextual models, these spatial regression models account for the geographic proximity between clusters allowing for a more robust and revealing analysis of the associations between both area- and individual-level factors and individual HIV status. Using spatial regression methods, this paper aims to answer: 1) How do the associations between area-level factors, individual behaviors, and individual HIV status vary within Malawi? Chloropleth (color variation) maps illustrate spatial patterns, providing a visual representation of frequency distributions of key variables of interest. Geographic Information Systems (GIS) enable mapping of the spatial regression results to illustrate associations between area- and individual-level variables and HIV status at both the global and local levels.

This research has several advantages over previous studies. In Malawi, a country with one of the world's highest HIV burdens, it is unknown whether area-level factors influence individual HIV status and whether these factors operate through behavioral pathways. It is also unknown whether gender affects these associations. Previous studies in rural Malawi looked at the drivers or effects of HIV, but they mostly focused on small geographic areas (Barden-O'Fallon, deGraft-Johnson et al. 2004; Hatchett, Kaponda et al. 2004; Watkins 2004; deGraft-Johnson, Paz-Soldan et al. 2005; Helleringer and Kohler 2005; Schatz 2005; Kohler, Behrman et al. 2007) or individual behavioral factors (Zachariah, Spielmann et al. 2003; Smith and Watkins 2005; Morah 2007). In contrast, this research uses a nationally-representative probability sample of rural Malawians and triangulates data from the Malawi Demographic and Health Survey individual interview, HIV testing, and geographic information components in conjunction with area-level, spatially-oriented data on access and socio-economics. The study explores whether area-level factors drive the spread of HIV through their influence on individual behavior, potentially revealing a causal pathway between area- and individual-level factors and HIV infection. Moreover, the research explores the moderating role of gender, revealing whether these area- and individual-level relationships vary between men and women. Unlike much research on macro-level drivers of HIV, this research applies a theory-informed conceptual model using The Political Economy of Health, providing guidance on how these area-level effects affect individual behavior and lending clarity to the interpretation of the findings (Parker, Easton et al. 2000; Diez Roux 2002). Overall, the research uses multiple data sources to draw conclusions about how area-level factors influence individual HIV status.

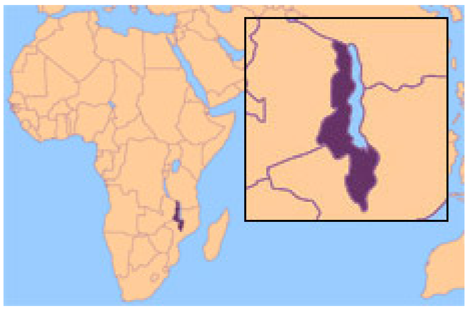
The spatial component of this study adds to the growing emphasis on the linkages between health and place and makes potentially important contributions over previous research. First, although contextual models may incorporate location information, "a deeper understanding of spatial variations in health outcomes may be gained by building notions of space into statistical models and measuring contextual factors across continuous space" (Chaix, Merlo et al. 2005) (p.179). Of fundamental importance, spatial studies do more than reveal the existence of a disparity. Spatial analysis shows the geographic location of differences and provides a visual representation of the distributions of key variables (Weir, Pailman et al. 2003). The specificity of area- and individual-level associations provides critical information for tailored policy and intervention development and helps researchers answer who, why, and where questions in the analysis of HIV transmission (Chirwa 1997; Craddock 2000). Lastly, presentation of spatial regression can be a very effective tool to inform community decision makers and help them visualize a public health problem (Richards, Croner et al. 1999).

In sum, this study reveals how people and place matter in the context of HIV in rural Malawi and produces geographically-specific results. In combination, the mixed methodology offers a more comprehensive picture of the relationships between area-level factors, individual risk behaviors, and HIV in rural Malawi. Elucidation of the multiple pathways that influence HIV status could be instrumental in informing future policies or interventions to address the spread of the epidemic in rural Malawi.

BACKGROUND

Why Malawi? Why HIV?

According to the 2004 Malawi Demographic and Health Survey, 10% of men and 13% of women are infected with HIV nationwide (National Statistical Office Malawi and ORC Macro 2005), and 56.8% of all infections are among women (UNAIDS 2004). AIDS in Malawi, as in sub-Saharan Africa in general, is spread mainly through heterosexual sex, and the epidemic is generalized



throughout most of the population. HIV spread from the southern regions to the central and northern regions (Bello, Chipeta et al. 2006), and the highest prevalence rates are in major urban areas, including Blantyre and Lilongwe, and in the southern region (PEPFAR 2007). In Lilongwe, prevalence among anti-natal care patients decreased from 27% in 1996 to 16.9% in 2003 (Bello, Chipeta et al. 2006). Unlike urban areas, prevalence in rural areas appears to be increasing (Bello, Chipeta et al. 2006; Bryceson and Fonseca 2006), and the absolute number of rural people who are infected currently outnumber urban residents by about three to one (National AIDS Council Malawi 2003; National Statistical Office Malawi and ORC Macro 2005; Bryceson and Fonseca 2006).

HIV prevention and care is improving slowly. In 2005, only 2.3% of HIV-positive women accessed prevention of mother to child transmission (PMTCT) services (UNAIDS 2005); however, by 2006, 137,996 pregnant women were tested for HIV and 25% accessed PMTCT services (UNAIDS 2007). Currently, the number of PMTCT sites numbers over 150, more than 10% of the antenatal care facilities. Nevertheless, 30,000 children become infected annually through perinatal transmission (UNICEF 2008). Although treatment sites are expanding and services improving, gaps remain: approximately 15% of more than 114,000 HIV+ people accessed anti-retroviral treatment in 2007 (UNAIDS 2007).

Similar to other sub-Saharan countries, HIV prevalence among women in Malawi is higher among those with earlier sexual debut, multiple partners, ever-married, higher education, and higher socio-economic status (National Statistical Office Malawi and ORC Macro 2005). For men, migration, marriage, lack of circumcision, higher education, and higher socio-economic status are also related to a higher likelihood of HIV infection (National Statistical Office Malawi and ORC Macro 2005).

Malawi ranks among the lowest in the world on the United Nations Development Programme's human development index with a ranking of 165 out of 177 countries (UNDP 2007). Of Malawi's approximately 13 million people, 80% live in rural areas (UNICEF 2008). The main source of livelihood for rural Malawians is agriculture and natural resource utilization, and the majority of their household consumption is spent on food (Benson, Chamberlin et al. 2005). Although more than 85% of children attend primary school, approximately 25% attend secondary school, and adult women are 72% as likely to be literate as men (UNICEF 2008). Maternal and child health indicators are also poor. Contraceptive prevalence is reported at 42%, and more than 90% of women receive antenatal care, yet only 54% of women are attended by a skilled birth attendant or deliver in a healthcare setting (UNICEF 2008). The total fertility rate of 5.7 contributes to a high maternal mortality ratio of 980/100,000 (UNICEF 2008).

What We Know: Individual-Level Risk Factors

Behavioral factors

Behavioral factors that put individuals at risk of acquiring HIV are well understood, including low condom use, high risk sex, and migration. Infrequent or inconsistent condom use and high risk sex (multiple partners, sex with prostitutes) are positively associated with HIV status (Sheeran and Taylor 1999; Van Rossem, Meekers et al. 2001; Giles, Liddell et al. 2005; Bryan, Kagee et al. 2006). Early sexual initiation is also associated with increased risk of sexually transmitted disease (Manzini 2001; Harrison, Cleland et al. 2005; Hallett, Gregson et al. 2007), placing people at higher risk of acquiring HIV (Auvert 2001; Glynn, Carael et al. 2001). These behavioral risk factors are linked with HIV status in Malawi. In Malawi, over 20% of men and women who had an STI in the previous 12 months were infected with HIV in 2005(National Statistical Office Malawi and ORC Macro 2005), and a recent study in Lilongwe found that 40% of STI clinic patients tested positive for acute HIV infection (Pilcher, Price et al. 2004).

The perception of condoms as containing AIDS or for use only outside marriage remains prevalent in Malawi, and urging condom use connotes a lack of trust, fear of disease, or association with commercial sex work (Chimbiri 2007). Condom use is low: only 30% of women and 47% of men used a condom with their last non-spousal/non-regular partner (National Statistical Office Malawi and ORC Macro 2005). Even among men who know they are HIV positive, condom use only reaches 40% (Morah 2007). Among youth, poorer boys and girls are less likely to use condoms and are more likely to sexually debut earlier than their wealthier peers (National Statistical Office Malawi and ORC Macro 2005; Madise 2007).

Multiple, concurrent sexual partnerships are key, and often neglected, determinants in the spread of HIV (Morris and Kretzschmar 1997; Anderson 1999; Shelton, Halperin et al. 2004). Men and women in Africa are more likely to have simultaneous, long-term partnerships that facilitate the spread of HIV (Halperin and Epstein 2004). In Malawi, polygyny and extra marital partnerships are common (Chimbiri 2007). Concurrent partnerships increase the risk that sexually active individuals will be in contact with someone who is at the early or acute stage of HIV infection, the stage when a person is more likely to transmit the virus and spread the disease (Quinn, Wawer et al. 2000; Pilcher, Price et al. 2004; Cohen and Pilcher 2005). Although women may also engage in multiple partner sex (Kuate-Defo 2004; Tawfik and Watkins 2007), in general the increased risk of infection from multiple partnerships reflects male social norms (Nnko, Boerma et al. 2004; Chimbiri 2007; Helleringer and Kohler 2007)

The circular movement of migrants, both men and women, also plays a role in the transmission and spread of HIV in sub-Saharan Africa (Zuma, Gouws et al. 2003; Coffee, Garnett et al. 2005; Lurie 2006) and in Malawi (Mtika 2007). In Malawi, men migrate from rural to urban areas or internationally almost as a rite of passage into adulthood (Chirwa 1997). Migration may exacerbate practices of multiple partnerships and risky sex, increasing HIV risk among those who spend large periods of time away from home (Mtika 2007). Malawian men who spend more than one month away from home are 4% more likely to be infected with HIV than men who do not migrate (National Statistical Office Malawi and ORC Macro 2005).

Lastly, low rates of HIV testing and knowledge about HIV risk are apparent in Malawi. Only 13% of women and 15% of men have ever been tested and received results for HIV, and urban residents are twice as likely to be tested as their rural peers (National Statistical Office Malawi and ORC Macro 2005). Low testing rates may reflect misconceptions about how easily HIV is transmitted from one person to another. A recent study on the reliability of self-reported likelihood of HIV infection in Malawi showed that of those who inaccurately assessed their status, 88% overestimated their risk of infection (Bignami-Van Assche, Chao et al. 2007). Recent qualitative research in rural Malawi also found that some men who engage in risky behavior claim HIV+ status without ever being tested (Kaler 2003), demonstrating prevalent misconceptions about inevitability of infection and the inaccurate belief that HIV is highly infectious (Kaler 2003; Bignami-Van Assche, Chao et al. 2007).

Demographic factors

Demographic risk factors such as education, religion, ethnicity, socio-economic status, and gender also play a role in an individual's risk of becoming infected with HIV. Research on the association between education and HIV infection is mixed. Previous studies indicate linkages between HIV and both higher and lower education levels in various countries (Smith, Nalagoda et al. 1999; Lagarde, Carael et al. 2001; Glynn, Carael et al. 2004; Gavin, Galavotti et al. 2006; Barnighausen, Hosegood et al. 2007); but in Malawi, the risk of infection increases with education for men and women (National Statistical Office Malawi and ORC Macro 2005). Marriage also increases a woman's risk of HIV (Glynn, Carael et al. 2003; Nour 2006; Hirsch, Meneses et al. 2007; Smith 2007), and this holds true in Malawi (National Statistical Office Malawi and ORC Macro 2005). Age is another important factor: in Africa, younger women and older men are more likely to be infected than older women and younger men (Glynn, Carael et al. 2001; Gregson, Nyamukapa et al. 2002; Luke 2003). In Malawi, women under age 24 are more than three times more likely that their male age peers to be infected (National Statistical Office Malawi and ORC Macro 2005). Lack of information about HIV among youth may fuel the disproportionate infection levels among young people. Using a nationally representative survey of youth in four countries, Burkina Faso, Ghana, Malawi, and Uganda, only 20% of Malawian adolescent males reported consistent condom use, the lowest of the four countries (Bankole, Ahmed et al. 2007). Older youth (ages 15-19) were 4.3 times more likely to have had two or more partners in the last 12 months as compared to younger (ages 12-14) youth, a finding that was only significant in Malawi (Madise 2007). Adolescent girls in Malawi were also only half as likely as their male peers to respond correctly to three statements about condom use (Bankole, Ahmed et al. 2007).

Socio-economic status (SES) appears important in the context of HIV infection rates and risk taking behaviors; however, the relationship between individual socio-economic status and HIV remains unclear (Hargreaves 2002; Wojcicki 2005; Bingenheimer 2007). Previous research in sub-Saharan Africa notes a significant and positive association between individual SES and risk of HIV (Barnighausen, Hosegood et al. 2007; Lopman, Lewis et al. 2007; Mishra, Assche et al. 2007), possibly related to urbanicity, longer survival, and the increased number of multiple partners among wealthier people, especially men (Shelton, Cassell et al. 2005). Others find increased risk behaviors among those of lower SES (Hargreaves 2002), including the unemployed (Gavin, Galavotti et al. 2006; Kalichman, Simbayi et al. 2006). Still others note no effect of individual-level poverty on sexual health behavior or HIV risk (Wojcicki 2005; Dinkelman, Lam et al. 2007). Poor or single measures of SES may factor into the unclear and contradictory relationship between individual-level SES and HIV (Wojcicki 2005).

Moving Beyond Emphasis on Individuals

Individual behaviors and attributes play crucial roles in the HIV epidemic, and individual-level theories demonstrate the relationship between individual-level factors such as knowledge, attitudes, and practices with HIV risk taking behaviors (Wilson, Dubley et al. 1991; Basen-Engquist 1992; Adih and Alexander 1999; Volk and Koopman 2001; Agha 2002; de Paoli, Manongi et al. 2004; Macintyre, Rutenberg et al. 2004; Mashegoane, Moalusi et al. 2004; Hounton, Carabin et al. 2005). Yet, despite almost 20 years of HIV prevention and intervention research aimed at changing individual-level risk factors, HIV continues to spread in sub-Saharan Africa. A focus on individuals may not provide effective solutions due to the other levels of influence on human health and wellbeing, including both the physical environment (e.g., geography, road networks, and household building materials) and the social environment (e.g., social ties, poverty, and politics) (Stokols 1992). HIV prevention and treatment must move beyond the individual level to a more complex set of economic, social, structural, and cultural factors that influence the behaviors and health of population groups (Hobfoll 1998; Craddock 2000; Parker 2001). Expanding from emphasis on individuals behaviors to the area-level factors that may drive those health behaviors gives warranted consideration to the myriad influences on individual action.

Challenges in defining and determining *place*

Where an individual lives matters for overall health and wellness (Mayer 1989; Diez Roux 2001; Roux 2001; Dietz 2002; Sampson, Morenoff et al. 2002; Diez Roux 2004; Cummins, Curtis et al. 2007; Entwisle 2007; Lachaud 2007), and research strongly suggests that similar people behave differently in different places (Duncan, Jones et al. 1998). Clusters of all-cause morbidity and mortality demonstrate these linkages between people and place (Oakes 2004). Yet, a common definition of *place*, *neighborhood* or *areas of influence* remains elusive (Diez Roux 2001; O'Campo 2003). Similar studies may show demonstrably different results based on the definition of neighborhood and the type of variables used to measure complex issues within those specific areas (Soobader and LeClere 1999; Kawachi and Berkman 2003; O'Campo 2003).

As a result of the diversity of research that examines place-based effects, these types of studies may be called multi-level (O'Campo 2003), contextual effects (Duncan, Jones et al. 1998), area (Diez Roux 2001), or ecological (McLeroy, Bibeau et al. 1988) studies, each with a distinct analytic approach. Because “place” or “neighborhood” are complicated concepts to measure (Kawachi and Berkman 2003), administrative boundaries are often used to approximate place-based, community-level, or area-level influences on individuals. Administrative boundaries, however, may be arbitrary and may not reflect the true or theoretically-important area of influence to assess macro-level influences on individuals (Diez Roux 2001). Nevertheless, these sources are useful because the data may be readily available. Despite their shortcomings, geographically-based definitions of *place, community,* or *area*, including those associated with census tracks or service proximity, allow for the examination of macro-level influences and have been used effectively in previous studies (Macintyre 1997; Blacker 2004; Fisher 2008).

The dearth of neighborhood or ecological studies may be due to the difficulty in determining causation and parceling out the strength of various levels of influence (Diez-Roux 2000; Sampson, Morenoff et al. 2002). To conceptualize problems of individuals in geographic areas, and community effects on those same people and their behavior, requires consideration of multiple levels of interaction between people and place (Pickett and Pearl 2001). *Compositional effects* (the characteristics of the individuals who live in a specific place) and *contextual factors* (the infrastructure in the local physical and social environment) both require attention (Macintyre, Ellaway et al. 2002). These factors may influence individuals directly or indirectly (Manski 2000) through diverse pathways including: 1) *endogenous* effects if individual behavior affects the behavior of all individuals in the neighborhood (social norms); 2) *correlated* effects because people in a neighborhood usually have similar traits or exposure to institutions (socio-economics, educational opportunities); and, 3) *contextual or exogenous* effects external to individuals such as place effects (road quality, service availability, crime level) (Manski 2000; Dietz 2002).

Greater understanding of how area-level effects influence individual behaviors and, in turn, health outcomes such as HIV, could be used to improve future research, policy, and intervention efforts. Therefore, to fill this gap and expand research into the macro-level drivers of HIV, this study focuses on area-level contextual and compositional influences that potentially shape individual behavior and, in turn, HIV status in rural Malawi. These area-level effects include the role of socio-economic indicators, such as income inequality and poverty (composition effects), and access to services, including roads, cities, and healthcare (contextual effects), in the areas in which individuals live. For the purposes of this study, *area-level* is defined by aggregate enumeration areas, a census-defined boundary that includes approximately 500 households. This *area* contains approximately the same number of people as a United States census track (http://www.census.gov/geo/www/cob/tr_metadata.html#gad), a boundary used by previous studies of area-level or neighborhood effects (Macintyre 1997).

CHAPTER 2

THEORETICAL SUPPORT

The Importance of Ecological Factors on Health

Increased focus on macro-level influences on individual-level outcomes is necessary to provide a more holistic picture of human health and wellness (Kawachi and Berkman 2003; Entwisle 2007). A more expansive approach will require exploration and articulation of the complex pathways between macro-level factors and individual outcomes (Kawachi and Kennedy 1999; Diez Roux 2001; O'Campo 2003). However, macro-level theories that explain or predict the behavior of groups in various contexts are few, and there is a need for well reasoned theory about the mechanisms that connect area of residence and health (Macintyre, Ellaway et al. 2002).

Although ecological theory is not as well developed as individual-level theory, there are several frameworks that apply a multi-level lens to elucidate how macro-level factors influence individual health behaviors and outcomes. The Political Economy of Health (PEH) framework is "a critical, historical, and interdisciplinary perspective which examines the political, economic, and social context within which health and illness are defined, treated, and managed" (Minkler, Wallace et al. 1994) (p. 114). Although much political economy research focuses on the influence of government and the role of politics, health research using a PEH approach tends to emphasize the way in which history, development and persistence of structural inequalities based on class, ethnicity, race, or gender exacerbates conditions of poor health (Altman 1999; Farmer 1999; Parker, Easton et al. 2000; Farmer, Léandre et al. 2001; Parker 2001; Whiteside and De Waal 2004; Lindgren, Rankin et al. 2005; Hunter 2007; Mtika 2007; Parikh 2007). These structural disparities, or structural violence (Farmer 2003), include the ways that societies foster economic deprivation, social isolation, inequitable power structures, and inadequate healthcare, all of which affect the poor and more vulnerable members of society (Krieger 1999; Krieger 2001).

Despite the emphasis on the macro-level factors that influence individual health, the PEH does not remove the individual as a player and decision maker. Rather, PEH draws attention to associations between people and aspects of their social and economic environment that may limit individual choice, constrain behavioral possibilities, and restrict an individual's ability to make positive health decisions (Minkler, Wallace et al. 1994; Minkler 1999). In this manner, the PEH framework rejects the placement of blame solely on individuals for their poor health (Doyal and Pennell 1979; Doyal 1995; Farmer 1999; Farmer 2003; Farmer, Nizeye et al. 2006; Ruger and Kim 2006; Loewenson 2007) and instead looks at the macro-level factors that reduce an individual's choices and power to effect change.

Other macro-level, socio-ecological frameworks maintain that individuals are both affected by, and affect, their physical and socio-cultural environment, and that interactions between individuals and their areas are critical components of health behaviors (McLeroy, Bibeau et al. 1988; Stokols 1992; Krieger 1999). Stokols notes that individual behavior has multiple influences and that promotion of human well-being should be founded on a keen understanding of the synergies between various environmental and personal factors (Stokols 1992). McLeroy and colleagues (McLeroy, Bibeau et al. 1988) identified five levels of influence for health-related behaviors: intrapersonal; interpersonal; community; organization; and society. This socio-ecological framework emphasizes an integrated approach to health promotion by looking at both the individual-level influences on a person's health behaviors as well as the environmental and contextual effects of their surroundings. Examination of these higher-level factors requires acknowledging the myriad influences on individual behavior and the ways in which individuals "embody" the political, economic, and social forces of the environments in which they live (Krieger 1999; Krieger 2005).

Acceptance and promotion of the view that individual HIV risk behaviors must be considered within the greater socio-economic environment is critical (Baylies 2000; Fenton 2004; Msisha, Kapiga et al. 2008). In the context of HIV, the PEH heuristic provides an explanatory framework to understand behavioral explanations and solutions that move beyond individuals and micro-level analysis (Setel 1994; Farmer 1999; Krieger 1999; Minkler 1999; Farmer, Léandre et al. 2001; Whiteside and De Waal 2004; Farmer, Nizeye et al. 2006; Raphael 2006). Applying the political economy approach to HIV/AIDS in sub-Saharan Africa may illuminate the linkages between individual behavior and the culture and socio-economics of the place in which they live (Altman 1999; Lindgren, Rankin et al. 2005; Hunter 2007; Mtika 2007; Parikh 2007), including the role of gender (Doyal 1995). Overall, the PEH provides a much-needed framework within which to understand the associations and pathways between area-level factors, HIV risk taking behaviors, and individual HIV status (Diez-Roux 1998; Kalipeni, Oppong et al. 2007).

The Behavioral Link: How Ecological Factors Affect Individual Health

Neither the PEH framework nor other macro-level theories define a set of concrete constructs for empirical investigation in area-level studies. However, the PEH heuristic proposes that ecological factors that facilitate societal or economic inequities may influence how individuals behave and make choices. In the context of HIV, these factors include economic underdevelopment; migration and mobility; and power differentials by class and gender (Parker, Easton et al. 2000; Wellings, Collumbien et al. 2006). These forces create a “risk environment” where factors external to the individual, such as inequity, poverty, and discrimination, increase vulnerability to HIV infection (Parker, Easton et al. 2000; Rhodes, Singer et al. 2005) through the creation of social, emotional, and physical facilitators of HIV risk behavior (Farmer 1999; Farmer, Nizeye et al. 2006). For the powerless, these facilitators effectively limit the ability to make positive health decisions, restrict agency, and reduce control over their bodies (Wellings, Collumbien et al. 2006), ultimately silencing the voices of those most vulnerable to, and most affected by, HIV (Amaro and Raj 2000). As guided by the PEH, economic inequality, poverty and access may be critical drivers on the HIV epidemic in sub-Saharan Africa and in Malawi, and these factors are explored in this research.

Area-level Factors: the Role of Socioeconomics and Access

The roots of PEH stem from a critique of capitalism's role in creating and perpetuating health disparities. According to Lesley Doyal, there is always a close relationship between economic and physical health, and capitalism "not only systematically undermined the health of the population, but has also created obstacles to the realization of effective health policies" (Doyal and Pennell 1979) (p.137). Poverty is one of the most influential ecological risk factors for poor health status (Minkler 1999), and population patterns of good and poor health are highly correlated with areas of wealth and poverty (Krieger 2001). However, poverty is a difficult concept to measure (Wojcicki 2005; Coudouel 2008), and the relationships between poverty and health at the ecological level are complex. Poverty does not directly cause HIV, but AIDS and poverty are mutually reinforcing (Gillies, Tolley et al. 1996; Craddock 2000; Mosley 2004; Freedman and Poku 2005; Kalichman, Simbayi et al. 2006; Masanjala 2007). HIV infection is most prevalent among people in their most economically productive years (between the ages of 15-49) with negative ramifications on their household income and livelihoods (FAO 2003; Heuveline 2004; Mather, Donovan et al. 2005). As poorer persons are less likely to access treatment and care (Phelan, Link et al. 2004), the resulting poverty increases individual susceptibility to HIV much as it does for other health problems such as tuberculosis and malnutrition (Farmer 1999).

The PEH also suggests that economic hierarchy and social stratification affect health status, and both absolute poverty and the relative distribution of wealth affects health (Kawachi and Kennedy 1997). Income inequality has both direct and mediated influences on health behaviors and health outcomes (Soobader and LeClere 1999). However, the effects of income inequality on health are not always clear (Coburn 2000; Mackenbach 2002). Part of the reason for this lack of clarity be that income inequality and economic disparities affect health status through behavioral mediators (Kawachi and Kennedy 1999; Wilkinson and Pickett 2006), including decreased trust, lack of social cohesion, and fewer social ties between people (Kawachi and Kennedy 1997; Kawachi and Berkman 2000). Countries with higher levels of income inequality are among those with higher HIV prevalence (Fenton 2004), and income inequality has been linked to increased risk for sexually transmitted infections (Holtgrave and Crosby 2003) as well as to an increase in concurrent sexual partnerships (Adimora and Schoenbach 2002). These studies expose a possible pathway between income inequality, individual behavior, and HIV status; but, these relationships have not been well tested in the context of HIV or in developing countries.

Poverty and income inequality are apparent in Malawi. In 2000, 67% of rural populations and 55% of urban residents were below the poverty line (National Economic Council Malawi 2000). The country-level Gini coefficient of .38 indicates relatively high overall income inequality, and the national poverty headcount (% living below the poverty line) of 54% remained relatively stable from 1997-2005 (World Bank 2008) showing that poverty may not be decreasing over time.

In addition to the effects of poverty and income inequality, access to roads, cities and health services are important factors in determining individual health choices and outcomes. Drawing from the PEH framework, access to treatment and care often reflects class, gender, and racial disparities in social and economic systems (Doyal and Pennell 1979). Inequity in access to resources and services, including health, negatively influences individual health behaviors and outcomes (Doyal and Pennell 1979; Minkler and Cole 1992; Minkler, Wallace et al. 1994; Doyal 1995; Doyal 2001; Phelan, Link et al. 2004). Access to healthcare services is unevenly distributed in much of sub-Saharan Africa (Ruger and Kim 2006; Tanser, Gijsbertsen et al. 2006; Loewenson 2007). Although many lack access to basic healthcare services including HIV prevention and treatment centers (Muula 2004; Hardon 2005), women frequently fare worse (Parker, Easton et al. 2000; Loewenson 2007). In the context of

HIV, previous studies suggest poor access to services is a barrier to positive behaviors such as seeking HIV testing or receiving HIV test results (Nuwaha, Kabatesi et al. 2002). Rural residents generally have fewer HIV testing facilities, poor health infrastructure, and less access to health facilities than urban areas (UNAIDS 2008), limiting their individual choice for healthcare.

In Malawi, rural areas have high population density and are characterized by poor roads and limited physical, economic, and social infrastructure (Bryceson and Fonseca 2006). Roads serve as an indicator for access to markets, livelihood opportunities, and services (Smith, Gordon et al. 2001), and road quality may serve as a proxy for mobility (Greig and Koopman 2003), a factor known to be associated with HIV (Doyal 2001). A study in South Africa using GIS to map HIV prevalence among pregnant women and healthcare center proximity to primary or secondary roads showed that women with homesteads closer to a road were more likely to be infected than women who lived further from these main transportation arteries (Tanser, Lesueur et al. 2000). Proximity to an urban area may also be associated with an increased risk of HIV transmission (Girdler-Brown 1998). Urban HIV rates are higher across most of sub-Saharan Africa (UNAIDS/WHO 2007), including Malawi (National Statistical Office Malawi and ORC Macro 2005). Workers are exposed to formal or informal sex workers in urban transit areas, providing a partial explanation for the migration and urban links to HIV (Chirwa 1997). Similarly, relationships between higher HIV rates and proximity to market areas are evident (Gabrysch, Edwards et al. 2008). Truckers, tourism, prostitution, traders, and refugees along these same road networks also encourage the spread of HIV through unsafe sexual practices (Chirwa 1997). These access factors may influence the behaviors linked to increased risk of HIV, including migration, paying for sex, sex without a condom, or multiple partner sex.

Therefore, this study examines the influence of area-level socioeconomics on individual HIV risk behaviors, and in turn, HIV, through examination of the role of area-level income inequality, measured by the Gini coefficient, and area-level poverty headcount, an indicator of absolute poverty. Examination of both absolute poverty (poverty headcount) and relative poverty (income inequality) is an advantage over previous research that used singular measures (Kawachi and Kennedy 1999). This research also explores the influence of access to major roads, access to major urban areas, and proximity to healthcare clinics on individual HIV infection, exploring the pathways through individual-level risk behaviors that may mediate these associations.

Could Ecological Factors Have Differential Effects on Individuals?

Individual-level SES

As noted previously, the relationship between individual socio-economic status and health outcomes is unclear. As suggested by the PEH heuristic, this muddled relationship could result from the intersection of factors at both the macro- and individual-level, including socio-economic resources (Phelan, Link et al. 2004).

Although not HIV-specific, previous research in developed countries shows that area-level effects may influence health outcomes over and above socio-economic factors at the individual level (Macintyre, Maciver et al. 1993; Pickett and Pearl 2001; Macintyre, Ellaway et al. 2002). In a study comparing sexual activity among black and white teens in the US, neighborhood economic and segregation traits were associated with race differences in risk of sex (Billy, Brewster et al. 1994; Brewster 1994). Also, in a review of research in developed countries on the effects of neighborhoods on health, Pickett found that neighborhood-level social and ecological factors had a significant influence on individual morbidity, mortality, or health behavior health status above the contributions of individual SES (Pickett and Pearl 2001).

Studies in developing countries that consider the relationships between both individual- and area-level socio-economics on health are rare. Montgomery et al used data from urban samples in Demographic and Health Surveys in 85 countries to determine the influence of both individual and community SES on health outcomes (Montgomery and Hewett 2005). They found that household SES was predictive of unmet need for modern contraception, attended birth, and height for age while community-level factors were predictive of birth attendance (Montgomery and Hewett 2005). Recent research by Gabrysch in Zambia suggests an association between neighborhood factors and HIV risk behaviors (Gabrysch, Edwards et al. 2008). In a cross sectional study of the influence of socio-economic status on sexual risk behaviors among young women, they found that women in lower and middle class neighborhoods as well as those near markets were more likely to be infected while proximity to health centers was protective even after adjusting for some individual-level behaviors (Gabrysch, Edwards et al. 2008). Lastly, a recent cross-sectional study on multiple levels of influence on the distribution of HIV in Tanzania revealed place-based effects, including neighborhood and regional poverty, on individual HIV status (Msisha, Kapiga et al. 2008). However, this study revealed only the existence of a significant contextual influence of poverty without further illumination of the reasons for this association or its variation within Tanzania.

These studies point out that macro-level, socio-economic influences may have a differential effect on health and health behavior net of individual-level socio-economic factors. Although the role of interactions helps distinguish the effects of individual social class from area-level effects (Macintyre, Maciver et al. 1993), in the current study, preliminary analysis of interactions between area-level effects and individual-level SES in models of HIV risk-taking behaviors or HIV status proved non significant for men and women. Further exploration of moderation by individual-level SES is not pursued. Individual-level socio-economic status is included as a control in models adjusted for demographic factors.

Gender and HIV

Macro-level factors may affect women differently than men. Both the PEH and the Theory of Gender and Power, developed by Connell in 1987, recognize that gender relations, social norms of masculinity and femininity, and economic power are all directly related to adverse health outcomes among women (Connell 1987; Doyal 2000; Wingood and DiClemente 2000; Doyal 2001). Biology compounds these factors. During unprotected sexual intercourse, women's risk of becoming infected is four times higher than men's, due in large part to larger areas of exposed, sensitive skin that is prone to tear in the vagina as compared to the penis (UNICEF 2002; Lamptey, Johnson et al. 2006). These biological risk factors (Blocker and Cohen 2000; Glynn, Carael et al. 2001; Quinn and Overbaugh 2005), exacerbated by gender inequity and power differentials that limit women's decision making (Craddock 2000; Ghosh and Kalipeni 2005; Luke 2005), partially explain the disproportionate rates of HIV among women across much of sub-Saharan Africa (Luke 2003; Kim and Watts 2005; Quinn and Overbaugh 2005; Wellings, Collumbien et al. 2006; Sa and Larsen 2007). In Malawi, aspects of the social, legal, and political-economic environment reinforce gender inequality reducing women's rights to govern their sexual and reproductive health and increasing their vulnerability and risk for HIV infection (Kathewera-Banda 2005).

Women *embody* social discrimination, economic disadvantage, and inequality (Krieger 1999; Krieger 2005), and these economic asymmetries influence how women use their bodies for work (Krieger 2001). Poverty, lack of economic opportunities, and inequality force many women in rural Africa to engage in risky survival behaviors and coping livelihood strategies (Masanjala 2007), including dependence on sexual relationships for financial support (Gregson, Nyamukapa et al. 2002; Gupta 2002; Luke and Kurz 2002; Kelly, Gray et al. 2003; Luke 2006). In Malawi, young men know that it is their responsibility to provide economically for their partners and women know that they will be providing sex. "A sexual relationship cannot exist without a male-to-female transfer of money or gift" (Poulin 2007) (p. 2387). The intersections of socio-economics and gender may produce an irony that women's short-term survival tactics, including risky sexual behaviors, may lead to HIV infection (Craddock 2000).

Not all women depend on relationships for material support: these relationships may form social support and social insurance, enabling both men and women to mitigate the threat and reality of poverty (Swidler and Watkins 2007). Regardless of the type of support women seek through these sexual relationships, they still have less power to determine the circumstances of sex. Compromised gender-based power is linked to less consistent condom use, less contraceptive use, and increased vulnerability to STI/HIV (Blanc 2001; Luke and Kurz 2002; Dunkle, Jewkes et al. 2004; Pettifor, Measham et al. 2004). Both marital and non marital relationships demonstrate power imbalances (Luke 2003; Longfield 2004). Talking about condoms implies a lack of trust and defies traditional gender norm expectations for women (Maman, Campbell et al. 2000; Pettifor, Measham et al. 2004; Manuel 2005), and this holds true in Malawi (Schatz 2005). A qualitative study of 60 women in urban Malawi revealed inequality between married men and women that limits women's decision-making and ability to protect themselves against infection through condom use (Ghosh and Kalipeni 2005).

Although the focus on gender frequently centers on women, men should be included in research about HIV as they control many of the risk behaviors (Maman, Campbell et al. 2000; Mane and Aggleton 2001). Men control the who, what, where, when, and how of sexual intercourse, especially with younger partners (Sayles, Pettifor et al. 2006), and they have greater access to employment, money, and power than women (Gupta Rao 2002). Qualitative research in Malawi reveals that rural women are clearly constrained in their behaviors and have less access to income and social power than men (Schatz 2005). Social ideals around masculinity are achieved by men controlling women (Kumar, Gupta et al. 2002; Hunter 2005): in Malawi, a man may commit to marrying a woman by giving her or her parents a gift that symbolizes "the man's access and claim to the woman's sexual territory, and the exclusion of other men from her" (Chirwa 1997) (p.7). The virility, status and masculinity equated with having multiple partners and not using condoms may also evolve into pride at being HIV+ among some men, a finding that would have extremely detrimental effects on future prevention efforts (Kaler 2003).

There are variations in gender roles and relations within Malawi, between areas and over time (Davison 1993), and not all women lack power in their relationships. Women have several ways to protect themselves against HIV infection: they may have agency to talk with their husbands about the risks of multiple partners; seek advice in their social network; confront girlfriends; or threaten divorce (Schatz 2005; Smith and Watkins 2005). Between some young partners, even those who exchange money, condoms may be suggested or rejected by men or women (Poulin 2007).

Due to the plethora of evidence confirming the impact of gender on social power, sexual health and wellness, and high risk behaviors, this study explores whether the relationships between area-level effects, individual behaviors, and HIV status differ by gender. Stratified analysis reveals whether area-level factors operate through individual behaviors to influence individual HIV status of men and women through distinct pathways.

CHAPTER 3

EXPLORING AREA-LEVEL RELATIONSHIPS

Determining the Context of Area- and Individual-level Associations

To accurately determine the linkages between the areas in which people live and their behaviors, models that recognize the nesting of individuals within areas or clusters are necessary. Contextual models simultaneously parcel out the relative influence of individual- and area-level effects on individual-level outcomes while accounting for the non-independence of observations within areas (Blalock 1984; Diez-Roux 2000). Therefore, this study employs contextual analysis to determine which area-level factors influence individual HIV status. Although multi-level models also accomplish this, they require large samples within each cluster for accurate examination of within-cluster variation. This study design does not allow for within-cluster analysis due to the small number of people chosen within each cluster.

Contextual, hierarchical, or multilevel models “do not incorporate any notion of space and, as such, may be described as nonspatial: they consider the neighborhood affiliation of individuals but neglect spatial connections between neighborhoods" (Chaix, Merlo et al. 2005) (p. 177). Such neglect is a weakness of traditional modeling that aims to explore area-level effects. Although aspatial, these models are informational: these models offer a partial explanation of the distribution of predictors and outcomes, but they do not describe the distribution and scale of variation within a setting (Chaix, Merlo et al. 2005). Therefore, the same factors explored in the contextual analysis are used in subsequent spatial analysis to demonstrate the distribution and patterns of these relationships in Malawi.

Showing Context: the Advantages of GIS for Area Studies

The complementary spatial analysis provides several advantages over traditional exploration of area-level factors in health research. Primarily, GIS technology makes integrating and linking databases using geographic information possible and provides a method for combining data from multiple sources into a more comprehensive whole (Richards, Croner et al. 1999). Unlike traditional regression that assumes that observations are independent of one another or controls for this non independence, spatial analysis responds to autocorrelation by recognizing and adjusting for the fact that geographically proximate groups may have similar characteristics and influences should not be treated independently (Dietz 2002). Moreover, unlike multi-level models, spatial analysis reveals interactions by exploring how relationships vary, or affect individuals differently, by location, demonstrating moderation and distinct regional patterns. Furthermore, maps resulting from spatial analysis may present findings in a way that promotes improved knowledge acquisition, potentially accelerating the transition from research into practice (Rytkonen 2004). Through spatial analysis, this research examines relationships at a much finer scale than previous studies, allowing for the exploration of patterns in area- and individual-level factors that affect HIV status at the local level.

Although few studies apply mixed methods in developing countries or in the context of HIV, combining spatial and regression analysis in health research is gaining momentum (Chaix, Merlo et al. 2005). A small-scale study of health center client satisfaction in all districts in Malawi found significant spatial patterns between regions (Gideon 2007), indicating the importance of place in the context of Malawi. However, this study failed to look at space at a finer scale. Advancing the use of spatial methods, recent research on the distribution of disease shows potential to understand the macro-level drivers of HIV in South Africa (Kleinschmidt, Pettifor et al. 2007). Kleinschmidt et al tested the spatial association between various area-level effects including proportion employed, proportion educated, proportion of informal households and area-level HIV without adjusting for individual factors (Kleinschmidt, Pettifor et al. 2007). In their study, they took significant ecological variables associated with HIV status in logistic regression models and tested them in spatial models to determine where and how those parameters varied in space (Kleinschmidt, Pettifor et al. 2007). In spatial models, they found that the distribution of HIV in South Africa varied within provinces and districts and that area-level unemployment, ethnicity, and urbanicity were associated with average HIV prevalence levels (Kleinschmidt, Pettifor et al. 2007). Another study of poverty and HIV showed contrasting relationships at the individual and community levels in Burkina Faso (Lachaud 2007). Using the Demographic and Health Survey as well as an economic indicator survey, Lachaud used both spatial and aspatial regression to examine the relationship between individual HIV and both micro- and macro-level factors. In micro-economic analysis using probit models, he found a positive relationship between HIV and individual SES, also noting significant effects of residence, condom use, and religion, but not gender. At the provincial level, spatial lag models demonstrated a non-linear relationship between average provincial-level HIV and area-level measures of poverty. Migration, urbanization, and residence near transportation routes were significant in these spatial models, but area-level Gini was not (Lachaud 2007). Despite its strengths, Lachaud's study did not test the moderating role of gender in the spatial or aspatial models, and individual and area-level effects were not explored in the same model, preventing exploration of the strength of individual versus area-level influences.

Examination of relationships between individuals and small-scale areas may reveal how the direction and magnitude of associations varies over space (Chaix, Merlo et al. 2005). Although the geographic size of an area of influence defies easy determination, for the purposes of this paper, area-level factors will be designated by aggregate census enumeration areas comprised of approximately 500 households. Although limited by the available data to this unit of area-level influence, this definition of area-level effects falls between larger areas such as census tracks and smaller geographic units such as block groups, both of which have been used to measure macro-level influences in previous studies (Dietz 2002). As used in previous research, the terms *contextual*, *ecological*, *macro-level* and *area-level* will be used to discuss upper level effects in this study (Diez-Roux 1998).

STUDY OVERVIEW

This study applies the political economy of health (PEH) heuristic to explore HIV in rural Malawi. As discussed previously, and as shown in the model below, area-level socio-economic factors and access to resources and services are hypothesized to affect individual HIV status through the pathway of individual behaviors. Although previous studies note the importance of these area-level influences on individual HIV status (Zierler and Krieger 1997; Craddock 2000; Gould 2005; Villarreal 2006; Hunter 2007), there is a paucity of empirical research that analyzes these relationships in developing countries or in the context of HIV. To address these gaps, the first paper uses logistic regression to examine whether area-level factors including poverty (area-level Gini coefficient, area-level poverty headcount) and access (area-level road access, area-level healthcare, area-level distance to major city) influence individual HIV status in Malawi, and whether these factors operate through individual-level behaviors. The analysis is stratified by gender to determine whether these associations differ for men and women. These logistic models may be considered global models.

In the second paper, spatial regression methods are used to test relationships between area- and individual-level factors on individual HIV status in space. The analysis presents these relationships through maps, allowing for both a visual heuristic of the results and an indication of how these relationships may vary within Malawi. Presentation of spatial regression is advantageous: the visual images produced as part of the second paper may be better able to convey complex spatial patterns than tables or graphs (Moore and Carpenter 2002). These spatial models may be considered local models.

Research Questions:

- Paper 1: Using aspatial logistic regression methods: 1a) Are area-level factors associated with individual HIV status in Malawi?; 1b) Are these associations mediated by individual behavioral factors?; and, 1c) Do these relationships vary by gender?

- Paper 2: Using spatial regression methods: 1) How do the associations between area-level factors, individual behaviors, and individual HIV status vary within Malawi?

For paper 1, contextual logistic regression models are employed to examine factors that predict individual HIV status, the dichotomous dependent variable. Independent, area-level variables include Gini coefficient, poverty headcount, distance to major road, distance to major city, and healthcare access. Additional models include a composite mediator variable of high risk sex. Controls include ethnicity, religion, marital status, education and age, plus circumcision and migration for men. The analysis is stratified by gender.

For paper 2, spatial regression using geographically weighted regression (GWR) is utilized to determine whether there is place-based clustering of area- and individual-level influences on individual-level HIV status (Brunsdon, Fotheringham et al. 1998). GWR is a spatial analysis method that accounts for spatio-temporal correlation between observations, i.e., adjusting for the likelihood that observations closer in geographic proximity are more similar than observations further away. The method applies a heavier weight to nearer observations than to farther observations. GWR provides separate estimates of the parameters at each *observation*, i.e., the method provides beta coefficients for each individual separately and produces “local” models in addition to the global model. The results can be mapped for visual representation to qualitatively examine the spatial patterns of parameters of interest. For question 2, the dichotomous dependent variable is individual HIV status. Independent area-level variables include Gini coefficient, poverty headcount, road access, distance to major city, and proximity to healthcare facilities. Independent individual risk behaviors include condom use, multiple partners, and previous sexually transmitted infection; paid sex and migration are also considered for men. Controls include ethnicity, religion, marital status, education, and age, plus circumcision for men. The geographic analysis is stratified by gender.

Hypotheses

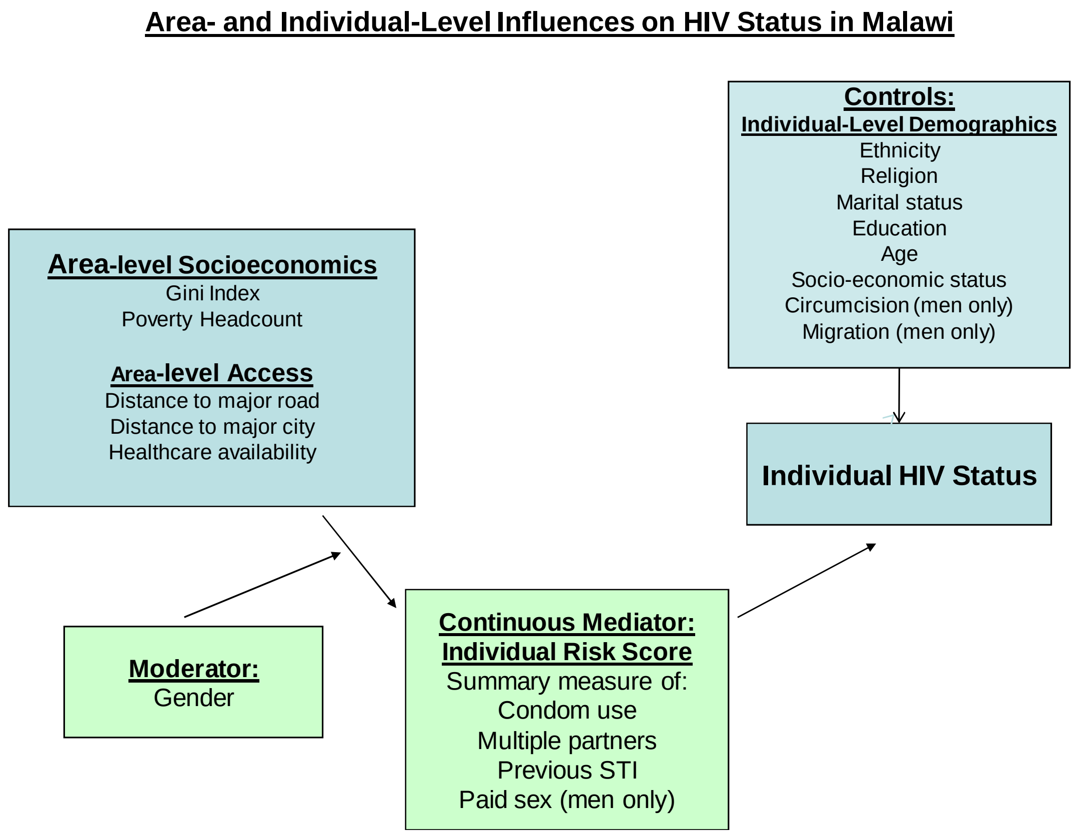
<u>For paper 1,</u> the following relationships are hypothesized:

- Persons from poorer areas and those with higher income inequality (as measured by poverty headcount and Gini) will be *more* likely to be infected with HIV than their peers from areas with better socio-economic indicators. Persons with greater access to roads and cities will be *more* likely to be infected with HIV that their peers with less access. Persons with greater access to healthcare services will be *less* likely to be infected than their peers with lower access to healthcare services.
- Persons from poorer areas and those with higher income inequality (as measured by poverty headcount and Gini) will be *more* likely to engage in risky behavior, and therefore, *more* likely to be infected with HIV than their peers from areas with better socio-economic indicators. Persons with greater access to roads and cities will be *more* likely to engage in risky behavior, and therefore, *more* likely to be infected with HIV than their peers with less access. Persons with greater access to healthcare services will be *less* likely to engage in risky behavior and, therefore, will be *less* likely to be infected with HIV than their peers with lower access to healthcare services.
- The relationship between area-level factors and HIV risk behaviors will be moderated by gender: qualitative comparison of the stratified results will suggest that the associations between area-level factors, individual behaviors, and HIV status will be stronger for women than for men.

For paper 2, the following relationships are hypothesized:

- The relationships between area-level factors, individual-level risk factors, and individual HIV status will vary by geographic area and by gender, demonstrating that the associations between these variables differ in space.

Figure 3.1: Conceptual Model



CHAPTER 4

STUDY DESIGN AND METHODS

The data for this secondary analysis come from several primary sources. All individual-level data and variables (demographic and behavioral) come from the Malawi Demographic and Health Survey, 2004 (MDHS), including the HIV and GPS components. The area-level poverty data come from Columbia University Poverty Mapping Project (Columbia University 2008). The area-level road, healthcare facility, and urban area proximity data are derived from digital maps of Malawi using widely accepted spatial measurement procedures. Because area-level poverty data are available only for rural households, this study sample is restricted to rural residents. This section will be divided into individual- and area-level components.

Individual-Level Data

Sampling frame

The Malawi Demographic and Health Survey 2004 (MDHS) uses the master sample frame from the Malawi 1998 census. Malawi has 27 districts, and each district has smaller administrative units, Traditional Authorities (n=350), each of which is divided into enumeration areas (EA) (n=9200). The census EAs serve as the frame for stage one of the two-stage sampling design (National Statistical Office Malawi and ORC Macro 2005).

Sample selection

The MDHS uses probability sampling methods; every selected individual or household has a known, non-zero probability of being selected. The design of the MDHS was a 2-stage cluster sample with a target of 15,140 households. MDHS expected 13,000 women to complete surveys based on the response rate for the 2000 MDHS. The Primary Sampling Unit (PSU) was the enumeration areas (EA). In stage one, EAs were selected with probability proportional to size based on the estimated number of households in each EA. An exhaustive list of all households within those EA was created by the National Statistics office to make sure the sampling frame was up to date. According to DHS, the optimal cluster size (the number of households selected per EA) ranges between 20-40, depending on the similarity expected between persons in the same cluster (ORC Macro 1996); approximately 29 households were selected in each cluster for the MDHS. To reach the target number of households, 522 clusters were randomly selected from the 1998 Malawi master census sampling frame, 64 in urban and 458 in rural areas (National Statistical Office Malawi and ORC Macro 2005). To select the households, a systematic sample was selected from each of the 522 clusters. All eligible women aged 15-49 years who usually lived in the household and who consented were interviewed. For men, every third household selected for the women's interview was included for the male questionnaire, and all men, aged 15-54 years, who usually lived in the household and who consented were eligible for interview. All households selected for the male questionnaire were also selected for the HIV test, including all eligible men and women within the household. Over 5000 male and female respondents agreed to the HIV test, offering a representative sample of men and women at the national level.

Sample households were selected to be a self-weighting fraction of households at the national level, in the three regions (North, Central, Southern), for rural and urban areas separately, and for each of the 10 largest districts (National Statistical Office Malawi and ORC Macro 2005). Because the districts vary in population, some districts were oversampled (Mulanje, Thyolo, Kasungu, Salima, Machinga, Zomba, Mangochi, Mzimba, Blantyre, and Lilongwe) to provide enough households for reliable estimates at the district level. More information about the general DHS survey methodology is available from ORC Macro (ORC Macro 1996).

Response rate

For the MDHS, 13,664 households completed interviews, a response rate of 98%. Of those who responded, 82% of the women and 80% of the men sampled lived in rural areas. The response rate was 94% among rural women and 85% of rural men.

For HIV testing, 2,485 rural women (response rate 71%) and 2,056 rural men (response rate 65%) accepted; 5.1% of women and 13.1% of men were absent on the day of testing (National Statistical Office Malawi and ORC Macro 2005). Mishra et al (Mishra, Barrere et al. 2008) conducted an analysis of bias caused by non response in 14 DHS surveys with HIV testing, including the MDHS, by comparing those: (1) interviewed and tested; (2) not interviewed but tested; (3) interviewed and not tested; and (4) not- interviewed and not-tested. Using common independent variables and logistic regression, they predicted HIV status of groups 3 and 4 based on the prevalence among groups 1 and 2 (Mishra, Barrere et al. 2008). From these models, they provided adjusted models of HIV prevalence for those not tested (Mishra, Barrere et al. 2008). Although Malawi had the highest differential in the response rate between the overall MDHS survey and the HIV component (25% lower among women and 23% lower among men), the effect of non-response on population level HIV prevalence estimates in all 14 countries were not significant, including in Malawi (Mishra, Barrere et al. 2008).

Sampling

Because the sample was not proportional among all districts, a final adjustment (weight) procedure was necessary to represent the true population estimates at the national level. Sampling weights in general, and in DHS, are adjustment factors that are applied to each case in survey analysis to account for differences in the probability of selection or interview due to design or implementation (Rutstein and Rojas 2006). These sample weights were produced by DHS by using both the probability of household selection and the response rate for households and individuals. Weights were standardized, and the sum of the household weights equals the total number of households in the entire sample. In Malawi, each of the largest 10 districts represents a domain, and the other 17 districts represent an additional domain. The domains vary in size; therefore, oversampling in domains of smaller size was necessary in order to allow for estimates at the district level (National Statistical Office Malawi and ORC Macro 2005). In an equal probability sample the probability of selection (f) is N/n, where N is the population and n is the sample size. However, in the MDHS, the probably of selection varies by domain, and a weight of $N/n = 1/f$ must be applied to each domain to make population level estimates of means or proportions (ORC Macro 1996). Weighting the sample corrected the potential bias, although the unweighted and weighted responses were very similar (ORC Macro 1996). Difference sampling weights were calculated for the female, male, and HIV samples. DHS sampling weights from the HIV sample are applied for this analysis.

Data and Data Collection

Demographic and behavioral information

The individual-level demographic and behavioral information comes from the 2004 Malawi Demographic and Health Survey (MDHS). The MDHS provides reliable estimates at the national level, regional level, for rural and urban areas separately, and for each of the 10 largest districts, placing the remaining 17 districts into 6 groups (National Statistical Office Malawi and ORC Macro 2005). The MDHS collects detailed information on myriad subject areas including fertility, sexual health, nutrition, and children’s health from women ages 15-49 and men ages 15-54. Questionnaires for households, women, and men were developed, tested, and translated into Chichewa and Tumbuka according to the general DHS methodology (Aliaga and Ren 2006). Interviewers received extensive training before implementing the survey, and appropriate consent procedures were approved by internal review boards in Malawi and in the USA.

HIV information

Information on HIV status also comes from the MDHS. The HIV results were voluntarily obtained from finger prick tests, and the dried blood spots were sent to an independent laboratory (ORC Macro 2005). According to DHS, the laboratory protocol includes an initial ELISA test followed by retesting of all positives as well as 10% of all negatives with a second ELISA (MEASURE DHS 2008). For discordant results, a Western blot test was performed (MEASURE DHS 2008). Tests were coded for confidentiality, and no test results were given to participants. Referrals to free testing sites were provided for those that wanted to know their HIV status, regardless of participation (National Statistical Office Malawi and ORC Macro 2005).

In comparison to HIV prevalence information from antenatal care (ANC) settings, the use of DHS HIV data is advantageous (Macro 2005). The rural ANC sites where HIV sentinel surveillance data is collected are generally located in small population centers that may not accurately reflect the patterns of HIV infection in more rural areas (Bello, Chipeta et al. 2006). Therefore, the HIV status information from the DHS gives more reliable estimates of HIV prevalence at the regional and population level (ORC Macro 2005; Mishra, Barrere et al. 2008).

GPS information

The MDHS collected GPS data according to the manual developed and tested by MEASURE DHS (Montana and Spencer 2004). During survey implementation, field staff took latitude and longitude coordinates using global positioning system (GPS) receivers at the central geographic point, centroid, of each MDHS cluster. To protect the confidentiality of individuals and reduce the possibility of identification of individuals from the combined data sources, MEASURE DHS scrambles the GPS coordinates for the clusters. This process reduces the likelihood of matching people to their exact location but leaves enough locational information for spatial analysis. Usually, the GPS receivers are accurate within 10 meters. In rural areas, all clusters were offset by up to 5km, a distance determined by ORC Macro to provide a 10 fold decrease in the ability to pinpoint exact cluster location (Montana and Spencer 2004), leaving each DHS cluster location within a 5km radius of the true location.

GPS coordinates for Malawi are available for 521 clusters, 458 of which are in rural areas. Two rural clusters, including their 14 observations, were dropped due to erroneous latitude or longitude, leaving 456 rural clusters for analysis. All raw coordinate data (latitude and longitude information) were imported into ArcGIS for mapping. Following standard protocols for visualizing data points on a spatial map, the points were projected using Universal Transverse Mercator (UTM) grid zone 36 south and referencing the World Geodetic System 84 (WGS84) datum, geographic location information that allows for 2-dimensional expression of spatial data. Through this projection process, it is possible to determine the distances between any two points in 2-dimensional measurement, i.e., meters (Montana and Spencer 2004).

Measures

A summary of individual-level variables is presented in Table 4.1

Table 4.1: Individual-level variables

Variable	Definition	Type of variable	Response Coding	Source
HIV Status	Infection with HIV-1 or HIV-2 on 2 tests of HIV status, including rapid and confirmation with Western Blot or ELIZA	Dependent	0 = uninfected; 1= HIV+	DHS HIV
Gender	Male or female	Moderator	Stratification	DHS
Sexual risk score	A risk score comprised of paid sex in last year; 2 or more sexual partners in last year; condom use with any of previous 3 sexual partners; or diagnosis/symptoms of sexually transmitted infection (STI) in past year (see elaboration below)	Mediator	For women, 0-3; For men, 0-4	DHS
SES	Household socio-economic status (see elaboration below)	Control	Ordinal – polychloric methods to create SES index *	DHS
Migration	Travel for more than one month in last 12 months	Control (men)	0 = no; 1 = yes	DHS
Region	Primary region of residence	Control	Dummy variable for North, Central and Southern regions	DHS
Age	Continuous age in years	Control	Continuous: 15-49 for	DHS

			women; 15-54 for men	
Marital Status	Never married; married/in union; previously married	Control	Dummy variables for: single; married/union; previously married	DHS
Circumcision	Circumcised or not	Control (men)	0 = no; 1 = yes	DHS
Education	Level of highest educational status reached	Control	Dummy variables for no education; primary ed.; more than primary ed.	DHS
Religion	Primary religion as reported	Control	Dummy variables: Christian; Muslim; Other	DHS
Ethnicity	Primary ethnicity as reported	Control	Dummy variables: Chewa; Lomwe; Yao; Other	DHS

The mediator measure, individual risk score, requires additional explanation. The MDHS asks several questions to ascertain risk for sexually transmitted infections (STI) and HIV. These questions include: 1) the number of sexual partners within the last year, including the relationship to the last three sexual partners; 2) condom use with the last three sexual partners; 3) previous STI or symptoms of STI; and, 4) for men only, whether they paid for sex in the last year. Previous studies indicate that condom use may be associated with perceived high level of susceptibility to HIV or to infection from their partner (Adih and Alexander 1999; Pranitha and Cleland 2005) or with other risk factors such as multiple partnerships (Mnyika, Klepp et al. 1997). Therefore, condom use with a recent sex partner, spouse or otherwise, is considered to reflect perceived risk of contracting or transmitting a sexually transmitted infection, including HIV, and self reported condom use is counted as a risk factor in the risk index. Based on previous examples of summary scores of individual risk behavior (Biglan, Metzler et al. 1990; Rosenthal, Moore et al. 1991; Dutra, Miller et al. 1999; Jemmott, Jemmott et al. 1999), the mediator variable of individual risk score is a summary measure created to reflect a continuous measure of increasing HIV risk behavior. For each risk (two or more non-marital partners in last year; condom use with recent partner; previous STI; paid sex), a point is assigned, making scores of 0-3 possible for women and 0-4 possible for men. Increasing risk score indicates higher risk.

Additionally, the SES variable requires elaboration. The variable for individual SES is a wealth index developed by DHS with the World Bank. The survey questions for the wealth index are integrated into all DHS surveys, and the components were tested in a number of countries (Rutstein 1999; Rutstein and Johnson 2004). This index of wealth incorporates household assets such as ownership of various items (e.g., bicycle, car, television), household dwelling characteristics, and infrastructure (e.g., housing materials, type of water and sanitation facilities). In Malawi, information on household assets was collected through the DHS household questionnaire, and principal components analysis was used to assign a weight or factor score to each asset (Vyas and Kumaranayake 2006). Next, each household asset score was standardized to a normal distribution with a mean of zero and a standard deviation of 1 (Gwatkin, Rutstein et al. 2000). The scores were then summed for each household, and individuals are assigned the score of the household in which they reside. Finally, the full sample was divided into population quintiles with equal numbers of individuals in each (National Statistical Office Malawi and ORC Macro 2005; Vyas and Kumaranayake 2006). In Malawi, the wealth index was prepared for the combined rural and urban samples (National Statistical Office Malawi and ORC Macro 2005) and was provided as part of the DHS dataset.

Area-Level Data

For the purposes of this study, *area-level effects* are defined by an aggregate of census enumeration areas comprised of approximately 500 households. The area-level variables come from several distinct sources and are not values aggregated from the MDHS. The poverty information comes from the Poverty Mapping Project while the access variables are derived from spatial maps of Malawi gathered from the UN, Malawi Ministry of Health, and the Danish International Development Agency (DANIDA).

Data

Poverty information

The area-level socio-economic data come from the Poverty Mapping Project (http://sedac.ciesin.columbia.edu/povmap/). These data are available from Columbia University and were elaborated in 2004-2005 in cooperation with the World Bank. The spatial units for the poverty mapping exercise are rural aggregated enumeration areas (EA) devised by the National Statistical Office of Malawi for the 1998 National Population and Housing Census, the same unit as utilized by the MDHS as the PSU. Each unit for the poverty mapping exercise aggregates approximately two or three EAs from the census, creating spatial units with a minimum of 500 households. The Poverty Mapping project links 20 economic indicators to aggregated EAs in Malawi using GIS shapefiles, making the data available for mapping and spatial analysis. The maps used for the census were digitized by the National Land Management Mapping Project of the Department of Surveys, and these digital shapefiles served as the basis for the spatial component of the poverty mapping project (Benson, Kanyanda et al. 2002). The boundaries of the census, and therefore the poverty mapping exercise, respect the administrative boundaries of the district and sub-districts. The poverty mapping dataset includes only rural populations and excludes the four major urban centers of Malawi - Blantyre, Zomba, Lilongwe, and Mzuzu. Towns and cities in rural areas are included.

Experts at Columbia University and the World Bank created these small area estimates of welfare and poverty, including the poverty headcount and Gini index using poverty mapping methods that are complex (Benson 2002; Benson, Chamberlin et al. 2005) and described in great detail by Elbers, Lanjouw, and Lanjouw (Elbers, Lanjouw et al. 2003). However, the basic premise is that poverty mapping is a method to combine data on income, welfare, or consumption from a detailed household survey with census data to provide estimates of poverty at the household level. In Malawi, models of household welfare were developed from analysis of the 1997–1998 Malawi Integrated Household Survey (IHS), a detailed, 2-stage cluster design survey of income and consumption designed to be representative at the district level (Benson 2002). Although the district level is acceptable for many uses, smaller spatial scales are required for targeted poverty programs at the community level (Benson 2002; Benson, Kanyanda et al. 2002; Benson, Chamberlin et al. 2005). To provide estimates at the household level, the detailed models of welfare from the IHS were applied to the 2.2 million households surveyed for the 1998 census (Benson 2002). First, household expenditure at the lowest administrative level (district) were estimated using a similar set of explanatory variables found in both the sample and the census (e.g. household size, education, housing type, etc.) Then, using these estimated coefficients and errors from the regression, poverty and welfare indicators were forecast for all households in the census (Elbers, Lanjouw et al. 2003). These household-level data were used to determine the poverty and welfare indicators for the aggregate EAs, allowing for a much smaller scale of analysis, with similar levels of error, commonly found in sample data (Benson 2002; Elbers, Lanjouw et al. 2003; Benson, Chamberlin et al. 2005). Poverty estimates were then averaged to provide a value for each aggregate EA in Malawi with populations greater than 500 households (Elbers, Lanjouw et al. 2003), although recent research suggests that areas of at least 1000 households may provide improved accuracy (Demombynes, Elbers et al. 2004). These socio-economic variables are compositional variables, representing aggregate and average values of the persons who live in these areas.

The complete poverty mapping dataset of Malawi includes measures of poverty for each of 3004 aggregate EA units as well as at the larger sub-district, district, and regional levels (Benson 2002; Benson, Kanyanda et al. 2002). The poverty mapping information is contained in Malawi base maps, allowing for the visualization of the poverty and welfare information in all 3004 EA units.

The area-level poverty information, as discussed above, is based on projections from the 1998 census, and both the MDHS and the poverty mapping exercise use the census sampling frame. The poverty variables are based on census information and represent population-level data, removing the necessity of weights. Therefore, separate sample weights are not applied to the economic information. Previous studies show that the small scale poverty estimates from poverty mapping exercises were robust using weighted GLS, OLS, or regressions using expansion factor weights (Elbers, Lanjouw et al. 2003).

Access information

I created the road network variables in ArcGIS using GIS road files of primary, secondary, tertiary, and district roads elaborated for the 1998 census and supported through funding by the Danish International Development Agency (DANIDA). The health facility location data come from a Japanese International Cooperation Agency study from 1997-2002 and improved through cooperation from the World Health Organization. The facilities geo-database includes geographic coordinates for public health centers, clinics, maternity wards, and hospitals throughout the country. Global positioning system coordinates were gathered from each public health clinic throughout the country, and these latitude and longitude values were uploaded to mapping software using ArcGIS. Then, I calculated the distance from each DHS cluster to its closest Ministry of Health clinic. The data for proximity to cities were derived from maps produced for the national census and available from the National Statistics Office in Zomba, Malawi. Using these files, I calculated the distance in kilometers from the location of each DHS cluster to the closest regional capital, Mzuzu, Lilongwe, or Blantyre.

These variables represent contextual factors, or exogenous influences from the infrastructure in the local physical and social environment.

Measures

A summary of area-level variables is described in Table 4.2.

Table 4.2: Area-level variables

Variable	Definition	Type of variable	Response Coding	Source
Income inequality	Gini coefficient of income inequality	Independent	Dummy variables: Gini coefficient in the 75th percentile or higher and Gini coefficient in the 26-74th percentile. Reference group: Gini in the lowest 25th percentile or below	Poverty Mapping Project at Columbia University
Poverty Headcount	Measure of the % of population that falls below the poverty line	Independent	Continuous from 0 to 100	Poverty Mapping Project at Columbia University
Distance to major road	Kilometers from DHS cluster point to the closest major road	Independent	Continuous	Derived from digital maps of Malawi road networks using ARCGIS software to determine the Euclidean distance to a major road, i.e., paved highway

Healthcare availability	Kilometers from DHS cluster point to the closest Ministry of Health clinic	Independent	Continuous	Derived from digital maps of Malawi healthcare clinics from the Ministry of Health, Malawi using ARCGIS
Distance to major city	Kilometers from the DHS cluster to the closest regional capital, Mzuzu, Lilongwe, or Blantyre	Independent	Continuous	Derived from UN digital maps of Malawi using ARCGIS

Some variables require elaboration. Area-level socio-economics are measured using poverty headcount and area-level Gini index. The Gini index is a measurement of income inequality in a given area (Wilkinson and Pickett 2006; Coudouel 2008) and has been shown to illuminate the influence of economic disparities on health (Lindstrom and Lindstrom 2006). Poverty headcount is the percent of the population whose income is below the poverty line (Coudouel 2008), and it has been shown to be a valid measure of economic deprivation (Krieger 2003). The Gini index and the poverty headcount represent related, but distinct, measures of poverty (Benson, Chamberlin et al. 2005). The poverty headcount is related to the poverty line and represents the density of absolute poverty; the Gini coefficient measures the distribution of wealth and provides information on relative poverty and economic disparities. Using both poverty headcount and Gini index to measure area-level socio-economic factors is an improvement over previous research that used single measures of area-level poverty (Robert 1999; Benson, Chamberlin et al. 2005).

High Gini and middle Gini variables were created by sorting all enumeration areas by Gini coefficient, from low (greater equality) to high (greater inequality). Quartiles were created, and each quartile was assigned a rank from 1-4, assigning “1” to the 25% in the lowest quartile (highest equality); “2” to the lower middle quartile; “3” to the higher middle quartile; and “4” to the highest quartile (highest inequality). Dummy variables were created for categories “1,” low Gini, “2-3”, combined (middle Gini), and “4,” high Gini.

Three variables measure access at the area level. Distance in kilometers to urban areas, roads, and health facilities was derived from existing GIS maps of Malawi that detail the location of road networks, health facilities, and major urban areas. Using accepted spatial methods, ArcGIS software was utilized to determine the distance between each DHS cluster point and a major road. The distance between each DHS cluster and the closest major road was recorded in the spatial database, giving a continuous measure of distance for each variable. The most recent Ministry of Health (MOH) facility location data is available from 2002, and the facilities are geocoded with latitude and longitude information. The distance from each DHS cluster point to the closest MOH facility was determined using ArcGIS software and recorded in the spatial database. For the proximity to urban areas variable, the distance from each DHS cluster to the closest regional capital –Mzuzu, Lilongwe, or Blantyre – was calculated and recorded using the same procedure.

Combining Individual- and Area-level Variables

To assemble the database for this contextual study, several data sources were combined using GIS software, ArcGIS (http://www.esri.com/software/arcgis/index.html). Additionally, the database for this study was formatted for utilization in several distinct software packages, including STATA 9.2 and ArcGIS 9.2, requiring the careful management, translation and transfer of the data.

Assigning individuals their area effects required several steps. As described in the DHS GPS section above, every cluster in the MDHS has a geographic location allowing the placement of each DHS cluster correctly on the digital map. This DHS cluster information was spatially joined to the poverty and access geographic datasets using widely accepted geographic processes, allowing for the visualization and utilization of information from all sources simultaneously. Through this process, each DHS cluster was assigned the poverty information (Gini, poverty headcount) from the aggregate EA in which it is located. The distance from each DHS cluster to a major road, health facility, and major urban area was determined using the distance calculation features included in ArcGIS software. Once each DHS cluster was linked to these datasets and the distance measures calculated, the complete database of DHS cluster information and its area-level attributes was exported into a database file that contains 456 observations, the number of rural DHS clusters.

The individual-level information from the MDHS database was linked to a separate HIV dataset using the individual identification numbers, creating one dataset of all demographic, behavioral, and HIV information at the individual level from the MDHS. This database is in STATA 9.2 format.

The area-level information was imported into STATA 9.2 and merged with the individual level data using a one-to-many merge. To do this, the area-level data set and MDHS dataset were sorted by cluster number. The one-to-many merge process assigned the same area-level variables to every individual within each cluster, but did not affect other individual level information. The individual-level demographic and health information remained unique for each individual observation.

DATA ANALYSIS

Power Calculation

Although the two-stage cluster design is cost-effective, there are losses in efficiency that affect the needed sample size. This loss is due to 1) the reduction in the effective sample size in a clustered design from a sample of *n* elements in a population to a sample of *n* elements within only selected α clusters and 2) to the similarity of people within sampled clusters, increasing the variance of the sample (Kish 1965). The intra-cluster correlation coefficient (ICC) is a measure to determine similarity between observations within the same cluster. Both the design effect and the intra-cluster correlation must be considered to correctly estimate the needed sample size for adequate power to detect differences in HIV status.

Power was calculated using the guidelines provided by the World Health Organization's manual for sample size determination in health surveys (Lwanga and Lemeshow 1991). In this study, the null hypothesis is that the proportion of those infected with HIV is equal between groups while the alternative hypothesis is that the proportion of those infected with HIV is greater among those with higher "exposure" to the area- and individual-level factors. In this scenario, with a significance level of 5% and 90% power to detect a true difference in proportions of 5 percentage points (6% vs. 11%), a sample of 474 is required in each group for a total of 948 persons (Lwanga and Lemeshow 1991). As this study uses a two-stage cluster design, adjustments must be made. To adjust for an average intra-cluster correlation of 0.10, an appropriate intra-cluster correlation for all DHS surveys (Aliaga and Ren 2006); a design effect of 1.351 (National Statistical Office Malawi and ORC Macro 2005); and, for non response of 10%, a sample of 1549 persons would be appropriate. For HIV testing, 2485 rural women (response rate 71%) and 2,056 rural men (response rate 65%) accepted. Therefore, the HIV subsample size is large enough to detect differences at the .05 significance level and 90% power in independent analysis for men and women.

Preliminary Analysis

Selection of modeling technique

Multi-level models are an increasingly-preferred analytical technique for data at multiple levels. However, multi-level models are not the best fit for this data for several reasons. First, multi-level models using data from multi-stage sampling designs require information on weights at all sampled levels. As the MDHS is a 2-stage cluster design, weights are required for both stages of sample selection. However, the MDHS does not publish these weights, and they are unknown. Without the upper level weights, modeling techniques and software such as generalized linear latent and mixed models (gllamm) cannot be used appropriately with a 2-stage cluster sample. Although there are methods to create weights for the upper level (clusters) using known weights from the lower level (individuals), this information is also not available from the MDHS. Information on the population of each sampled PSU is not easily obtainable, negating the ability to correct parameter estimates by adding a variable to control for the probability proportional to size sampling structure. Lastly, gllamm is computationally complex for dichotomous outcomes. It is likely that models including all covariates and measures to adjust for the subpopulation would not converge or would require lengthy time frames to run. Furthermore, cluster size is an issue for multi-level models, and the MDHS is not designed for intra-cluster analysis. Clusters in the sample vary from 1-23 in the full sample, but from 1-12 in the models stratified by gender. These are very small clusters for consideration in gllamm or other multi-level models and raise doubts as to the validity of conclusions of intra-cluster variation. Lastly, subpopulation analysis commands are not available in gllamm. However, analysis of subpopulations is central to the research questions, and it is critical to construct the estimates of standard errors for the selected persons of interest (rural, men/women, ever had sex) from the standard errors of the full sample. Therefore, this analysis will use contextual models that adjust for the sample design and subpopulation analysis. The contextual models also address the nested data appropriately. As discussed previously, these models adjust for the non-independence of observations within the same cluster, correctly estimating parameters and error terms.

Analysis plan

The 2-stage clustered design of the survey was not designed for within-cluster analysis due to the small number of households per cluster, between one and 29 households in each of the 456 rural clusters. Therefore, this analysis examines between-cluster differences. As the observations within clusters may be more similar than observations between clusters, the errors may be correlated. Without adjusting for this probability, the possibility of committing a type I error is created; that is, finding an effect or a relationship when there is none (Duncan, Jones et al. 1998). Therefore, this contextual analysis employs STATA SVY commands that adjust for the multi-level sampling design. The SVY commands are specifically designed for survey data and consider the nesting of the data, individuals within clusters, to provide less biased estimates of the parameters and the standard errors. DHS provides variables for the cluster number and strata, and these were utilized in the SVY commands. The (subpop) command also allows for estimation of correct standard errors in analysis of a subsample of the data by calculating the standard errors within the entire sample population while using only selected observations in the regression model. Weights from the HIV sample were applied to each observation to provide correct population-level estimates from the sample. The subsample includes only rural residents, male or female, who have sexually debuted.

For questions 1 and 2, univariate analysis of all individual- and area-level effects show variable distributions. Correlation tests of all area- and individual-level factors determine if independent variables, both area- and individual-level, are highly correlated. Tests of multicollinearity in male and female models show a variance inflation factor of 1.55 for men and 1.53 for women among all included variables considered for analysis, indicating low multicollinearity among the variables. Summary statistics, including the mean and standard deviation, of all variables are reported.

Study population description

The sample is restricted to sexually active men and women selected for HIV testing in rural areas of Malawi: 2,091 women and 1,827 men. Females included in the sample vary in age from 15-49, with the largest percentage, 26%, in the 20-24 age group. Almost 80% of the female sample is currently married or in union, 17% of whom are in a polygynous union. The predominant religions for the women's sample are Christian (37%), Catholic (24%) and Muslim (12%). Chewa is the most prevalent ethnic group in the sample (34%) followed by Lomwe (18%), and Yao (13%). The majority of the women (65%) have 1-4 years of primary school; no women in the sample have a secondary education. Wealth is distributed almost evenly between the lowest 4 quintiles, leaving only 10% of women in the highest wealth quintile. Almost half of the sample (48%) is from the South, the most populous area of the country.

In comparison to the women, men are older with an age range from 15-54, with the largest percentage, 20%, between the ages of 25-29 ($p<.01$). The majority (74%) of men is currently married or in union, but a larger percent has never been married: 22% as compared to 5% of women ($p<.01$). Eight percent of the men in the sample are in a polygynous union, less than half of the reported value from the female sample ($p<.01$). Similar to the women, men are Christian (38%), Catholic (22%) and Muslim (10%), and Chewa is the most prevalent ethnic group (35%) followed by Lomwe (18%), and Yao (12%). Overall, men are more educated than women. Although a similar proportion of men complete grade 4, 20% of men complete primary school, more than double the percent of women ($p<.01$). Men are more likely to be in a higher wealth quintile than women ($p<.01$), but only 11% of rural men are in the highest wealth category. Among men, 45% are from the South, slightly less than the percentage of women from the same region ($p<.05$). Additionally, 12% of the men were away from their homes for more than one month of the previous 12 months, and 22% of all men are circumcised.

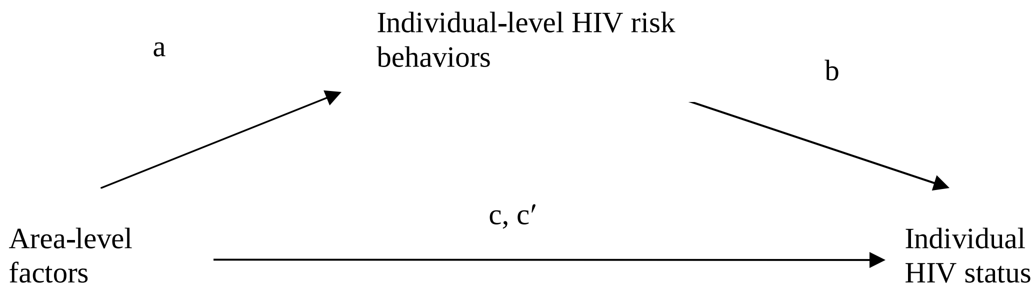
Correlations reveal some patterns in the associations between key variables for men and women. Among individual-level variables, variables for condom use, STI, and multiple partners correlate between .07 and .31 for women. The ethnic groups correlate between .25 and .40 with region, showing moderately strong correlations between ethnic group and residence. Also, Lomwe ethnicity is negatively correlated with distance to a major city while Yao is positively correlated, showing distinct patterns of ethic group residence. Yao are more likely to be Muslim with a correlation of .74. Muslims appear to live further from major roads with a positive correlation of .34. Among women, there is a negative correlation between married and multiple partners (-.47) and with overall risk (-.31). There is a moderate correlation (.31) between those who had multiple partners and those who recently used a condom. Among men, there is a .44 correlation between those who have multiple partners and those who recently used a condom. Again, there are moderate correlations between ethnic group and region, linking ethnic groups to specific areas of residence. Yao men are more likely to be Muslim (.72) and circumcised (.55) than other men.

Analysis plan for research question 1

Question 1 is addressed using a contextual analysis model (Diez-Roux 1998) that incorporates area-level variables into individual-level models with individuals as units of analysis. Analysis of these contextual (area-level) effects uses STATA 9.2. As the outcome variable is dichotomous, multivariate logistic regression models are utilized. In individual bivariate analysis of HIV status regressed on each area-level effect, significance of variables is measured by z tests. In multivariate models, singular variables are tested for significance using z tests while joint significance of variables are measured by adjusted Wald chi-square. Pearson chi-square tests are used to test differences in proportions.

Marginal effects for significant independent variables are calculated using the average of the probabilities method, simulating the average effect of changes in the variable within the sample. Log odds and confidence intervals are reported.

Using the steps proposed by Barron and Kenny (Baron 1986), tests for mediation examine the attenuation of effects between area-level factors and individual HIV status with the addition of individual risk behavior variables. Mediation is assessed in individual models of each area-level variable, producing 5 mediation models for women and 5 for men. Each model includes one area-level factor, the individual-level HIV risk score, as well as demographic controls. Formal tests of significant mediated effects are assessed using the difference in coefficients method after standardizing the regression parameters.



The 4 steps to test for mediation proposed by Barron and Kenny are (Baron 1986):

1. IV significantly associated with DV - area-level factors associated with individual HIV status – path c
2. IV significantly associated with mediator – area-level factors associated with individual HIV risk behaviors (path a)
3. Mediator significantly associated with DV - individual HIV risk behaviors associated with individual HIV status (path b)
4. Relationship between IV and DV no longer significant when the mediator is in the analyses and the mediator is still significant* – area-level factors no longer associated with individual HIV status with individual-level HIV risk behaviors included in the model (c′)

*Step 4 is modified to allow for partial mediation, i.e., that the effect of an area-level variable may remain significant with the addition of mediators (Frazier, Tix et al. 2004). For the purposes of this study, partial mediation is an attenuation of 10% in the main effect with the addition of the mediating variables.

The moderating effects of gender are explored through stratified analysis, and the odds ratios qualitatively compared between men and women.

Preliminary models for research question 1

The models describe individual-level data where "i" is the value of an individual who resides in area, "j". All models are examined for men and women separately.

Model 1a

Pr (HIV +) = 1/1+ $e^{-[\beta 0_{i} + \beta 1_{ij} \text{(Area-level variable)} + \beta 2_{i} \text{demographic controls} + \epsilon]}$

Model 1b

Individual Risk Score = $\beta_{0i} + \beta 1_{ij}$ (Area-level variable) $+ \epsilon$

Model 1c

Pr (HIV +) = 1/1+ $e^{-[\beta 0_{i} + \beta 1_{ij} \text{ individual HIV risk score} + \beta 3_{i} \text{demographic controls} + \epsilon]}$

Model 1d

Pr (HIV +) = 1/1+ $e^{-[\beta 0_{i} + \beta 1_{ij} \text{(Area-level variable)} + \beta 2_{i} \text{ individual HIV risk score} + \beta 3_{i} \text{demographic controls} + \epsilon]}$

Note: For simplification, these generic models reflect 5 separate models of area-level effects including: Gini_high Gini_middle (reference group: Gini_low); poverty headcount; distance to major road; distance to a major city; and distance to Ministry of Health clinic. Models are run separately for men and women.

Analysis plan for research question 2: spatial regression using GWR3

For the second question, all area- and individual-level factors are examined simultaneously to determine whether the relationships vary by geographic location, adjusting for the spatial correlations of geographically-related observations.

Geographically weighted regression (GWR) is a statistical method to analyze whether relationships between predictors and outcomes vary in continuous space. Non spatial regression produces estimates for the study area as a whole. In contrast, GWR produces estimates that describe how associations vary over space, allowing for local level variation across geographic areas and populations. The spatial analysis reveals if the relationships between independent and dependent variables vary by area, and area-level parameters are mapped to visually represent the results. In this manner, GWR provides a way to visualize the regression results and allows for comparison of more traditional analysis methods with spatially-adjusted models.

In spatial analysis, observations closer to one another in space are more influential than observations further away, and weights are applied to determine how much influence "neighbors" have on individual observations. Observations closest to the regression point (individual location) are weighted more heavily than observations farther away. Data from geographically distant points have weights that approach zero, essentially excluding them from influencing the estimates. In this spatial analysis method, GWR analyzes associations around each data point to produce local parameter estimates (Fotheringham, Brunsdon et al. 2002).

The basis of GWR are local level estimates of the regression model, estimating β_{ij} for variables in location (p_i) for each variable j at every location i (Brunsdon, Fotheringham et al. 1998), in this case, the individual. It is likely that the regression model is not static or fixed in space and that the parameter estimates may vary between individuals. For instance, if a radius r is drawn around a person, (p_i) , and an ordinary least squares regression model was fitted using only observations from within r , then the β could be considered as local estimates of the associations between variables within r geographic range of p_i (Brunsdon, Fotheringham et al. 1998). These local regression models provide sets of parameter estimates that are allowed to vary without requiring an estimation of *how* the overall regression model functional form varies in space, basically, letting the data express itself without restrictions (Brunsdon, Fotheringham et al. 1998).

Determining the sphere of influence for each data point is complex. It is assumed that each individual will be influenced more by closer persons than by those located further away. The notation, r, denotes the radius of the circle of influence for each individual. The regression model for each location, p_i, could be weighted such that all observations within r would be weighted as 1 while those outside of the radius would have 0 weight. Using this method, the weight for each p_i would be 1 if d_{ij}

$<r$ or 0 otherwise (Brunsdon, Fotheringham et al. 1998). *r* is also named the bandwidth, or a radius around a data point, and all observations outside of that radius have a zero weight or no influence. The greatest weakness of this approach is that it does not allow for influence to gradually decrease with distance: if the *r* is too small, few observations will be included, but if *r* is too large, the local model will approximate the global model (Brunsdon, Fotheringham et al. 1998). The extreme model also assumes that each included point will contribute equally and that the weight-distance relationship applies equally for all areas, a function that may be inappropriate in locations where data points are not equally distributed in space.

To overcome this problem, spatially adaptive weighting functions apply smaller bandwidths (smaller areas of influence) in areas where the data points are grouped closely together and larger fields of influence where data points are distributed across a larger geographic area (Brunsdon, Fotheringham et al. 1998; Charlton, Fotheringham et al. 2006). Therefore, the weight should be calculated using a Gaussian distance decay measure that allows the sphere of influence to decrease with distance, allocating greater weights to geographic areas closer to one another than to those further away (Brunsdon, Fotheringham et al. 1998). These weights are also referred to as spatially adaptive kernels (Charlton, Fotheringham et al. 2006). Kernel functions, or kernels, are weighting functions in non-parametric equations, i.e., estimations of area of influence. The formula for weighting spatially adaptive kernels may be represented as (Brunsdon, Fotheringham et al. 1998; Charlton, Fotheringham et al. 2006):

$$\alpha_{ij} = [1 - (d_{ij}/h_i)^2]^2 \text{ if } d_{ij} < h_i$$

$$= 0 \text{ otherwise}$$

where α_{ij} is the weight given to point *j* in the regression equation for point *i*; d_{ij} is the distance between points *i* and *j*; and the fixed radius of influence, *r*, is replaced by *h*, a measure that allows the area of influence to gradually decrease with distance and where h_i is the Nth nearest EA distance from

i. *h* is referred to as the bandwidth. In this model, for observation *i*, if $\alpha_{ij} = 0.5$, then the data from point *j* will contribute only half as much as the data at point *i*.

For these K (kernel) functions, the desired properties are (Brunsdon, Fotheringham et al. 1998):

1. $K(0) = 1$;

2. $\lim_{d\to\infty} [K(d)] = 0$; and

3. K is a monotonically decreasing function for positive real numbers

Estimating parameters in GWR

GWR is a method that requires a specific software package for analysis, GWR3 (Fotheringham, Brunsdon et al. 2002). The results from GWR3 contain the β values, the standard errors, and the exponents of these results, all of which are positive, to aid mapping. Because binary GWR works best when there are not many 0 values, localities that do not have variation in the dependent value will not converge. To solve this problem, different bandwidths (or areas of influence) are tested to create a geographic area with enough variation in the dependent variable for the GWR model to perform well. Also, in logistic GWR, each location *i* has its own unique parameter estimates, β_i. To apply GWR to binary, or logistic, models, the model must be fitted using iteratively reweighted least squares. This process does not allow for smoothing, i.e., parameter estimates can only be obtained in the clusters of interest and may not be estimated outside of the areas with data points (Fotheringham, Brunsdon et al. 2002).

In addition to providing a set of local β coefficients for each relationship in the model, GWR3 results also contain a set of standard errors and diagnostics including pseudo r-squared and pseudo-t values at every regression point, i.e., individual (Fotheringham, Brunsdon et al. 2002). The GWR3 files that contain both the parameter estimates and their geographic location are too voluminous for conventional analysis, but they can be imported into a GIS program, such as ArcGIS, and displayed graphically. The results of GWR3 also provide a global model, similar to the population-averaged logistic regression, with parameter estimates, standard errors, and t-values.

The second component of GWR results focuses on the local models, providing a calibration report on the Akaike Information Criterion (AIC) (corrected version) calculated at various bandwidths or areas of influence to show the speed of convergence to find the optimal bandwidth (Charlton, Fotheringham et al. 2006). Similar to the global model results, the results for the local models include: the number of observations, the number of independent variables, specified bandwidth, number of regression points, residual sum of squares, number of parameters, standard errors, the Akaike Information Criterion (corrected), and the coefficient of determination (calculated by comparing predicted and observed values from different models at each regression point) (Charlton, Fotheringham et al. 2006). Increased coefficient of determination and decreased AIC when comparing the global to the local model suggest that the local model may better fit the data (Charlton, Fotheringham et al. 2006). Additional information on the geographically weighted regression software may be found in Fotheringham, 2002 (Fotheringham, Brunsdon et al. 2002).

The GWR3 method determines the optimal bandwidth through a convergence process similar to optimizing the maximum likelihood function in logistic regression. Because of the computational complexity in determining the optimal bandwidth, GWR3 has limitations in the number of observations and variables that may be used in any single spatial regression. Therefore, it will be necessary to run separate analysis for men and women to determine how the associations between area-and individual-level factors with individual HIV status vary in space. Bandwidth selection is optimized for models of men and women separately.

To display the local regression model results and facilitate interpretation, individual regression points are used to predict parameter values over continuous space through interpolation (Childs 2004). Interpolation is a method to create smooth surface maps and allow for the visualization of relationships between data points. Spline interpolation methods use a mathematical function that takes regression points and minimizes the variation between them, passing through known values to create a smooth surface of variability over space (Childs 2004). For this analysis, the ArcGIS Spatial Analyst spline tool is used to interpolate the surface with cell sizes of 1000 meters.

CHAPTER 5

PAPER 1

Title: It's not just *who you are* but *where you live*: exploring area-level influences on individual HIV status in rural Malawi

ABSTRACT

In Malawi, approximately 1 million people are infected with Human Immunodeficiency Virus (HIV). Although HIV rates are decreasing in urban areas, infection rates are increasing among rural populations. Individual-level risk factors play critical roles in the patterns and presence of HIV in Malawi; however, area-level socio-economic and access factors receive less empirical investigation. To fill this gap, this research uses a nationally representative probability sample of rural Malawians linked to spatially-oriented, area-level socio-economic and access data in logistic regression models 1) to reveal relationships between area-level factors and individual HIV status and 2) to determine whether these relationships are mediated by individual risk behaviors. Stratified analysis explores the role of gender. The Political Economy of Health frames interpretation. Area-level socio-economic factors include relative and absolute poverty; access factors include distance to roads, cities, and health clinics. Mediators include condom use, sexually transmitted infections, multiple partnerships, and paid sex. Among women, higher income inequality and proximity to a major road are associated with increased odds of HIV; the negative association between distance to healthcare and HIV status is mediated by individual risk behaviors. For men, proximity to a major road or to a health clinic is associated with increased odds of HIV infection. The study confirms that place matters in the context of HIV in Malawi, and that the influence of these factors differs for men

and women. The greater socio-economic and access environment must be considered for effective HIV prevention efforts in rural Malawi.

INTRODUCTION

In 2007, 2.7 million people worldwide were newly infected with Human Immunodeficiency Virus (HIV) (UNAIDS/WHO 2008). Of new infections in 2007, 68% were in Sub-Saharan Africa, and 61% of people living with HIV in sub-Saharan Africa are women (UNAIDS/WHO 2007). In Malawi, approximately 1 million people are infected with HIV (USAID 2008), and the prevalence rate varies from 6-20% throughout the country with higher rates in urban areas and in the Southern Region (UNAIDS 2007). The majority of Malawians, 80%, live in rural areas where HIV rates are increasing (Bryceson and Fonseca 2006). Individual-level risk factors such as low condom use (Munthali, Zulu et al. 2006) and multiple partnerships (Kaler 2004) play critical roles in the patterns and presence of HIV in Malawi. Macro-level processes receive less empirical investigation. However, area-level influences such as socio-economic factors and access to resources may drive these individual behaviors (Armour 2006; Mtika 2007) and, in turn, individual HIV status. Greater understanding of macro-level influences may be critical to ameliorating the HIV epidemic.

This study aims to reveal the relationships between area-level factors and individual HIV status in rural Malawi and to determine whether these relationships are mediated by individual-level behaviors. The study uses contextual models that adjust for individual demographic factors and explores gender-based interactions. Area-level socio-economics (Gini coefficient of income inequality, poverty headcount of absolute poverty) and access factors (distance to roads, healthcare, and major cities) are explored. Mediators include indicators relevant to HIV transmission such as condom use, multiple partners, previous sexually transmitted infection, and paid sex. This paper aims to answer three questions: 1) Are area-level factors associated with individual HIV status in rural

Malawi? 2) Are these associations mediated by individual behavioral factors? 3) Do these relationships vary by gender?

Previous studies in rural Malawi looked at drivers or effects of HIV but focused mostly on small geographic areas (Barden-O'Fallon, deGraft-Johnson et al. 2004; Hatchett, Kaponda et al. 2004; Watkins 2004; deGraft-Johnson, Paz-Soldan et al. 2005; Helleringer and Kohler 2005; Schatz 2005; Kohler, Behrman et al. 2007) or individual behaviors (Zachariah, Spielmann et al. 2003; Smith and Watkins 2005; Morah 2007). In contrast, this research links data from a nationally-representative probability sample of rural Malawians with area-level, spatially-oriented data on socio-economics and access using Geographic Information Systems (GIS) technology. GIS provides a method for combining data from multiple, geographically-referenced sources into a more comprehensive whole (Richards, Croner et al. 1999). Moreover, this study uses the Political Economy of Health framework to guide conceptualization and understanding of how area-level effects may affect individual behavior, and, in turn, HIV, clarifying interpretation of results. These findings could inform tailored research, policy, and intervention efforts to ameliorate the HIV epidemic in rural Malawi.

BACKGROUND

According to the 2004 Malawi Demographic and Health Survey (MDHS), 10% of men and 13% of women of reproductive age are infected with HIV nationwide (National Statistical Office Malawi and ORC Macro 2005); 56.8% of all infections are among women (UNAIDS 2004). AIDS in Malawi, as in sub-Saharan Africa in general, is transmitted mainly through heterosexual sex, and the epidemic is generalized throughout the population, spreading from southern regions northward (Bello, Chipeta et al. 2006). Although the highest HIV prevalence rates are in major urban areas (PEPFAR 2007), 80% of Malawi's approximately 13 million people live in rural areas (UNICEF 2008) where HIV prevalence appears to be increasing (Bello, Chipeta et al. 2006; Bryceson and Fonseca 2006). The absolute number of infected persons in rural areas outnumbers urban infections by more than 3 to

1 in Malawi (National AIDS Council Malawi 2003; National Statistical Office Malawi and ORC Macro 2005) and by more than 2 to 1 in the 25 African countries with high HIV prevalence (FAO 2008). Increased focus on HIV among rural populations is warranted.

What We Know: Individual-Level Risk Factors

Demographic risk factors such as marital status, gender, age, socio-economic status, and education play key roles in HIV status. Marriage increases a woman's risk of HIV (Glynn, Carael et al. 2003; Nour 2006; Hirsch, Meneses et al. 2007; Smith 2007). In Malawi, women who have never been married are less likely to be infected than currently married women while women who are separated, divorced, or widowed have the greatest risk of infection (National Statistical Office Malawi and ORC Macro 2005). Women under age 24 are more than three times more likely than their male same-age peers to be infected in Malawi (National Statistical Office Malawi and ORC Macro 2005), showing distinct gender and age differences. Although socio-economic status (SES) appears important in the context of HIV infection and risk taking behaviors, the relationship between individual socio-economic status and HIV in sub-Saharan Africa remains unclear (Hargreaves 2002; Wojcicki 2005; Bingenheimer 2007). Previous research notes positive associations between individual SES and HIV risk (Barnighausen, Hosegood et al. 2007; Lopman, Lewis et al. 2007; Mishra, Assche et al. 2007), negative associations between individual SES and HIV risk (Hargreaves 2002) or no effect of individual-level poverty on sexual health behavior or HIV risk (Wojcicki 2005; Dinkelman, Lam et al. 2007). In Malawi, HIV is more prevalent among persons of higher socio-economic status (National Statistical Office Malawi and ORC Macro 2005). Previous studies in sub-Saharan Africa also find differences in the strength and direction of associations between education level and HIV infection (Smith, Nalagoda et al. 1999; Lagarde, Carael et al. 2001; Glynn, Carael et al. 2004; Gavin, Galavotti et al. 2006; Barnighausen, Hosegood et al. 2007). In Malawi, HIV prevalence is higher among men and women with more years of education (National Statistical Office Malawi and ORC Macro 2005).

Behavioral factors that increase risk are well understood. Infrequent or inconsistent condom use and high risk sex (multiple partners, sex with prostitutes) are positively associated with HIV status (Sheeran and Taylor 1999; Van Rossem, Meekers et al. 2001; Giles, Liddell et al. 2005; Bryan, Kagee et al. 2006). Condom use in Malawi is low: in the 2004 MDHS, only 30% of women and 47% of men reported condom use with their last non-spousal/non-regular partner (National Statistical Office Malawi and ORC Macro 2005). In Malawi, men and women may only use condoms with partners when they perceive an increased risk of HIV infection (Chimbiri 2007), and even among men who know they are infected, only 40% reported condom use in a recent study (Morah 2007). Sexually transmitted infections (STI) also increase risk of HIV (Auvert 2001; Glynn, Carael et al. 2001). In Malawi, over 20% of men and women who reported an STI in the previous 12 months were infected with HIV in 2005 (National Statistical Office Malawi and ORC Macro 2005), and a recent study in Lilongwe found that 40% of STI clinic patients tested positive for acute HIV infection (Pilcher, Price et al. 2004). Furthermore, multiple, concurrent sexual partnerships are key determinants in the spread of HIV (Morris and Kretzschmar 1997; Anderson 1999; Shelton, Halperin et al. 2004), and polygyny and extra marital partnerships are common in Malawi (Chimbiri 2007). Although women may engage in multiple partner sex (Kuate-Defo 2004; Tawfik and Watkins 2007), the increased risk of infection from multiple partnerships reflects male behavioral norms (Nnko, Boerma et al. 2004; Chimbiri 2007; Helleringer and Kohler 2007). The circular movement of migrants, both men and women, also plays a role in the transmission and spread of HIV (Zuma, Gouws et al. 2003; Coffee, Garnett et al. 2005; Lurie 2006; Mtika 2007). Prevalence among Malawian men who spend more than one month away is 4% higher than among men who do not migrate (National Statistical Office Malawi and ORC Macro 2005).

Moving Beyond Emphasis on Individuals

There are a number of theories that explain the relationship between individual-level factors, such as knowledge, attitudes, and practices, and HIV risk behaviors (Wilson, Dubley et al. 1991; Basen-Engquist 1992; Adih and Alexander 1999; Volk and Koopman 2001; Agha 2002; Macintyre, Rutenberg et al. 2004; Mashegoane, Moalusi et al. 2004; Hounton, Carabin et al. 2005). Yet, despite 20 years of programmatic and policy effort aimed at changing individual-level risks, HIV continues to spread in sub-Saharan Africa. A focus on individuals may not be sufficient due to other levels of influence on human health and wellbeing, including the physical environment (e.g., geography, road networks, and household building materials) and the social environment (e.g., social ties, poverty, and politics) (Stokols 1992). HIV prevention and interventions must move beyond the individual to a more complex set of economic, social, structural, and cultural factors (Hobfoll 1998; Craddock 2000; Parker, Easton et al. 2000; Parker 2001; Msisha, Kapiga et al. 2008).

Challenges in defining and determining *place*

Where an individual lives matters for overall health and wellness (Mayer 1989; Diez Roux 2001; Dietz 2002; Sampson, Morenoff et al. 2002; Diez Roux 2004; Cummins, Curtis et al. 2007; Entwisle 2007), and research strongly suggests that similar people behave differently in different places (Duncan, Jones et al. 1998). The characteristics of the individuals who live in a specific place and the infrastructure in the local physical and social environment require consideration (Macintyre, Ellaway et al. 2002), including direct and indirect influences (Manski 2000). Although research on neighborhood effects is growing, “place-based” or “neighborhood-level” effects are complicated concepts to measure due, in large part, to divergent definitions of “neighborhoods” (Kawachi and Berkman 2003; O'Campo 2003). As a result, geographically-based definitions of *place*, *community,* or *area*, including those associated with census tracks or service proximity, allow for the examination of macro-level influences and have been used effectively to study place-based effects on health (Macintyre, Ellaway et al. 2002), AIDS mortality (Blacker 2004), and genetics (Fisher 2008). For the purposes of this study, *area-level* is defined as the aggregate enumeration area, a census-defined boundary of approximately 500 households.

The Importance of Ecological Factors on Health

Although ecological-level theory is not as developed as individual-level theory, the Political Economy of Health (PEH) applies a multi-level lens to clarify how macro-level factors influence individual behaviors and outcomes. The PEH emphasizes how history, development and persistence of structural inequalities based on class, ethnicity, race, or gender fosters economic deprivation, social isolation, inequitable power structures, and inadequate healthcare, especially among the poor and vulnerable (Altman 1999; Farmer 1999; Krieger 1999; Parker, Easton et al. 2000; Krieger 2001; Parker 2001; Lindgren, Rankin et al. 2005; Hunter 2007). The PEH draws attention to how the social and economic environment limits individual choice, constrains behavior, and restricts one's ability to make positive health decisions (Minkler, Wallace et al. 1994; Minkler 1999), thus rejecting the placement of blame solely on individuals for their poor health (Doyal and Pennell 1979; Doyal 1995; Farmer 2003; Farmer, Nizeye et al. 2006; Ruger and Kim 2006; Loewenson 2007). Individual HIV risk behaviors should be considered within a greater socio-economic context (Baylies 2000; Fenton 2004). Applying the PEH to the HIV/AIDS epidemic in sub-Saharan Africa may illuminate linkages between individual behavior and the socio-economics of the places where they live (Altman 1999; Whiteside and De Waal 2004; Lindgren, Rankin et al. 2005; Farmer, Nizeye et al. 2006; Hunter 2007; Mtika 2007; Parikh 2007).

The Behavioral Link: How Ecological Factors Affect Individual Health

Although the PEH framework does not specify constructs, ecological factors that facilitate inequity, including economic underdevelopment, mobility, and power differentials by class and gender, influence how individuals behave and make choices (Parker, Easton et al. 2000; Wellings, Collumbien et al. 2006). Poverty, economic inequality, and access may be critical drivers of HIV in rural Malawi.

Poverty is one of the most influential ecological risk factors for poor health (Minkler 1999; Krieger 2001), and both absolute and relative poverty affect health status (Kawachi and Kennedy 1997; Soobader and LeClere 1999). Yet, poverty is a difficult concept to measure (Wojcicki 2005; Coudouel 2008), and the relationships between poverty and health at the ecological level are complex. HIV is not directly caused by poverty, but AIDS and poverty are mutually reinforcing (Gillies, Tolley et al. 1996; Craddock 2000; Mosley 2004; Freedman and Poku 2005; Kalichman, Simbayi et al. 2006; Masanjala 2007). HIV affects individuals in their most economically productive years, reducing incomes and livelihood opportunities across households and communities (FAO 2003; Heuveline 2004; Mather, Donovan et al. 2005). Communities characterized by poverty may not offer positive social environments for health (Campbell and Jovchelovitch 2000), and poverty exacerbates the impact of AIDS in already vulnerable areas (Gillespie, Kadiyala et al. 2007). In addition to absolute poverty, relative economic deprivation matters. In areas where income inequality reflects social class divisions, the distribution of wealth is likely related to health outcomes (Wilkinson and Pickett 2006). Income inequality is linked to increased risk for sexually transmitted infections (Holtgrave and Crosby 2003) and concurrent sexual partnerships (Adimora and Schoenbach 2002), and countries with higher levels of income inequality are among those with higher HIV prevalence (Fenton 2004). The effects of income inequality on health are most likely indirect (Coburn 2000; Mackenbach 2002): decreased trust, lack of social cohesion, and fewer social ties in areas of higher income inequality may have negative effects on health (Kawachi and Kennedy 1997;

Kawachi and Berkman 2000). In Malawi, both absolute poverty and income inequality are evident. In 2000, 67% of rural populations were below the poverty line (National Economic Council Malawi 2000). The country-level Gini coefficient of 0.38 indicates relatively high overall income inequality, and the percent living below the poverty line remained stable at 54% from 1997-2005 (World Bank 2008). Consideration of both absolute and relative poverty is advantageous over research that uses singular measures (Kawachi and Kennedy 1999).

In Malawi, rural areas are largely characterized by limited physical, economic, and social infrastructure (Bryceson and Fonseca 2006). Inequity in resource and service distribution negatively impacts individual health behaviors and outcomes (Minkler and Cole 1992; Minkler, Wallace et al. 1994; Doyal 1995; Doyal 2001; Phelan, Link et al. 2004). Access to treatment and care reflects disparities in social and economic systems (Doyal and Pennell 1979), and healthcare resources (Ruger and Kim 2006; Tanser, Gijsbertsen et al. 2006; Loewenson 2007) including HIV prevention and treatment centers (Nuwaha, Kabatesi et al. 2002; Muula 2004; Hardon 2005) are unevenly distributed in much of sub-Saharan Africa. Women (Parker, Easton et al. 2000; Loewenson 2007) and rural residents (UNAIDS 2008) generally fare worse in health service availability than men or urban counterparts. Roads also serve as an access indicator. Markets, livelihood opportunities, and services are associated with road quality (Smith, Gordon et al. 2001), and distance to roads may be a proxy for mobility (Greig and Koopman 2003), a factor known to be associated with HIV (Tanser, Lesueur et al. 2000; Doyal 2001). Access to urban areas is also associated with increased risk of HIV transmission (Girdler-Brown 1998; Gabrysch, Edwards et al. 2008) in part because urban transit areas facilitate risk behaviors such as multiple partnerships and prostitution (Chirwa 1997). To measure the role of access on HIV risk behaviors, and in turn HIV, area-level proximity to health services, roads, and urban areas are explored.

The differential effect of gender

Both the PEH and the Theory of Gender and Power, developed by Connell in 1987, recognize that gender relations, social norms of masculinity and femininity, and economic power directly relate to adverse health outcomes among women (Connell 1987; Wingood and DiClemente 2000). Biological risk factors (Blocker and Cohen 2000; Glynn, Carael et al. 2001; UNICEF 2002; Quinn and Overbaugh 2005; Lamptey, Johnson et al. 2006), exacerbated by gender inequity and power differentials that limit women's decision making (Craddock 2000; Ghosh and Kalipeni 2005; Luke 2005), partially explain the disproportionate rates of HIV among women across much of sub-Saharan Africa (Luke 2003; Kim and Watts 2005; Quinn and Overbaugh 2005; Wellings, Collumbien et al. 2006; Sa and Larsen 2007), including Malawi (Kathewera-Banda 2005). Women *embody* social discrimination, economic disadvantage, and inequality (Krieger 1999; Krieger 2005), forcing engagement in risky survival behaviors and coping livelihood strategies (Masanjala 2007) including dependence on sexual relationships for financial support (Gregson, Nyamukapa et al. 2002; Gupta 2002; Luke and Kurz 2002; Kelly, Gray et al. 2003; Luke 2006). The intersections of socio-economics and gender produce an irony that women's short-term survival tactics may lead to HIV infection (Craddock 2000).

The drivers of HIV among men also merit special attention since men control many decisions and HIV risk behaviors (Maman, Campbell et al. 2000; Mane and Aggleton 2001), especially with younger partners (Sayles, Pettifor et al. 2006). Social ideals around masculinity are achieved by men controlling women (Chirwa 1997; Kumar, Gupta et al. 2002; Hunter 2005), and men have greater access to employment, money, and power than women (Gupta Rao 2002). In rural Malawi, traditional marriage gifts symbolize a man's affection and commitment, but also claim a wife as sexual territory (Chirwa 1997). Male status and virility may be equated with multiple partners and not using condoms (Kaler 2003).

STUDY DESIGN AND METHODS

Although previous studies note the importance of area-level influences on individual HIV status (Zierler and Krieger 1997; Craddock 2000; Gould 2005; Villarreal 2006; Hunter 2007), there is a paucity of empirical research that explores these relationships at both the area- and individual-level or that reveals the mechanisms by which area-level factors affect individual HIV status. To address these gaps, this paper examines whether area-level socio-economic and access factors influence individual HIV status in rural Malawi and whether these factors operate through individual-level behaviors. The differential effects of gender on these associations are also considered, further addressing gaps in knowledge.

Conceptual Model

Informed by the PEH framework (Figure 5.1), it is hypothesized that:

- Persons from areas of higher poverty and higher income inequality will be *more* likely to be HIV infected than their peers from areas with better socio-economic indicators. Persons with greater access to roads and cities will also be *more* likely to be HIV infected than their peers with less access. However, those with greater access to healthcare services will be *less* likely to be infected than their peers with lower access to healthcare.
- Persons from areas of higher poverty and higher income inequality as well as those with greater access to roads, and cities will be *more* likely to engage in risky behavior, and therefore, *more* likely to be HIV infected than their peers. Persons with greater access to healthcare services will be *less* likely to engage in risky behavior and, therefore, *less* likely to be infected with HIV than their peers.

- Relationships will differ for men and women: the associations between area-level factors, individual behaviors, and HIV status will appear stronger for women than for men.

DATA and MEASURES

Individual-Level

All individual-level data and variables, including the HIV and GPS components, come from the Malawi Demographic and Health Survey, 2004 (MDHS). The standard DHS survey methodology is available from ORC Macro (ORC Macro 1996). The MDHS uses the master sample frame from the Malawi 1998 census, and enumeration areas serve as primary sampling units for stage one of the two-stage clustered sampling design (National Statistical Office Malawi and ORC Macro 2005). To reach the target of approximately 15,000 households, 522 clusters were randomly selected, 64 in urban and 458 in rural areas, and approximately 29 households were systematically sampled from those clusters (National Statistical Office Malawi and ORC Macro 2005). In every selected household, all women, ages 15-49, who usually lived in the household were eligible for interview. In every third selected household, all men, ages 15-54 years, who usually lived in the household were eligible for interview. For the 2004 MDHS individual interview, the response rate was 96% among rural women and 87% among rural men (National Statistical Office Malawi and ORC Macro 2005).

All households selected for the male questionnaire were also selected for the HIV test, and all women age 15-49 and all men age 15-54 were eligible for HIV testing. Of 4,071 women and 3,797 men eligible for the HIV test; 2,686 women and 2,581 men accepted, an overall response rate of 70% for women and 63% for men. Of those tested, 2,485 women (response rate 71%) and 2,056 men (response rate 65%) were rural residents (National Statistical Office Malawi and ORC Macro 2005). An analysis of bias caused by non response on overall population-level HIV estimates in the MDHS was not significant (Mishra, Barrere et al. 2008).

Due to problems with the urban Lilongwe sample response rates in the MDHS (National Statistical Office Malawi and ORC Macro 2005) and the availability of area-level data for only rural populations, the study population is restricted to rural residents, both men and women, who accepted HIV testing. The sample is further restricted to those who have sexually debuted and are at risk of HIV through sexual transmission, enabling analysis of risk behavior as well as reducing inclusion of those infected with HIV at infancy or through other transmission routes. Thus, the study population for this contextual analysis includes 2,091 women and 1, 827 men.

The MDHS collected detailed information on myriad subject areas including fertility, sexual health, nutrition, and children's health (Aliaga and Ren 2006). Interviewers received extensive training, and appropriate consent procedures were approved by internal review boards in Malawi and the USA. Voluntary HIV testing was conducted as part of the 2004 MDHS using dried blood spots. Dried blood was tested using a standard protocol (ORC Macro 2005; MEASURE DHS 2008). Tests were coded for confidentiality, and no results were provided. Referrals to free testing sites were offered (National Statistical Office Malawi and ORC Macro 2005). The 2004 MDHS also collected Global Positioning System (GPS) data for all selected clusters, and correct geographic coordinates are available for 456 rural clusters (Montana and Spencer 2004). To protect confidentiality, clusters were offset by up to 5km (Montana and Spencer 2004).

Individual-level variables are listed in Table 5.1. The dependent variable is a binary measure of individual HIV status, positive or negative. Variables with known associations with HIV are included as controls in multivariate models, including ethnicity, religion, marital status, region, socio-economic status, education, and age as well as migration and circumcision for men.

Several variables require elaboration. The variable for individual SES is a wealth index developed by DHS with the World Bank and integrated into all DHS datasets (Rutstein 1999; Rutstein and Johnson 2004). This index incorporates ownership of household assets (e.g., bicycle, car, television), housing characteristics, and infrastructure (water and sanitation facilities). In Malawi, the full sample was divided into equal population wealth quintiles (National Statistical Office Malawi and ORC Macro 2005; Vyas and Kumaranayake 2006).

The mediator measure, individual risk score, also requires additional information. The MDHS asks several questions to ascertain risk for sexually transmitted infections (STI), including: the number of, and relationship with, sexual partners within the last year; condom use with the last three sexual partners; previous STI or symptoms of STI; and, for men only, whether they paid for sex in the last year. In this study, individual risk score is a continuous measure of increasing HIV risk behavior based on previous summary measures of risky behavior (Biglan, Metzler et al. 1990; Rosenthal, Moore et al. 1991; Dutra, Miller et al. 1999; Jemmott, Jemmott et al. 1999).

Although *lack* of condom use is a known risk factor for HIV, for the purposes of this summary risk score, condom *use* is indicative of risky behavior and requires elucidation. In Malawi, condoms are perceived principally for use outside marriage or stable partnerships, and condom use is generally associated with fear of disease, lack of trust, multiple partnerships, or commercial sex work (Schatz 2005; Chimbiri 2007; Poulin 2007). Although unmarried men may use condoms for both disease and pregnancy prevention, married men use condoms predominantly for disease prevention with extramarital partners while women use condoms when they fear infection from their partners, marital or otherwise (Chimbiri 2007). Other studies confirm that condom use may reflect a high level of perceived susceptibility to HIV (Adih and Alexander 1999; Pranitha and Cleland 2005) or higher risk behaviors (Mnyika, Klepp et al. 1997; Sa and Larsen 2007). Therefore, condom use with a recent sex partner, spouse or otherwise, is considered a risk factor in this context.

To create the mediator, each risk factor (2 or more non-marital partners in last year; condom use with a recent partner; previous STI; paid sex), is given 1 point, assigning final scores of 0-3 for women and 0-4 for men. Higher risk scores indicate increasing risk.

Area-Level

A summary of area-level variables is included in Table 5.1. The area-level socio-economic data come from the Poverty Mapping Project at Columbia University (Columbia University 2008) completed in 2004-2005 with support from the World Bank. In Malawi, the Poverty Mapping Project produced spatially-oriented socio-economic data only for rural populations; no information is available for residents of major urban centers, including Blantyre, Lilongwe, and Mzuzu. The poverty mapping methods utilized to create small area estimates of welfare and poverty are highly complex. Detailed methodology is available from Elbers, Lanjouw, and Lanjouw (Elbers, Lanjouw et al. 2003). Malawi specific information is available from the International Food Policy Research Institute (Benson 2002; Benson, Chamberlin et al. 2005). Spatial units for the Malawi poverty mapping exercise are rural aggregated enumeration areas (EA) devised by the National Statistical Office of Malawi for the 1998 National Population and Housing Census, the same sampling frame utilized by the MDHS. In Malawi, each spatial unit for the poverty mapping exercise aggregates approximately 2 or 3 EAs from the census, including a minimum of 500 households. The complete poverty mapping dataset for Malawi includes 20 socio-economic measures, including Gini coefficient and poverty headcount, for each of 3004 rural aggregate EAs linked to GIS shapefiles (Benson 2002; Benson, Kanyanda et al. 2002).

Area-level socio-economics are measured using area-level Gini index and poverty headcount. The Gini index is a measurement of income inequality in a given area (Wilkinson and Pickett 2006; Coudouel 2008). Gini may illuminate the influence of economic disparities on health (Lindstrom and Lindstrom 2006). Poverty headcount is the percent of the population whose income is below the poverty line (Coudouel 2008), a valid measure of economic deprivation (Krieger 2003). Using both is an improvement over singular measures (Robert 1999; Benson, Chamberlin et al. 2005). High Gini and middle Gini variables were created by sorting all enumeration areas by Gini coefficient, from low (greater equality) to high (greater inequality). Equal quartiles were created, and each quartile was assigned a rank from 1-4, assigning “1” to the 25% of enumeration areas in the lowest quartile (highest equality); “2” to the lower middle quartile; “3” to the higher middle quartile; and “4” to the highest quartile (highest inequality). In the analysis, group “1”, lowest Gini, serves as the reference for middle Gini (groups 2-3) and group “4”, high Gini.

The three variables used to measure access at the area level (distance to a major urban area, distance to a major road, and distance to a Ministry of Health clinic) were derived from existing GIS maps of Malawi. Using accepted spatial methods, ArcGIS software was utilized to determine the Euclidean distance in kilometers between each DHS cluster point and the factor of interest. The road network variables were created using GIS road files created for the 1998 census and supported through funding by the Danish International Development Agency (DANIDA). The Ministry of Health facility location data come from a Japanese International Cooperation Agency study from 1997-2002 and improved through cooperation from the World Health Organization. The Ministry of Health (MOH) facilities database includes geographic coordinates for all MOH clinics operating in 2002. The data for proximity to a major city (Mzuzu, Lilongwe, Blantyre) is derived from digital maps produced for the national census and available from the National Statistics Office in Zomba, Malawi.

Combining Individual- and Area-level Variables

Data sources were combined using GIS software, ArcGIS (ESRI 2008). Assigning individuals their area effects required several steps. Every MDHS cluster has a geographic location allowing the correct placement of each cluster on the digital map. This DHS cluster information was spatially joined to the poverty and access geo-datasets, allowing for the visualization and utilization of all sources simultaneously. Through this process, each DHS cluster was assigned the poverty and access information of its aggregate EA. The distance from each DHS cluster to a major road, health facility, and major urban area was determined using the distance calculation features in ArcGIS software. The complete database of DHS clusters with area-level attributes was exported into a file for use in STATA 9.2. Area-level factors were one-to-many merged with the individual level data (including HIV) in STATA, assigning the same area-level variables to every individual within each cluster. All other individual level information remains unique.

DATA ANALYSIS

To address the nesting of individuals within clusters and employ sampling weights, complex survey data analysis is conducted using STATA 9.2 (STATA 2007), and standard errors are corrected for both the clustered survey design and analysis of subpopulations[1]. As the primary outcome variable is dichotomous, multivariate logistic regression models are utilized. In bivariate analysis, significance of variables is measured by z tests. In multivariate logistic models, single variables are tested using z tests; joint significance is tested by adjusted Wald chi-square. Pearson chi-square tests for differences in proportions. Marginal effects for significant independent variables are calculated using the average of the probabilities method, simulating the average effect of a change in an independent variable with other variables held at their mean. Tests of multicollinearity in full male and female models reveal variance inflation factors of 1.55 for men and 1.53 for women, indicating low multicollinearity.

Mediation analysis is conducted using steps proposed by Barron and Kenny (Baron 1986). To determine whether area-level factors are associated with the continuous mediator, individual risk score, linear regression models will be used with t-tests of significance. Mediation by individual risk score is assessed in 5 separate mediation models for men and women that include one area-level

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[1] Although multi-level models are an increasingly-preferred analytical technique for data at multiple levels, they are not the best fit for this data. First, sampling weights are not available for all data levels, negating the ability to accurately adjust the estimates for the different probabilities of selection for the 2-stage clustered sampling design. Second, the MDHS is not designed for intra-cluster analysis; cluster sizes from one-12 observations are too small for reliable estimates of within cluster variation. Lastly, most multilevel modeling techniques do not correctly adjust standard errors in analysis of subsamples.

factor, the individual-level HIV risk score, and demographic controls. Formal tests of mediated effects are assessed using the difference in coefficients method after standardizing the regression parameters (Sobel 1982). The moderating effects of gender are explored through stratified analysis and qualitative comparison of the results.

RESULTS

Descriptive statistics

Sample characteristics, by gender, are detailed in Table 5.2. Levels of individual risk behavior differ for men and women. While 7% of women had more than one partner in the last year, 24% of men had multiple sexual partners in the same timeframe ($p<.01$). Among those who have sex, 4% of women and 14% of men used a condom with a recent sex partners ($p<.01$). Ten percent of women and 6% of men ($p<.01$) had a sexually transmitted infection in the previous 12 months. Among men, 22% had ever paid for sex. Although comparison is inexact as male respondents may report up to 4 risk behaviors while women may report only 3, the summary score of individual risk behavior suggests differences between men and women. Among women, 83% report no risky behaviors as compared to 57% of men reporting no risk ($p<.01$). Among women, 3% reported two or more risk behaviors; 16 % of men reported similarly ($p<.01$). No men received an individual risk score of “4.”

As expected, area-level factors are similar between women and men. For the area in which they live, the average poverty percent (percent of residents under the poverty line) is 65% for both men and women. On average, men and women live the same distance from a major city (73km), major road (11km), and MOH clinic (5km). Approximately 50% of women and men live in areas of middle income inequality while 24% of men and 28% of women live in an area of higher income inequality.

Associations between area-level factors and individual-level HIV status

Bivariate logistic regression models reveal associations between key area- and individual-level variables and HIV status by gender (Table 5.3). Among women, the odds of infection increase with age (OR 1.03, p<.01 [1.01 - 1.04]). Previously married women are more likely to be infected than currently married women (OR 2.30, p<.01 [1.70 – 3.10]. Faith is also significantly associated with HIV status: Muslim women are more likely to be infected than women of other faiths (OR 1.54, p<.05 [1.06 - 2.24]). Women who identify as Lomwe (OR 1.52, p<.05 [1.07 - 2.15]) or Yao (OR 1.45, p<.1 [0.99 - 2.1]) are more likely infected while Chewa (OR 0.52, p<.01 [0.35 - 0.78]) are less likely infected in comparison to all other ethnic groups. In comparison to women in the south, women in the north (OR 0.26, p<.01 [0.14 - 0.48]) or central (OR 0.34, p<.01 [0.24 - 0.49]) are less likely to be infected. Wealthier women are more likely to be infected than poorer peers (OR 1.18, p<.01 [1.06 - 1.33]). Education is not associated with HIV status among women.

For behavioral factors, women with multiple, non-union partners in the last year (OR 1.81, p<.05 [1.14 - 2.9]); STIs (OR 1.98, p<.01 [1.34 - 2.92]); or any condom use with a recent sex partner (OR 1.90, p<.05 [1.07-3.38]) are more likely to be infected than women without these risk factors. Overall, women with higher HIV risk scores are more likely to be infected than those with lower risk scores (OR 1.63, p<.01 [1.29 - 2.07]).

Among area-level factors, bivariate analysis demonstrates that women in areas of highest income inequality have increased odds of infection (OR 1.85, p<.01 [1.15- 2.96]) compared to women in areas of low income inequality. Also, the odds of HIV infection decrease slightly with increasing distance from either a major road (OR 0.98, p<.05 [0.96 -1.00]) or a MOH clinic (OR 0.89, p<.01 [0.84 - 0.95]). There is no association between HIV status and either area-level distance to major city or percent poor.

For men, bivariate associations show that age is also positively associated with HIV status (OR 1.05, p<.01 [1.03 - 1.06]). Never married men are less likely to be infected (OR 0.09, p<.01

[0.04 - 0.23]) in comparison to married men. Among ethnic groups, Chewa are significantly less likely to be infected (OR 0.38, p<.01 [0.22 - 0.65]) while Lomwe are more likely to be infected (OR 1.86, p<.01, [1.19 - 2.91]) in comparison to all other ethnic groups. The likelihood of HIV infection decreases in the north (OR 0.22, p<.01 [0.11- 0.44]) and central (OR 0.31, p<.01 [0.19- 0.50]) in comparison to the south. Like females, men in higher wealth categories are more likely to be infected than poorer men (OR 1.4, p<.01 [1.18 - 1.65]). Unexpectedly, circumcised men are more likely to be infected that their uncircumcised peers (OR 1.5, p<.05 [0.99 - 2.37]). Men with primary education are less likely to be infected than men with higher education (OR 0.65, p<.1 [0.41- 1.04]). Migration and religion are not associated with HIV status for men.

Behavioral factors are also significant. Among individual risk factors, men who had a STI (OR 1.98, p<.05 [1.04 - 3.76]) or paid for sex (1.45, p<.1 [0.98 - 2.16]) are more likely to be HIV positive than men who do not engage in these behaviors, However, men who have multiple partners have lower odds of infection (OR 0.61, p<.1 [0.376 - 0.99]) than men who report one or no sexual partners. Recent condom use is not significantly associated with HIV status. Likely due to the divergent, and unexpected, relationships between component parts and HIV status, individual risk score is not significantly associated with HIV status among men.

In bivariate analysis of area-level factors for men, only distance to MOH clinic is significantly associated with HIV status: men who live further from clinics are less likely to be infected than men who live closer (OR 0.89, p<.01 [0.82 - 0.96]). All other area-level factors are not significantly associated with HIV status for men.

Multivariate analysis

Table 5.4, columns 2 and 4, shows the results from multivariate models of HIV status that include one area-level factor and all individual-level demographic controls for men and women. Individual risk index is included in the models in column 3 and 5. For women, area-level socio-economic and access factors are associated with individual HIV status over and above the contribution of individual-level demographic factors (Table 5.4, Column 2). Women who live in areas of higher income inequality (Gini in the highest 25th percentile or above) have increased odds of HIV infection (OR .1.56, p<.01 [1.0 – 2.41]) in comparison to women in areas of lowest income inequality. Moreover, women who live further from a major road (OR 0.98, p<.01 [0.96 - 0.99]) or further from a MOH clinic (OR 0.93, p<.05 [0.88 - 0.99]) are less likely to be infected than women who live closer to a major road or to a clinic.

Among men (Table 5.4, Column 4), area-level access factors are independently associated with individual HIV status over and above the contribution of individual demographic characteristics. Men who live further from a major road (OR 0.98, p<.1 [0.96 -1.00]) or further from a MOH clinic (OR 0.92, p<.05 [0.85 – 1.00]) are less likely to be infected than men who live closer.

Predicted probabilities illustrate the independent effects of a change in a significant area-level factor on the probability of HIV infection for an average person, keeping all other demographic and behavioral factors at their means (Figure 5.2). For an average women, the probability of HIV infection increases by 5.0 percentage points moving from an area of lower income inequality to an area of high income inequality. The incremental effect of an increase in 10 km from a MOH clinic decreases the probability of HIV infection for women by 5.2 percentage points. Also, among women, every additional 10 km in distance from a major road decreases the probability of HIV infection by 2.5 percentage points. Among men, living 10km further from a MOH clinic decreases the probability of HIV infection by 4.4 percentage points while 10km further from a major road reduces the probability of infection by 1.5 percentage points.

Mediation

To determine whether individual behaviors mediate relationships between area-level factors and individual HIV status, 4 criteria must be met: 1) area-level factors must be associated with individual HIV status; 2) area-level factors must be associated with individual HIV risk score; 3) individual HIV risk score must be associated with individual HIV status; and, 4) area-level factors must no longer be associated with individual HIV status with individual HIV risk score included in the model. Criteria 4 will also allow for partial mediation (Frazier, Tix et al. 2004) measured by a 10% attenuation in the main effect with the addition of the mediator.

Table 5.4, columns 2 and 4, shows the associations between area-level factors and HIV that satisfy step 1. To satisfy the second step, area-level factors must be significantly associated with the continuous mediator (Table 5.5). Among women, both kilometers to MOH clinic (β= -0.012, p<.01 [-0.02- -0.003]) and kilometers to major city (β= -0.001, p<.1 [0.001- - 0.0001]) are significantly and negatively associated with the mediator. No other area-level factor is significantly associated with HIV risk score among women. Among men, kilometers to major city is negatively associated with risk behavior (β= -0.002, p<.05 [-0.003 - .0003]). No other area-level factor is significantly associated with HIV risk score among men.

Completing the third step (Table 5.6), individual risk score is significantly associated with increased odds of HIV infection for women (OR 1.86, p<.01 [1.39 - 2.48]) but not for men (OR 1.23 [0.96 - 1.59]). Mediation is explored further only for women.

For the fourth step (Table 5.4, Columns 3 and 5), area-level adjusted odds ratios and significant associations remain largely unchanged with the addition of individual risk score, controlling for demographic factors. Among women, the positive association between higher income inequality and higher risk of HIV increases by 0.02. The negative association between Km to major road and HIV remains unchanged. The odds ratio for Km to MOH increases by approximately 0.01, controlling for individual risk score. The individual risk score is significant in all models: an increase in risk score is associated with a 1.8 increase in the odds of infection.

Following the steps of Barron and Kenny, only the relationships between Km to MOH, individual risk behavior, and individual HIV status among women satisfies the steps for mediation.

Using the Sobel test (Sobel 1982), mediation is significant at the $p<.05$ level. These relationships are displayed in Figures 5.3 and 5.4. Among men, individual risk behavior is not a mediator between any area-level factor and individual HIV status.

DISCUSSION

As forecast by the PEH, area-level socio-economic and access factors have a significant influence on individual HIV status above the contribution of individual-level demographic and behavioral factors, and these factors differ by gender. Income inequality has a significant, and direct, influence on HIV status only for women while distance to a major road and a MOH clinic are significant for both men and women. For the most part, however, these effects are not mediated by the considered HIV risk behaviors, including condom use, multiple partnerships, STI, and paid sex. Although a direct effect is evident, area-level factors cannot *cause* HIV, and the mechanism by which these area-level factors affect HIV remain largely unidentified. The PEH framework aids interpretation of these results.

Among women, income inequality is an important driver of HIV infection, affirming study hypotheses. In multivariate analysis, women in areas of higher income inequality are significantly more likely to be infected than women in middle or low income inequality areas. These influences are not mediated by the considered individual risk behaviors. The PEH clarifies interpretation and offers guidance on potential mechanisms to link area-level income inequality with HIV status among women.

According to the PEH, factors external to the individual, such as inequity, poverty, and discrimination, may create a “risk environment” that increases vulnerability to HIV infection (Parker, Easton et al. 2000; Rhodes, Singer et al. 2005) through the creation of social, emotional, and physical facilitators of HIV risk behavior (Farmer 1999; Farmer, Nizeye et al. 2006). Areas of higher income inequality may produce more social unrest (Kawachi and Kennedy 1999), potentially increasing power differentials by economic status or gender and creating an impetus for risk behavior. For women, the dual influences of poor economic circumstances and low relationship power may have deleterious effects. Women may turn to sexual relationships for financial support (Meekers and Calves 1997; Ghosh and Kalipeni 2005; Kathewera-Banda 2005; Dunkle, Jewkes et al. 2007; Poulin 2007; Swidler and Watkins 2007), but in sub-Saharan Africa (Maman, Campbell et al. 2000; Pettifor, Measham et al. 2004; Manuel 2005) and in Malawi (Ghosh and Kalipeni 2005; Schatz 2005; Chimbiri 2007), proposing condom use implies a lack of trust and defies traditional gender norms, limiting women's ability to protect against HIV infection.

Income inequality may also influence HIV transmission by making women choose between an immediate risk (violence and loss of financial assistance) or long-term consequence (HIV/AIDS) (Maman, Campbell et al. 2000; Luke and Kurz 2002). A recent study in Moshi, Tanzania determined that individual behaviors such as multiple partnerships and condom use explained only a fraction of women's HIV risk in comparison to the explanatory power of associations between gender inequity, sexual violence and HIV (Sa and Larsen 2007). Proposing that the effect of income inequality on HIV status operates through gender-based power or violence, instead of the hypothesized pathway through individual risk behavior, is plausible. In Malawi, 30% of married women reported abuse of some kind by their husband/partner and almost 80% reported at least one controlling behavior by their husbands including limiting exposure to friends/family, accusations of infidelity, or not trusting her with money (National Statistical Office Malawi and ORC Macro 2005). Sexual violence and relationship power warrant exploration as possible mediators between area-level effects and risk behaviors for women.

There are similarities in relationships between area-level influences and HIV risk for men and women. First, as expected, increasing distance from a major road is directly associated with decreasing odds of HIV for women and men above and beyond the contribution of individual-level demographic and behavioral factors. As alluded to in the PEH, this finding signifies that lack of access, or remoteness, may be protective against HIV infection. Greater distances or cost of travel in more isolated locations may prohibit travel and reduce mobility (Porter 2002), thereby reducing behavioral risks associated with these activities in Malawi (Mtika 2007). However, despite hypotheses linking access to HIV through risk behaviors, the relationship between road access and HIV status is not mediated by the considered individual risk behaviors for men or women. For men, migration presents a plausible explanation of the link between road access and HIV. Of rural men in Malawi, 12% reported spending more than one month away from home in 2005 (National Statistical Office Malawi and ORC Macro 2005). However, post hoc analyses of migration as a mediator between area-level access to roads and HIV status in models with and without behavioral controls indicate no significant mediation. Previous migration experiences and frequent trips of shorter duration are not included in the MDHS, and questions about migration are not asked of women, potentially missing key indicators of access and mobility. Determination of the causal mechanism between distance to roads and HIV status requires further elucidation.

Second, and in contrast to the stated hypotheses, distance to a MOH clinic is negatively associated with HIV status for both men and women: those who live closer to a MOH clinic have greater odds of infection than those who live further away. Among women, this relationship is mediated by individual risk behaviors: women who live closer to MOH clinics are more likely to engage in risky behaviors and, therefore, are more likely to be infected with HIV than women who live further from MOH clinics. These relationships are unexpected and contradict previous research. A recent study of community-level influences on men's extramarital sex in Zambia found that health worker activity is associated with a decrease in extramarital sex among men (Benefo 2008) indicating that proximity to healthcare is protective against risky behavior. Another study from Zambia found that proximity to health centers was protective against sexual risk behaviors among young women, adjusting for individual-level behaviors (Gabrysch, Edwards et al. 2008). Therefore, explanation of the direct and mediated effects of distance to MOH requires caution. First, sicker people could select to live near clinics, especially if the clinics provide HIV-related services, causing a spurious association. Second, clinics are likely located in market centers, making distance to MOH a potential proxy for access to smaller commercial center, a place where men and women may meet extramarital partners (Swidler 2007). These potential reasons cannot be investigated in the current study.

Additional associations among men are puzzling. Unlike women, the composite mediator, individual risk score, is not independently associated with HIV status for men. This lack of correlation is likely due to the effect of *unexpected* and negative relationships between both condom use and multiple partners with HIV in combination with *expected* and positive relationships between paid sex and previous STI with HIV status. The four components of the mediator variable may effectively cancel each other, removing any significant association. Even so, in post hoc analysis examining the role of paid sex and previous STI as independent mediators in the relationship between area-level factors and HIV status for men, no significant mediation was identified.

Gender hierarchies provide a layer of explanation for these results, affirming the linkages between power differentials and HIV suggested by the PEH. Societal and relationship power may allow men to better buffer the negative effects of area-level factors through control over individual-level factors (Craddock 2000). Men have lower risk of HIV transmission per sex act than women (UNICEF 2002; Lamptey, Johnson et al. 2006), and men hold almost exclusive decision-making power in sexual relationships (Blanc 2001; Luke and Kurz 2002; Dunkle, Jewkes et al. 2004; Pettifor, Measham et al. 2004; Dunkle, Jewkes et al. 2006). As a result, men generally control partner selection and condom use, reducing their odds of infection. Again, the lack of mediation by individual risk behaviors is unexpected, calling attention for the need of additional research into the pathways between area-level influences and HIV status for men and women.

Socio-cultural factors provide additional insight into the direct relationships between area-level factors and HIV status. Demographic factors, including ethnicity and religion, are significant predictors of HIV status among rural Malawians in bivariate models, demonstrating possible religious or cultural factors that influence risk. Among men and women, living further from major roads decreases the odds of infection in comparison to those who live closer to major roads, possibly due to the strength of cultural norms or practices in more remote locations (Posner 2004). The significance of ethnicity is also telling: Chewa women and men are less likely to be infected than other ethnic groups. As Chewa society is matrilineal (Benson, Chamberlin et al. 2005), it is possible that women from this ethnic group hold more power over their sexual and social relationships, decreasing the risks among both genders. Other ethnic groups, such as Lomwe or Yao, have higher rates of infection (National Statistical Office Malawi and ORC Macro 2005), possibly indicating the role of traditional practices on HIV risk. Study of cultural practices and rituals that might influence HIV status would provide context for these possible explanations.

The results of this study affirm that area-level factors contribute to the spread of HIV in rural Malawi and that these effects differ by gender. In response, interventions should consider disparities in area-level socio-economics and access, as well as gendered-power differentials, to be effective. Two community-level programmatic strategies show promise. First, building social capital and increasing social support may buffer the negative influences of socio-economic disparities on health (Kawachi and Kennedy 1997; Kawachi and Berkman 2000; Holtgrave and Crosby 2003), and this finding may apply in the context of HIV. Among men, a recent study in Zambia found that social disorganization increases the likelihood of risk behavior (Benefo 2008), implying that improved social cohesion may reduce risk taking. Strengthening social support could prove beneficial for women as well. Programs aimed at encouraging positive behavior change through increasing women's access to both social and economic capital demonstrate that easing gender and economic disparities may reduce risk behaviors (Pronyk, Harpham et al. 2008; Pronyk, Kim et al. 2008). However, social capital is not always positive. In a case study from South Africa, the relationship between membership in a community organization and sexual health behaviors varied in direction and strength by age and gender, demonstrating complex links between social capital and health behaviors

(Campbell, Williams et al. 2002). As this study shows that women's odds of HIV infection increase in areas of higher income inequality, consideration of interventions that build positive social capital may prove a viable intervention strategy in rural Malawi.

Second, this study reveals gender-based differences in associations between area-level factors, individual-level risk behaviors, and HIV status in rural Malawi. As suggested by the PEH, community-level interventions that empower women and reduce gender-based discrimination may prove successful in ameliorating the spread of HIV. In Malawi, some women defy traditional gender roles and protect themselves against HIV by talking with their husbands, seeking advice in their social network, confronting girlfriends, or threatening divorce (Schatz 2005; Smith and Watkins 2005). Also, among some young partners, even those who exchange money, condoms may be recommended or rejected by men or women (Poulin 2007), and attitudes and behaviors among some Malawian men are changing to reduce their risks of transmitting or spreading HIV (Schatz 2005; Smith and Watkins 2005; Kalipeni, Oppong et al. 2007). However, to increase the speed of change, men need to be targeted at the community-level, and responsibility for safe sex must be shared equally between men and women to reduce the spread of HIV (Rankin, Lindgren et al. 2005; Greene, Mehta et al. 2006). Including and promoting male participation in future interventions aimed at changing gender-based discrimination and reducing gender inequities would bolster the likelihood of an effective and sustainable solution (Eaton, Flisher et al. 2003; Wellings, Collumbien et al. 2006).

This study is not without limitation. Primarily, the cross-sectional design limits the ability to determine causality. However, the temporality of long-term, area-level influences on HIV risk behaviors likely predates the influence of individual risk behaviors on HIV, allowing postulation of causal pathways between area- and individual-level factors and HIV infection. There are also several variables of interest that are unavailable in the current data set including whether women engage in transactional sex (sex for money) and whether women migrate for work. Moreover, potential underreporting of risk and protective behaviors or differences among those who were not willing to have the HIV test could bias the results. A recent study on HIV testing uptake in Malawi noted that women who lived closer to roads, whose husbands refused testing, or who perceived higher HIV risk were more likely to refuse testing (Kranzer, McGrath et al. 2008). Additional selection effects are possible as people are likely to self select into neighborhoods, making area effects less randomly distributed among populations (Sampson, Morenoff et al. 2002; Oakes 2004). Lastly, geographic information from developing countries is sparse and inconsistent. The most updated health center information comes from 2002, and the selection of only Ministry of Health supported clinics attempts to address the reach of government health facilities, assuming similar quality and available services. The direction and magnitude of these biases cannot be determined with the available data. Despite these considerations, the complete dataset is rich and offers a unique opportunity for analysis of the multiple linkages between people and place in the context of HIV in sub-Saharan Africa.

CONCLUSION

To the author's knowledge, this is the first study that examines *whether* and *how* area-level socio-economic and access factors influence HIV status in rural Malawi, and if these relationships vary by gender. Using the Political Economy of Health framework, this study confirms that place matters in the context of HIV in Malawi, and that the influence of these factors differs for men and women. Although individual risk behaviors play a role in the relationship between some area-level factors and individual HIV status, they did not in others, suggesting that other pathways require elucidation. Future research should explore other mediators, such as gender-based violence and gender norms, to explain the relationships between area-level effects and both individual-level behaviors and HIV status. Complementary research of these relationships at a finer spatial scale may help translate these findings into tailored policy or programmatic strategies. Expanding emphasis from individual behaviors to the area-level factors that may drive those behaviors gives warranted consideration to the myriad influences on individual actions and outcomes.

Table 5.1: Description of individual- and area-level variables

Variable	Definition	Type of variable
Individual-Level		
HIV Status	Dichotomous: Infected with HIV or not	Dependent
Gender	Male or female	Moderator
Condom	Dichotomous: condom use with any of previous 3 sexual partners	Component of mediator
Paid Sex	Dichotomous: ever paid for sex	Component of mediator for men only
Multipart	Dichotomous: 2 or more sexual partners in last year	Component of mediator
STI	Dichotomous: Diagnosis/symptoms of sexually transmitted infection within past year	Component of mediator
Individual Risk Score	Continuous summary score of risk behaviors	Mediator
SES	Continuous household socio-economic status	Control
Age	Continuous age in years	Control
Marital Status	Dummy variables for never married and previously married. Reference group: currently married.	Control
Education	Dummy variables for no education and primary ed (reference group: secondary education or more.	Control
Religion	Dummy variables of primary religion as reported	Control
Ethnicity	Dummy variables of primary ethnicity as reported	Control

Region	Dummy variables for region of the country: Northern and Central. Reference group: Southern	Control
Migration	Dichotomous: travel one month in last 12 months	Control for men
Circumcision	Dichotomous: circumcised or not	Control for men
Area-Level		
Income inequality	Dummy variables: Gini coefficient in the 75th percentile or higher and Gini coefficient in the 26-74th percentile. Reference group: Gini in the lowest 25th percentile or below	Independent
Poverty Headcount	Continuous: percent of population below the poverty line	Independent
Distance to major road	Continuous: Km from DHS cluster point to closest major/district road	Independent
Healthcare availability	Continuous: KM from DHS cluster to closest Ministry of Health clinic	Independent
Distance to a major city	Continuous: Km from DHS cluster to the closest regional capital, Mzuzu, Lilongwe, or Blantyre	Independent

Table 5.2: Descriptive percentages of key variables among men and women

		% Women, n=2091	% Men, n=1827
Age**	15-19	12	12
	20-24	26	21
	25-29	19	20
	30-34	16	16
	35-39	11	11
	40-44	10	10
	45-49	7	6
	50-54	n/a	3
Religion	Christian	37	38
	Muslim**	12	10
	Catholic	24	22
Region**	North	13	13
	Central	39	43
	South	48	45
Ethnicity	Chewa	34	35
	Yao	13	12
	Lomwe	18	18
Education***	None	27	14
	Primary 0-4	64	65
	Grade 5 or higher	9	21
Marital status***	Never married	5	22
	Married/Union	77	74

	Previously married	18	4
Wealth quintile (SES)***	Lowest	19	14
	Second	24	23
	Middle	25	27
	Fourth	23	25
	Highest	10	11
Circumcised		n/a	22
Migrate		n/a	12
Multiple partners in last year***		7	24
Recent condom use***		4	14
Previous STI in last 12 months***		10	6
Ever had paid sex		n/a	22
Risk score***	0	83	57
	1	14	27
	2	2	12
	3	1	4
HIV+ status***		13.8	9.6

Chi square results of difference in proportions, * p<.1, **p<.05, ***p<.01

Table 5.3: Bivariate associations between key variables and HIV status

	Women	Men
Individual-level demographics and behaviors		
Age	1.03*** [1.014 – 1.042]	1.05*** [1.032 – 1.062]
Marital Status		
Previously married	2.30*** [1.70-3.10]	.739 [.307-1.77]
Never married	.564 [.236-.226]	.092*** [.037-229]
Current married	1.00	1.00
Educational status		
No education	1.03 [.613-1.72]	.702 [.361-1.36]
Grades 1-4	.829 [.525-1.31]	.653* [.408-1.04]
Grade 5 or higher	1.00	1.00
SES	1.18*** [1.057 - 1.328]	1.4*** [1.176 - 1.650]
Religion		
Christian	1.09 [.794-1.50]	1.03 [.682-1.54]

Muslim	1.54** [1.06-2.24]	1.21 [.650-2.23]
Other	1.00	1.00
Ethnicity		
Chewa	.523*** [.349-.783]	.375*** [.218-.645]
Lomwe	1.52** [1.07-2.15]	1.86*** [1.19-2.91]
Yao	1.45* [.994-2.14]	1.25 [.671-2.33]
Other	1.00	1.00
Region		
North	.263*** [.144-.480]	.215*** [.105-.439]
Central	.338*** [.236-.485]	.310*** [.191-.504]
South	1.00	1.00
Migrate	n/a	1.38 [.81 - 2.35]
Circumcised	n/a	1.5** [.993 - 2.37]
Individual-level risk factors		
Individual risk score	1.63*** [1.291 - 2.065]	1.037 [.845 - 1.27]

Condom use	1.90** [1.07 - 3.38]	.932 [.554 - 1.57]
Multiple partners	1.81** [1.14 - 2.90]	.61* [.376 - .99]
STI in last 12 months	1.98*** [1.34 - 2.92]	1.98** [1.04 - 3.76]
Ever had paid sex	n/a	1.45* [.978 - 2.156]
Area-Level		
Income inequality		
High Gini	1.85** [1.15-2.96]	1.16 [.631-2.13]
Medium Gini	1.44 [.922-2.26]	1.04 [.616-1.78]
Gini Low	1.00	1.00
Percent poor	.994 [.987 - 1.004]	.999 [.987 - 1.012]
Km to major city	1.0 [.996 - 1.003]	.999 [.994 - 1.004]
Km to major road	.98** [.964 - .995]	.98 [.962 - 1.005]
Km to MOH	.89*** [.840 - .950]	.89*** [.819 - .956]

Results from logistic regression models. Unadjusted odds ratios. 95% CI in brackets. p *<.1, p **<.05, p ***<.01

Table 5.4: Associations between area-level factors and HIV status

	Women	Women	Men	Men
Model 1	AOR	AOR, including risk score	AOR	AOR, including risk score
Income inequality				
Gini high	1.56**	1.58**	.984	.964
	[1.01-2.41]	[1.01-2.47]	[.539-1.79]	[.529-1.75]
Gini medium	1.31	1.34	1.17	1.17
	[.881-1.95]	[.892-2.02]	[.717-1.91]	[.715-1.91]
Gini low	1.00	1.00	1.00	1.00
Individual risk score		1.87***		1.24
		[1.41-2.46]		[.959-1.61]
Model 2				
Percent poor	.996	.996	.999	.999
	[.998-1.00]	[.998-1.00]	[.987-1.01]	[.987-1.01]
Individual risk score		1.86***		1.23
		[1.39-2.47]		[.957-1.59]
Model 3				
Km to major city	1.00	1.00	1.00	1.00
	[.997-1.00]	[.997-1.00]	[.995-1.01]	[.995-1.01]
Individual risk score		1.87***		1.23
		[1.41-2.49]		[.959-1.60]

Model 4				
Km to major road	.975***	.975***	.981*	.982*
	[.962-.988]	[.962-.988]	[.962-1.00]	[.963-1.00]
Individual risk score		1.87***		1.22
		[1.39-2.50]		[.941-1.59]
Model 5				
Km to MOH	.933**	.942**	.919**	.921**
	[.88-.989]	[.889-.999]	[.848-.995]	[.851-.997]
Individual risk score		1.81***		1.23
		[1.35-2.42]		[.949-1.58]

Results from logistic regression models. p *<.1, p **<.05, p ***<.01. 95% CI in brackets. Adjusted for region, education, SES, ethnicity, religion, marital status, and age (migration and circumcision for men).

Table 5.5: Associations between area-level variables and individual risk score

Individual risk score	Women AOR	Men AOR
Income inequality		
Gini high	-0.026 [-.098 - .044]	.089 [-.049 - .228]
Gini middle	.033 [-.100 - .032]	-.019 [-.119 - .228]
Gini Low	0.00	0.00
Percent poor	.0007 [-.0009 - .002]	-.0004 [-.0027 - .0018]
Km to major city	-.0006* [-.001 - .00008]	-.0015** [-.0026 - -.0003]
Km to major road	-.0002 [-.002 - .001]	-.0015 [-.005 - .002]
Km to MOH	-.012*** [-.018 - - .003]	-.004 [-.020 - .012]

Results from linear regression models. p *<.1, p **<.05, p ***<.01. 95% CI in brackets. Adjusted for region, education, SES, ethnicity, religion, marital status, and age (migration and circumcision for men).

Table 5.6: Associations between individual HIV risk score and HIV status

HIV Status	Women AOR	Men AOR
Risk score	1.86*** [1.39 - 2.48]	1.23 [.958 - 1.59]

Results from logistic regression models. p *<.1, p **<.05, p ***<.01. 95% CI in brackets. Adjusted for region, education, SES, ethnicity, religion, marital status, and age (migration and circumcision for men).

Figure 5.1: Area- and individual-level influences on HIV status in Malawi

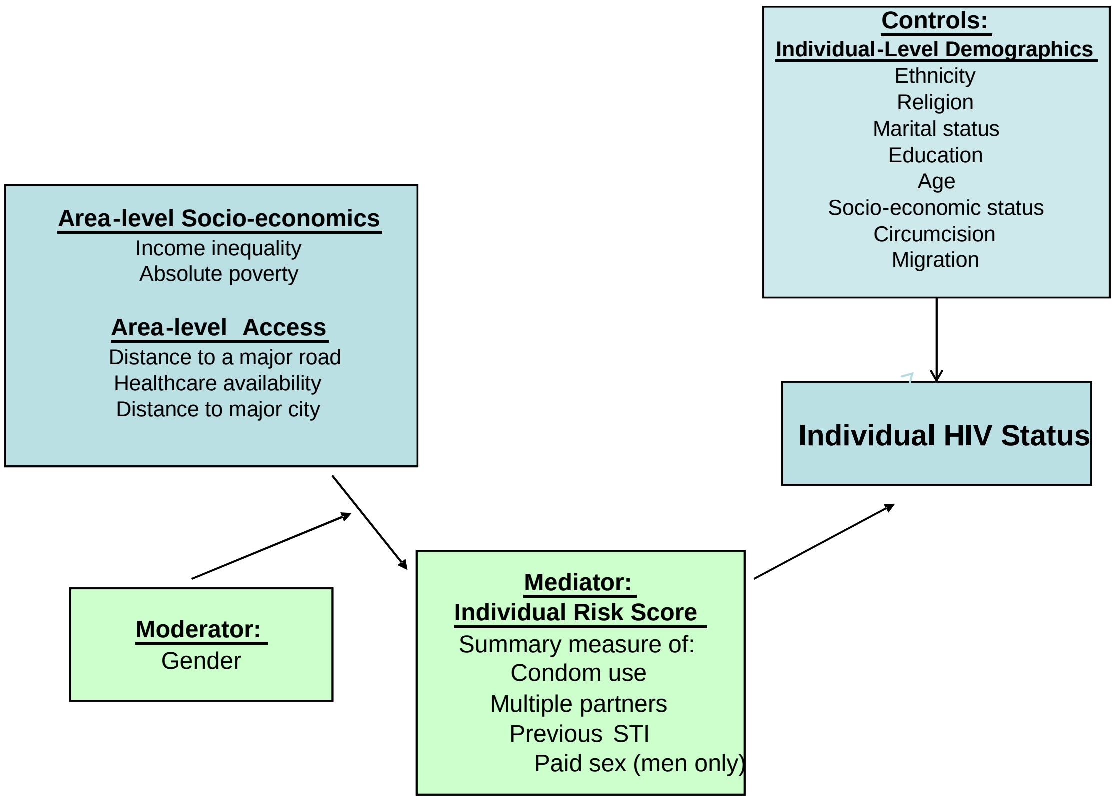
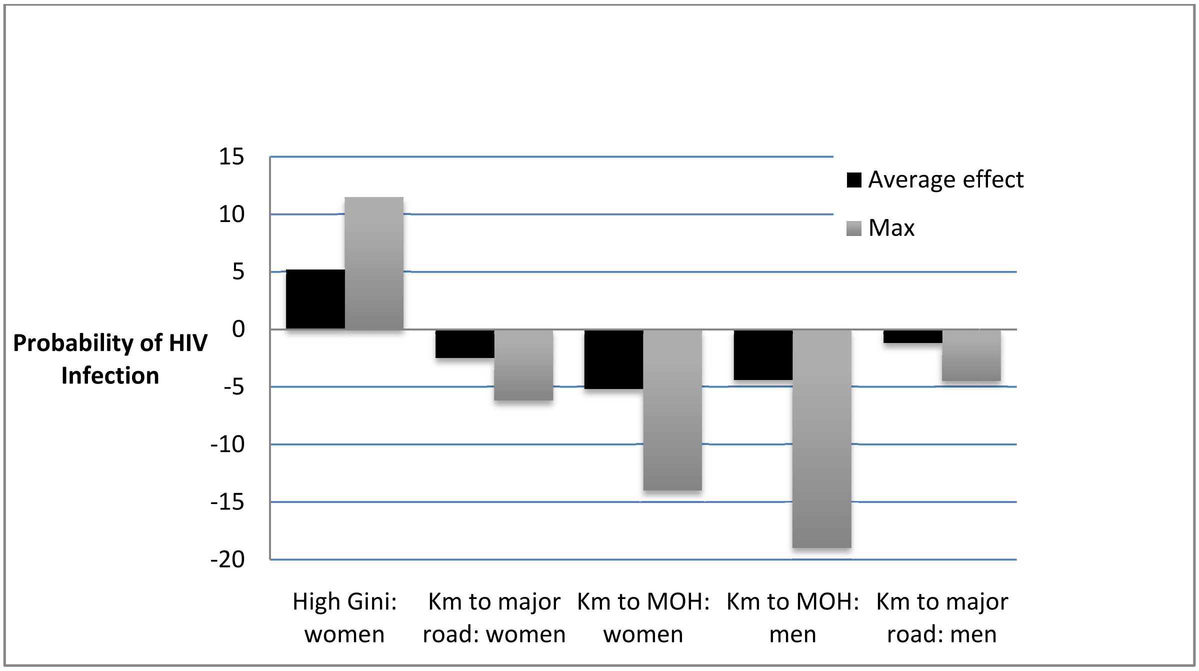


Figure 5.2: The average effect of a change* in significant area-level factors on HIV status in rural Malawi



* The effect of moving to an area of high income inequality from an area of low income inequality. The effect of moving 10 kilometers farther from a major road or MOH clinic.

Figure 5.3: Significant factors in the associations between area-level factors, individual behavior and individual HIV status for women

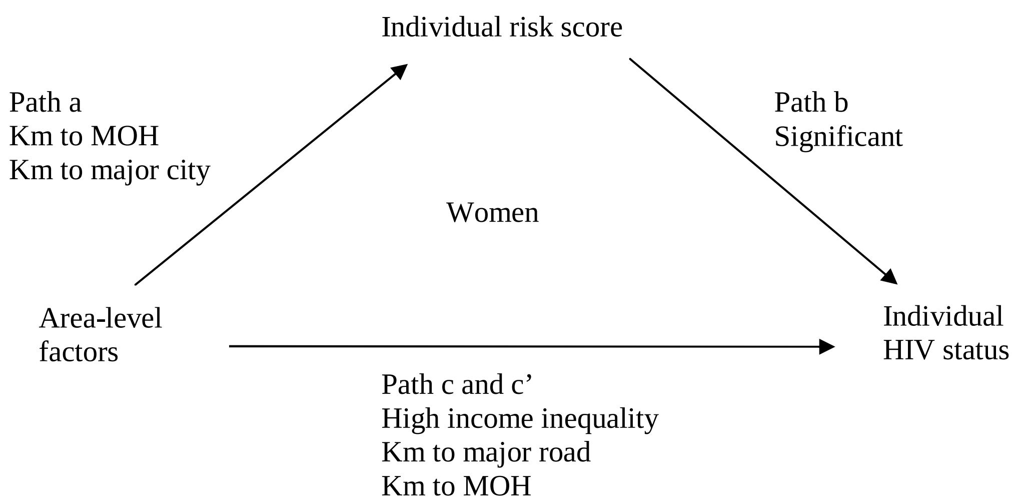
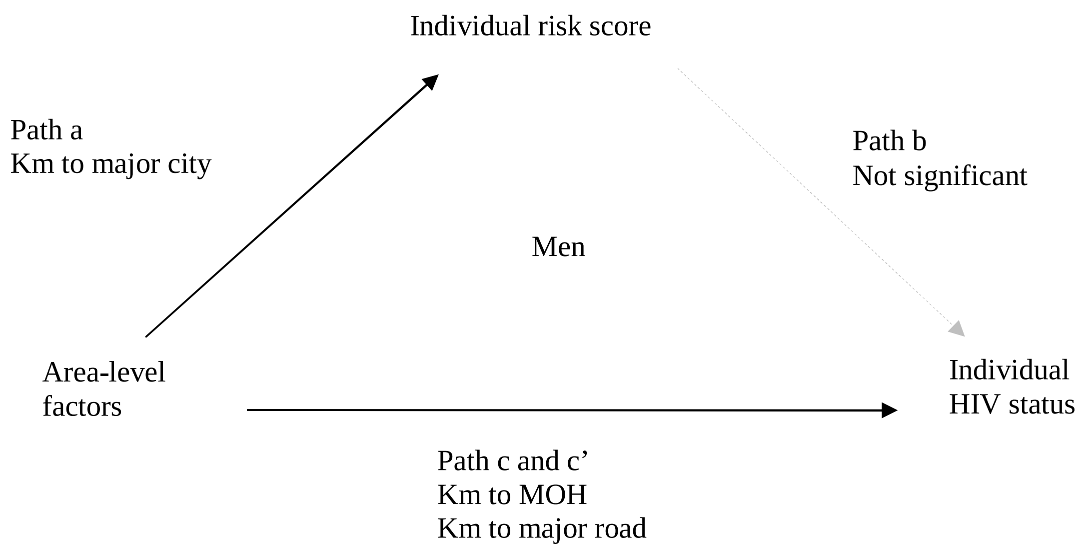


Figure 5.4: Significant factors in the associations between area-level factors, individual behavior and individual HIV status for men



CHAPTER 6

PAPER 2

The *who* and *where* of HIV in rural Malawi: Exploring the effects of person and place on individual HIV status

Caryl Feldacker

ABSTRACT

Few studies use a spatial approach to explore relationships between people and place in sub-Saharan Africa or in the context of Human Immunodeficiency Virus (HIV). This paper uses individual-level demographic and behavioral data linked to area-level, spatially-oriented socio-economic and access data to determine how the relationship between area- and individual-level risks and individual HIV status vary in rural Malawians using geographically weighted regression. The Political Economy of Health theoretical framework aids interpretation. Area-level factors include income inequality, absolute poverty, and access to roads, cities, and health clinics. Individual-level factors include high risk sex and sexually transmitted infections. Stratified analysis reveals the role of gender. Spatial models show significant, local-level variation and indicate that area-level factors drive patterns of HIV above individual-level contributions. In distinct locations, women who live further from health clinics, major roads, and major cities are less likely to be infected. For men, HIV status is strongly associated with migration patterns in specific areas. The paper thus concludes that local-level, gender-specific approaches to HIV prevention are necessary.

INTRODUCTION

Where an individual lives matters for overall health and wellness (Mayer 1989; Diez Roux 2001; Dietz 2002; Sampson, Morenoff et al. 2002; Diez Roux 2004; Cummins, Curtis et al. 2007; Entwisle 2007; Lachaud 2007), and similar people behave differently in different places (Duncan, Jones et al. 1998). Contextual, hierarchical, or multilevel models used to examine place-based effects on individuals typically address only the attributes of a specific location, neglecting the spatial distribution and proximity of factors between people and neighborhoods (Chaix, Merlo et al. 2005). As a result, non-spatial models provide only a partial explanation of associations between area- and individual-level predictors and outcomes. In contrast, spatial studies do more than reveal the existence or location of an association: spatial analysis shows where differences are and provides a visual, geographic representation of key associations (Weir, Pailman et al. 2003).

Use of spatial methods is gaining momentum in health research (Macintyre, Ellaway et al. 2002). Yet, only a few studies explore associations between health and place in developing countries (Bujakiewicz and Mulolwa 1993; Ezekiel 1993; Tanser 2001; Benson, Chamberlin et al. 2005; Kandala, Magadi et al. 2006; Kazembe, Kleinschmidt et al. 2006). Understanding of spatial relationships in sub-Saharan Africa or in the context of Human Immunodeficiency Virus (HIV) remains poor. In Malawi, a country where approximately 1 million people are infected with HIV (UNAIDS 2007), and rural infection rates are rising (Bello, Chipeta et al. 2006; Bryceson and Fonseca 2006), little is known about how characteristics of people and place interact to facilitate the spread of HIV. Spatial exploration of the area- and individual-level drivers of HIV may fill a critical gap in understanding by helping researchers answer the who and where questions of HIV transmission in Malawi (Chirwa 1997; Craddock 2000) and by enabling better targeted prevention and treatment efforts.

Previous studies of the drivers of HIV in rural Malawi focus on small geographic areas or on individual behavior (Barden-O'Fallon, deGraft-Johnson et al. 2004; Watkins 2004; Helleringer and

Kohler 2005; Smith and Watkins 2005; Kohler, Behrman et al. 2007; Morah 2007). Area-level socio-economic and access factors that enable the spread of HIV receive less attention (Armour 2006; Mtika 2007). To move from an emphasis on individuals to complex economic, social, structural, and cultural drivers of the HIV epidemic (Hobfoll 1998; Craddock 2000; Parker 2001), spatial methods provide several advantages. Primarily, geographic information systems (GIS) technology makes linking databases using geographic information possible and simplifies integration of data from multiple sources into a comprehensive whole (Richards, Croner et al. 1999). Additionally, spatial regression reveals interactions and explores whether the direction, magnitude, and distributions of associations vary over space (Chaix, Merlo et al. 2005). Lastly, mapped results promote improved knowledge acquisition, potentially accelerating the transition from research into practice (Rytkonen 2004).

Two recent spatial studies elucidate variations in the relationships between area-level effects and area-level HIV prevalence in Sub-Saharan Africa. Kleinschmidt et al tested and mapped spatial associations between area-level socio-economic factors and area-level HIV prevalence among youth, concluding that unemployment, ethnicity, and urbanicity were associated with intra-province variations in HIV prevalence and that these associations varied by gender in South Africa (Kleinschmidt, Pettifor et al. 2007). Furthermore, Lachaud used spatial lag models to examine associations between individual- and aggregate-level poverty and provincial HIV prevalence in Burkina Faso (Lachaud 2007). Provincial HIV prevalence was significantly associated with spatial variation in migration, urbanization, and proximity to transportation routes, but the relationship with area-level poverty was not linear (Lachaud 2007).

Building upon previous research, this study provides insight into the drivers and distribution of HIV infection in rural Malawi by exploring spatial associations between area-level factors, individual risk behaviors, and individual HIV status using geographically weighted regression. The research uses a nationally-representative probability sample of rural Malawians and links individual-level demographic and behavioral data with area-level, spatially-oriented access and socio-economic indicators, creating a comprehensive database of individual- and area-level variables. Associations are mapped, providing a visual representation of geographically specific results. A theoretically-informed conceptual model using the Political Economy of Health (PEH) theoretical framework guides variable selection and clarifies interpretation. The role of area-level socio-economic (income inequality and absolute poverty) and access indicators (distance to roads, healthcare, and major cities) are explored, and individual-level factors including condom use, high risk sex, multiple partners, and migration are also considered. Gender is examined through stratified analysis. Because definition and measurement of *place-based* or *neighborhood-level* effects are complex (Kawachi and Berkman 2003), administrative boundaries may be used to approximate the boundaries of area-level influences on individuals (Macintyre 1997; Blacker 2004). For the purposes of this study, the boundaries for *area-level* are defined as the aggregate enumeration area, a census-defined boundary that includes approximately 500 households.

BACKGROUND

An estimated 1 million people are infected with HIV in Malawi (USAID 2008): 10% of men and 13% of women nationwide (National Statistical Office Malawi and ORC Macro 2005). Although the highest prevalence rates are in major urban areas (PEPFAR 2007), 80% of Malawi's approximately 13 million people, live in rural areas (UNICEF 2008) where HIV rates are rising (Bello, Chipeta et al. 2006). The absolute number of rural people who are infected currently outnumber urban residents by about 3 to 1 (National Statistical Office Malawi and ORC Macro 2005). Increased focus on HIV among rural populations is warranted.

Demographic factors such as education, religion, ethnicity, socio-economic status, age and gender play key roles in HIV risk. In Malawi, marriage increases a woman's risk of HIV, with the highest rates among those divorced or widowed (National Statistical Office Malawi and ORC Macro

2005). Women under age 24 are more than 3 times more likely than their male age peers to be infected in Malawi (National Statistical Office Malawi and ORC Macro 2005), showing clear gender and age dimensions to the epidemic. Infection rates increase among those with higher education and socio-economic status for men and women, and infection patterns vary by ethnicity and religion (National Statistical Office Malawi and ORC Macro 2005).

Behaviors like poor condom use (Munthali, Zulu et al. 2006) and multiple partnerships (Kaler 2004) affect the patterns and presence of HIV in Malawi. In Malawi, condoms are often reserved for sexual encounters with partners who are perceived as higher risk of HIV infection, especially extra-marital partners (Chimbiri 2007). As a result, overall condom use in Malawi is low: only 30% of women and 47% of men report using condoms with their last non-spousal/non-regular partner (National Statistical Office Malawi and ORC Macro 2005). Sexually transmitted infections (STI) are also related to an increased risk of HIV: in Malawi, over 20% of men and women who had an STI were infected with HIV in 2005 (National Statistical Office Malawi and ORC Macro 2005). Furthermore, multiple, concurrent sexual partnerships are key determinants in the spread of HIV (Morris and Kretzschmar 1997), and extra marital partnerships are common in Malawi (Kuate-Defo 2004; Chimbiri 2007; Tawfik and Watkins 2007). Lastly, migration plays a role in the transmission and spread of HIV (Zuma, Gouws et al. 2003; Coffee, Garnett et al. 2005; Lurie 2006; Mtika 2007). HIV prevalence is 4% higher among men who migrated in 2005 than those who did not (National Statistical Office Malawi and ORC Macro 2005).

Framing space in the context of HIV

The PEH framework emphasizes how inequalities based on class, ethnicity, race, or gender exacerbate conditions of poor health by fostering social isolation, economic deprivation, power differentials, inequity in access to resources, and insufficient healthcare (Minkler, Wallace et al. 1994; Farmer 1999; Krieger 1999; Farmer, Léandre et al. 2001; Parker 2001; Whiteside and De Waal 2004;

Hunter 2007). Applying the PEH to spatial studies of HIV in sub-Saharan Africa may illuminate linkages between individual behavior and area-level socio-economic contexts (Altman 1999; Lindgren, Rankin et al. 2005; Hunter 2007; Mtika 2007; Parikh 2007).

The PEH identifies poverty as one of the most influential ecological risk factors for poor health status (Minkler 1999), and population patterns of good and poor health are highly correlated with areas of wealth and poverty (Krieger 2001). HIV infection is most prevalent among people in their economically productive years (FAO 2003; Heuveline 2004; Mather, Donovan et al. 2005), and poorer persons are less likely to access treatment and care (Phelan, Link et al. 2004). Also consistent with the PEH, the relative distribution of wealth affects health status (Kawachi and Kennedy 1997). Countries with higher levels of income inequality are among those with higher HIV prevalence (Fenton 2004), and income inequality is linked to increased risk for sexually transmitted infections (Holtgrave and Crosby 2003) and to concurrent sexual partnerships (Adimora and Schoenbach 2002). In Malawi, 67% of rural populations were below the poverty line in 2000 (National Economic Council Malawi 2000). The country-level Gini coefficient of 0.38 indicates relatively high overall income inequality, and the percent of people living below the poverty line remained relatively stable at 54% from 1997-2005 (World Bank 2008).

Access to health services, roads, and cities are also important factors in determining individual health choices and outcomes. Access to treatment and care often reflect class, gender, and racial disparities in social and economic systems (Doyal and Pennell 1979). Rural residents generally have less access to health facilities than residents of urban areas (UNAIDS 2008), and women frequently fare worse overall (Parker, Easton et al. 2000; Loewenson 2007). Moreover, roads serve as an indicator for access to livelihood opportunities and services (Smith, Gordon et al. 2001; Porter 2002) and serve as a proxy for mobility (Greig and Koopman 2003; Porter 2007), a factor associated with HIV (Doyal 2001). Roads to urban areas may also be associated with an increased risk of HIV transmission (Girdler-Brown 1998) while urban transit zones are associated with paid sex and multiple partners (Chirwa 1997).

Lastly, the gendered dimension of the AIDS epidemic warrants attention. Biological risk factors (Blocker and Cohen 2000; Glynn, Carael et al. 2001; Quinn and Overbaugh 2005), exacerbated by gender inequity and power differentials (Ghosh and Kalipeni 2005; Luke 2005), partially explain higher rates of HIV among women across much of sub-Saharan Africa (Luke 2003; Kim and Watts 2005; Wellings, Collumbien et al. 2006; Sa and Larsen 2007). Poverty and inequality force many women in rural Africa to depend on sexual relationships for financial support (Gregson, Nyamukapa et al. 2002; Gupta 2002; Luke and Kurz 2002; Kelly, Gray et al. 2003; Luke 2006; Masanjala 2007). In these relationships, women's decision making power is limited, reducing condom use and increasing vulnerability to HIV (Blanc 2001; Dunkle, Jewkes et al. 2004; Pettifor, Measham et al. 2004). The intersections of socio-economics and gender may produce an irony that women' short-term survival tactics may lead to HIV infection (Craddock 2000). Although a gender focus frequently centers on women, men generally control the specifics of sex (Sayles, Pettifor et al. 2006), and understanding the drivers of HIV infection among men is crucial.

STUDY DESIGN AND METHODS

Conceptual Model and Hypotheses:

The PEH informs the study's conceptual model (Figure 6.1). It is hypothesized that:

- Area-level socio-economic factors, including income inequality and absolute poverty, will influence HIV such that persons in areas of *greater* relative or absolute poverty will be *more* likely to be infected while those in areas of *lower* relative or absolute poverty will be *less* likely to be HIV infected. Access to roads, healthcare, and urban centers also influence individual HIV status such that those with *greater* access to roads and urban areas will be *more* likely to be infected while those closer to Ministry of Health (MOH) clinics will be *less* likely to be infected.

- Individual-level risk factors such as condom use, previous sexually transmitted infection, multiple partners and migration (for men only) will *increase* the likelihood of infection.
- Relationships between both area- and individual-level factors will vary non-randomly in strength and magnitude over space.
- The strength of both area- and individual-level relationships will be greater for women than for men.

The study population is restricted to rural residents.

Individual-Level Data

All individual-level data come from the Malawi Demographic and Health Survey, 2004 (MDHS). A summary of individual-level variables is presented in Table 6.1. The 2004 MDHS is a nationally-representative probability survey of demographic and health information for men and women of reproductive age. The standard DHS survey methodology is available from ORC Macro (ORC Macro 1996). The MDHS uses the master sample frame from the Malawi 1998 census, and enumeration areas serve as primary sampling units for stage one of the two-stage clustered sampling design (National Statistical Office Malawi and ORC Macro 2005). With a target of approximately 15,000 households, 522 clusters were randomly selected, 64 in urban and 458 in rural areas, and households were systematically sampled from those clusters (National Statistical Office Malawi and ORC Macro 2005). All women aged 15-49 years who usually lived in the household were interviewed; every third household for the women's interview was selected for the male questionnaire. All households selected for the male questionnaire were selected for the HIV test. For the overall 2004 MDHS, the response rate was 98%. For HIV testing, 2,485 rural women (response rate 71%) and 2,056 rural men (response rate 65%) accepted (National Statistical Office Malawi and

ORC Macro 2005). A study on the effect of non-response on population-level HIV estimates in Malawi found no significant bias (Mishra, Barrere et al. 2008). For the current research, the full MDHS HIV sample is restricted to rural residents and to those who have sexually debuted and are at risk of HIV through sexual transmission: 2,091 women and 1, 827 men.

The MDHS collects detailed information on myriad subject areas including fertility, sexual health, nutrition, and children's health (Aliaga and Ren 2006). Interviewers received extensive training before implementing the survey, and consent procedures were approved in Malawi and the USA. As part of the MDHS, HIV results were voluntarily obtained and dried blood spots tested using a standard protocol (ORC Macro 2005; MEASURE DHS 2008). The MDHS also collected Global Positioning System (GPS) data for all selected clusters (Montana and Spencer 2004). To protect the confidentiality of individuals, all clusters were randomly offset by up to 5km, with one point moved up to 12 km (MEASURE DHS 2008), a minimal error unlikely to affect influences at the area-level scale. GPS coordinates for Malawi are available for 456 rural clusters. Following standard protocols for visualizing data points on a spatial map, the points were projected in ArcGIS using UTM grid zone 36 south and referencing the WGS84 datum.

Several individual-level variables require elaboration. The variable for individual SES is a wealth index incorporating household assets (e.g., bicycle, car, television), dwelling characteristics, and infrastructure (e.g., housing materials, type of water and sanitation facilities). The combined rural and urban samples were divided into population wealth quintiles (National Statistical Office Malawi and ORC Macro 2005). Also, in settings with low overall condom use, *actual use* of a condom reflects higher perceived risk of, or susceptibility to, HIV from an infected partner (Adih and Alexander 1999; Pranitha and Cleland 2005). Therefore, condom *use* with a recent sex partner, spouse or otherwise, is considered a risk factor.

Area-Level Data

A summary of area-level variables is described in Table 6.1. The area-level socio-economic data come from the Poverty Mapping Project at Columbia University (Columbia University 2008). The project was supported by the World Bank and completed in 2005. Experts at the World Bank created small area estimates of welfare and poverty using poverty mapping methods that are complex. General details on the methodology are available from Elbers, Lanjouw, and Lanjouw (Elbers, Lanjouw et al. 2003), and specific information for the Malawi study is available from the International Food Policy Research Institute (Benson 2002; Benson, Chamberlin et al. 2005). The spatial units for the poverty mapping exercise are rural aggregated enumeration areas (EA) devised by the National Statistical Office of Malawi for the 1998 National Population and Housing Census, the same sampling frame utilized by the MDHS. Each unit for the poverty mapping exercise aggregates 2 or 3 EAs from the census, creating spatial units with a minimum of 500 households. The complete poverty mapping dataset of Malawi includes 20 measures of poverty and welfare, including the poverty headcount and Gini index, linked to GIS shapefiles for each of 3004 aggregate EAs (Benson 2002; Benson, Kanyanda et al. 2002). The poverty mapping dataset includes only rural populations and excludes the four major urban centers of Malawi: Blantyre, Zomba, Lilongwe, and Mzuzu. Towns and cities in rural areas are included.

Several socio-economic variables require elaboration. The Gini index is a measurement of income inequality in a given area (Coudouel 2008) and can be used to show the influence of economic disparities on health (Lindstrom and Lindstrom 2006). Poverty headcount is the percent of the population whose income is below the poverty line (Coudouel 2008), a valid measure of economic deprivation (Krieger 2003). The Gini index and the poverty headcount represent related, but distinct, measures of poverty (Benson, Chamberlin et al. 2005). High Gini and middle Gini variables were created by sorting all enumeration areas by Gini coefficient, from low (greater equality) to high (greater inequality). Equal quartiles were created, and each quartile was assigned a rank from 1-4, assigning “1” to the 25% of enumeration areas in the lowest quartile (highest equality); “2” to the lower middle quartile; “3” to the higher middle quartile; and “4” to the highest quartile (highest inequality). In the analysis, group “1”, lowest Gini, serves as the reference for middle Gini (groups 2-3) and group “4”, high Gini.

The three variables used to measure area-level access, distance to a major urban area, distance to a major road, and distance to a Ministry of Health (MOH) clinic, are derived from existing GIS maps of Malawi. Using ArcGIS software the Euclidean distance was measured between each DHS cluster point and the factor of interest. The road network variables were created using GIS road files created for the 1998 census and supported through funding by the Danish International Development Agency. The health facility latitude and longitude coordinates come from a Japanese International Cooperation Agency study from 1997-2002, aided by the World Health Organization. The data for proximity to cities is derived from digital maps produced for the national census and available from the National Statistics Office in Zomba.

Combining Individual- and Area-level Variables

GIS software, ArcGIS (ESRI 2008) enabled the assembly of the comprehensive database for this contextual study. Every cluster in the MDHS has a geographic location allowing the placement of each DHS cluster correctly on the digital map. This DHS cluster information was spatially joined to the poverty and access geographic datasets, allowing for the visualization and utilization of information simultaneously. Each DHS cluster was assigned the poverty and access information in the aggregate EA in which it is located. The distance from each DHS cluster to a major road, health facility, and major urban area was also determined using the Euclidean distance calculation features in ArcGIS. The complete database of DHS cluster information with area-level attributes was exported into a database file containing 456 observations, the number of rural DHS clusters. The area-level information was imported into STATA 9.2 (STATA 2007) and merged with the individual level data (including HIV) assigning the same area-level variables to every individual within each cluster, but leaving all other individual level information unique. The database was re-exported into ArcGIS, and each individual was randomly scattered approximately 50 meters from the cluster location using the ArcGIS Duplicate Remover, providing a unique location for every observation. Lastly, this final database was divided by gender, and datasets exported in comma separated values files for use in spatial analysis software.

DATA ANALYSIS

Multivariate, logistic, geographically weighted regression (GWR) models are used to test all individual- and area-level factors, taking explicit account of proximity relationships (Fotheringham, Brunsdon et al. 2002). Geographically weighted regression software, GWR3, is used for analysis (Fotheringham 2005), and the logistic model is fitted using iteratively reweighted least squares. GWR3 produces 2 types of results. First, GWR3 calculates an overall model of global associations, similar to traditional population-averaged logistic regression models, with parameter estimates, standard errors, and t-values. Global odds ratios are reported. Second, and more importantly, GWR calculates local parameter estimates at each observation point, determining associations between independent predictors and HIV status for 2,091 women and 1,827 men. To estimate local models, the influence (weight) of observations within a specific geographic range (bandwidth) are determined using a distance decay weighting system, assigning more weight to observations closer to the local regression point than to those farther away. Selection of the optimal bandwidth is automated using a cross validation (CV) approach in GWR3 software for separate models for men and women. This convergence process determines the bandwidth for all regression points, reducing the CV score until the number of included observations provides stable global and local parameters. In this study, the optimal fixed bandwidth in decimal degrees is 1.55 for women and 2.38 for men. Monte Carlo simulation tests of spatial variation compare the variance of the observed model parameters against

100 random calibrations of the same model, providing t-statistics of significance for local parameters (Fotheringham, Brunsdon et al. 2002). Local t-statistics are mapped to visually represent spatial variations in significant associations. Additional information on geographically weighted regression and GRW3 software may be found in Fotheringham, 2002 (Fotheringham, Brunsdon et al. 2002).

To display the local model results and facilitate interpretation, individual regression points are used to predict parameter values over continuous space through interpolation (Childs 2004). Interpolation is a method to create smooth surface maps and allow for the visualization of relationships between data points. Spline interpolation methods use a mathematical function that takes regression points and minimizes the variation between them, passing through known values to create a smooth surface of variability over space (Childs 2004). For this analysis, the ArcGIS Spatial Analyst spline tool is used to interpolate the surface with cell size of 1000 meters.

RESULTS AND DISCUSSION

Descriptive statistics

Individual-level characteristics are detailed in Table 6.2. Levels of individual risk behavior differ for men and women. While 7% of women had more than one partner in the last year, 24% of men had multiple sexual partners in the same timeframe ($p<.01$). Among those who have sex, 4% of women and 14% of men used a condom with a recent sex partners ($p<.01$). Also, 10% of women and 6% of men ($p<.01$) had a sexually transmitted infection or its symptoms in the previous 12 months. Among men, 22% had ever paid for sex.

As expected, area-level factors are similar between women and men. Men and women live the same average distance from a major city (73km); major road (11km); and MOH clinic (5km). The average poverty percent (percent of residents under the poverty line) is 65%. As defined, almost equal percentages of women and men live in an area within the middle half of income inequality, 51% of women and 50% of men, while 24% of men and 28% of women live in areas with the highest level of income inequality.

Global associations between individual- and area-level risk factors and HIV

A key advantage of spatial analysis is the ability to show the distribution and scale of spatial variation. However, global model results for men and women are presented first to frame the discussion of differences at the local level. Global models, presented in Table 6.3 by gender, are spatially stationary and represent population-averaged results.

Among women, several individual-level behavioral variables are significantly associated with HIV status. As expected, women with STIs are more likely to be infected with HIV than those without (OR 1.84, $p<.01$). Possibly confirming condom use as a proxy for perceived risk of, or susceptibility to, infection from a partner (Chimbiri 2007), use of condoms with a recent sex partner increases the odds of HIV infection by 2.01 ($p<.01$). Surprisingly, multiple partners are not associated with HIV status in the global model. Among area-level factors, and in contrast to hypotheses, the odds of infection decrease with increasing distance to a MOH clinic (OR 0.94, $p<.05$). There are no other significant associations between HIV status and other area-level factors among women at the global level.

For men, only previous sexually transmitted infection is significantly associated with HIV (OR 2.04, $p<.01$) among individual risk factors. Migration and paid sex have no association with HIV at the global level. In contrast to global results for women, recent condom use and multiple partners are also not significantly associated with HIV. Among area-level factors, similar to women, men who live further from MOH clinics are less likely to be infected (OR 0.93, $p<.05$). No other area-level factors are significantly associated with HIV status for men.

From global to local models: mapping spatial variation of relationships

Local spatial regression models provide a specificity of area- and individual-level associations with HIV status based on geographic location. Mapping results allows for visual presentation of the relationships within rural Malawi. Application of the PEH guides interpretation of the results. Although there is risk of committing the individualistic fallacy (applying individual-level findings to draw aggregate conclusions) (Diez-Roux 1998; Diez Roux 2002), local regression models can be cautiously and thoughtfully interpreted as average effects of the independent variable of interest on HIV status among men or women in that specific location, controlling for all other factors.

All variables from the global multivariate model are tested in local multivariate models stratified by gender. Decreased AIC (corrected) from the global to the local model suggests the local model fits the data better (Charlton, Fotheringham et al. 2006), and a decrease of more than 3 points is considered significant (Fotheringham, Brunsdon et al. 2002). Among women, the 15 point drop in the AIC (corrected) suggests that the local models are a better fit and demonstrates that the global model may mask considerable variation in the drivers of HIV in rural Malawi. However, the 5 point drop in the AIC (corrected) from the global to the local model for men suggests only a small increase in fit from the global to the local model, signifying less spatial variation overall.

Local regression model results are presented Tables 6.4 and 6.5. Factors that are significant in local models for more than 10% of the study population, by gender, are illustrated in Figures 6.2-6.5 for women and Figures 6.6-6.8 for men. These figures display relationships with significant spatial variation. In each map pairing, maps on the left side depict significance, illustrating where local t-statistics denote significant associations between the variable of interest and individual HIV status. Student t-values of ±1.96 indicate significance at the .05 level. Darker shades represent geographic areas where the variable is significantly associated with odds of HIV infection. Lighter areas indicate a non significant relationship with the variable of interest. Paired maps on the right show the distribution of the variable of interest within the study population.

Local spatial variation in associations between area- and individual-level factors and HIV among women

Local regression models indicate significant spatial variation in the associations between individual- and area-level factors and HIV status for women in rural Malawi. Although individual risk factors are significant, the significance of area-level factors above the contribution of individual-level influences provides evidence for the importance of place-based effects, confirming relationships proposed by the PEH.

Among hypothesized area-level drivers of HIV, three access factors exhibit significant spatial variation. First, distance to a major road is negatively and significantly associated with HIV status for 25% of women located in the Central Region near transportation arteries connecting Lilongwe and areas along the Mozambique border (Figure 6.2). For these women, living closer to a major road increases the odds of infection. Conversely, this finding suggests that women in more remote or isolated locations, further from major roads, are less likely to be infected than women who live closer to major thoroughfares. In other parts of the country, the association varies in sign and is not significant. This finding supports a recent study in South Africa using GIS to map HIV prevalence among pregnant women, concluding that women living in homesteads closer to a road were more likely to be infected than women who lived further from main transportation arteries (Tanser, Lesueur et al. 2000). Less access to roads may reduce risk behaviors through decreased access to markets and broader social networks, resulting in fewer additional sex partners (Tawfik 2007).

Second, distance to a major city is also significant and negative for 27% of the sample clustered in the middle of the country between Lilongwe and Mzuzu (Figure 6.3). Women in this area are less likely to be infected if they live further from a major city. The relationship between distance to a major city and HIV status is not static, and the association is positive in parts of the country including near Blantyre. In more isolated locations, especially in the Northern Region, distance or cost of travel may be prohibitive (Porter 2002), offering partial explanation for lower odds of HIV in areas further from cities or major roads. This finding affirms possible links between remoteness and reduced risk of infection.

Third, similar to the global model, distance to a MOH clinic is negatively associated with HIV status: women who live further from MOH clinics are less likely to be infected than female peers who live closer to a MOH clinic. As illustrated in Figure 6.4, this relationship is significant for 29% of women clustered in the Central and Southern Regions. The direction of this association is unexpected and puzzling, conflicting with both expectations and previous research showing proximity to health centers as protective against HIV for women after adjusting for some individual-level behaviors (Gabrysch, Edwards et al. 2008). It is unlikely that access to these services increases a woman's likelihood of infection. Rather, it is possible that clinics are purposefully placed in areas of higher risk, thereby causing endogeneity and confounding the results, or that people who are sick or HIV-infected may select to live near clinics. Lastly, clinics are likely located in smaller commercial centers, making this variable a proxy for distance to market center.

Individual-level risk factors also exemplify significant spatial variation. Previous sexually transmitted infection is significantly and positively associated with HIV status for 93% of women (Figure 6.5), covering the entire Central and Southern Regions of the country. The strength and geographic breadth of this relationship reaffirms the results of the global model, demonstrating the importance of this risk factor. Condom use is significant in fewer than 10% of local models, and multiple partners is not significant in any location, perhaps attributable to low reporting (Tawfik 2007).

Socio-cultural factors may influence these relationships. Consideration of these factors merits attention in future research. In both global and local models, Chewa women are less likely to be infected, and this relationship is significant for more than half of the sample. Chewa society is matrilineal (Benson, Chamberlin et al. 2005), and it is possible that women from this ethnic group hold more power over their sexual and social relationships, decreasing their risks. Other traditions such as polygamous marriage are associated with increased odds of infection for 30% of rural women, demonstrating the possible strength, but differential effect, of cultural practice on HIV risk.

Overall, the local model adds detail to the importance and distribution of these key relationships among women. The significance of the area-level variables in local models suggests that global associations dilute important drivers of HIV in specific geographic areas. In particular, and as supported by the PEH, the significance of distance to roads, cities, and clinics suggests that women are less likely to be infected in more isolated areas. Contrary to the conceptual model, income inequality and absolute poverty are not associated with HIV status in global or local models. This lack of association may be due to the pervasive nature of poverty in rural Malawi, masking relationships that might be evident in more economically diverse areas.

Spatial variation in associations between area- and individual-level factors and HIV among men

As expected from the global model, and in contrast to the female sample, there is little spatial variation and few significant factors associated with HIV at the local level among men. Among men, three risk factors show significant spatial variation at the local level, providing only a marginal improvement over the global model.

At the area-level, distance to a MOH clinic is significantly associated with HIV status for 10% of men clustered near the southern shores of Lake Malawi in Machinga and Mangochi Districts on the border with Mozambique, setting this location apart from other rural regions (Figure 6.6). Although the relationship between distance to MOH clinic and HIV remains negative throughout the country, only men who live further from a MOH clinic in this area are significantly less likely to be infected. Similar to the women, the direction of this relationship is unexpected and contradicts previous research noting the association between community-level health worker activity and decreased extramarital sex among men in Zambia (Benefo 2008). As suggested previously, it is unlikely that health clinic proximity increases the odds of HIV infection for men. Rather, it is more likely that MOH clinics serve as a proxy for smaller commercial centers and that commercial hubs in these lakefront districts may be dissimilar to other locations in Malawi. Further research into the specific characteristics of men in this distinct area warrants investigation. No other area-level factors are significant for men in local models.

Demonstrating the value of the local model to reveal relationships watered down at the global level, migration is significant and positive for 47% of men in local models (Figure 6.7). Men who live in the center of the country, mostly between the districts of Mangochi and central Mazimba (including areas around Lilongwe and Mzuzu), who migrate are more likely to be infected with HIV than men who do not. In areas of significance, men may follow distinct migration patterns, working or traveling in particular areas of neighboring countries that increase their risk, especially through additional sex partners (Chirwa 1997).

Among individual-level risk behaviors, only STI is associated with HIV status for men in the global and local models, demonstrating the importance of this factor across much of rural Malawi. Previous STI is positively associated with HIV status for the entire area and significant for 75% of men (Figure 6.8). This relationship is not significant in the Northern Region, an area of lower STI prevalence.

Individual-level demographic factors further explain patterns of infection among men. Increasing age and socio-economic status are associated with increased odds of infection for almost all rural men. Similar to women, socio-cultural factors may also influence individual risk (Morah 2007). Among men, as with women, Chewa ethnicity is significantly associated with decreased HIV risk. As noted previously, Chewa are traditionally matrilineal, and men frequently move into the homestead of the wife’s family at marriage (Benson, Chamberlin et al. 2005; Chimbiri 2007), potentially increasing gender equality and reducing risk behaviors. Additionally, Chewa show preference for marriage within their ethnicity (Posner 2004), suggesting a level of protection among closed social networks.

Contrary to theoretically-informed hypotheses, most area-level factors are not associated with HIV for men. In part, the lack of significant associations may reflect the heightened status of men in comparison to women. In Malawi, men have more access to income and hold more social power than women (Schatz 2005). Social norms of masculinity and marriage include controlling women (Chirwa 1997), largely providing men with decision-making power over partner selection and use of condoms (Kaler 2003). This status may allow men to buffer negative influences of area-level socio-economic factors such as poverty or inequality (Craddock 2000). Also, improvements in rural infrastructure may enable men's mobility, smoothing underlying differences in access.

CONCLUSION

This study demonstrates that *place* matters in the context of HIV in rural Malawi, and that the strength of area- and individual-level drivers of HIV vary in space. This spatial analysis calls attention to two important conclusions. First, gender plays a role in the spatial determinants of HIV: the influence of area-level factors and HIV status are exacerbated for women. The PEH clarifies these findings. The socio-economic environment in Malawi may reinforce gender inequality and reduce women's rights to govern their sexual health (Kathewera-Banda 2005). As a result, women literally *embody* the discrimination, economic disadvantage, and inequality they face (Krieger 1999; Krieger 2005). Within couples, *embodiment* translates to compromised gender-based power, diminishing a woman's ability reduce HIV risk through refusal of sex or insistence on condoms (Blanc 2001; Luke and Kurz 2002; Dunkle, Jewkes et al. 2004; Pettifor, Measham et al. 2004; Schatz 2005).

Second, spatial analysis affirms that area-level socio-economic and access factors play a significant role in increasing HIV risk above and beyond individual-level contributions. Drawing on the PEH for interpretation, ecological factors such as economic underdevelopment, mobility, and power differentials create social and economic "risk environments" that limit individual choice, constrain behavior, and restrict ability to make positive health decisions (Minkler, Wallace et al.

1994; Minkler 1999), increasing vulnerability to HIV infection (Parker, Easton et al. 2000; Rhodes, Singer et al. 2005). In response, reducing poor health outcomes such as HIV infection requires moving from an emphasis on individual behavior to consideration of macro-level factors that reduce an individual's power to effect change (Doyal 1995; Farmer 1999; Farmer 2003).

Using spatial methods to explore place-based effects on HIV in Malawi presents several challenges. First, people are likely to self select into neighborhoods, making area-level effects less randomly distributed among the populations (Sampson, Morenoff et al. 2002; Oakes 2004). Also, geographic information from developing countries is sparse, and combining multiple geographic layers from various sources with different scales may add small errors in location information, potentially allocating individuals to incorrect geographic areas. The inclusion of only Ministry of Health clinics attempts to reflect reach of government health facilities, but the effects of excluding private health care and other clinic options have unknown effects on measuring access to health services. Lastly, although the global regression models showed no significant multicollinearity among variables, multicollinearity is still possible in local models (Wheeler and Tiefelsdorf 2005). The magnitude and direction of biases cannot be determined with the available data.

Overall, the results contribute to the growing body of evidence connecting health and place, expanding application of spatial methods to the context of HIV in sub-Saharan Africa. To successfully address the complexity of the epidemic, solutions will need to account for differences between both individuals and the areas in which people live. Although this study reveals *where* area- and individual-level factors drive HIV in rural Malawi, *why* and *how* HIV is influenced by these factors remains unanswered. Additional studies at finer spatial scales and complementary qualitative research would elucidate these relationships in rural Malawi.

Table 6.1: Variable descriptions

Variable	**Definition**	**Type of variable**
Individual-Level		
HIV Status	Infection with HIV-1 or HIV-2 on 2 tests of HIV status, including rapid and confirmation with Western Blot or ELIZA	Dependent
Gender	Male or female	Moderator
Condom	Condom use with any of previous 3 sexual partners	Independent
Multipart	2 or more sexual partners in last year	Independent
STI	Diagnosis/symptoms of sexually transmitted infection within past year	Independent
Migration	Travel for more than one month in last 12 months	Independent for men
Paid Sex	Ever paid for sex	Independent for men
SES	Household socio-economic status	Control
Age	Continuous age in years	Control
Marital Status	Dummy variables for never married; married; and previously married	Control
Polygyny	Multiple marital union	Control
Education	Dummy variables for no education, primary education, >= secondary education	Control
Religion	Dummy variables for Christian; Muslim; other	Control

Ethnicity	Dummy variables for Chewa; Lomwe; Yao; Other	Control
Circumcision	Circumcised or not	Control for men only
Area-Level		
High Gini	Gini coefficient in the 75th percentile or higher	Independent
Middle Gini	Gini coefficient in the 26th – 74th percentile	Independent
Absolute poverty	% of population below the poverty line (poverty headcount)	Independent
Distance to a major road	Km from DHS cluster point to closest major road	Independent
Healthcare availability	KM from DHS cluster to closest Ministry of Health clinic	Independent
Distance to a major city	Km from DHS cluster to the closest regional capital, Mzuzu, Lilongwe, or Blantyre	Independent

Table 6.2 – Descriptive proportions of key variables among men and women

		% Women, n=2091	% Men, n=1827
Age**	15-19	12	12
	20-24	26	21
	25-29	19	20
	30-34	16	16
	35-39	11	11
	40-44	10	10
	45-49	7	6
	50-54	n/a	3
Religion	Christian	37	38
	Muslim**	12	10
	Catholic	24	22
Region**	North	13	13
	Central	39	43
	South	48	45
Ethnicity	Chewa	34	35
	Yao	13	12
	Lomwe	18	18
Education***	None	27	14
	Primary 0-4	64	65
	Grade 5 or higher	9	21
Marital status***	Never married	5	22
	Married/Union	77	74

Previously married	18	4
Wealth quintile (SES)*** Lowest	19	14
Second	24	23
Middle	25	27
Fourth	23	25
Highest	10	11
Polygyny***	17	8
Circumcised	n/a	22
Migrate	n/a	12
Multiple partners in last year***	7	24
Recent condom use***	4	14
Previous STI in last 12 months***	10	6
Ever had paid sex	n/a	22
Risk score*** 0	83	57
1	14	27
2	2	12
3	1	4
HIV+ status***	13.8	9.6

Chi square results of difference in proportions, * p<.1, **p<.05, ***p<.01

Table 6.3: Global model parameters for women and men

	Women				Men			
Parameter	**Estimate**		**t-value**	**Odds Ratio**	**Estimate**		**t-value**	**Odds Ratio**
Intercept	-4.081	(0.681)	-5.99***	0.02	-4.298	(0.632)	-6.79***	0.014
Individual-level demographic								
Age	0.021	(0.008)	2.63***	1.02	0.027	(0.010)	2.77***	1.03
Education	-0.024	(0.127)	-0.19	0.98	0.047	(0.151)	0.30	1.05
Current marriage	1.204	(0.464)	2.59***	3.33	2.119	(0.469)	4.51***	8.31
Previous Marriage	2.046	(0.460)	4.44***	7.73	1.566	(0.587)	2.66***	4.78
Polygyny	0.219	(0.187)	1.17	1.24	-0.087	(0.343)	-0.25	0.91
SES	0.249	(0.055)	4.48***	1.28	0.250	(0.076)	3.27***	1.28
Chewa	-0.653	(0.200)	-3.26***	0.52	-0.727	(0.247)	-2.94***	0.48
Lomwe	0.271	(0.192)	1.41	1.31	0.248	(0.232)	1.06	1.28
Yao	0.251	(0.272)	0.92	1.28	-0.188	(0.373)	-0.50	0.82
Christian	0.026	(0.149)	0.17	1.02	0.035	(0.184)	0.18	1.03
Muslim	0.080	(0.267)	0.30	1.08	0.114	(0.395)	0.28	1.12
Circumcised					0.013	(0.243)	0.05	1.01
Individual-level risk factor								
Multpart	0.402	(0.279)	1.44	1.49	0.048	(0.284)	0.16	1.05
STI	0.612	(0.202)	3.02***	1.84	0.714	(0.306)	2.33***	2.04
Condom use	0.697	(0.307)	2.27***	2.01	0.438	(0.274)	1.59	1.54
Paidsex					0.058	(0.197)	0.29	1.06
Migrate					0.421	(0.245)	1.72	1.52

Area-level factor								
Gini high	0.193	(0.192)	1.00	1.21	-0.241	(0.245)	-0.98	0.78
Gini middle	-0.010	(0.173)	-0.056	0.99	0.036	(0.205)	0.17	1.03
MOH clinic	-0.060	(0.026)	-2.34***	0.94	-0.071	(0.033)	-2.12**	0.93
Major road	-0.013	(0.007)	-1.90	0.99	-0.013	(0.009)	-1.49	0.98
Major city	0.001	(0.002)	0.36	1.00	0.001	(0.002)	0.23	1.00
Poverty %	0.001	(0.004)	0.15	1.00	0.003	(0.005)	0.56	1.00
Log-likelihood:	-797.350						-512.785	
Akaike Information Criterion:	1640.700						1079.570	
Corrected AIC (AICc)	1641.234						1080.410	

Standard errors in parentheses. *p<.1, **p<.05, ***p<.01

Table 6.4: Comparison of Local Parameter summaries to global parameter for women

Label	From Local Parameter Model						Global model parameter
	Minimum	Lwr Quartile	Median	Upr Quartile	Maximum	% with significant local t value	
Intrcept	-7.449	-5.328	-4.309	-3.959	-3.589	100	-4.081
Demographic factors							
Age	0.018	0.018	0.020	0.022	0.040	83	0.021
Education	-0.364	-0.031	0.005	0.015	0.028	0	-0.024
Chewa	-0.795	-0.725	-0.580	-0.410	0.149	65	-0.653
Lomwe	-0.950	0.073	0.109	0.341	0.525	0	0.271
Yao	0.029	0.062	0.106	0.354	0.838	0	0.251
Christian	-0.054	-0.004	0.023	0.034	0.853	0	0.026
Muslim	-0.317	-0.161	0.015	0.093	0.167	0	0.080
Previous marriage	1.263	2.174	2.355	2.416	2.477	91	2.046
Current marriage	-0.165	1.286	1.507	1.620	1.674	80	1.204
Polygyny	-0.617	0.164	0.314	0.421	0.512	30	0.219
SES	0.209	0.238	0.257	0.269	0.702	100	0.249
Individual-level risk factors							
STI	0.497	0.546	0.573	0.653	1.139	93	0.612
Multiple	0.249	0.307	0.339	0.392	1.546	0	0.402

partner							
Condom	0.466	0.542	0.603	0.711	0.851	6	0.697
Area-level factors							
Gini high	0.046	0.209	0.227	0.244	0.259	0	0.193
Gini medium	-0.519	0.035	0.041	0.045	0.104	0	-0.010
Km to MOH	-0.064	-0.057	-0.050	-0.045	-0.007	29	-0.060
Km major road	-0.025	-0.016	-0.012	-0.011	0.011	25	-0.013
Km to major city	0.000	0.001	0.002	0.005	0.008	27	0.001
Poverty %	-0.007	-0.004	0.000	0.008	0.015	2	0.001
	Local Logistic Model Diagnostics						
	Log Likelihood:						-767.07
	Akaike Information Criterion						1623.78
	Corrected AIC						1625.79

Table 6.5: Comparison of Local Parameter values to global model for men

Label	From Local Parameter Model						Global model parameter
	Minimum	Lwr Quartile	Median	Upr Quartile	Maximum	% with significant local t value	
Intercept	-6.4597	-4.7847	-4.2412	-3.9487	-3.7850	100	-5.441
Demographic factors							
Age	0.0414	0.0422	0.0442	0.0481	0.0613	100	0.027
Educ	-0.2266	-0.1149	0.0170	0.1856	0.6866	5	0.047
Chewa	-0.8238	-0.8114	-0.7913	-0.6902	-0.2466	90	-0.727
Lomwe	0.0553	0.1144	0.2101	0.3428	0.6380	0	0.228
Yao	-0.5939	-0.2826	-0.2644	-0.2482	-0.2038	0	-0.188
Christ	-0.1181	-0.0367	0.0596	0.1909	0.3135	0	0.035
Muslim	-0.3338	-0.1934	-0.0167	0.2343	1.4324	0	0.114
Married	2.0686	2.1064	2.1459	2.1864	2.5262	100	2.119
Previously married	1.1702	1.2052	1.2594	1.3220	2.9428	46	1.566
Polygyny	-0.4715	0.1625	0.3358	0.4296	0.4689	0	-.087
SES	0.0701	0.1865	0.2306	0.2749	0.3137	87	0.250
Circum	-0.5643	-0.0370	0.0410	0.0714	0.0860	0	0.013
Individual-level risk factors							
STI	0.4819	0.6691	0.7192	0.7806	0.8612	75	0.714
Multiple	-0.5606	-0.5463	-0.5273	-0.5116	-0.4428	0	0.048

partners							
Condom	0.3721	0.4436	0.4940	0.5418	0.8477	0	0.438
Paidsex	-0.2062	0.1195	0.1727	0.1902	0.2184	0	0.058
Migrate	0.3491	0.4320	0.5126	0.5852	0.6776	47	0.421
Area-level factors							
Gini high	-0.4634	-0.3864	-0.3167	-0.2467	-0.1782	0	-0.241
Gini mid	-0.6623	-0.0794	0.0415	0.1097	0.1435	0	0.036
MOH	-0.0687	-0.0663	-0.0645	-0.0589	-0.0528	10	-0.071
Km to major road	-0.0190	-0.0175	-0.0159	-0.0152	-0.0110	0	-0.013
Km to major city	0.0015	0.0027	0.0031	0.0034	0.0038	0	0.001
Poverty %	-0.0002	0.0006	0.0027	0.0066	0.0186	0	0.003
	Local Logistic Model Diagnostics						
	Log Likelihood						-497.811
	Akaike Information Criterion						1073.530
	Corrected AIC						1075.272

Figure 6.1: Conceptual model

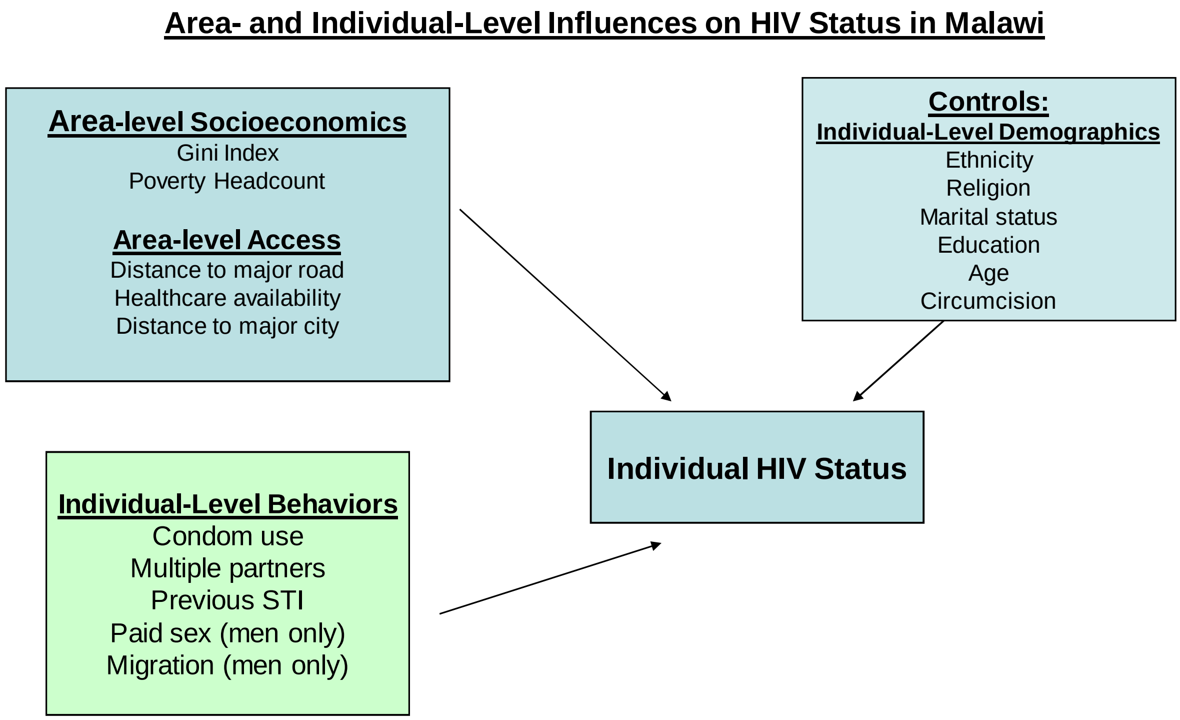
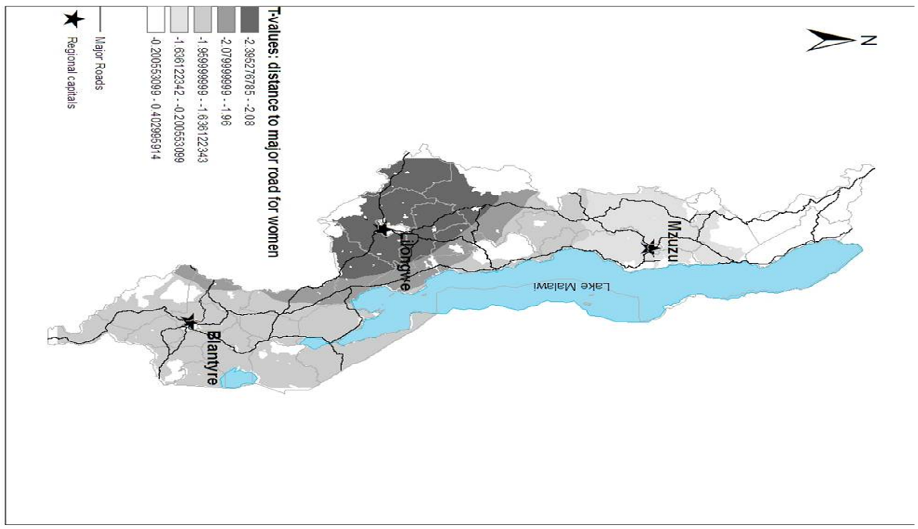


Figure 6.2: Distance to major road t values and distribution for women



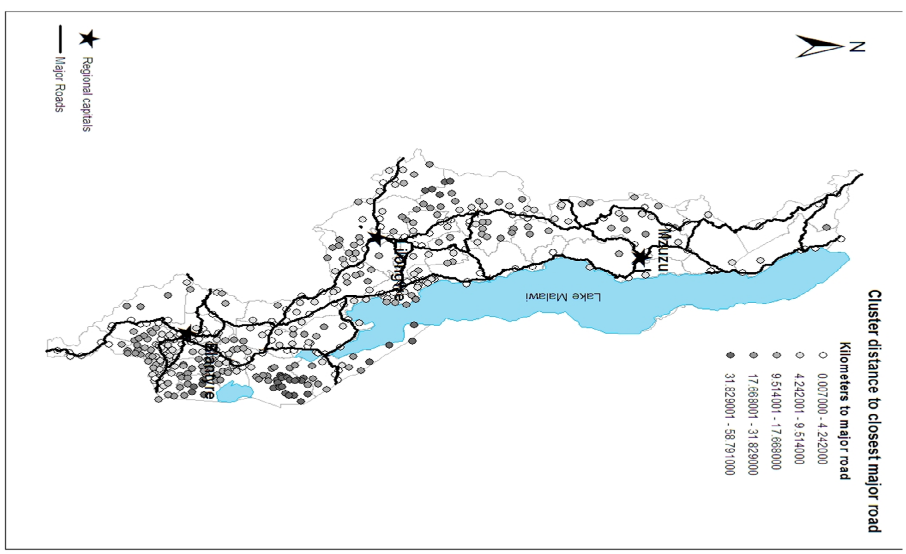


Figure 6.3: Distance to major city t values and distribution for women

Figure 6.4: Distance to MOH t values and distribution for women

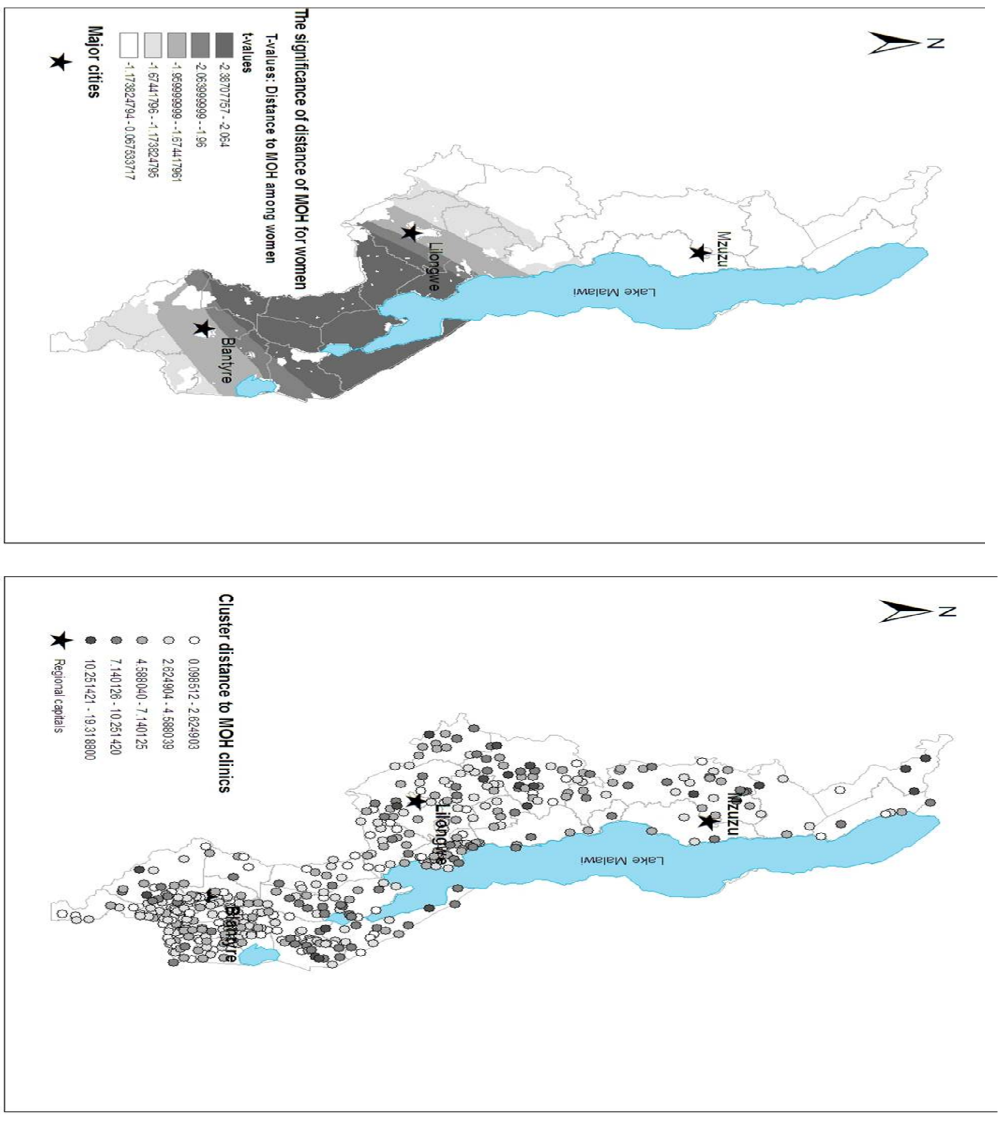
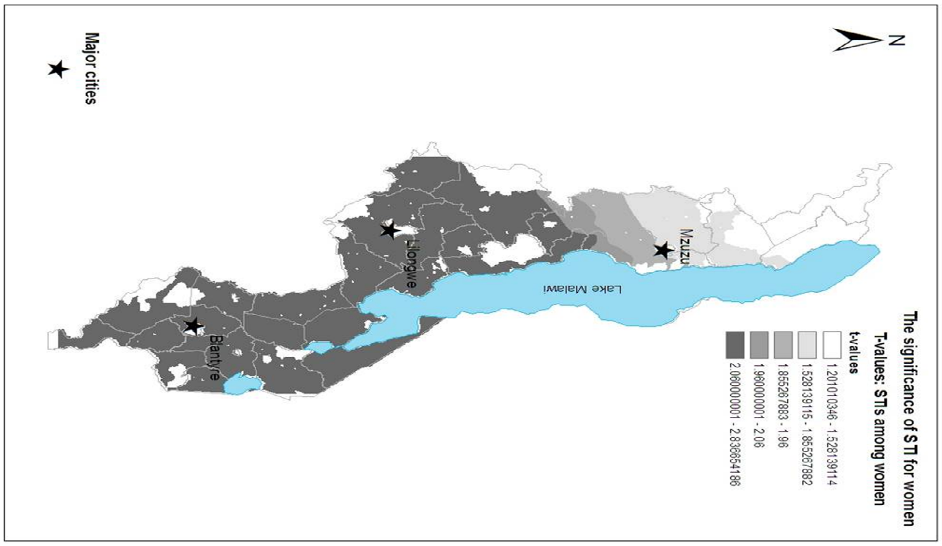


Figure 6.5: STI t values and distribution for women



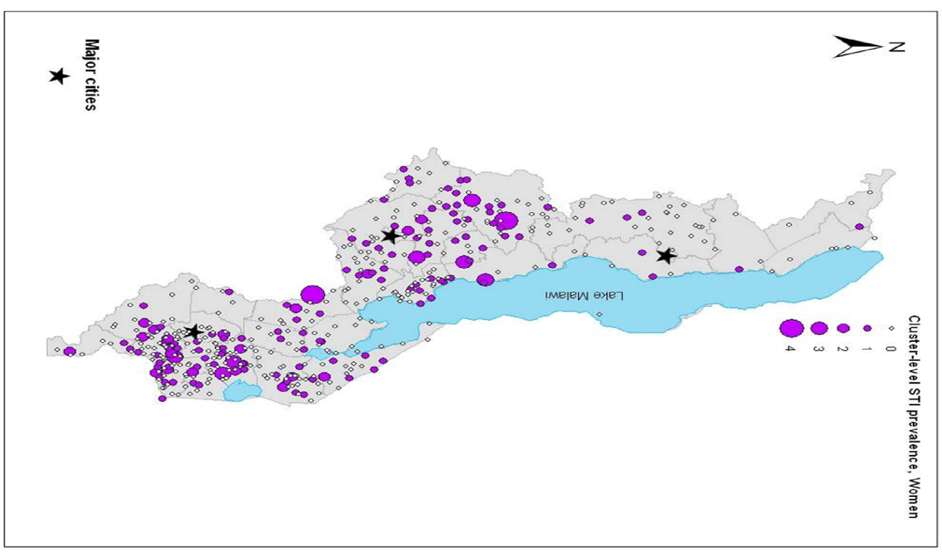
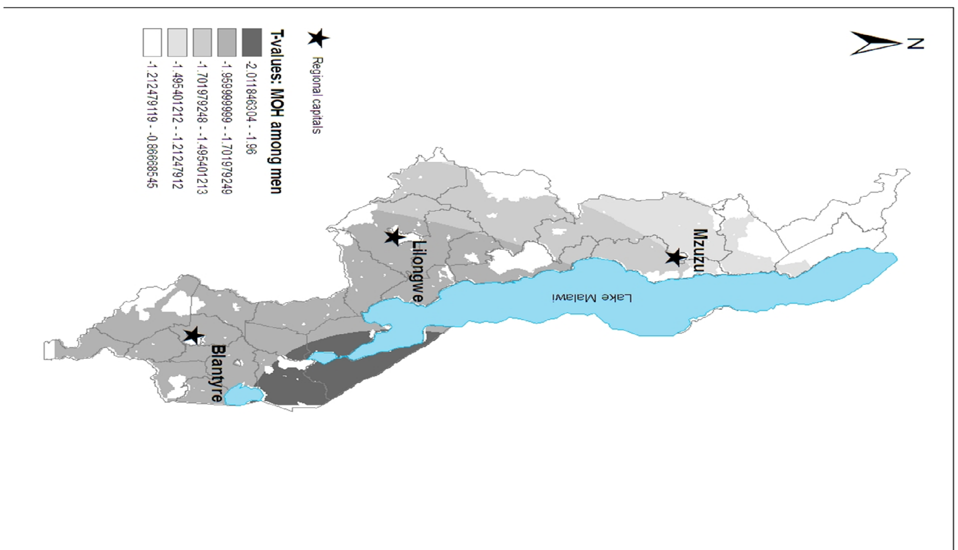


Figure 6.6: Distance to MOH clinic t values and distribution for men



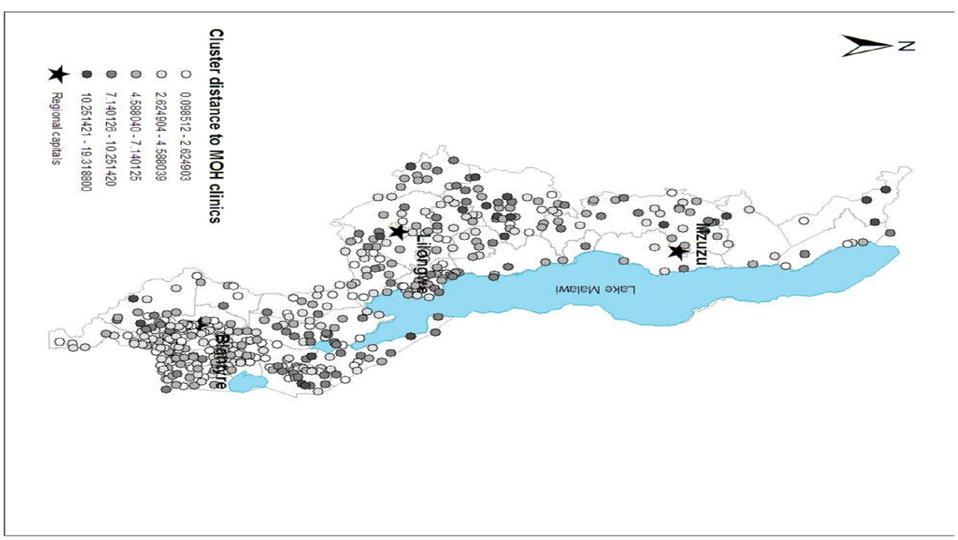


Figure 6.7: Migration t values and distribution for men

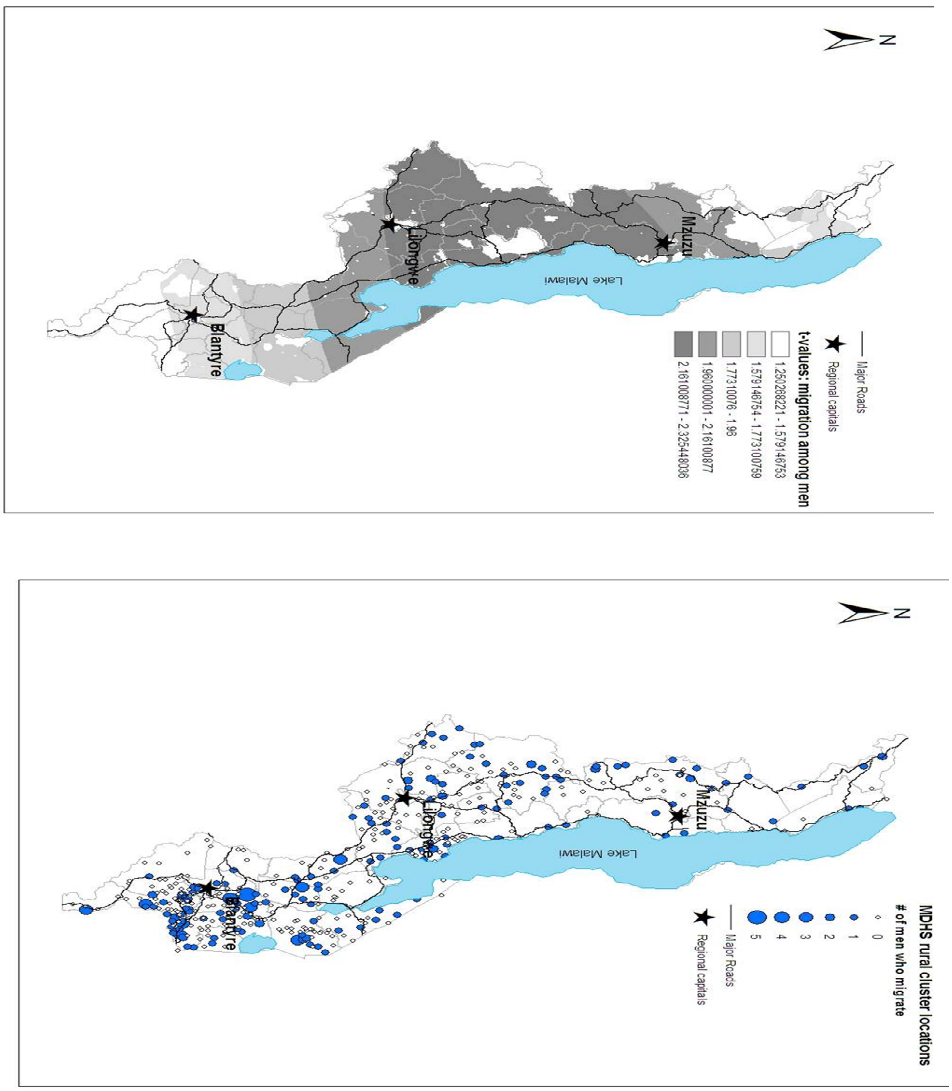
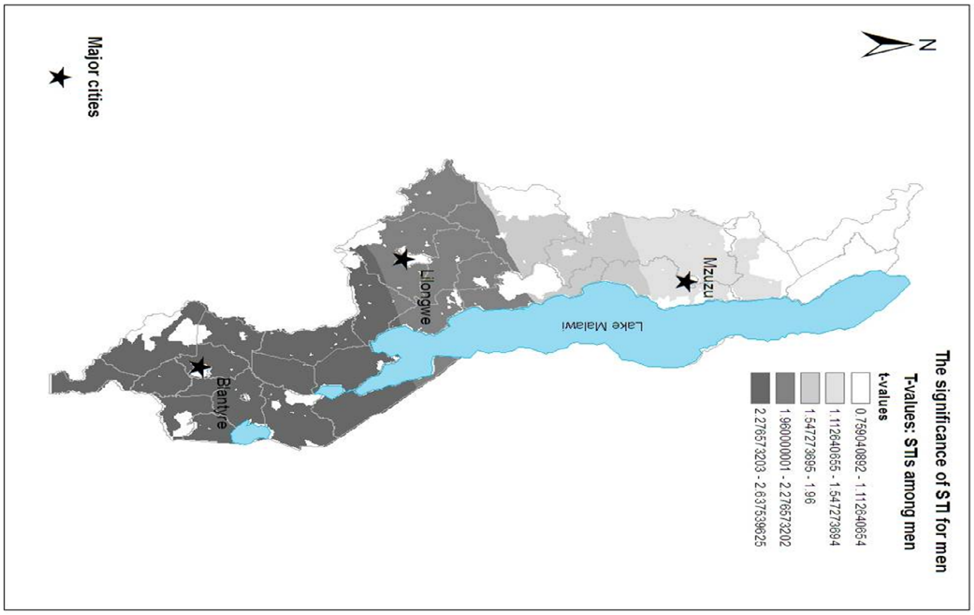
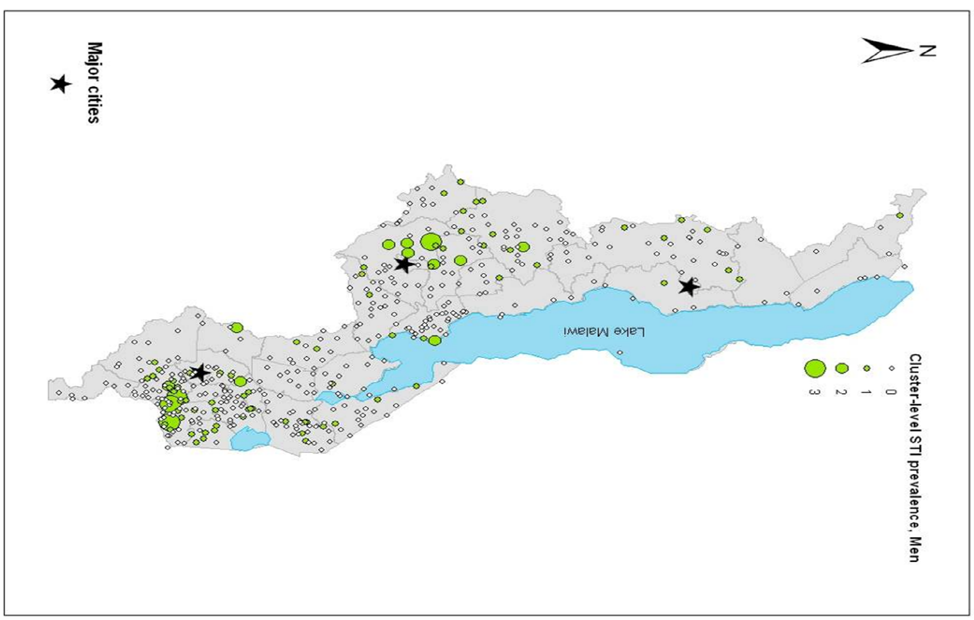


Figure 6.8: STI t values and distribution for men





CHAPTER 7

CONCLUSION

In combination, the logistic and spatial regression models provide complementary perspectives on how the characteristics of people and place affect HIV status in rural Malawi. A brief review of the results provides several valuable insights.

First, a comparison of the logistic regression to the global spatial model provides a population-averaged perspective on the epidemic, confirming that area-level socio-economic and access factors significantly influence HIV status above and beyond the contribution of individual-level behavioral and demographic variables. Largely, the results from the logistic model closely replicate the findings from the global spatial regression model, demonstrating consistency of results. Among women, distance to a MOH clinic is significant and negatively associated with HIV status across global models: women who live closer to MOH clinics have increased odds of infection in comparison to their female peers who live farther. Also, women who live farther from major roads are less likely to be infected than women who live closer; this relationship is significant in the global logistic regression model and marginally significant in global spatial models, showing a clear trend in the global association. However, higher income inequality increases the odds of HIV infection among women only in aspatial models, reducing the overall impact of this association. At the individual-level, condom use with any of the last 3 partners and recent STI are significant and positively associated with HIV status in both the logistic and global spatial models. Dissimilarly, although both global models reveal a positive relationship between multiple partners and HIV status, it is only significant in the logistic regression model, decreasing the overall importance of this factor.

For men, distance to MOH clinics is significant and negatively associated with HIV status in both aspatial and spatial models: men who live further from a MOH clinic are less likely to be infected than men who live closer. Among individual-level factors, both global models show that STI increases the odds of HIV infection. Multiple partners is significant and, unexpectedly, protective for men only in logistic models, reducing the strength of this association. Consistency between aspatial and spatial models lends support to the strength of specific results at the global level.

Second, the local spatial models are an improvement over global models, especially for women, offering clues about where, how, and for whom these relationships matter in rural Malawi. Among women, significance of area-level factors in global models does not necessarily translate to associations at the local level. Both distance to MOH and distance to major road are important drivers of HIV overall, but their influence is significant for only 29% and 25%, respectively, of women when examined at a finer spatial scale. Furthermore, although diluted in global regression models, distance to major city is positively and significantly associated with HIV status for 27% of women, showing the importance of this area-level driver of HIV among women in a distinct region. Lastly, although the influence of condom use and multiple partners disappears at the local level, the positive and significant effect of STI on HIV status is almost ubiquitous (93%), demanding attention of this critical driver of the epidemic. These local level results call attention to spatial variability in the drivers of HIV in specific geographic areas, advising the need for local rather than national-level determination of intervention priorities.

Among men, the local model adds interesting detail about how the drivers of HIV vary in rural Malawi. Primarily, although diluted in the global model, migration is significant for 47% of men in the local spatial regression model. Distinct migration routes in some areas may increase HIV risk while migration patterns to or from other locations may incur no additional risk. Among men, individual-level movement may overshadow area-level effects, potentially underscoring individual mobility over static location as a risk factor for men. Second, unlike all other area-level factors, distance to MOH clinic is significant in the global model and for 10% of men in the local model, setting an area near the southern Lake Malawi shores apart from other rural regions. The overlapping risk among men who migrate and live closer to MOH clinics in these southern lake districts warrants investigation. Lastly, similar to women, previous STI is a critical driver of HIV for the vast majority of men (75%), indicating a priority intervention appropriate for most rural Malawians.

Finally, from both logistic and spatial regression, the effects of gender are clear: area- and individual-level risk factors affect men and women differently. Qualitative comparison of the results by gender suggests that area-level factors influence women more strongly than men: both spatial and aspatial models indicate that women are more affected by socio-economic and access factors in the areas in which they live than men. Although this finding affirms study hypotheses, the extent of gender-based variation confirms the need for distinct and divergent approaches to assuaging the HIV epidemic. Aspects of the social, cultural, and economic environment reinforce gender and socio-economic inequality in rural Malawi. For women, area-level effects are exacerbated, reducing their ability to govern their sexual and reproductive health and increasing their vulnerability and risk for HIV infection. For men, the impact of these same area-level factors appears diminished, providing evidence that men's higher position in society may help them buffer negative influences in the areas in which they live. Surprisingly, behavioral mediators are largely non significant in the relationship between area-level factors and individual HIV status. As informed by the PEH, these findings confirm expected and direct relationships between area-level factors and HIV status and affirm the critical role of gender in these associations. However, the results also reveal that unidentified factors outside of these individual risk behaviors serve as mediators between area- level factors and HIV status. Further examination of these mechanisms is required.

These papers fill a gap in previous research on area- and individual-level influences on HIV status, specifically in rural Malawi. This study begins to answer the *how* questions in understanding the influence of area-level factors on individual behavior and HIV status. The use of the Political

Economy of Health framework to inform the conceptual model and guide interpretation of the results strengthens the findings, offering explanatory pathways between area- and individual-level factors and HIV infection. Moreover, this research confirms the importance of gender on the associations between both area- and individual-level factors with HIV status, demonstrating its influence at all levels of society.

The spatial component of this study adds to the growing emphasis on the linkages between health and place and makes important contributions over previous research. First, the spatial analysis illuminates distinct patterns in the area- and individual-level factors that affect HIV status in rural Malawi, providing a specificity of associations based on location. Second, the spatial model results may be more effective in aiding decision makers in the selection of where to intervene and what factors warrant consideration in a specific geographic space (Richards, Croner et al. 1999). By providing visual representations of the relationships, the maps may motivate hypotheses generation to answer the *who* and *where* questions of HIV transmission (Chirwa 1997; Craddock 2000), potentially increasing participation in tailored policy and intervention design. Although geographic analysis does not provide answers, a strength of spatial analysis is its ability to serve as an impetus for further studies to determine not just *where*, but *why*, the relationships vary in space.

The results of this research reveal where and for who place matters in the context of HIV in rural Malawi and elucidate multiple pathways that affect HIV status. The results from the logistic and spatial regression confirm that area-level factors have a significant influence on HIV in rural Malawi, and maps illustrate the variations among these relationships in space. The influences of both individual- and area-level effects are significant, but they are not stagnant, reinforcing the dynamic nature of the HIV/AIDS epidemic. Consideration of multiple levels of influence on both people and the places in which they live is critical to the development of effective and appropriate HIV prevention efforts. Innovative and adaptive responses require equal participation by men and women to slow the spread of the HIV epidemic in rural Malawi.

APPENDICES

Appendix 1: Summary of area-level variables

Variable	Mean	Std. Dev.	Min	Max
Gini	0.35	0.06	0.12	0.67
Gini_high	0.22	0.41	0.00	1.00
Gini_middle	0.44	0.50	0.00	1.00
Gini_low	0.21	0.41	0.00	1.00
Km_moh	5.08	2.87	0.10	19.32
Km_major road	11.20	11.92	0.01	58.79
Km_major city	79.42	40.32	5.08	222.72
Poverty %	63.82	16.86	11.56	97.34

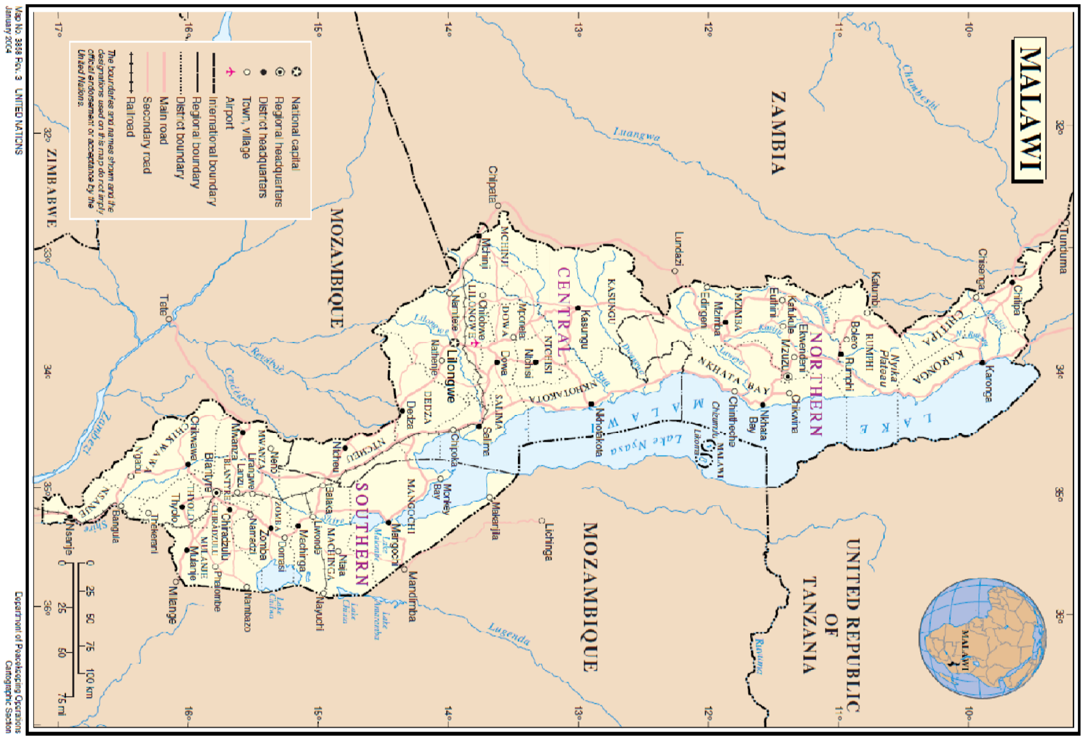
Appendix 2: Variance inflation factor among key variables for women:

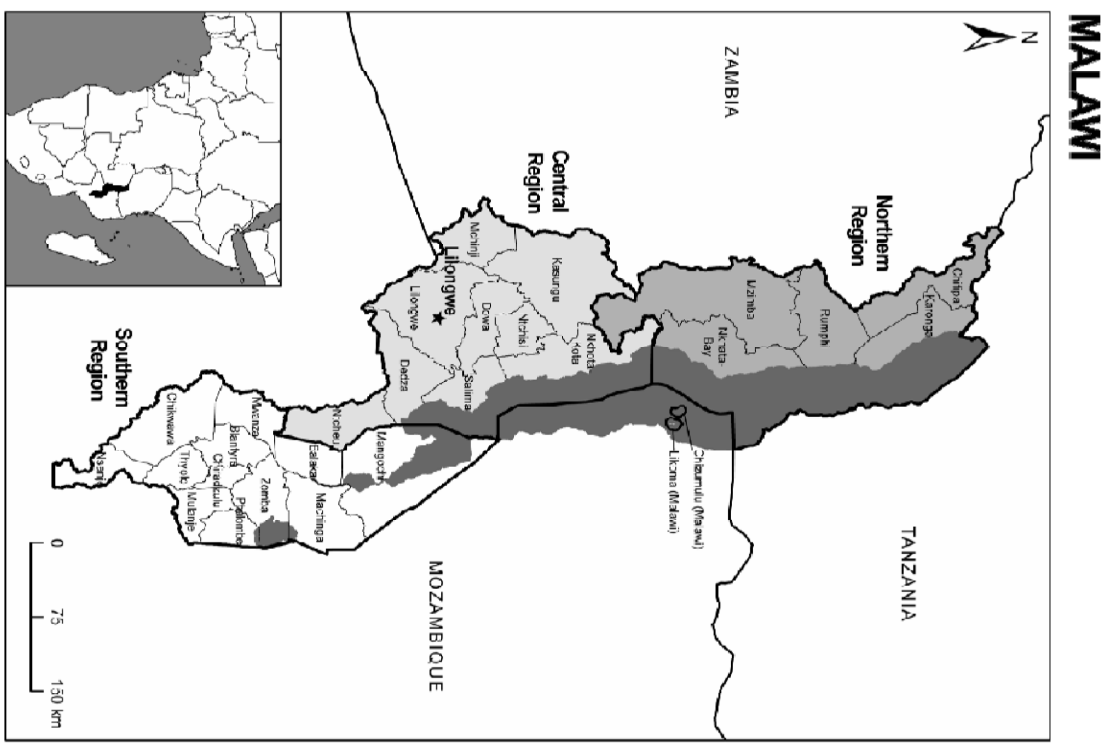
Variable	VIF	SQRT VIF	Tolerance	R-Squared		Variable	VIF	SQRT VIF	Tolerance	R-Squared
gini_high	1.24	1.11	0.8055	0.1945		gini_high	1.24	1.11	0.8051	0.1949
gini_low	1.22	1.11	0.8165	0.1835		gini_low	1.23	1.11	0.8154	0.1846
km_moh	1.16	1.08	0.8601	0.1399		km_moh	1.16	1.08	0.8599	0.1401
km_distrd	1.6	1.26	0.6257	0.3743		km_distrd	1.6	1.26	0.625	0.375
km_majrd	1.53	1.24	0.6548	0.3452		km_majrd	1.53	1.24	0.6545	0.3455
km_medcity	1.42	1.19	0.7035	0.2965		km_medci	1.42	1.19	0.7035	0.2965
km_majcity	1.49	1.22	0.6715	0.3285		km_majcit	1.49	1.22	0.6705	0.3295
pov_pct	1.13	1.06	0.8846	0.1154		pov_pct	1.13	1.06	0.8827	0.1173
newrisk3	1.14	1.07	0.8747	0.1253		multipart	1.44	1.2	0.6958	0.3042
polygny	1.1	1.05	0.9078	0.0922		usedcondc	1.16	1.08	0.8591	0.1409
region	2.38	1.54	0.4202	0.5798		sti	1.04	1.02	0.9602	0.0398
muslim	2.57	1.6	0.3884	0.6116		polygny	1.11	1.05	0.9007	0.0993
christian	1.2	1.1	0.8314	0.1686		region	2.39	1.54	0.4191	0.5809
yao	2.92	1.71	0.3427	0.6573		muslim	2.58	1.61	0.3871	0.6129
lomwe	1.86	1.36	0.5382	0.4618		christian	1.21	1.1	0.8291	0.1709
tumbuka	1.85	1.36	0.5408	0.4592		yao	2.92	1.71	0.3421	0.6579
chewa	1.96	1.4	0.5104	0.4896		lomwe	1.86	1.36	0.5377	0.4623
educ	1.38	1.17	0.7252	0.2748		tumbuka	1.87	1.37	0.535	0.465
age	1.19	1.09	0.839	0.161		chewa	1.96	1.4	0.5096	0.4904
hiv_status	1.08	1.04	0.9229	0.0771		educ	1.38	1.17	0.7246	0.2754
married	1.23	1.11	0.8148	0.1852		age	1.2	1.09	0.8348	0.1652
ses	1.18	1.09	0.8446	0.1554		hiv_status	1.09	1.04	0.919	0.081
						married	1.4	1.18	0.7129	0.2871
Mean VIF	1.54					ses	1.19	1.09	0.8428	0.1572
						Mean VIF	1.53			

Appendix 3: Variance inflation factor among key variables for men:

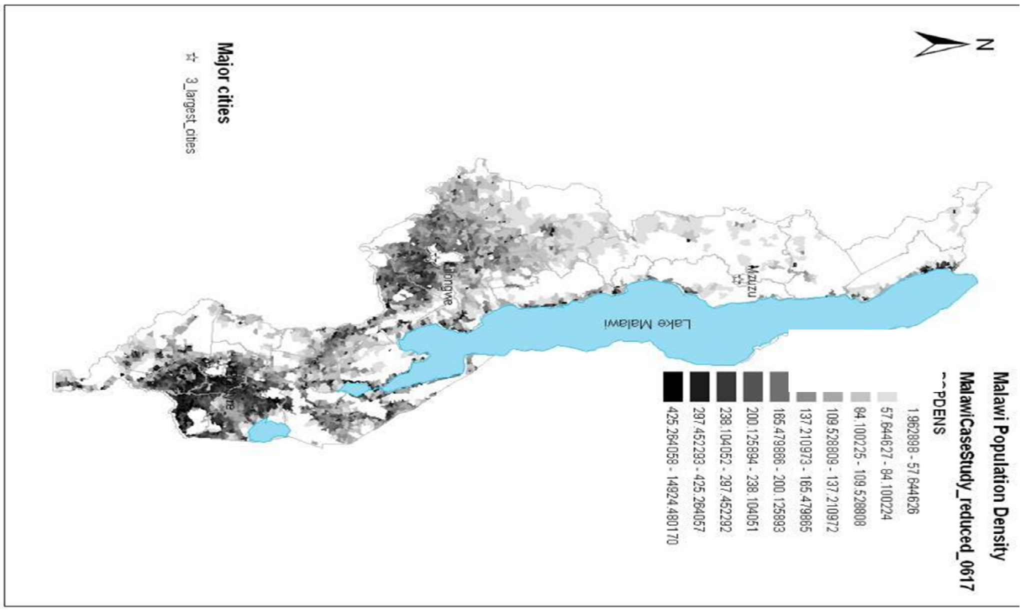
Variable	VIF	SQRT VIF	Tolerance	R-Squared		Variable	VIF	SQRT VIF	Tolerance	R-Squared
gini_high	1.26	1.12	0.7956	0.2044		gini_high	1.26	1.12	0.7947	0.2053
gini_low	1.23	1.11	0.8158	0.1842		gini_low	1.23	1.11	0.8155	0.1845
km_moh	1.16	1.08	0.8602	0.1398		km_moh	1.17	1.08	0.8581	0.1419
km_distrd	1.55	1.24	0.647	0.353		km_distrd	1.55	1.24	0.6462	0.3538
km_majrd	1.49	1.22	0.6693	0.3307		km_majrd	1.5	1.22	0.6676	0.3324
km_medcity	1.41	1.19	0.7076	0.2924		km_medci	1.42	1.19	0.7064	0.2936
km_majcity	1.43	1.2	0.7001	0.2999		km_majcit	1.45	1.21	0.6878	0.3122
pov_pct	1.15	1.07	0.8724	0.1276		pov_pct	1.15	1.07	0.8713	0.1287
newrisk3	1.25	1.12	0.7982	0.2018		multipart	1.83	1.35	0.5456	0.4544
polygny	1.13	1.06	0.8882	0.1118		paidsex	1.1	1.05	0.9056	0.0944
region	2.23	1.49	0.449	0.551		sti	1.03	1.01	0.9747	0.0253
muslim	2.9	1.7	0.3453	0.6547		usedcondc	1.32	1.15	0.7577	0.2423
christian	1.17	1.08	0.8515	0.1485		polygny	1.25	1.12	0.7998	0.2002
yao	2.82	1.68	0.3552	0.6448		region	2.24	1.5	0.4472	0.5528
lomwe	1.84	1.36	0.543	0.457		muslim	2.92	1.71	0.3424	0.6576
tumbuka	1.79	1.34	0.56	0.44		christian	1.17	1.08	0.8511	0.1489
chewa	1.88	1.37	0.5306	0.4694		yao	2.83	1.68	0.3538	0.6462
educ	1.21	1.1	0.8248	0.1752		lomwe	1.85	1.36	0.5407	0.4593
age	1.53	1.24	0.6531	0.3469		tumbuka	1.79	1.34	0.5583	0.4417
hiv_status	1.07	1.03	0.9338	0.0662		chewa	1.89	1.37	0.5293	0.4707
married	1.64	1.28	0.6102	0.3898		educ	1.23	1.11	0.8159	0.1841
migrate	1.05	1.02	0.9568	0.0432		age	1.54	1.24	0.6491	0.3509
circum	2	1.41	0.501	0.499		hiv_status	1.08	1.04	0.9292	0.0708
ses	1.15	1.07	0.8715	0.1285		married	1.84	1.36	0.5442	0.4558
						migrate	1.05	1.02	0.9562	0.0438
Mean VIF	1.55					circum	2.01	1.42	0.498	0.502
						ses	1.15	1.07	0.8704	0.1296
						Mean VIF	1.55			

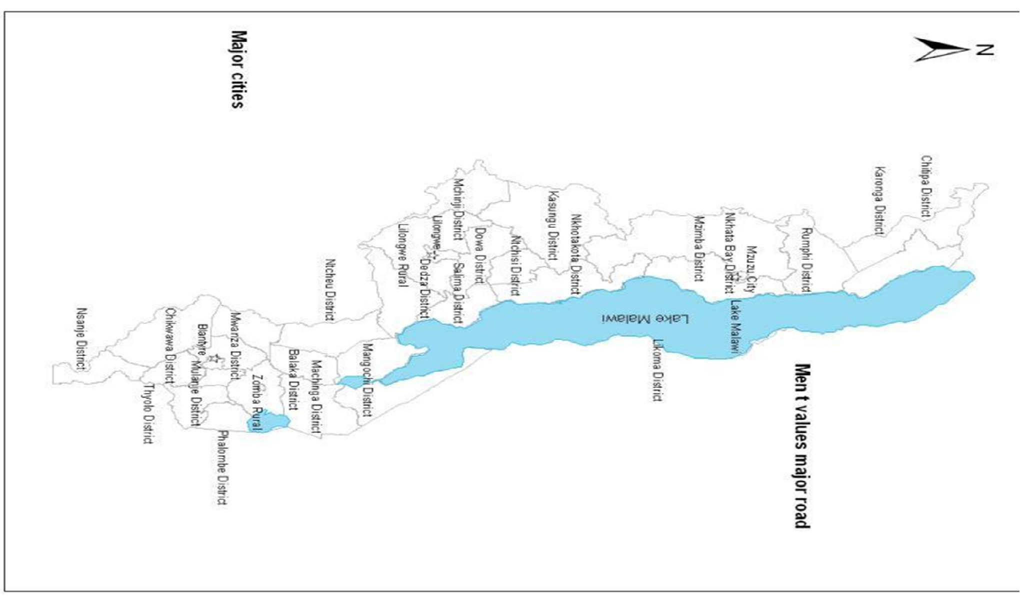
Appendix 4: Map of Malawi



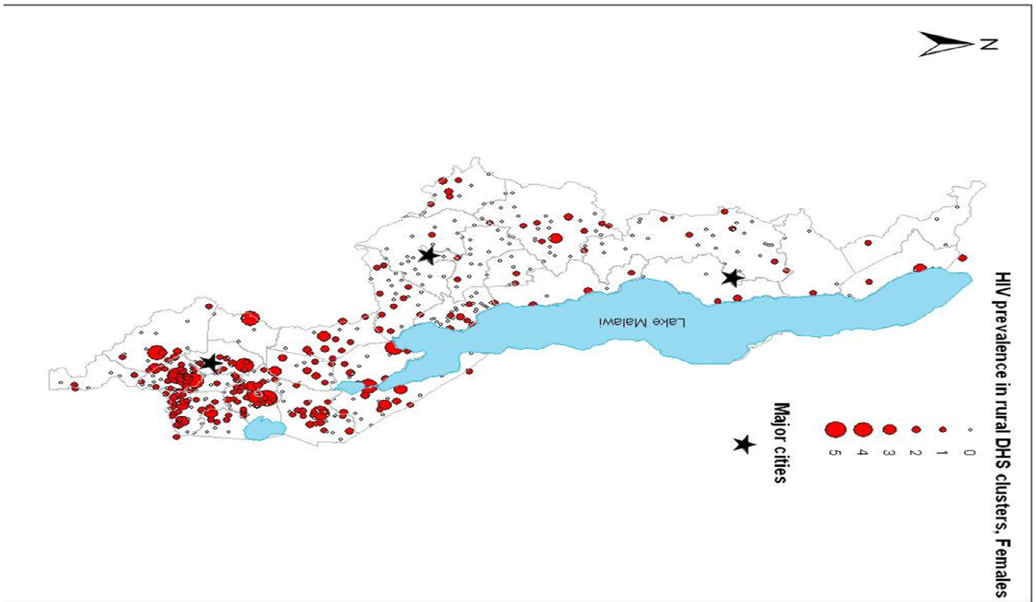


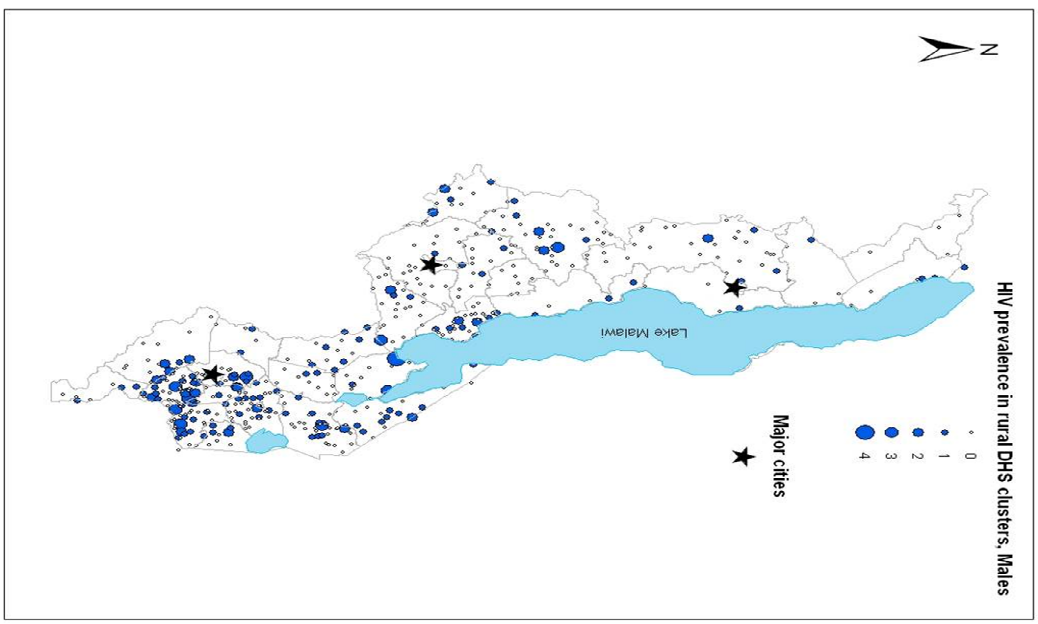
Appendix 5: Malawi Population Density and Districts





Appendix 6: HIV prevalence by cluster and gender





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