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Targeting Interventions to Reduce Chlamydia-Related Disparities in Kalamazoo County using GIS and Statistical Analysis

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TARGETING INTERVENTIONS TO REDUCE CHLAMYDIA-RELATED DISPARITIES IN KALAMAZOO COUNTY USING GIS AND STATISTICAL ANALYSIS

by

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The annual incident rates of chlamydia continue to rise within Kalamazoo County despite an increase in public health campaign, particularly for persons between the ages of 15-24. This trend in incidence rates of chlamydia by age also shows strong disparities in race/ethnicity and gender at state and county levels. With the increasing burden on the cost of treatment of chlamydia, which is one of the many sexually transmitted infections, targeting high risk populations offers a means of reducing the cost and the spread of the infection. This has shaped attention of researchers and policy makers to the complexity of the processes in social, economic and environmental factors as key determinants in health outcomes such as chlamydia.

With increasing use of Geographic Information System (GIS) and statistical methods in these studies, key geographical patterns have been found to help in planning intervention programs to remedy the situations. This study therefore investigates the geographic patterns of chlamydia cases and to quantify the factors related to chlamydia-disparities within the neighborhoods for planning location-based interventions in Kalamazoo County. The study found that populations at high risk of acquiring chlamydia live within areas with a high density of cases in the cities relative to other areas. The study found three main core areas of high density of cases of chlamydia to immediately target for intervention programs among high risk populations. The findings in this study are consistent with previous studies that, socioeconomic status remains the highest predictive factor in health disparities.

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CHAPTER I

INTRODUCTION

Over the past decade, many studies have emphasized the complexity of the processes that contribute to an individual's health outcome by incorporating social, economic and neighborhood-level characteristics of the population for prediction (Krieger et al., 2003; Stewart et al., 2011; Bell et al., 2013). Despite increasing research in public health indicating geographical patterns of high of disease risk in disadvantaged areas, most health surveillance systems do not capture the individual-level socioeconomic characteristics which are valuable in monitoring health disparities in a population (Krieger et al., 2003).

The role of geography in studying factors that contribute to health disparities at the individual level and neighborhood level has increased in recent years due to advances in Geographic Information Systems (GIS) (Cromley & McLafferty, 2012). GIS provides a means of visualizing areal differences in poverty, unemployment, income and area characteristics, particularly those indicative of social deprivation at the census tract-level. These differences can then be linked directly to individual level health outcomes data and has thus enhanced the study of disparities in health outcomes (Cromley & Mclafferty, 2012).

Recent studies have identified the increase in infectious diseases in human populations as a global threat to human health despite scientific and medical advances in reducing these infections as a cause of death to humans (Morens et al., 2004). The World Health Organization (WHO) reports this may be due many complex factors which accounts for the changing risky sexual behaviors (WHO, 2016). It is important to focus research on carefully defined populations, examine the identified target populations, and involve them in the design, implementation and evaluation of programs to reduce the spread of sexually transmitted infections (STI) (WHO, 2016). This will also help in the identification of significant factors that lead to disparities in that community while appropriate interventions are planned to meet the population at high risk of infections.

Many studies have identified populations with a higher risk of acquiring an STI to be concentrated in core groups and areas (Bernstein et al., 2004; Bush et al., 2008, Gesink et al., 2011). A recent national longitudinal survey of adolescents to adult health study found that STI diagnosis rates were independently associated with both racial/ethnic identity and with low income neighborhoods (Harling et al., 2013). Poverty has also been identified as one of the key individual, and most contextual variable in health disparities research (Krieger et al., 2003).

These studies each emphasize that social, economic and environmental processes contribute collectively to place individuals potentially participating in high risk sexual behaviors in neighborhoods with low-value housing, exposure to prostitution, illicit drug use, and limited access to health care resources (Krieger et al., 2003; Law et al., 2004; Semaan et al., 2007; Bush et al., 2008; Thomas et al., 2009; Sullivan et al., 2011; Hippe et al., 2012; Tobin et al., 2012; Harling et al., 2013). These processes contribute to how places differ in terms of the resources and the levels of risk that affect their populations. Such results have generated increasing public health concern directed at the identification of these areas to account for the health disparities between different groups of people in the population (Cromley & McLafferty, 2012).

Statement of the Problem

Most research in the United States tends to focus analysis of disparities in STI prevalence at the state level or within a single large city. Examples include North Carolina (Sullivan et al, 2011), South Carolina (Stewart et al., 2011), Massachusetts and Rhode Island (Krieger et al., 2003) and the large metropolitan cities of Baltimore (Bernstein et al., 2004), Chicago (Thomas et al., 2009) and San Francisco (Gesink et al., 2011). Although analysis of these scales is important in formulating policies and allocation of resources to combat the burden of STI, much needs to be done at local scales where public health officers are tasked with implementing targeted interventions across urban/rural boundaries. Even when screening programs are implemented, constraints such as mobility related to age, income, disability and access to transportation may result in highly localized patterns of spatial interaction (Cromley & McLafferty, 2012). These challenges may lower screening rates for high risk populations living in rural areas than in urban areas.

In the United States, the most frequent reported STI in the nation and statewide is chlamydia (Center for Disease Control, 2015; Michigan Department of Health and Human Service, 2015). According to the ranking of 83 counties in Michigan by the Michigan Department of Health and Human Service (MDHHS, 2015) statistics division, in 2014, Kalamazoo County ranked sixth with the total number of reported chlamydia infections (2,048) and a rate 791.3 cases per 100,000 populations.

This study will utilize secondary data of reported positive confirmed chlamydia cases from 2006 to 2014 in the Michigan Data Surveillance System (MDSS) for Kalamazoo County to account for areas in the county with high concentration of cases. Two main hypotheses were investigated in this study. The first hypothesis is that, areas with unusually high density of cases of chlamydia, contain high risk populations and constitute the core areas to target for interventions. The second hypothesis is that, neighborhood characteristics in poverty, low educational status, unemployment rate and environment conditions (urban-rural) influence why some individuals are at a high risk of acquiring chlamydia and hence the associated disparities.

Objectives and Research Questions

The goal of this study is to investigate the geographic patterns of chlamydia cases and to quantify the factors related to chlamydia-disparities within the neighborhoods for planning location-based interventions in Kalamazoo County. To achieve this goal, two main objectives will need to be achieved in this study.

1. Visualize the density of positive reported confirmed cases of chlamydia (2006 - 2014) using GIS.
    - Geocode
    - Kernel density estimation (KDE) of chlamydia cases per sq. km
    - Describe the spatial patterns observed from the KDE maps
2. Statistically assess patterns
    - Hypothesize the factors that influence the density of chlamydia cases
    - Statistically test associations between the factors and density of chlamydia cases
    - Quantify and compare the factors with the highest predictive power

In order to achieve these objectives, specific research questions that will be investigated in this study include: Are there unusually high spatial concentration of chlamydia cases scattered or in discernible patterns in Kalamazoo County? Are these noticeable core areas of transmission of chlamydia different for various high risk populations in terms of age, gender and race? Are there disparities with areas with a high density of cases when consideration is given to neighborhood level characteristics of poverty, unemployment, low educational status in urban-rural environments?

Study Area

Kalamazoo County is located in the southwestern part of Michigan. It has an estimated total population of 256,725, consisting of 78.9 percent (Caucasian and Non-Hispanic) white, 11.2 percent (African-American and Non-Hispanic) black, 4.5 percent Hispanics/Latinos and 5.4 percent others (consist of the population self-identified as two more races, Asians, American Indian, Alaska Native, Native Hawaiian and Other Pacific Islander) (US Census Bureau, 2013).

Within the county, there are two major cities, Kalamazoo and Portage. The rest of the areas are smaller municipalities which may be either township or villages. Figure 1 shows a map of the major cities and small municipalities in Kalamazoo County with a locator map to show the location of the county in Michigan.

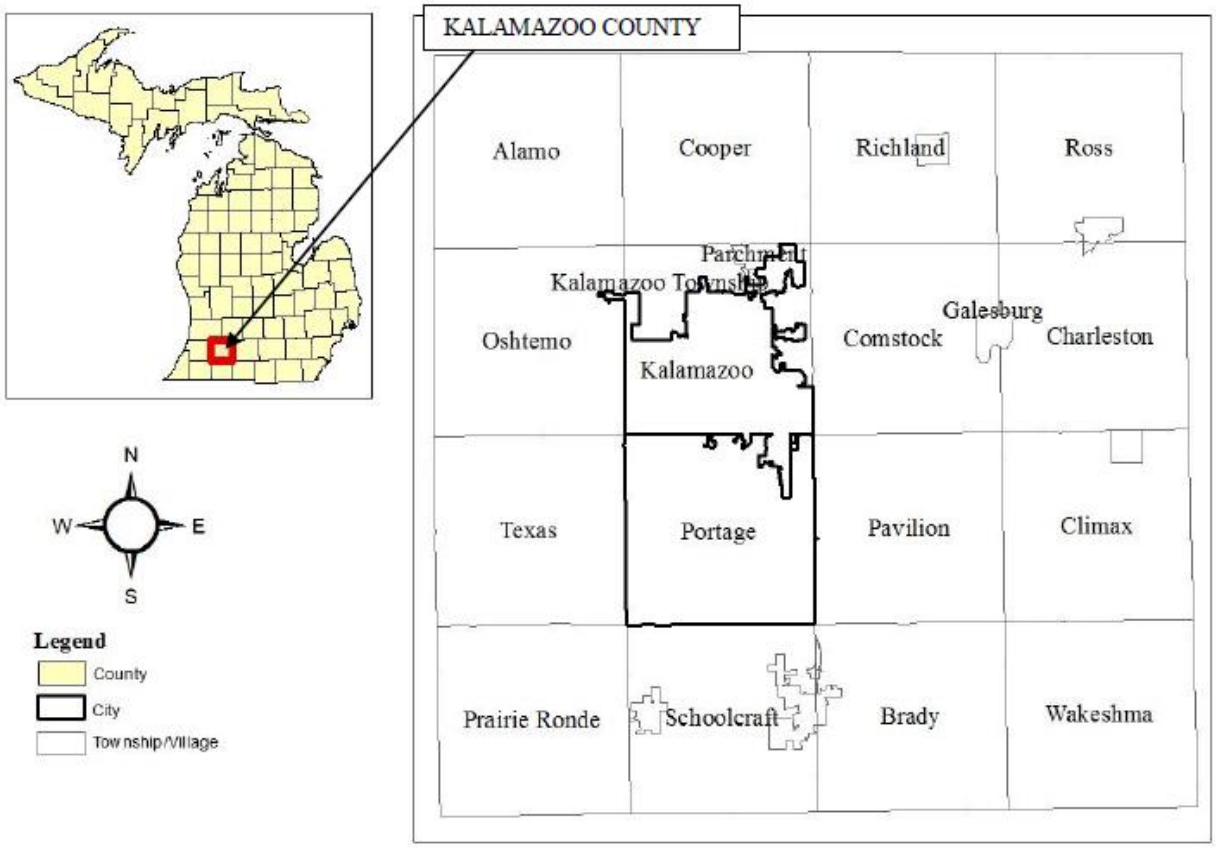

Figure 1. Local administrative districts in Kalamazoo County, Mi. Kalamazoo County is in southwest Michigan.

In Kalamazoo County, an urban-rural county in southwest Michigan, chlamydia rates have been increasing annually since before 2006 and gonorrhea rates doubled from 2013 to 2014; rates for both are higher than the state average. Figure 2 shows comparison of annual incidence rates per 100,000 in population between Kalamazoo County and State of Michigan. It can be observed that the incidence rates of chlamydia in Kalamazoo County have doubled from 372 per 100,000 in population in 1994 to 791.3 cases per 100,000 populations at the end of 2014.

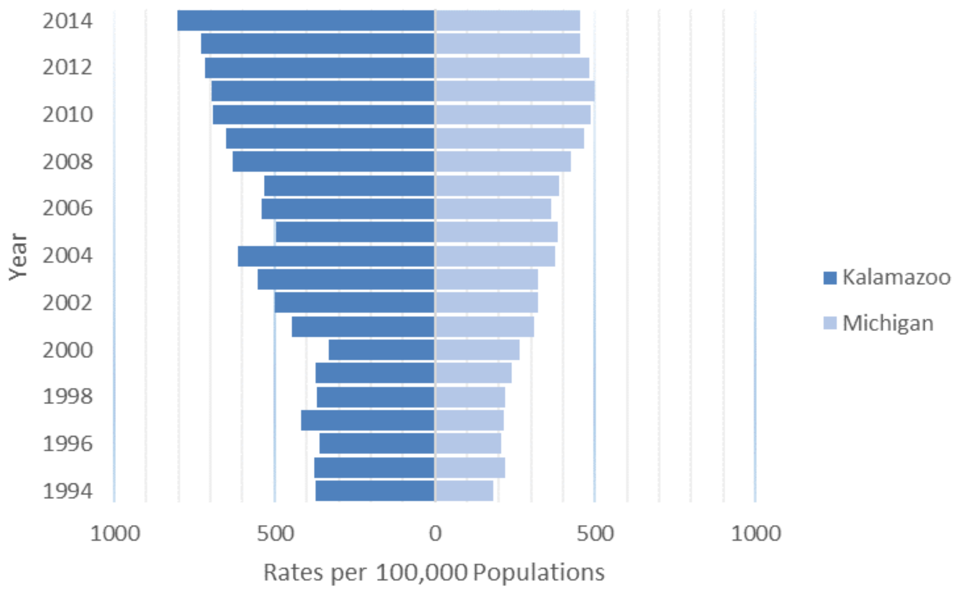

Figure 2. Annual incidence rates of chlamydia between Kalamazoo County and Michigan from 1994-2014 (Source: Kalamazoo County Health & Community Services, STI Surveillance Report, 2014).

Likewise, Michigan's state rate has also doubled from 184 in 1994 to 454 per 100,000 in population at the end of 2014. Significantly, the rates has been increasing every year for both county and state with some few exceptions. In Kalamazoo County, the rates declined relative to the previous year only in 1996, 1998, 2000, 2005 and 2007. The state rates also declined relative to the previous year only in 1996 and 2006. Generally, the incidence rates of chlamydia in Kalamazoo County are nearly twice the state average for every year of comparison.

Brief Description of the Thesis Chapters

The rest of the thesis is comprised of four chapters. Chapter II reviews the literature on geography and public health, mapping communicable diseases, the burden of health care in the United States, the factors that contribute to health disparities and differences in health care and outcomes in urban and rural areas. Chapter III details the research design and methods used in this study. It discusses: selection of the study area, the GIS visualization techniques in the study and the statistical analysis leading to the two models developed for this study. This chapter ends by fitting the theoretical framework for the model to be developed in this research and why a three level model was assumed to conduct this study. Chapter IV presents both the descriptive analysis of the KDE maps and results of the statistical analysis performed in this study. The final chapter focuses on discussion, conclusion and recommendations for future works.

CHAPTER II

LITERATURE REVIEW

This chapter reviews the relevant literature on the topic of this thesis and situates the central questions of the thesis. It focuses on the following; geography and public health with emphasis on using GIS in public health research. It further reviews the literature on analyzing the spread of communicable diseases with emphasis on STI. This chapter elaborates on the burden of health care in the United States, health disparities and discusses the differences that exist between urban and rural areas in terms health outcomes and resources.

Geography and Public Health

Health is not the absence of disease, but the state of physical, social and emotional well-being (Cromley & McLafferty, 2012). The places we are born, reside, or visit directly impact our health experiences: the food we eat, the air we breathe, the infections we are exposed to and the health services we can access. The interrelation between places contributes to the environmental risk of an individual's pattern of living and can influence health outcomes (Tunstall et al., 2004, Dummer, 2008). Poor health is to some extent mitigated by the geography when health services beneficial to an individual are available and accessible. For example, community actions such as targeting public health interventions, locating health care facilities, monitoring epidemics all have a geographic context.

The reason for using geography to study disease or health care is derived from appreciation of factors causing non-uniformity of disease distribution. These factors include physical and environmental factors; social, economic and cultural factors; and genetic factors

(Moore & Carpenter, 1999). In turn, these factors are geographically unevenly distributed and may pose a significant impact on the intensity and extent of a particular disease (Moore & Carpenter, 1999). The physical fabric of places is therefore the most obvious and immediate direct determinate of public health (Tunstall et al., 2004). Population movements between places over time is another conceptual dimension that the consideration of geography can contribute to the understanding of health (Tunstall et al., 2004).

Geography primarily emphasizes spatial relations and patterns by exploring the social, cultural and political contexts for health within a framework of spatial organization (Dummer, 2008). Understanding geography, including the arrangement of health services and the location and nature of environmental exposures, is crucial in assessing the interrelations inherent in many health-related risk exposures.

Many studies with geographic themes such as inequalities in health care (Krieger et al., 2003; Grady, 2006), accessibility to health services (McLafferty & Grady, 2005; Luo & Qi, 2009), and determining population at risk (Bush et al., 2008) are of immense relevance in public health. The key proponent in most of these research is the use of Geographic Information Systems (GIS). Indeed, GIS technologies has been used in data collection, mapping the data and performing spatial analysis for targeting public health interventions for populations and places with greatest need (Cromley & McLafferty, 2012). For example, GIS ring maps were created by Ontario public health agency during the outbreak of pandemic H1N1 influenza virus in Canada to determine which areas in Ontario had highest weekly cases in space and in time to target interventions (Johnson, 2009).

In addition, Kernel Density Estimation (KDE) in GIS has also been used widely in investigating the spatial accessibility to health services in urban areas (McLafferty and Grady, 2005; Widener et al., 2012). GIS can also be useful in public health in locating physicians across geographic space so that patients can easily assess them when needed (McLafferty et al., 2012). A study in New York city using KDE also have found that self-rated health of adults above 50 years old, is influenced by their peer-density within a walkable distance of 0.5 mile and suggest need for place-based health interventions (Widener et al., 2012). GIS has also been used extensively in STI research to define "core areas" to target screening interventions for chlamydia, gonorrhea and syphilis ((Bush et al., 2008; Emch et al., 2012; Tobin et al., 2012).

Despite all the advantages gained in using GIS, it is imperative to note some problems related to geocoding errors. The user must recognize that accuracy of analysis depends on the quality of the address information in the data (McLafferty et al., 2012). For example, a study in Chicago using the data from American Medical Association found that most physicians report their mailing addresses, usually synonymous with personal residential address, and not the address where the health care is provided (McLafferty et al., 2012). These errors were socially and geographically unevenly distributed and this resulted in over-estimation of physicians practicing in some high-income suburban areas, and under-estimation in areas in the central city where most health facilities were concentrated (McLafferty et al., 2012). Also, using case data for reported West Nile virus in South Dakota, the study found that there were spatial variation and clustering of geocoding errors (Wey et al., 2009). Therefore, data for geocoding must be thoroughly checked for quality and may require ground-truth inspection before accepting the output in order not to bias the statistical analysis (Krieger et al., 2003).

Lastly, it is important to note the problems associated with aggregating disease rates over space and time will result in gains in data stability but may result in loss of information. Therefore, it is imperative to consider an appropriate means of standardizing the rate, the scale and data classes in mapping disease rates and the ecologic fallacy problem (Moore & Carpenter, 1999; Dummer, 2008). All data is subject to problems of incompleteness and inaccuracies due to measurement error (McLafferty et al., 2012). The identification of a disease spatial pattern is therefore dependent on the choice of scale. Thus, the selection of a particular scale may ignore spatial variations in another, but using different scales for analysis can aid to confirm a hypothesis of a study (Moore & Carpenter, 1999). In general, geography basically is linked to health and for that matter important in public health (Dummer, 2008).

Mapping Communicable Diseases

The distinctive feature of communicable diseases (those that are spread from person to person) is that the disease spreads over time and varies spatially throughout an outbreak in a community (Bian et al., 2012; Cromley & McLafferty, 2012). A substantial body of literature highlights the importance of using maps to determine the spatial patterns and explain the spread of a disease in order to support epidemiological reasoning in medical research (Moore & Carpenter, 1999; Tunstall et al., 2004; Dummer, 2008).

The mode of transmission of communicable diseases will necessitate the kind of geographical questions to be asked, the type of analysis to be performed and the type of data layers needed to be included in mapping the disease in GIS (Cromley & McLafferty, 2012). For example, the spread of STI is embedded in broader concepts of identity, sexuality and gender. This is because, the relationships among individuals spreading the infections are hidden from view, and not clearly visible in the day-to-day movements of people that comprise traditional spatial patterns of human interaction. In this case, understanding the social and geographical process that influences immunity in different people, their susceptibility to and risk of infection, and the severity of the infection is crucial in explaining the geography of such infectious diseases (Cromley & Mclafferty, 2012).

Many studies have identified populations with a higher risk of acquiring an STI as being concentrated in core groups and areas (Bernstein et al., 2004; Bush et al., 2008, Gesink et al., 2011). “Core group” has been described as persons with repeat infections and persons with more than one sexual partner (Gunn et al., 2000, Bernstein et al., 2004), but this definition can vary among researchers (Gesink et al., 2011). An important but often overlooked component of core group descriptions has been to find whether group members also are being infected with other STIs thereby forming a common core area of transmission (Gunn et al., 2000; Law et al., 2004).

Defining a core group remains a challenge in research due to the high level of confidentiality necessary when working with STI data and the need to protect subjects to prevent stigmatization. However, GIS techniques provide researchers with tools to analyze areas of unusual spatial concentrations of STI cases and allow for the identification of patterns of transmission and the core group to target for interventions (Cromley & McLafferty, 2012). Recent studies utilizing spatial data provide evidence of a direct relationship between core areas and the concentration of repeat infections or core groups (Bush et al., 2008; Emch et al., 2012; Tobin et al., 2012).

Within core areas, researchers have identified localized sexual networks with core population groups (Rietmeijer et al., 2002; Bernstein et al., 2004; Law et al., 2004; Bian et al., 2012). This suggests that STIs, like any other communicable disease, usually spread through localized networks in the neighborhood because individuals interact more with their neighbors than with those located further away (Bernstein et al., 2004; Bain et al., 2012). A study in North Carolina found that incidence rates were higher in core areas than outside core areas because of local partner selection (Law et al., 2004). Core areas represent a continuing source of infection and are critical to STI transmission because they account for high rates of sustaining the STI during non-epidemic periods and act as reservoirs for infection to outside areas (Cromley & McLafferty, 2012).

The diffusion of epidemics to new locations have triggered more sophisticated modelling and mapping techniques to track the disease patterns. Traditionally, modelling the temporal trajectory of individuals in the social network of transmission of communicable diseases has been studied in interactions among three groups; susceptible(S) infected (I) and recovered (R) individuals, with the assumption that individuals are static at a location (Bian & Liebner, 2007; Bian et al., 2012). These studies incorporate more temporal data for the (S) and (I) populations with less consideration of the spatial dynamics that occurs due to mobility, and interaction between the individuals (Bian & Liebner, 2007; Bian et al., 2012). A study of individual vulnerability to influenza using the daily routine contacts made by individuals offers a spatial-temporal approach in studying the heterogeneous, mobile, and interacting individuals, the three-population and two-scale social network in northeastern states of US. (Bian et al., 2012).

In recent years, the proliferation of mobile devices with Global Positioning Systems (GPS) capabilities and mapping applications have revolutionized incorporating real time mapping of communicable diseases directly from the field to track outbreak locations and monitor the path of transmission. For example, GPS innovative technologies used by field workers on the wake of outbreak of the Ebola virus in Nigeria enabled real time reporting location of individuals infected, and helped authorities to initiate early warnings, treatment and containment of Ebola was useful in curtailing its spread (Tom-Aba et al., 2015). A study in Brazil also found that, by using GPS enable mobile devices with a mapping visualization application, epidemiologist and health researchers were able to collect accurate location-based patient data in remote geographical regions to monitor the spread of cutaneous leishmaniasis and bartonellosis (Cesario et al., 2012).

Many studies rely on mapping data collected in state-wide surveillance systems to monitor communicable diseases, such as; North Carolina (Sullivan et al., 2011), South Carolina (Fede et al., 2011), Massachusetts and Rhode Island (Krieger et al., 2003). However, with the advent of real-time mapping devices, there exist a possibility of tracking emerging and re-emerging of different communicable diseases especially in remote areas (Cesario et al., 2012; Tom-Aba et al., 2015). In fact, there is no one preferred procedure in mapping communicable diseases, and studies suggest early reporting of the disease from the related location (address) to be critical in public health efforts to prevent the disease from spreading to new locations (Gunn et al., 2000, Bernstein et al., 2004).

Burden of Health Care in the United States

Historically in the United States, reforms have been initiated by grassroots social movements and the demand for universal health care could benefit from such campaigns (Hoffman, 2003). However, the diversity in social movements such as: reproductive rights for the feminist movement, desegregation for the civil rights movement, disease research and drug access for the AIDS advocacy movement all express different concerns depending on what they deemed is urgent and immediate. This differs from the need for a long-term change in the health care system (Hoffman, 2003). Most advocate movements admit there are limitations to universal access to health care, reduction in state budgets for Medicaid, discrimination for Medicare and Medicaid beneficiaries (Hoffman, 2003; Alliance for Democracy Oregon, 2015). The universal health care movement is therefore confined, and efforts are made to serving the uninsured and underinsured in the society (Hoffman, 2003; Alliance for Democracy Oregon, 2015).

Health care spending in the United States represents a growing share of the national income and is projected to increase from 16 percent of the gross domestic product to 20 percent by 2018 (Sisko et al., 2009). Reducing this toll on the national budget, will require health care reforms that considers substantial cost containment and shifts in the distribution of health care costs within the population (Sisko et al., 2009). A study to examine the financial burden of health care budget for working families of various income levels found that even with growing income, the rapid growth of health care spending is already eroding standards of living for the middle class (Polsky & Grande, 2009).

The growth in health care spending is disproportionately felt by middle income working families because their wages are growing more slowly and health care makes up a larger proportion of their budget (Polsky & Grande, 2009). In most cases, the burden of employer contributions to health care premiums falls on the worker rather than the employer which may lead to many families dropping private health insurance coverage altogether if new reforms are not made (Polsky & Grande, 2009).

The government in response to these concerns and others enacted the Affordable Care Act in 2010, a new comprehensive health insurance reform to: expand coverage, hold insurance companies accountable, lower health care costs, guarantee more choice and enhance quality of care for all Americans (Centers for Medicare & Medicaid Services, 2016). The effect of the Affordable Care Act since its introduction has been felt in the rising cost in health insurance for both small businesses and individuals who are responsible for renewing health coverage from insurers, as compared to large corporations who usually hire agencies to administer health insurance for their employers (Herrick, 2014).

According to the Centers for Diseases Control and Prevention (CDC), across the US, nearly 20 million new incidences of STIs are diagnosed annually, costing the American health system about 16 billion dollars in treatment costs (CDC, 2015). The 2014 annual surveillance report for STI shows a significant percentage increase in reported cases since 2013 for chlamydia (2.8%), gonorrhea (5.1%), primary and secondary syphilis (15.1%) and congenital syphilis (27.5%) (CDC, 2015). According to CDC, the annual surveillance report captures only a fraction of the true burden of STIs in the US because of asymptomatic character in STI causing them to be unreported; while other data on some STI such as human papillomavirus, herpes simplex virus, and trichomoniasis are not routinely reported (CDC, 2015)

In effect, as new and reemerging patterns of infectious diseases occur, the US healthcare system will need to focus resources on reducing high burden and high consequence diseases and strengthening efforts for early detection and rapid response to emerging infections (Khabbaz et al., 2014). Another means of effectively directing limited health care resources is by adopting universal screening for sexually transmitted infections (STI) in high prevalence regions and selective screening in low prevalence regions (Stein et al., 2008). A study recently completed for the United State Preventive Services Task Force (USPSTF) recommends routine STI screening for young women below the age of 24 years and in older women with high risk of infection as a strategy to reduce chlamydia and gonorrhea (Lefevre, 2014). These strategies all highlight the importance of utilizing place-based interventions to control an outbreak of STI in communities, thereby reducing impacts and cost of treatment at a later stage.

Health Disparities in the United States

The growing concern on health disparities has dominated several discussions across the world, including the United States, for almost a century now (Gibbons, 2005). Whereas most studies have highlighted that disparities are significant among minorities, a British Whitehall cohort study of civil servants found that a social-class health based gradient existed even among well employed elites (Mamot et al., 1978; Gibbons, 2005). A disparity in health outcome or status is therefore simply defined as the differences that occur by gender, race or ethnicity, socio-economic status, disability, geographic location, and sexual orientation in a health outcome (Steele et al., 2007).

In the United States, researchers and policy makers have become aware that neighborhood social, economic and physical characteristics persist to place different groups of people at a disadvantage concerning health outcomes (Kreiger et al., 2003; Bell et al., 2013). Many studies have further confirmed the contextual effect neighborhood of residence has on a number of health outcomes, including obesity and diabetes (Ludwig et al., 2011; Laraia et al., 2012), lead exposure (Whelan et al. 1997; Sharmer et al., 2007; Oyana & Margai, 2010) and STI

(Law et al., 2004; Semaan et al., 2007; Bush et al., 2008; Thomas et al., 2009; Tobin et al., 2012).

For instance, a study using survey data collected from the 1995 Program on Human Development in Chicago and homicide rates found that neighborhoods with high rates of incarceration had higher rates of STI as compared to those with low incarceration rates (Thomas et al., 2009). Socio-cultural determinants of health, primarily those indicative of neighborhood deprivation such as percentage single mothers and low socioeconomic status have been associated with gonorrhea rates in North Carolina (Sullivan et al., 2011).

A recent nationwide US study using individual scale information for young adults in the Add Health Survey found STI diagnosis rates were independently associated with both racial/ethnic identity and with low income neighborhoods (Harling et al., 2013). Poverty has also been identified as one of the key individual, and most contextual variable, in health disparities research (Krieger et al., 2003). The use of illicit substances has been found to influence high-risk sexual behavior but their geographic distribution can vary for different communities. (Krieger et al., 2003; Thomas et al., 2009; Harling et al., 2013).

These studies all emphasize why there are varying geographic disparities in health outcomes especially in STI incidence and prevalence within neighborhoods with low-value housing, exposure to prostitution, illicit drug use, and limited access to health care resources (Krieger et al., 2003; Law et al., 2004; Semaan et al., 2007; Bush et al., 2008; Thomas et al., 2009; Sullivan et al., 2011; Hippe et al., 2012; Tobin et al., 2012; Harling et al., 2013). Public health research is not only concern with identifying the disparity that exist for a health outcome but also understanding the processes that contribute to how places differ in terms of the resources and the levels of risk that affect their populations (Cromley & McLaffferty, 2012).

Whereas factors that account for a disparity in health outcomes and status varies, two main factors have been identified for chlamydia in the United States; they are 1) biological factors at the individual level and 2) socioeconomic and behavioral factors (Office of Disease Preventions and Health Promotion, 2016).

At the individual level, the Centers for Diseases Control and Prevention (CDC) have annually reported in its surveillance nationally that, the annual incidence of chlamydia are highest among youth between the ages of 15 to 24 years old (CDC, 2015). This age range is associated with high risk sexual behaviors from a public health perspective (CDC, 2015, Weinstock et al., 2004; Advocates for Youth, 2010).

A substantial body of literatures has explored factors that influence adolescent sexual behaviors by examining more closely individual or proximal ecologic factors (e.g., family, peer and partner) (Moreau, 2013). In these studies, many have found that incidence rates of STI by age also show strong disparities in race/ethnicity and gender at state and county levels (Semaan et al., 2007; CDC, 2015). Racial disparities in chlamydia in the United States are correlated with other determinants of health status, such as socioeconomic differences for blacks than whites and other race group (Krieger et al., 2003). This is because persons from racial and ethnic minority populations may have poor access to health and medical services and inconsistent relationships with health care providers because of the lack of doctors in many minority communities (Steele et al., 2007). Other studies also suggest that, the huge disparity that exist among race/ethnic groups may be due to the fact that people of the same race are more likely to choose partners in their race than from another leading to a more localized pattern and a higher risk of acquiring that STI (Thomas et al., 2009; Sullivan et. al., 2011).

Gender is also a key factor to the disparities that exist at the individual level primarily because of the biological make-up of females and males, such that males are more often asymptomatic for chlamydia than for gonorrhea. It is also expected that females are screened more frequently than their male counterparts (CDC, 2015). Females may also experience serious STI complications such as pelvic inflammatory disease, ectopic pregnancy, infertility, and chronic pelvic pain if the infection is not treated early (CDC, 2015). All these individual factors combine to create significant disparities in the overall rate of STI reporting, incidence, prevalence, morbidity, or survival rates in the population as compared to the health status of the general population (Steele et al., 2007).

Socioeconomic and behavioral factors are usually experienced at the neighborhood level, and these factors are amongst many cause serious obstacles to STI prevention due to their influence on social and sexual networks, access to and provision of care, willingness to seek care, and social norms regarding sex and sexuality (Steele et al., 2007, Sullivan et. al., 2011). In the United States, certain vulnerable populations' past experience with segregation and discrimination may also exacerbate the influence of these factors (Steele et al., 2007). This often creates a long interval, sometimes years, between acquiring an STI and recognizing a clinically significant health problem and this can increase chances of spreading the disease amongst a core group (Steele et al., 2007). Perhaps the most important social factors contributing to the spread of STIs in the United States are the stigma associated with STI and the general discomfort of discussing intimate aspects of life, especially those related to sex (Office of Disease Preventions and Health Promotion, 2016).

Urban and Rural Differences in Health

A substantial literature on disparities in health care between rural and urban areas in the U.S. are widespread and widely discussed in recent literature (Ricketts, 2000; Hart et al., 2005; Douthit, 2015). Studies conducted since the establishment of the Affordable Care Act have continued to find significant differences in health care services, access and health status of residents in rural versus urban areas (Weinhold & Gurtner, 2014; Douthit et al., 2015). The largest differences concern scarcity of healthcare technology and limited access to high quality providers in rural areas (Ricketts, 2000; Hart et al., 2005; Douthit et al., 2015). Residents of rural areas have longer travel times to access basic health care screening services; for example, a 2015 study found that women in 19 rural counties in Missouri had a one-way travel time to mammography services of over 45-minutes by car (Williams et al., 2015). The same study found a higher rate of late-stage breast cancer diagnoses among rural women in the state compared to women living in more urban areas (Williams et al., 2015). Other studies have reported poorer overall health among residents of rural areas, although this could be confounded by an average age of residents and other socioeconomic factors (Ricketts, 2000; Hart et al., 2005; Weinhold & Gurtner, 2014).

Differences in health care seeking behavior may play an additional role in urban-rural differences in health (Hart et al., 2005; Ziller & Lenardson, 2009; Douthit et al., 2015). Population studies have revealed that lower education and income levels among some rural residents may increase reluctance to seek healthcare services (Ricketts, 2000; Hart et al., 2005).

However, despite a higher uninsured rate in rural areas, the Maine Rural Health Research Center reported that rural residents of that state are more likely to have a usual health care provider than residents of urban centers (Ziller & Lenardson, 2009). Additionally, care differences between rural and urban areas may vary based on the type of health care service; a recent Michigan study of postpartum contraceptive use found no significant variation of geography for that healthcare outcome (Starr et al., 2015).

People's physical location, e.g., urban and rural living situation, in addition to social networks and social stigma, also contribute to place some individuals at a disadvantage of contracting an STI through sexual networks (Steele et al., 2007). A person may have only one sex partner, but if that partner is a member of a risky sexual network, then the person is at higher risk for STIs than a similar individual from a non-risky network a case for rural areas with low population (Sullivan et al., 2011). Thus factors such as availability and low density of partners within a sexual network, may also contribute to the transmission of STI and hence lead to a more localized pattern in the rural areas. Living in the rural area may also act as a proxy for low physician density and poor access to STI health services

Studies mapping STI have further explained that constraints on mobility related to age, low income, disability and poor access to transportation may lead to highly localized patterns of spatial interactions and may differ for urban-rural areas (Cromley& McLafferty, 2012). Transportation issues results in late/missed appointments and hesitation to make follow up appointments during treatment of the STI. Comparative studies on STI rates between cities and their surrounding suburbs have found that STI spreads through flows and social interactions. Studies show that the highest incidence of STI in suburban communities is strongly correlated with the volume of workers who commute to central cities (Cromley & McLafferty, 2012; Sullivan et al., 2011).

A study mapping and comparing STI rates in urban and rural settings in North Carolina found that rurality was associated with decreased rates of gonorrhea for blacks and increased rates for Native Americans outside the mountains (Sullivan et al., 2011). This suggests that by mapping STI clusters across rural and urban areas, and identifying spatial patterns can lead to information that could be used in interventions to halt potential epidemics that spread disease from urban to rural areas (Cromley& McLafferty, 2012). This study will therefore also evaluate the difference in density of cases between urban and rural areas in Kalamazoo County.

Summary

The context of place in the health of a person is increasingly been applied in health research in recent times (Tunstall et al., 2004; Dummer, 2008; Cromley & McLafferty, 2012). Geographic Information System and statistical methods have been used in most these studies, to identify populations high risk of acquiring the disease and to help in planning interventions. Most research in the United States tends to focus their analysis of STI at the state level or within a single large city. Examples include North Carolina (Sullivan et al., 2011), South Carolina (Fede et al., 2011), Massachusetts and Rhode Island (Krieger et al., 2003) and the large metropolitan cities of Baltimore (Bernstein et al., 2004), Chicago (Thomas et al., 2009) and San Francisco (Gesink et al., 2011). Many studies of STI at the state and metropolitan scales have all identified significant factors such as poverty, low education status, unemployment, incarceration rates and illicit drugs in core areas with high incidence and prevalence of STI (Krieger et al., 2003; Sullivan et al., 2011; Hippe et al., 2012; Tobin et al., 2012).

The identification of core areas in STI research is important because these areas represent a continuing source of infection and are critical to STI transmission, particularly during non-epidemic periods (Cromley & McLafferty, 2012). Although analysis of these scales is important in formulating policies and allocation of resources to combat the burden of STI, much needs to be done at local scales where public health officers are tasked with implementing targeted interventions across urban-rural boundaries. This study therefore is to provide a more local analysis of chlamydia to identify core areas where there are unusually high density of cases and to account for the factors at the neighborhood level that influence the observed pattern.

CHAPTER III

METHODOLOGY

This chapter details the research design and methods used to conduct the research. It discusses the study design and population, measures and GIS methods or tools that are used, description of variables, conceptual model framework and statistical analysis.

Study Design and Population

This study was a retrospective record review of secondary data for reported confirmed cases of chlamydia in Kalamazoo County from 2006 to 2014. Data was retrieved from Michigan Diseases Surveillance System (MDSS) in collaboration with local health officials. MDSS data is continuously collected by health care providers and laboratories that conduct tests on chlamydia and who are responsible to report positive confirmed cases to MDSS as part of a federal law. This study was approved by the Western Michigan University (WMU) Human Subjects Institutional Review Board. The letters of approval for the study are attached as Appendix A.

Measures

The demographic information included in MDSS data at the individual level is age, race and gender (male vs female). Age was re-categorized to: less than 14 years, 15-24 years, 25-34 years and greater than 35 years to match age ranges available at the census tract level for comparisons. Race was simplified to three categories due to sample size: black (African-American and African-American partially mixed with another race), white (Caucasian) and other race (all others not self-identifying with either African-American or Caucasian).

Cases of chlamydia were defined as positive confirmed cases that were reported to the MDSS. Each STI case was matched to a unique patient identifier generated in the surveillance system. For individuals with multiple reports of the same infection, a case was considered new if the second positive test occurred more than 14 days after the first positive test (Gunn et al, 2000; Bernstein et al., 2004). For those that occurred within 14 days, it was considered one continuing case and information from the earliest date was used in the analysis.

Geocoding of Chlamydia Cases

Residential street addresses associated with the individual records were geocoded with ArcGIS 10.3.1 (ESRI 2015) software using a street centreline shapefile obtained from the Kalamazoo County Planning Department with streets updated in 2014. Residential addresses that could not be automatically geocoded in the GIS software were checked with Google Maps and manually placed in the appropriate locations.

Density Maps

Kernel density estimation (KDE) was used to generate density surfaces for chlamydia cases. Consideration was given to all cases, age (less than 14 years, 15-24 years, 25-34 years and greater than 35 years), race as black (African-American and African-American partially mixed with another race), white (Caucasian) and other race (all others not self-identifying with either African-American or Caucasian) and gender (male vs female) with chlamydia separately. KDE was used to assess the spatial concentration of cases. While varying bandwidth can influence outputs, density maps are not affected by the size and shape of aggregation unit boundaries (Mclafferty et al; 2012). This study used one kilometer as the bandwidth to search for cases concentrated within a square kilometer area. Compared with other bandwidth distances (results not shown) the one km bandwidth revealed more local variations while maintaining a relatively smooth continuous surface. KDE maps were visually examined to determine the differences in the spatial concentration of chlamydia between urban and rural areas in the county.

Neighborhood Level Variables

The neighbourhood level variables in the analysis included poverty, education and population density. American Community Survey (ACS) five year estimates for 2013 (2009-2013) were used at the census tract level. For this study, poverty was defined as the percentage of the population determined to be living below the US poverty line as shown in Figure 3.

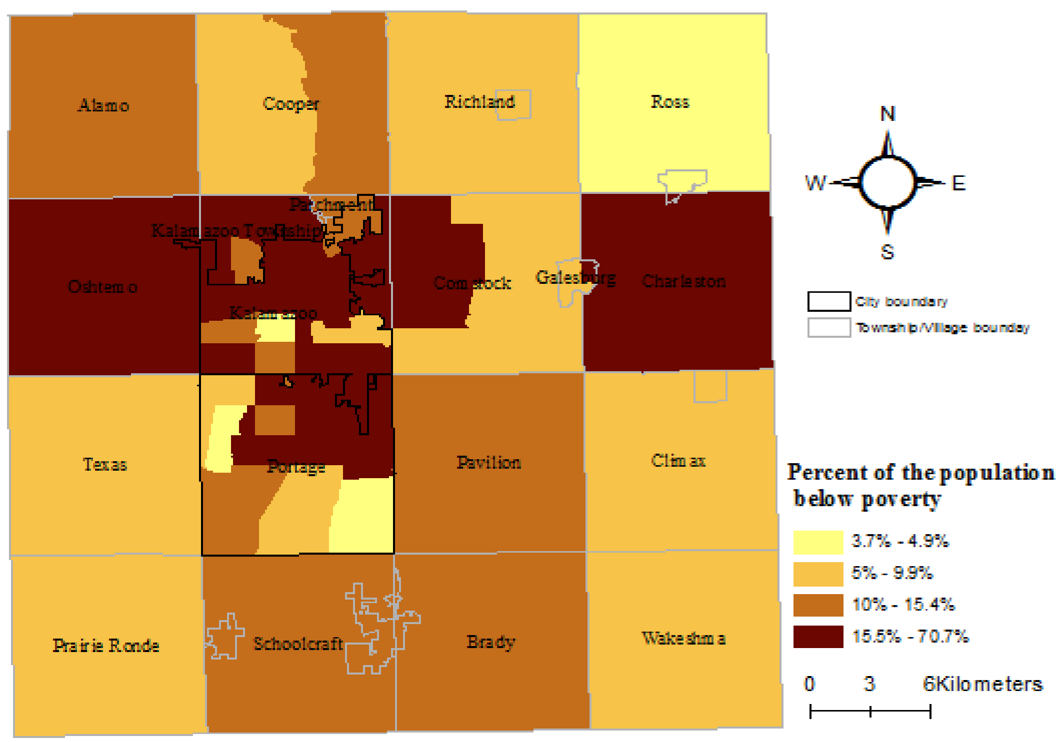

Figure 3. Distribution of percent of population below the poverty line in Kalamazoo County (Source: ACS, 2009-2013).

Poverty was included in the model because it has been identified as one of the key individual, and most contextual variable, in health disparities research (Krieger et al., 2003). In Kalamazoo County, it can be seen from Figure 3 how poverty varies between census tracts in urban areas (city of Kalamazoo and city of Portage) as compared to the smaller municipalities.

Educational status was defined as the percentage of the population with less than high school degree in a census tract. Figure 4 shows the spatial distribution of the percent of the population with less than high school degree in Kalamazoo County.

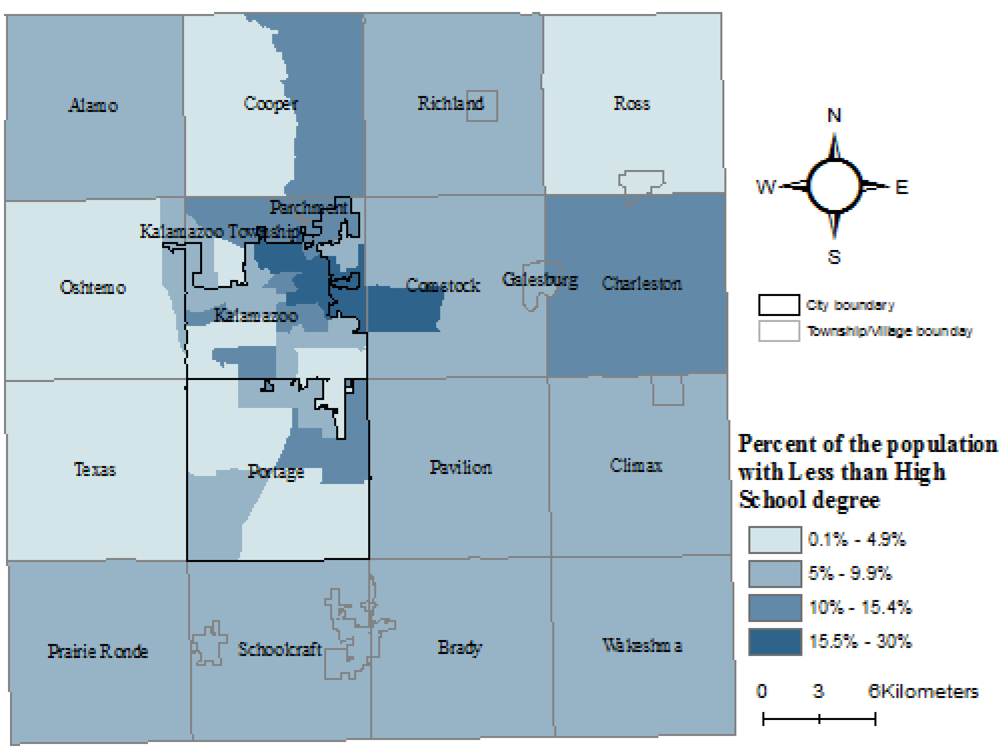

Figure 4. Distribution of percent of the population with less than high school degree (Source: ACS, 2009-2013).

Education status was included in the model because it has been identified in other STI research as critical in controlling the spread of the infections by embarking on community education on safe protective sex (Krieger et al., 2003).

For this study, unemployment rate was defined as the percentage of the population 16 years or older in the labor force who are unemployment (ACS, 2013) as shown in Figure 5. The spatial distribution of unemployment rate shows a high spatial clustering of census tracts with high rates in City of Kalamazoo and Portage.

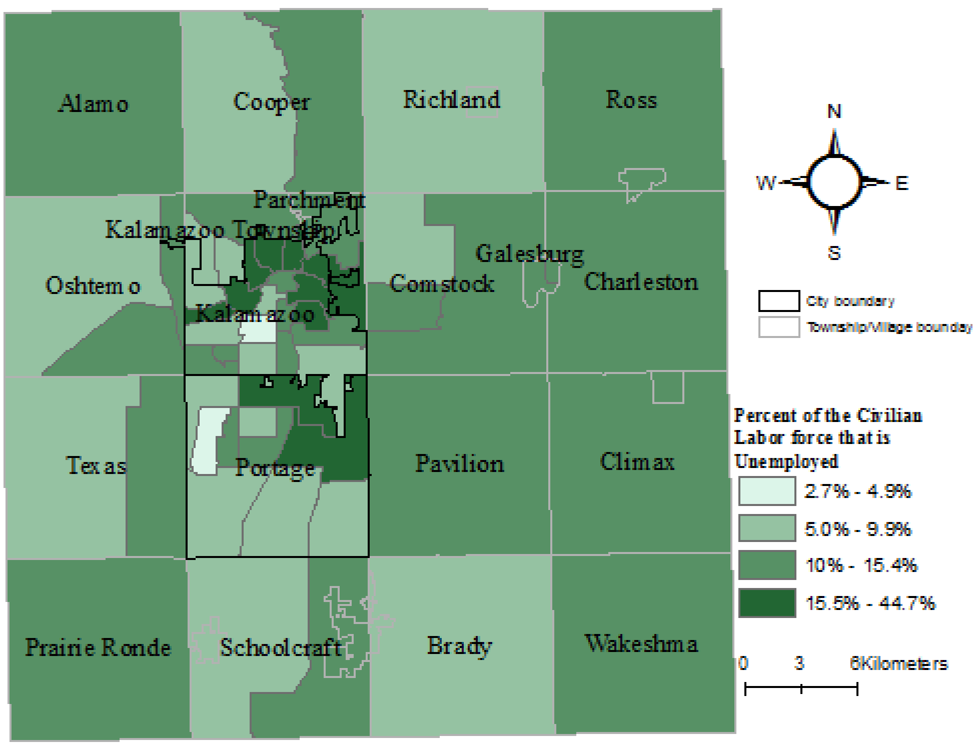

Figure 5. Distribution of percent of the population aged 16 years or older in the labor force who are unemployed (Source: ACS, 2009-2013).

Subsequently, population density was thought to be a confounding factor that could impact the number of cases reported in urban areas than the rural areas, therefore this was included in the model. The ACS population estimates for 2013 was used to generate the population density variable used in the statistical analysis. Figure 6 shows the spatial distribution of population density in Kalamazoo County.

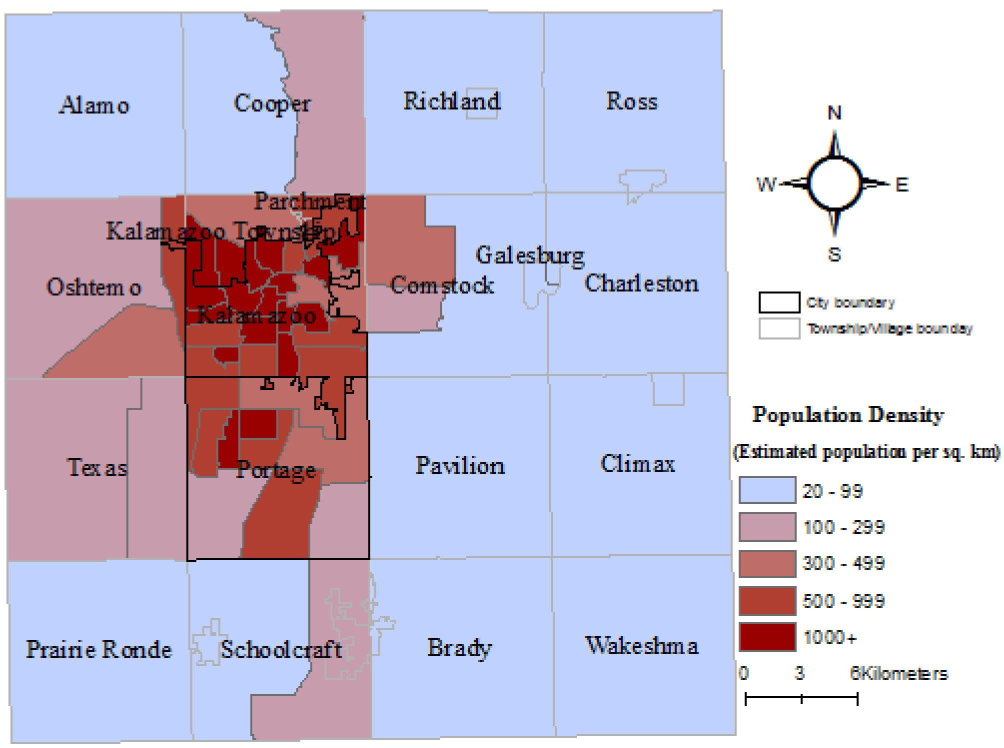

Figure 6. Distribution of the estimated population per square kilometer in Kalamazoo County (Source: ACS, 2009-2013).

The population density map (Figure 6) clearly shows a denser population in urban areas than in rural areas. It is important to note census tracts in small municipalities (rural areas) of

Comstock and Oshtemo with high population densities of over 300 populations per sq. km as this may impact the number reported confirmed chlamydia cases in this vicinity from 2006 to 2014.

Urban and Rural Areas

For this particular study, comparing the differences between urban and rural areas was considered very important. For that reason, the two major cities (Kalamazoo and Portage) were categorized as urban areas and the other small municipalities in Kalamazoo County as rural areas. This made for easy comparison of the geographic patterns observed for this nine year study period. Any case that accurately geocoded within the boundaries of Kalamazoo and Portage was assigned the dummy variable of 0 (urban) while 1 (rural) was given otherwise to a case that falls outside their city limits.

Conceptual Model Framework

This study assumed a three scale level multiscale model to estimate the density of chlamydia cases per square kilometer to examine the factors that relate to STI disparity in Kalamazoo County. The conceptual model framework of individual factors, neighborhood level factors and the community urban/rural factor for the model is shown in Figure 7.

In Figure 7, the first level accounts for the density of chlamydia cases surrounding an individual according to their age and gender and race within a walkable distance of one kilometer. The second level determines the relationship between the density of chlamydia cases for an individual and their socioeconomic variables at the census tract scale. The third level is included to find the differences in the density of chlamydia cases for an individual living in either urban or rural areas in Kalamazoo County.

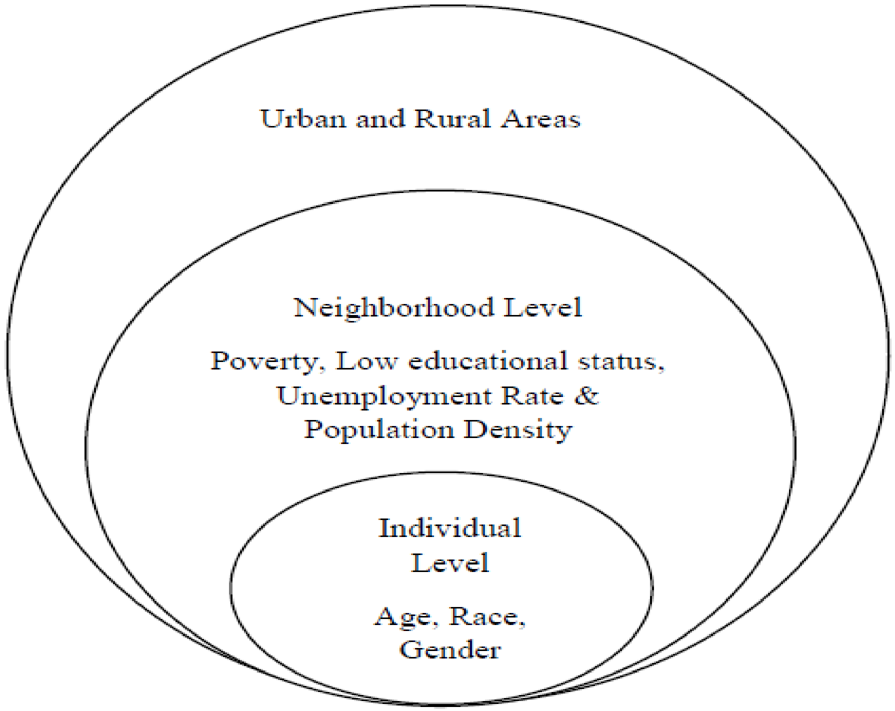

Figure 7. Conceptual model framework of variables at multi-scale that contribute to an individual's risk of contracting chlamydia.

Statistical Analysis

All statistical analysis was performed in SPSS statistical software. Dummy variables were generated for each categorical group by creating a new field and populating that field with a value 0 or 1. The 0/1 coding is a result of the fact that the dummy variable is a nominal categorical variable, and 0/1 coding corresponds to absence/presence. This also facilitates the interpretation of regression coefficients.

In view of this, for this study, categorical dummy variables at the individual level included gender (female, male), age (less than 14 years, 15-24 years, 25-34 years and greater than 35 years) and race (black, white, and other race). The baseline for comparing the coefficients at the individual level was (male, 15-24 years, and black).

As is standard in regression analysis, the dependent variable was examined to check whether it was normally distributed. All variables were entered into a multiple regression to test the linear relationship between dependent variable, the density of cases surrounding an individual, and the explanatory variables. All variables were tested at the 95% level of significance in the model.

The results of these analyses were used to address the research questions of the study and conclusions as well as the recommendations were made to identify and quantify the factors related to chlamydia-disparities within the neighborhoods for planning location-based interventions in Kalamazoo County.

CHAPTER IV

ANALYSIS AND RESULTS

This chapter presents the analysis and results of the study. It focusses on three main areas. The first is the descriptive analysis of the chlamydia data from 2006 to 2014. The second is the analysis of the output of the GIS methods employed in this study. The third is the statistical analysis of the model output that shows the most significant variables to explain the chlamydia-related disparity.

Descriptive Analysis of Chlamydia Data

Between January 1, 2006 and December 31, 2014, the total number of chlamydia cases reported to MDSS was 14992. During this nine-year period, the lowest number of cases reported was in 2007 (N=1302) while the highest number of cases reported was in 2014 (N=2059). The percent change in the number of reported cases from the start year and the end year of the study was 56.1%. The total number of unique individuals infected with chlamydia was 10373 for the entire period. Table 1 shows the frequency of cases for unique individuals with chlamydia, the total number of shared and percentages in the individuals from 2006 to 2014.

The most common number of infections per individual with the bacteria was one; however, individuals were reported with up to eleven separate chlamydia infections. Whereas those with one infection accounted for 51.7% those with multiple cases of the bacteria accounted for 48.3% of the total reported cases during this nine-year period (Table 1).

Table 1. Frequency of cases of chlamydia infections for individuals with single and multiple cases and total percent of cases by infection from 2006 to 2014, Kalamazoo County.

Infections per Individual	Individuals with chlamydia	Number of total cases	Percent of total cases
1	7758	7758	51.7%
2	1578	3156	21.1%
3	556	1668	11.1%
4	243	972	6.5%
5	121	605	4.0%
6	54	324	2.2%
7	26	182	1.2%
8	17	136	0.9%
9	11	99	0.7%
10	7	70	0.5%
11	2	22	0.1%
	10373	**14992**	

The annual incidence rates of chlamydia for the individual characteristics of age, race and gender were calculated and compared using the five-year population estimates from ACS, 2009-2013 data. The incidence rates of chlamydia from 2006 to 2014 in terms of age (less than or equal to14 years, 15-24 years, 25-34 years or greater than 35 years) were consistently about twice as high for individuals between 15-24 years than the other age groups (Figure 8). Only individuals in the 14 years and younger group, had annual incidence rates less than 50 cases per 100,000 populations, while individuals 35 and older had annual incidence rates between 50 to 100 cases per 100,000 populations for all the years counted (Figure 8). However, annual incidence rates among young adults (15-24 year olds) has been rising since 2006 when it was 730.2 cases per 100,000 populations to as high of 1197.9 cases per 100,000 populations in 2014

(Figure 8). The intermediate age group (25-34 year olds) during this nine-year period recorded an annual incidence rate between 150 to 400 cases per 100,000 populations (Figure 8).

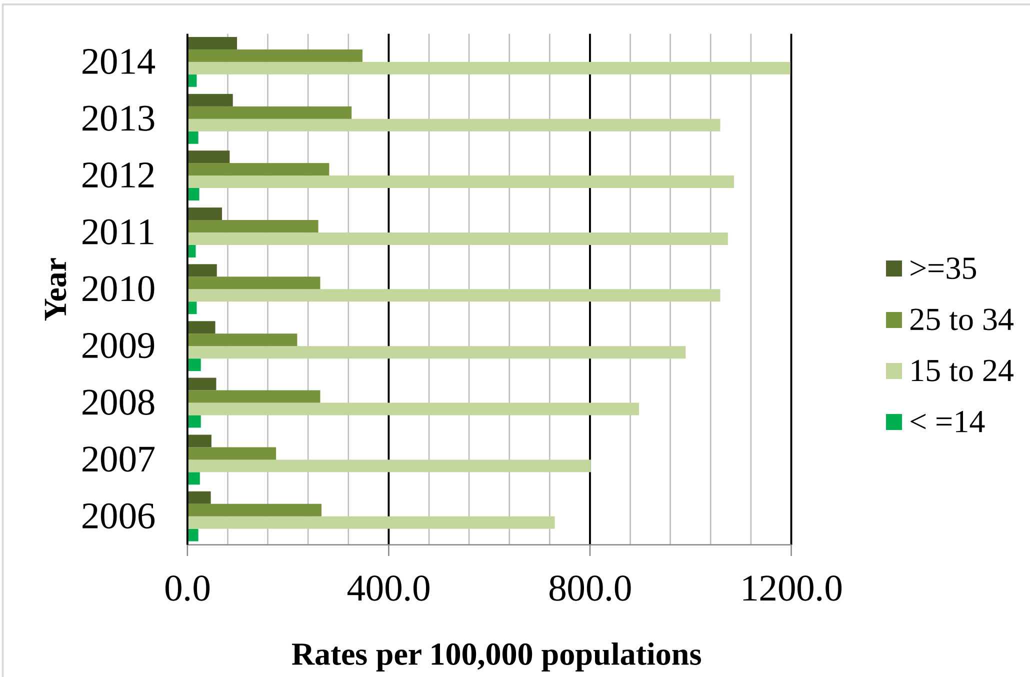

Figure 8. Annual incidence rates of chlamydia cases per 100,000 populations between age groups <=14, 15 to 24, 25 to 34, and >=35 year olds from 2006 to 2014 in Kalamazoo County.

Considering race, blacks recorded the highest annual incidence rates when compared with whites and those in the other racial group (Figure 9). In Figure 9, it can be observed that the annual incidence rates for blacks annual increased starting from 585.6 cases per 100,000 populations in 2006 to 801.3 cases per 100,000 populations in 2014 with exceptions in 2010 and 2011 when the rates decreased slightly from the previous year (Figure 9). Similarly, the annual incidence rates for whites doubled over the study period, starting in 2006 when it was 364.3

cases per 100,000 populations to 729.4 cases per 100,000 in 2014. The rates for whites decreased from the previous year only in 2007 and increased annually thereafter for the study period. For individuals in the other race group, the annual incidence rates almost always remained between 100 to 150 cases per 100,000 populations for all the years examined.

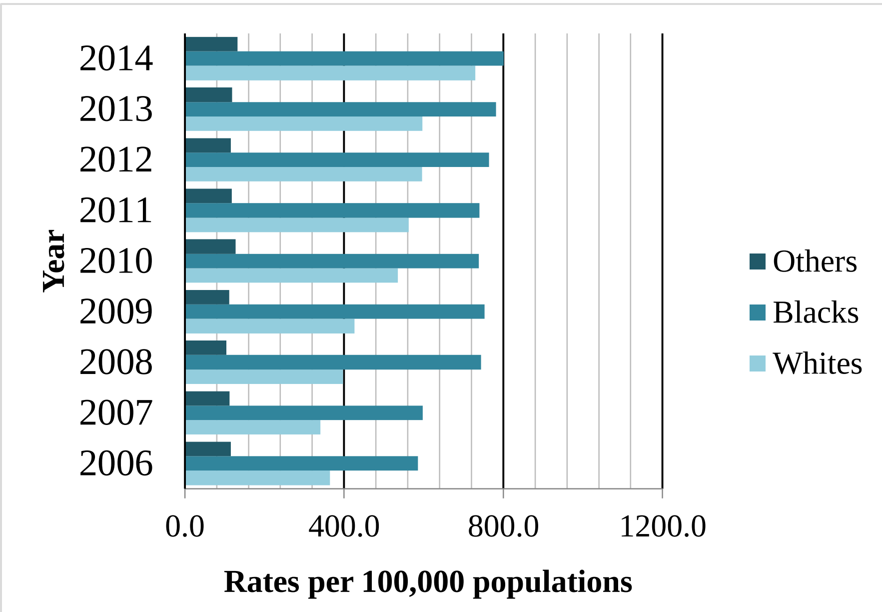

Figure 9. Annual incidence rates of chlamydia per 100,000 populations between whites, blacks and others from 2006 to 2014 in Kalamazoo County.

Lastly, considering gender, the annual incidence rates for females was always twice that of their male counterparts in this study (Figure 10). For females, the annual incidence rate rose from 700.3 cases per 100,000 populations in 2006 to 1109.8 cases per 100,000 populations in 2014 (Figure 10).

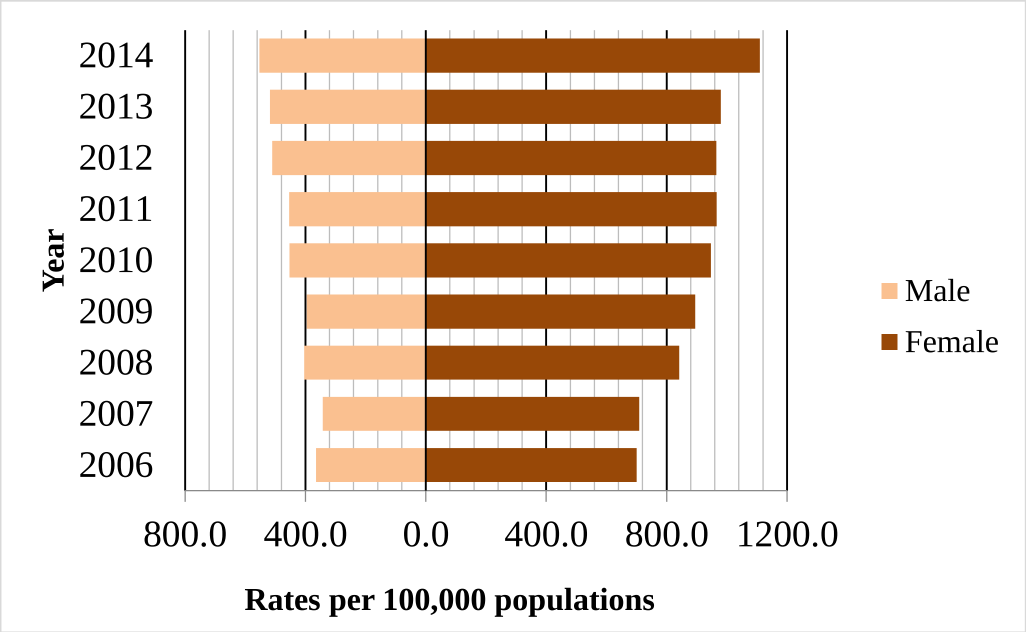

Figure 10. Annual incidence rates of chlamydia per 100,000 populations between males and females from 2006 to 2014 in Kalamazoo County.

For males, the annual incidence rate rose from 365.1 cases per 100,000 populations in 2006 to a high of 553.3 cases per 100,000 populations in 2014 (Figure 10). For both females and males, the annual incidence rates increased steadily from the previous year during this study period.

Geocoding Results

Of the total 14,992 reported confirmed cases of chlamydia during this nine-year study period, 14,788 (98.6%) of their residential addresses were geocoded with acceptable accuracy. A total of 204 (1.4%) cases could not be geocoded for this study. Addresses that could not be placed were partly due to missing addresses, records with zip codes, but no street name, and addresses with no reference in the street centerline file. Further analysis in this study is based only on the accurately geocoded cases. The results after geocoding are shown in Table 2.

Table 2. The demographic characteristics of accurately geocoded cases and unmatched cases.

Characteristics	Reported Cases No.	Accurately Geocoded No.	Unmatched No.
Gender			
Males	4947	4890	57
Females	10045	9898	147
Race			
Whites	5631	5529	102
Blacks	8054	7972	82
Others	1307	1287	20
Ages			
< =14	247	243	4
15 to 24	11014	10872	142
25 to 34	2978	2941	37
>=35	753	732	21

Geographic Patterns on Kernel Density Maps

Kernel density maps show estimated densities of chlamydia cases from 2006 to 2014 in Kalamazoo County. For this study, densities 50+ cases per sq. km is always considered as severe, densities from 31 to 50 cases per sq. km is considered as high, densities from 6 to 30 cases per sq. km is considered as moderate and from 0 to 6 cases per sq. km is negligible (not shown) is used to describe the patterns observed. It is imperative to also note all legends are the same, so all density maps are comparable. When all cases of chlamydia are considered, it is evident there is one big central area with severe densities 50+ cases per sq. km that stretches from the northern half of the city of Kalamazoo through to the east and northwest side of the city limits (Figure 10). This area with severe densities 50+ cases per sq. km also extends into the neighboring Comstock Township, Parchment Township, Oshtemo Township and Kalamazoo

Township (Figure 11). In addition, there are seven sub-regions with severe densities 50+ cases per sq. km (Figure 11). Four of these sub-regions can be found in the northern half of the city of Portage, one in the southwest of the city of Kalamazoo, one in the east of Comstock Township while one also connects Richland Township and Comstock Township (Figure 11). The last sub-region with severe densities 50+ cases per sq. km is isolated in Pavilion Township (Figure 11).

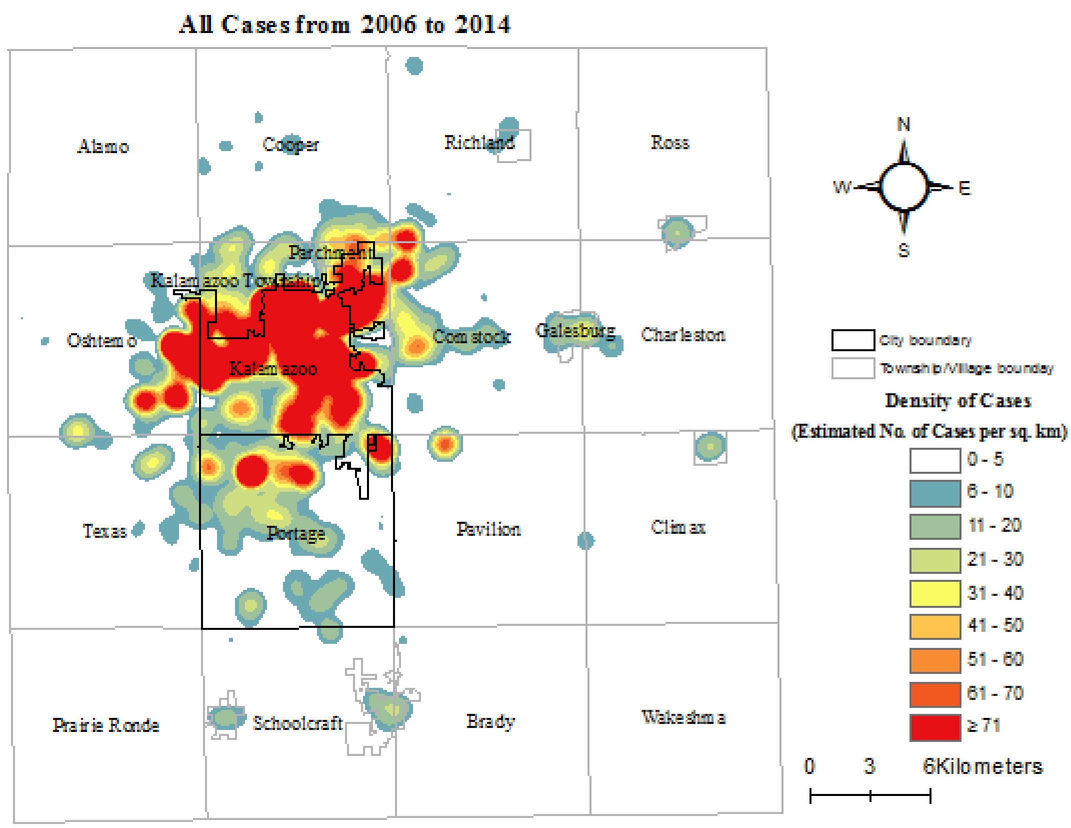

Figure 11. Density of all confirmed cases of chlamydia per sq. km in Kalamazoo County, MI, 2006-2014.

High densities from 31 to 50 cases per sq. km were not only observed in proximity to areas with severe densities but in isolated areas in the northeast of Texas Township, south of

Oshtemo Township and in the village of Galesburg (Figure 11). Also, moderate densities from 6 to 30 cases per sq. km were not only connected to areas with high densities, but were also observed in isolation. Isolated areas with moderate densities includes Schoolcraft Township, Brady Township, Texas Township, Climax Township, Ross Township, Richland Township, Cooper Township, Comstock Township, Pavilion Township and in the southern half of the city of Portage (Figure 11).

There is a single area in the northeast of the city of Kalamazoo city with high densities from 31 to 50 cases per sq. km for individuals less than or equal to 14 years (Figure 12.a). This high density area is surrounded by moderate densities from 6 to 30 cases per sq. km area at the northeast of the city of Kalamazoo into neighboring Kalamazoo Township (Figure 12.a). For individuals between the ages from 15 to 24 years, one big area with severe densities 50+ cases per sq. km covers northern half of the city of Kalamazoo through to the east and northwest side of the city limits (Figure 12.b). This area with severe densities 50+ cases per sq. km also extends from the city of Kalamazoo into the neighboring Oshtemo Township and Kalamazoo Township (Figure 12.b). In addition, there are seven sub-regions with severe densities 50+ cases per sq. km (Figure 12.b). Four of these sub-regions can be found in the northern half of the city of Portage, one in the southwest of the city of Kalamazoo, one in the east of Comstock Township while one also connects Richland Township and Comstock Township (Figure 12.b). The last sub-region with severe densities 50+ cases per sq. km is isolated in the north of Pavilion Township (Figure 12.b). Apart from areas with severe densities that are surrounded by high densities from 31 to 50 cases per sq. km, five sub-regions were found separately (Figure 12.b). Two of these high density sub-region were found in the east of Comstock Township, one in the northwest of the city of Portage, while one each was found in Oshtemo Township and in the southwest of the city of Kalamazoo (Figure 12.b).

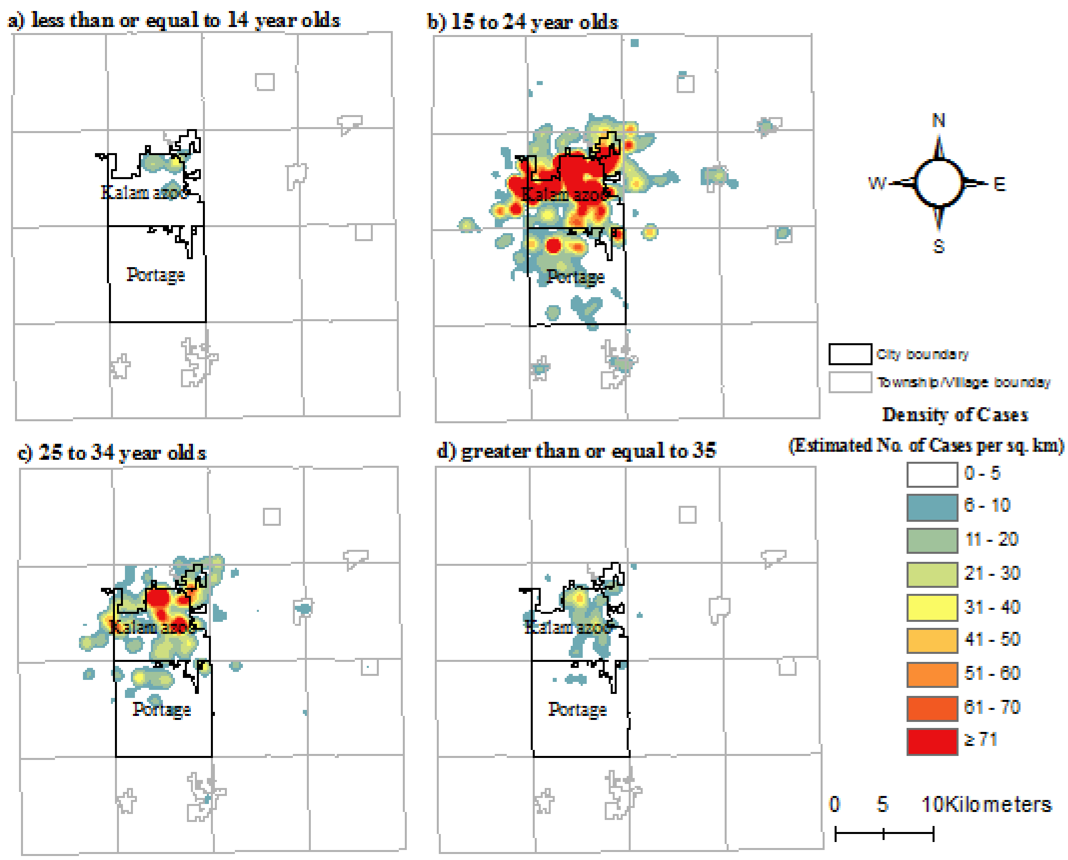

Figure 12. Density of cases per sq. km for age categories a) less than or equal to14 years b) from 15 to 24 years, c) from 25 to 35 years and d) greater than or equal to 35 years in Kalamazoo County, MI, 2006-2014.

Also, moderate densities from 6 to 30 cases per sq. km were observed near high density areas and in isolation. Isolated sub-regions with moderate density of cases for individuals from 15 to 24 years were observed in Texas Township, Oshtemo Township, Cooper Township, Comstock Township, Pavilion Township, and in the southern half of the city of Portage.

Moderate density sub-regions were also found in the village of Galesburg extends into Charleston Township, Climax Township, Ross Township, Richland Township, and in Schoolcraft Township.

For individuals from ages 25 to 34 years, four areas with severe densities 50+ cases per sq. km were found during this nine-year period (Figure 12.c). Two of these areas were found within the city limits of Kalamazoo in the north and east respectively (Figure 12.c). For the remaining two areas with severe densities 50+ cases per sq. km, one connects from the northeast of the city of Kalamazoo into Kalamazoo Township and the other connects from the west of the city of Kalamazoo into Oshtemo Township (Figure 12.c). While areas with severe densities had high densities from 31 to 50 cases per sq. km directly around them, there are three extra sub-regions of high densities (Figure 12.c). Out of these three sub-regions with high densities, two were found in the city of Portage, north and northeast respectively, while the other is in the southeast of the city of Kalamazoo (Figure 12.c). Also, moderate densities from 6 to 30 cases per sq. km were observed near high density areas and in isolation (Figure 12.c). Specifically, isolated areas with moderate density of cases for individuals from 25 to 34 years were observed in Texas Township, Comstock Township, Pavilion Township, Climax Township, Schoolcraft Township, and in the northern half of the city of Portage (Figure 12.c).

In addition, for individuals with ages greater than or equal to 35 years, a single area with high densities from 31 to 50 cases per sq. km was observed in the north of the city of Kalamazoo (Figure 12.d). This high density area was surrounded by a continuous moderate density area from 6 to 30 cases per sq. that covers the north of the city of Kalamazoo through to the southeast (Figure 12.d). This area with moderate densities also connects into neighboring parts of

Kalamazoo Township (Figure 12.d). Also, sub-regions with moderate densities were observed in the northern half of the city of Portage, east of Comstock Township, west of Kalamazoo Township and east of the city of Kalamazoo but this connects into Oshtemo Township (Figure 12.d).

Considering cases for whites, seven areas with severe densities 50+ cases per sq. km were found during this nine-year period (Figure 13.a). Two of these areas were found within the city limits of Kalamazoo in the north and southeast respectively (Figure 13.a). Out of the remaining five areas with severe densities 50+ cases per sq. km, one connects from the northeast of the city of Kalamazoo into Kalamazoo Township. Also, another area connects from the west of the city of Kalamazoo into Oshtemo Township and Kalamazoo Township (Figure 13.a). The last three areas with severe densities were found in the northern half of the city of Portage (Figure 13.a). While areas with severe densities had high densities from 31 to 50 cases per sq. km directly around them, there are six sub-regions of high densities (Figure 13.a). Out of these six sub-regions with high densities, two were found in the southwest of the city of Kalamazoo, two in the northwest of Comstock, one in the north of Pavilion Township and one in the southeast of Oshtemo (Figure 13.a). Besides high density areas which were immediately surrounded by moderate densities from 6 to 30 cases per sq. km, other sub-regions with moderate densities were scattered in the county (Figure 13.a). Sub-regions with moderate densities for whites were observed in Texas Township, Oshtemo Township, Cooper Township, Richland Township, Comstock Township, Pavilion Township, and in the southern half of the city of Portage (Figure 13.a). Moderate density sub-regions were also found in the village of Galesburg extends into

Charleston Township, Climax Township, Ross Township, Richland Township, and Schoolcraft Township (Figure 13.a).

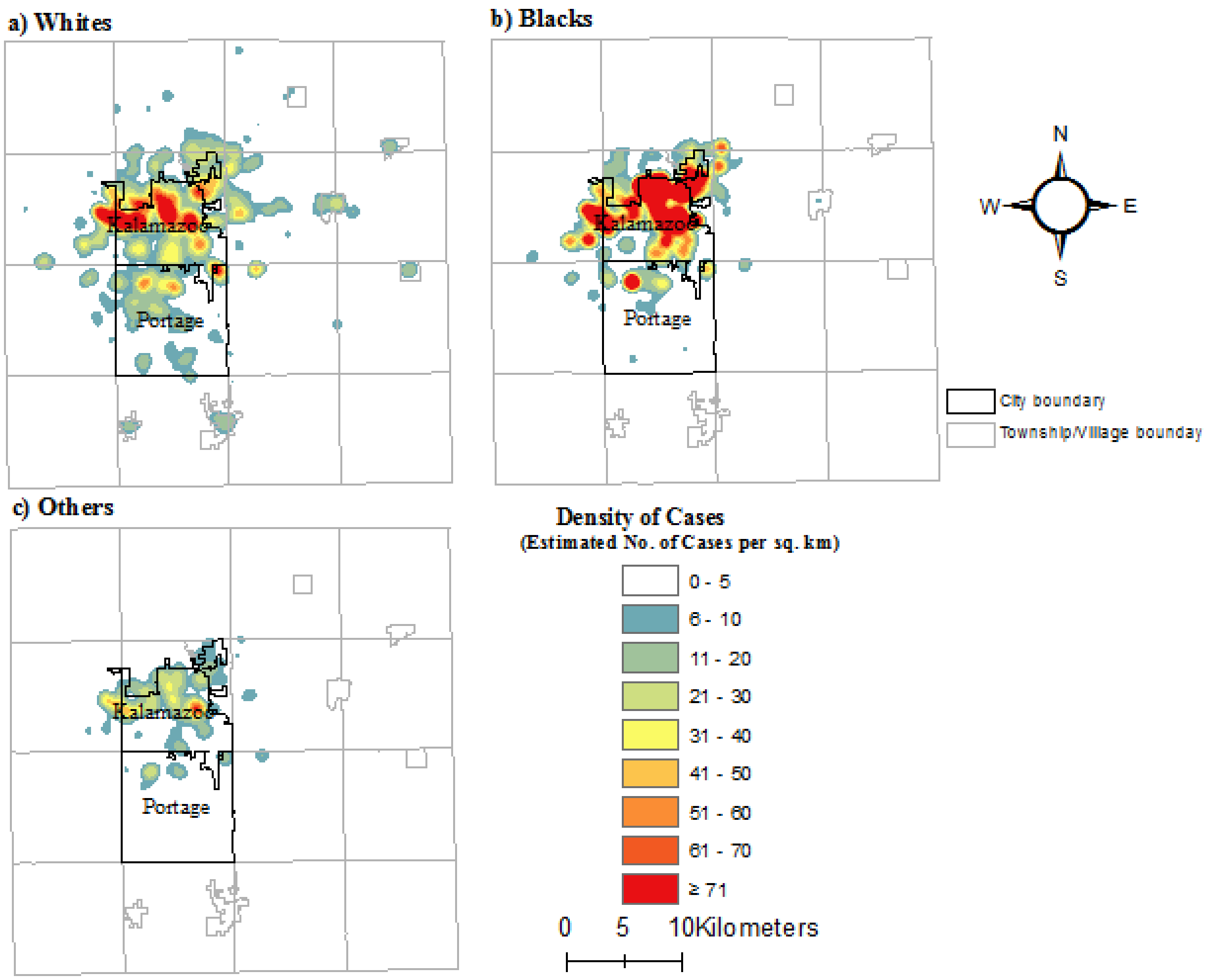

Figure 13. Density of cases per sq. km for race a) whites, b) blacks, c) others in Kalamazoo County, MI, 2006-2014.

There is one central large area with severe densities 50+ cases per sq. km for blacks that covers from the east of the city of Kalamazoo through to the north into the southeast of the city limits (Figure 13.b). This area with severe densities 50+ cases per sq. km also extends into the neighboring Comstock Township, Oshtemo Township and Kalamazoo Township (Figure 13.b). In addition, there are seven sub-regions with severe densities 50+ cases per sq. km (Figure 13.b). For these sub-regions, one connects Comstock Township and Richland Township while another one is within Comstock Township (Figure 13.b). For the remaining five sub-regions, two were observed in the southwest of the Oshtemo Township, one in the northwest of the city of Portage, one in the southeast of the city of Kalamazoo and the last connects the city of Kalamazoo and Oshtemo Township (Figure 13.b). Besides high densities from 31 to 50 immediately surrounding areas with severe densities, two isolated sub-regions with high densities were observed in the northeast of the city of Portage and one in Parchment Township (Figure 13.b). Subsequently, moderate densities from 6 to 30 cases per sq. km surrounded areas with high densities. Moderate densities were also separately observed in Pavilion Township, southern half of the city of Portage and Kalamazoo, in the northeast of Texas Township and in the village of Galesburg (Figure 13.b).

In addition, for the other race group, one area with severe densities 50+ cases per sq. km was observed in the southeast of the city of Kalamazoo (Figure 13.c). Whereas this area with severe densities were surrounded immediately by high densities from 31 to 50 cases, there were three extra sub-regions with high densities during this nine-year study (Figure 13.c). Two of these sub-regions with high densities was observed in the northern half of the city of Kalamazoo and one sub-region also connects the city of Kalamazoo at the east to Oshtemo Township (Figure 13.c). Moderate densities from 6 to 30 cases per sq. km surrounds areas with high densities but also separately in the northwest of Comstock Township, northern half of the city of Portage, south of the city of Kalamazoo and Oshtemo Township, and in the northwest of Pavilion Township (Figure 13.c).

Three main areas of severe densities from 50+ cases per sq. km was observed for males during this nine-year period (Figure 14.a). One of the areas which is to the northeast of the city of Kalamazoo connects into Kalamazoo Township (Figure 14.a).

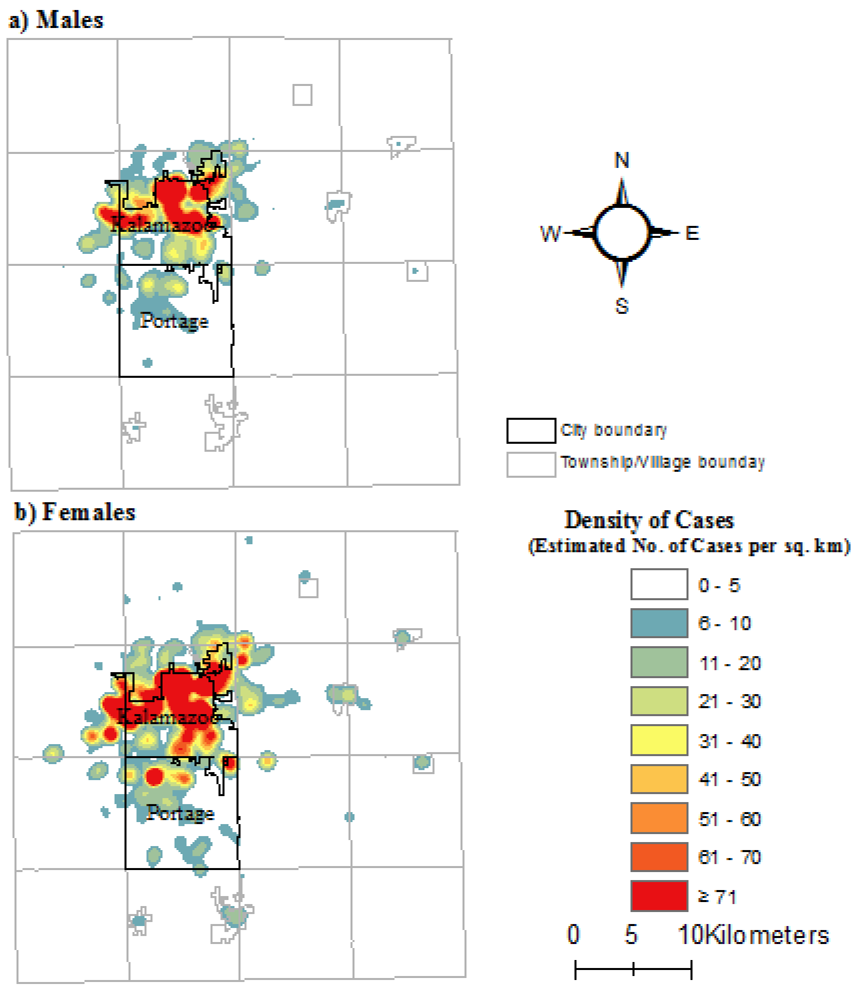

Figure 14. Density of cases per sq. km for gender a) males, b) females in Kalamazoo County, MI, 2006-2014.

For the other two areas with severe densities observed for males in this study, one of them connects the city of Kalamazoo at the west and Oshtemo Township, and the other area is in the west of Kalamazoo Township (Figure 14.a). Besides areas with severe densities that were immediately surrounded by high densities from 31 to 50 cases per sq. km, three sub-regions with high densities were also observed (Figure 14.a). Two of these high density sub-regions were observed in the northern half of the city of Portage and the other sub-region was observed in the south of the city of Kalamazoo (Figure 14.a). Moderate densities from 6 to 30 cases per sq. km surrounds areas with high densities and covers parts of Parchment Township, Kalamazoo Township, Comstock Township, Richland Township and south of the city of Kalamazoo (Figure 14.a). Also, moderate densities were observed separately in the northwest of Pavilion Township, northern half of the city of Portage, northeast of Texas Township, Ross Township, Climax Township, and in the village of Galesburg (Figure 14.a).

Considering cases in females, one big area with severe densities 50+ cases per sq. km covers northern half of the city of Kalamazoo through to the east and northwest side of the city limits (Figure 14.b). This area with severe densities 50+ cases per sq. km also extends from the city of Kalamazoo into the neighboring Oshtemo Township in the east, and in the north and east to Kalamazoo Township (Figure 14.b). In addition, there are eight sub-regions with severe densities 50+ cases per sq. km (Figure 14.b). Three of these sub-regions can be found in the northern half of the city of Portage, two in the southeast of Oshtemo Township, one Parchment Township, one in the northwest of Comstock Township, and the last sub-region connects Richland Township and Comstock Township (Figure 14.b). Apart from areas with severe densities that are surrounded by high densities from 31 to 50 cases per sq. km, four high density sub-regions were found separately (Figure 14.b). One each was found in the southwest of the city of Kalamazoo, northwest of the city of Portage, northwest of Pavilion Township and in the east of Comstock Township (Figure 14.b). Moderate densities from 6 to 30 cases per sq. km surrounds areas with high densities and covers parts of Parchment Township, Cooper Township, Oshtemo Township, Kalamazoo Township, Comstock Township, Richland Township, south of the city of Kalamazoo and the northern half of the city of Portage (Figure 14.b). Also, moderate densities were observed separately in the northeast of Texas Township, Cooper Township, and southern half of the city of Portage. Moderate density sub-regions were also observed in Ross Township, Climax Township, Schoolcraft Township, and in the village of Galesburg which connects into Charleston Township (Figure 14.b).

Compare Density Maps with Socioeconomic Choropleth Maps

Figures 3, 4, 5 and 6 show, respectively choropleth maps of the percentage of poverty, percentage of low educational status, unemployment rate and population density by census tracts in Kalamazoo County. In this urban-rural county, there is high local variation in percent of the population below the poverty line map (Figure 3), percent low educational status (Figure 4), unemployment rate (Figure 5) and population density (Figure 6). The maps show a spatial clustering of the population with poverty, high percentage in low educational status and high percentage of unemployment rate in areas with a high density of cases of chlamydia. These areas were identified by visually inspecting the density maps of all cases of chlamydia.

Notably, population density (Figure 6) is clearly higher in census tracts in urban areas (city of Kalamazoo and city of Portage) than in rural areas (other municipalities). The distribution of the population is highest in poorest census tracts in urban areas, and similar trends are evident in the percentage of low educational status and unemployment rate.

Statistical Analysis

The assumption made for the model to be developed was that, each independent variable at the individual level, neighborhood level, and urban-rural conditions all interact to influence the number of cases of chlamydia in Kalamazoo County. Multiple regression was used to examine the linear association between the multi-scalar independent variables and the aggregate number of cases over the nine-year period in a 1km area around each confirmed chlamydia case.

a) Raw Data of Density of cases

b) Transformed Density of cases

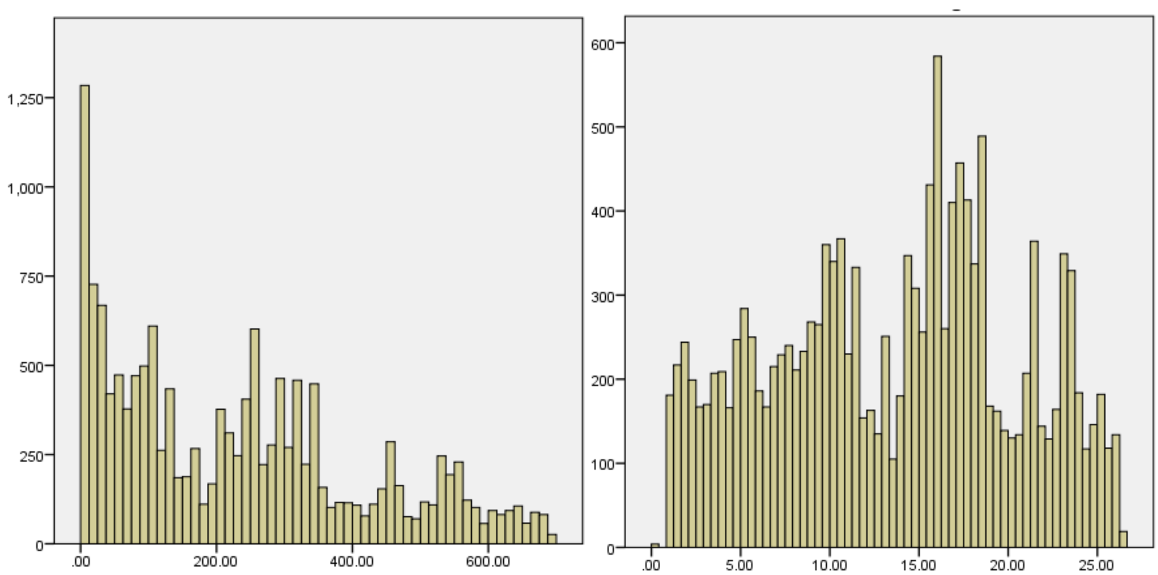

Figure 15. Histograms of the density of chlamydia cases within 1km from each reported positive case for an individual from 2006 to 2014 a) Raw data, b) Transformed data

Inputs were first examined for compliance with the assumptions of regression. The mean of the dependent variable (density of chlamydia cases per sq.km) was 229.1392. The median of this data was also 208.0286. Since the skewness value (0.643) was more than three times the skewness standard error (0.20) and thus indicated that the data is skewed to the right and not normally distributed as shown in the histogram (Figure 15.a). Due to the skewed nature of this initial dependent variable, the data were transformed by taking a square root of its value. Unlike the initial dependent variable, the skewness value (-0.074) of the transformed dependent variable was less than three times the skewness standard error (0.20) and this indicates the data is fairly normally distributed as shown in the histogram (Figure 15.b).

Multiple regression also operates under the assumption that the independent variables have no multicollinearity (Rogerson, 2015). This means that the correlation between two or more independent variables should not be high (Rogerson, 2015). Pearson Correlations were used to examine the correlations of the three continuous socioeconomic variables to determine whether there is multicollinearity between the variables. The results (Table 3) show a high correlation (0.843) between educational status and the unemployment rate at the neighborhood level. This value is above the threshold of (0.80). This show the variables are closely related and hence multicollinearity may be a problem between educational status and the unemployment rate. Poverty was fairly correlated with educational status (0.585) and the unemployment rate (0.586).

Table 3. Pearson correlation matrix for neighborhood level socioeconomic variables of percent poverty, percent low educational status and percent unemployment rate.

		Percent Poverty	Educational Status	Unemployment Rate
Percent Poverty	Pearson Correlation	1	.585**	.586**
	Sig. (2-tailed)		0.000	0.000
	N	14788	14788	14788
Educational Status	Pearson Correlation	.585**	1	.843**
	Sig. (2-tailed)	0.000		0.000
	N	14788	14788	14788
Unemployment Rate	Pearson Correlation	.586**	.843**	1
	Sig. (2-tailed)	0.000	0.000	
	N	14788	14788	14788

**. Correlation is significant at the 0.01 level (2-tailed).

Principal component analysis (PCA) was run on these three socioeconomic variables at the neighborhood level to reduce the redundancy between the multiple correlated variables. PCA is a variable reduction procedure used to address the issue of redundancy that may cause multicollinearity between variables (Rogerson, 2015).

The results of the PCA using extraction of components with Eigen Values greater than one show that, 78.9 percent of the variability in the original dataset in the socioeconomic variables can be explained by the extracted component. The loadings on the first extracted component (Table 4) showed a clear relationship between the variables and the component and hence added as socioeconomic status variable in the regression for further analysis.

Table 4. The percent of the variable that was extracted as part of the component.

	Component
	1
Percent Poverty	.802
Educational Status	.924
Unemployment Rate	.924

All the variables for the three multiscale level model were entered into the multiple regression as shown in Table 5. The omitted category refers to the group that was coded as 0 while their entered group were coded as 1. The omitted category will be accessed as the intercept after the regression has been run. The intercept will therefore represent black, 15-24 years, male and urban and will be compared to the variable in that same group. With the exception of the transformed density of cases which was the dependent variable been modeled, all the other variables that entered the regression are independent variables.

Table 5. The variables that entered the multiple regression, the base category in that group and the scale at which it was evaluated.

<table>
<tr><th>Entered Variable</th><th>Base Category</th><th>Scale</th></tr>
<tr><td>Transformed Density of Cases</td><td></td><td></td></tr>
<tr><td>White</td><td rowspan="2">Black</td><td rowspan="6">Individual Level</td></tr>
<tr><td>Other race</td></tr>
<tr><td><= 14 years</td><td rowspan="3">15-24 years</td></tr>
<tr><td>25-34 years</td></tr>
<tr><td>>= 35 years</td></tr>
<tr><td>Female</td><td>Male</td></tr>
<tr><td>Population density</td><td></td><td rowspan="2">Neighborhood Level</td></tr>
<tr><td>Socioeconomic Status</td><td></td></tr>
<tr><td>Rural</td><td>Urban</td><td>Urban-rural level</td></tr>
</table>

The results of the model predicted in this three multiscale model is summarized in Table 6. From the output of the multiple regression, this three multiscale model is statistically significant and explains 64.9 percent of the variability in the density of cases of chlamydia within every square kilometer (Table 6).

Table 6. Summary of the three multiscale model to predict the density of cases of chlamydia within every square of a kilometer.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.806[a]	.650	.649	4.00030

The test of analysis of variance (Table 7) using the F statistic assumes a null hypothesis that, the model has no predictive power or the coefficients in the independent variables are equal to zero. The results, however indicate that, the F statistic is significant and hence rejection of the null hypothesis. The conclusion is that, there is statistically enough evidence at $\alpha = 0.05$ (in fact, 0.001) to show that the model can predict the density of time-aggregated chlamydia cases around each confirmed diagnosis (Table 7).

Table 7. ANOVA test to determine if the model has a predictive power.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	438470.561	9	48718.951	3044.479	<.0001
	Residual	236483.362	14778	16.002		
	Total	674953.923	14787			

In this model, with the exception of ages less than or equal to 14 years and ages greater than or equal to 35 years, which was not significant at the 5% level of significance, all the independent variables were significant in predicting the density of cases of chlamydia per square kilometer (Table 8). The result indicates significant differences among the density of cases in the environs of individuals with different age, race and gender characteristics and among sub-regions of the community with different socioeconomic and environmental conditions of urban-rural characteristics. It is imperative to note that males, blacks, those of age 15 to 24 years and urban areas served as the reference categories, which were coded as 0, and so do not appear in Table 8 except as represented by the coefficient associated with the constant.

Table 8. Estimated coefficients at 5% level of significance and collinearity statistics of independent variables in the model.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
(Constant)	11.706	.103		113.209	<.0001	11.504	11.909		
White	-2.971	.075	-.213	-39.667	<.0001	-3.118	-2.825	.824	1.214
Other race	-1.712	.121	-.071	-14.115	<.0001	-1.950	-1.474	.926	1.080
<= 14 years	-.300	.261	-.006	-1.148	.251	-.811	.212	.984	1.016
25-34 years	-.071	.084	-.004	-.846	.398	-.235	.093	.966	1.035
>= 35 years	-.603	.154	-.019	-3.913	<.0001	-.906	-.301	.967	1.034
Female	.310	.072	.022	4.327	<.0001	.169	.450	.955	1.047
Population Density	.003	.000	.332	53.928	<.0001	.003	.003	.626	1.598
Rural	-.752	.090	-.052	-8.374	<.0001	-.928	-.576	.612	1.633
Socieconomic Status	3.224	.039	.477	82.883	<.0001	3.147	3.300	.715	1.398

With regards to the age of the patient with a confirmed case of chlamydia, regression analysis yielded an insignificant negative slopes for individuals less than or equal to 14 years ($\beta = -0.300$, $p > 0.05$), and individuals from 25 to 34 years ($\beta = -0.071$, $p > 0.05$) but a significant negative slope for individuals greater than or equal to 35 years ($\beta = -0.603$, $p < 0.05$) shown in Table 8. These values indicate that individuals less than or equal to 14 years and those from 25 to

34 have an overall lower density of cases of chlamydia relative to individuals aged 15 to 24 years. However, for such individuals, their density of cases was not significantly different from those aged 15 to 24 years because they all live closer to areas with higher density of cases. Whereas, individuals greater than 35 years live within areas with lower density of cases of chlamydia relative to individuals aged 15 to 24 years.

With regards to the race of the patient with a confirmed case of chlamydia, the results shown in Table 8 reveal a significant negative slope for whites ($\beta = -2.971$, $p < 0.05$) and other races ($\beta = -1.712$, $p < 0.05$). This indicates that, whites have a relatively lower density of cases than blacks because whites live within areas with lower density of cases of chlamydia relative to blacks. Also, individuals self-identified as neither black nor white (other race category) have a relatively lower density of cases than blacks, because they live within areas with lower density of cases of chlamydia relative to blacks.

For gender, the regression results yielded a significant positive slope for females ($\beta = 0.310$, $p < 0.05$) as shown in Table 8. This indicates that females have a relatively high density of cases of chlamydia than males, because females live within areas with higher density of cases of chlamydia relative to males. Subsequently, the results also show a significant negative slope for rural areas ($\beta = -0.752$, $p < 0.05$), indicates that individuals living in rural areas have relatively lower density of cases of chlamydia than individuals in urban areas. This is because individuals in rural areas live within areas with lower density of cases of chlamydia relative to urban areas.

With regards to socioeconomic status at the census tract level (neighborhood level), regression analysis yielded a significant positive slope ($\beta = 3.224$, $p < 0.05$) and population density ($\beta = 0.003$, $p < 0.05$) as shown in Table 8. This indicates that as socioeconomic status (poverty, low educational status, and unemployment rate) and population density increases, the density of cases within an area also increases respectively. Multicollinearity of the independent variables in this chlamydia density model was assessed by examination of the values of the variance inflation factor (VIF) or tolerance. The results indicate that, there are no issues with multicolinearity since all VIF values were less than the typical acceptance threshold of three as shown in Table 8. The lower and upper bound values for population density are marginal, but we accept it in this case as plausibly significant. Since, none of the confidence intervals for the slope estimate measured at the 5% level of significance include zero, all the independent variables are significant in the model.

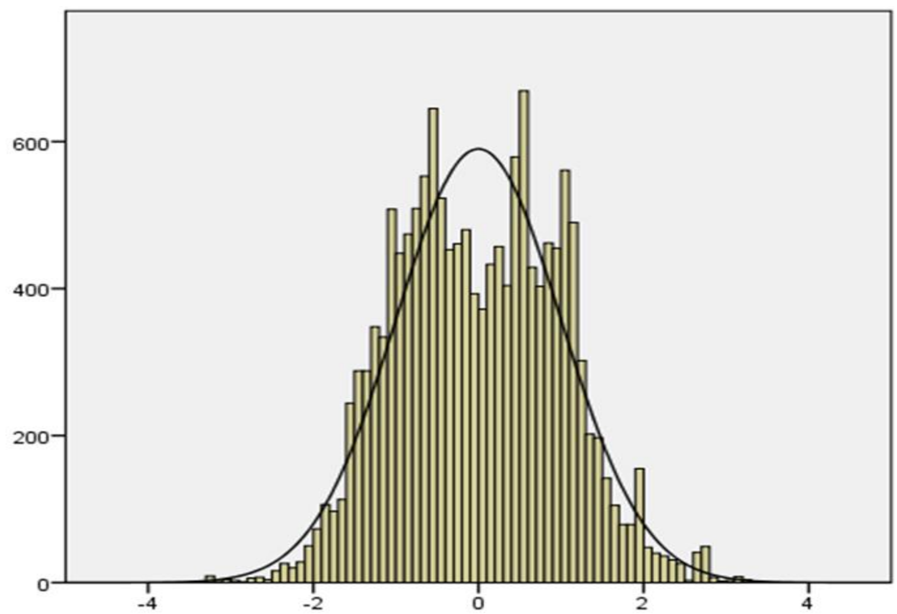

Figure 16. The histogram plot of the regression standardized residuals with a normal curve fitting.

Lastly, the residuals (Figure 16) from the model are normally distributed indicating that the predicted co-efficient are good for predicting the density of cases of chlamydia within every kilometer in Kalamazoo County.

Summary

The purpose of this chapter was to present the analysis and results of the study. The chapter focused on three main areas. The first was a descriptive analysis of the chlamydia data from 2006 to 2014. The second was the examination of the output of the GIS density maps created as part of this analysis. The third was the multi-scalar multiple regression analysis, which was used to determine which variables were significant in explaining chlamydia-related disparity. The results obtained were used to test the hypothesis of this study and is further discussed in the next chapter. Subsequently, suggestions on core areas to target location based interventions in Kalamazoo are also outlined in the next chapter. Future research recommendations based on the limitations that were not considered in this study is also provided in the next chapter.

CHAPTER V

DISCUSSION, LIMITATIONS, AND FUTURE RESEARCH

Discussion

The goal of this study was to investigate the geographic patterns of chlamydia cases and to quantify the factors related to chlamydia-disparities within neighborhoods for planning location-based interventions in Kalamazoo County. While previous studies on analysis of STI disparities have been conducted at the state and metropolitan scale, this study focused on a local scale in a county with mixed urban and rural settings.

From 2006 to 2014, the annual incidence rates of chlamydia for individuals from the age 15 to 24 years was twice that of all other age groups combined (Figure 7). This age range is associated with high risk sexual behaviors from a public health perspective (CDC, 2015, Weinstock et al., 2004; Advocates for Youth, 2010). This finding is consistent with CDC surveillance reports at the national level that, annual incidence rates of chlamydia are highest among youth between the ages of 15 to 24 years old (CDC, 2015). Also, the annual incidence rates for blacks were higher compared with whites and those in the other racial group (Figure 8). However, the annual incidence rates for whites have doubled from 364.3 cases per 100,000 populations in 2006 to 729.4 cases per 100,000 in 2014. During the same nine-year period, the rates for blacks increased from 585.6 cases per 100,000 populations in 2006 to 801.3 cases per 100,000 populations in 2014. For individuals in the other race group, the annual incidence rates almost always remained between 100 to 150 cases per 100,000 populations for all the years examined. The annual incidence rates for females was always double that of their male counterparts in this study (Figure 9). This could be due to more males being asymptomatic for chlamydia and females expected to being screened more frequently than their male counterpart (CDC, 2015).

It was first hypothesized that areas with unusually high density of cases of chlamydia contain high risk populations and constitute the core areas to target for interventions. The population at risk as defined through studies are individuals with a higher risk of acquiring an STI either by being concentrated in core groups or areas (Bernstein et al., 2004; Bush et al., 2008, Gesink et al., 2011). For this study, an area with severe densities defined as 50+ cases per sq. km was used as the threshold to define a core area. Thus, for the nine-year period considering all cases of chlamydia reported to MDSS, it is evident there is one big central core area with severe densities 50+ cases per sq. km that stretches from the northern half of the city of Kalamazoo through to the east and northwest side of the city limits (Figure 11). This core area also extends into the neighboring Comstock Township, Parchment Township, Oshtemo Township and Kalamazoo Township (Figure 11). In addition, there are seven smaller core areas with severe densities 50+ cases per sq. km (Figure 11). Four of these core areas were found in the northern half of the city of Portage, one in the southwest of the city of Kalamazoo, one in the east of Comstock Township while one also connects Richland Township and Comstock Township (Figure 11). The last core area with severe densities 50+ cases per sq. km is isolated in Pavilion Township (Figure 11).

Considering cases by age groups, this study found that, core areas with severe densities 50+ cases per sq. km could only be defined for individuals from 15 to 24 years and from 25 to 34, but not in the other groups; which had densities not above 50 cases per sq. km threshold

(Figure 12). However, for individuals from 15 to 24 years, the same geographic patterns of core areas were observed when all cases were mapped. Whereas, for individuals from 25 to 34 years, four core areas with severe densities 50+ cases per sq. km were found during this nine-year period (Figure 12.c). Two of these core areas were found within the city limits of Kalamazoo in the north and east respectively (Figure 12.c). For the remaining two core areas with severe densities 50+ cases per sq. km, one connects from the northeast of the city of Kalamazoo into Kalamazoo Township and the other connects from the west of the city of Kalamazoo into Oshtemo Township (Figure 12.c).

This study found that the density of cases for individuals less than or equal to 14 years and those from 25 to 34 was negatively insignificant. Thus, their overall densities are relatively lower than individuals aged 15 to 24 years. However, the density of cases around individuals less than or equal to 14 years and those from 25 to 34 years was not significantly different from those for individuals aged 15 to 24 years. Whereas, individuals greater than 35 years had a lower density of cases relative to individuals aged 15 to 24 years. This is because individuals greater than 35 years live within areas with lower density of cases of chlamydia relative to individuals aged 15 to 24 years.

Whereas the geographic patterns of chlamydia for whites were randomly scattered with varying intensity, the pattern for blacks were spatially concentrated and same with the other group. For whites, seven core areas with severe densities 50+ cases per sq. km were found during this nine-year period (Figure 13.a). Two of these core areas were found within the city limits of Kalamazoo in the north and southeast respectively (Figure 13.a). Out of the remaining five areas with severe densities 50+ cases per sq. km, one connects from the northeast of the city of

Kalamazoo into Kalamazoo Township. Also, another area connects from the west of the city of Kalamazoo into Oshtemo Township and Kalamazoo Township (Figure 13.a). The last three core areas with severe densities were found in the northern half of the city of Portage (Figure 13.a). There is one central large core area with severe densities 50+ cases per sq. km for blacks that covers from the east of the city of Kalamazoo through to the north into the southeast of the city limits (Figure 13.b). This core area with severe densities 50+ cases per sq. km also extends into the neighboring Comstock Township, Oshtemo Township and Kalamazoo Township (Figure 13.b). In addition, there are seven smaller core areas with severe densities 50+ cases per sq. km (Figure 13.b). For these smaller core areas, one connects Comstock Township and Richland Township while another one is within Comstock Township (Figure 13.b). For the remaining five smaller core areas, two were observed in the southwest of the Oshtemo Township, one in the northwest of the city of Portage, one in the southeast of the city of Kalamazoo and the last connects the city of Kalamazoo and Oshtemo Township (Figure 13.b). In addition, for the other race group, one core area with severe densities 50+ cases per sq. km was observed in the southeast of the city of Kalamazoo (Figure 13.c).

The study found that the density of cases for whites and other race was negatively and significantly lower than blacks. This indicates that, whites have a relatively lower density of cases than blacks because whites live within areas with lower density of cases of chlamydia relative to blacks. Also, individuals self-identified as neither black nor white (other race category) have a relatively lower density of cases than blacks, because they live within areas with lower density of cases of chlamydia relative to blacks.

This study found three core areas of severe densities from 50+ cases per sq. km for males during this nine-year period (Figure 14.a). One of the core areas which is to the northeast of the city of Kalamazoo connects into Kalamazoo Township (Figure 14.a). For the other two core areas with severe densities found in males, one of them connects the city of Kalamazoo at the west and Oshtemo Township, and the other core area is in the west of Kalamazoo Township (Figure 14.a).

Females on the other hand, had one big core area with severe densities 50+ cases per sq. km which covers the northern half of the city of Kalamazoo through to the east and northwest side of the city limits (Figure 14.b). This core area with severe densities 50+ cases per sq. km also extends from the city of Kalamazoo into the neighboring Oshtemo Township in the east, and in the north and east to Kalamazoo Township (Figure 14.b). In addition, there are eight smaller core areas with severe densities 50+ cases per sq. km (Figure 14.b). Three of these smaller core areas were found in the northern half of the city of Portage, two in the southeast of Oshtemo Township, one Parchment Township, one in the northwest of Comstock Township, and the last smaller core area connects Richland Township and Comstock Township (Figure 14.b).

This study also found that the density of cases for females was positively and significantly higher relative to males. This indicates that females live within areas with higher density of cases of chlamydia relative to males.

Thus, at the individual scale, there are disparities in the density of cases of chlamydia by age groups, race and gender. This study found that, increasing densities was more associated with individuals from age 15 to 24 years relative to the other age groups even though their density of cases of chlamydia was not significantly different from individuals less than or equal to 14 years and from 25 to 34 years. Whereas increasing densities for the race was more associated with blacks relative to whites and the other group. However, the density of cases in the other group was relatively higher than whites. Also, females significantly had an increased density of cases of chlamydia relative to males.

By comparing the geographic patterns found on all the Kernel density maps from 2006 to 2014, this study can conclude that chlamydia is spreading geographically from a more central core area in the city of Kalamazoo into neighboring Oshtemo Township, Kalamazoo Township and Comstock Township. This study suggests that interventions be targeted to seven core areas found during this nine-year period when all cases of chlamydia was considered to stop these core areas from erupting into epidemics. These core areas overlapped with high risk populations of individuals aged 15 to 24 years, females, males, blacks and whites than any other individual characteristic considered in this study. Four of these core areas were found in the northern half of the city of Portage, one in the southwest of the city of Kalamazoo, one in the east of Comstock Township while one also connects Richland Township and Comstock Township. The last core area which also need to be targeted is isolated in Pavilion Township.

The second hypothesis of this study was that, neighborhood characteristics in poverty, educational status and environmental conditions (urban-rural) influence why some individuals are at a high risk of acquiring chlamydia and hence the associated disparities. At the neighborhood scale socioeconomic status (poverty, low educational status, and unemployment rate) was positively and significantly associated with density of cases of chlamydia after controlling for individual level risk factors and environmental conditions (urban-rural). Thus, increasing low socioeconomic status (percentage of poverty, low educational status and unemployment) in a census tract will lead to increasing density of cases of chlamydia. Population density was positively and significantly associated with the density of cases of chlamydia, but had little impact on the overall model prediction. Comparing the geographic patterns observed in Kalamazoo and Portage cities (urban areas) and the other municipalities (rural areas) it is evident that more individuals with chlamydia reside in urban areas than rural areas. Also, at the urban-rural level, increasing density of cases of chlamydia was positively and significantly associated with urban areas relative to rural areas after controlling for factors at the individual and neighborhood scales.

These findings show significant differences in age, race, gender, urban and rural areas contribute to the research on disparities associated with STI at the local scale. This study computed the annual incidence rates in chlamydia, used GIS to map the differences in the spatial distribution of chlamydia to identify core areas and performed a three multiscale statistical analysis to determine which factors influence chlamydia-related disparities. This research further showed through the model developed that, populations at high risk of acquiring chlamydia live within areas with a high density of cases and hence the associated risk for each of the scales the individual is found in. Thus, the selection of a particular scale may ignore spatial variations in another, but using different scales for analysis can aid to confirm a hypothesis of a study (Moore & Carpenter, 1999). This study demonstrates how to assess chlamydia-related disparities using GIS and statistical analysis.

Limitations

There are many limitations to this study. The first is that this study only included those who were tested, so if rural residents are receiving less testing this could have affected the findings. Only day of STI testing, and not date of diagnosis or symptom onset, was available; hence it is limited in identifying how STIs spatially diffuse to new locations in the county. While varying bandwidth can influence outputs, this study used only one kilometer even though other bandwidth could be chosen. The visualization of high density areas may therefore be different if a different bandwidth is used but certainly the underlying trends would remain the same. Also, whereas KDE has an added advantage of avoiding the spatial size and shape of aggregation unit boundaries, it may also limit analysis since the extracted value for the point may actually not reflect the census tract it falls in. Moreover, this study did not take into the account whether the individual with the reported confirmed positive case lived in a specific census tract for a long time or moved in recently, for that reason, may lead to assigning a value at the neighborhood level which does not apply to that individual. Also many without symptoms may not be tested and this may vary by subgroups like less males tested than women and testing sites closer to populations in the cities and neighboring townships other townships further away from the cities.

Future Studies

It was hypothesized that areas with unusually high density of cases of chlamydia contain high risk populations and constitute the core areas to target for interventions. Definition for high risk populations was simplified in this study that such individuals live within core areas. Living with core areas may place an individual at risk if he/she belongs to a core group. Core groups may include individuals with multiple infections at a period of time. Considering that, about 48.3% of the cases of chlamydia reported from 2006 to 2014 were multiple cases, future study should examine this group as may lead to identifying the core group of transmission.

Whereas this study accessed the spatial concentration of cases to make suggestions for targeting interventions in Kalamazoo County, future research should employ mixed methods to determine ground truth why these core areas persist in some neighborhoods but not in others.

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APPENDIX A

HSIRB Approval Letters

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: September 22, 2014

To: Amy Curtis, Principal Investigator
Rajib Paul, Co-Principal Investigator
Kathleen Baker, Co-Principal Investigator
Prince Allotey, Student Investigator
Elizabeth Alward, Student Investigator
Virginia Vanderveen, Student Investigator

From: Amy Naugle, Ph.D., Chair Amy Naugle

Re: HSIRB Project Number 14-09-27

This letter will serve as confirmation that your research project titled "Mapping Community Health and Resources: STI and Death Records Data Mapping" has been **approved** under the **exempt** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study***)." Failure to obtain approval for changes will result in a protocol deviation. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

Reapproval of the project is required if it extends beyond the termination date stated below.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: September 21, 2015

251 W. Walwood Hall, Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: October 7, 2014

To: Amy Curtis, Principal Investigator
Rajib Paul, Co-Principal Investigator
Kathleen Baker, Co-Principal Investigator
Student Investigators: Prince Allotey, Elizabeth Alward
Claudio Owusu, Virginia Vanderveen

From: Amy Naugle, Ph.D., ~~Chair~~ Amy Naugle

Re: HSIRB Project Number 14-09-27

This letter will serve as confirmation that the change to your research project titled "Mapping Community Health and Resources: STI and Death Records Data Mapping" requested in your memo received October 7, 2014(to add student investigator Claudio Owusu) has been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: **September 21, 2015**

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PHONE: (269) 387-8293 FAX: (269) 387-8276