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A Spatial Temporal Analysis of Cardiovascular Disease Mortality Rate in the Central Savannah River Area by Using the Urban Health Index Approach

Carlf Cao

ABSTRACT

A Spatial Temporal Analysis of Cardiovascular Disease Mortality Rate in the Central Savannah River Area by Using the Urban Health Index Approach

By

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July 8, 2022

INTRODUCTION: Characterized as a condition that affects the heart or blood vessels, cardiovascular heart disease is the leading cause of death and illness in the United States and globally. This condition disproportionately affects individuals of lower socioeconomic status. The Urban Health Index (UHI) may be utilized to understand health inequities, allowing for more effective resource allocation and targeted community intervention programs.

AIM: The focus of this study is to geographically analyze and characterize socioeconomic conditions to better map and measure health inequalities in the Central Savannah River Area (CSRA) from 2000 to 2019.

METHODS: A literature review identified the social, physical, and environmental determinants associated with cardiovascular disease. The US Census Bureau database was accessed to obtain the four indicators of interest from the 2000 Decennial Census Summary File 3 (SF3) and the 2010-2015 American Community Survey (ACS). The UHI was utilized to quantify the health inequalities within the CSRA for six timeframes: 2000-2004, 2005-2009, 2010-2014, 2015-2019, 2000-2009, and 2010-2019. In addition, age-adjusted mortality rates of cardiovascular heart disease mirroring the designated timeframes were obtained from CDC Wonder. This allowed for the calculation of Pearson correlation coefficients to understand the association between the resultant index scores and age-adjusted mortality rate of cardiovascular disease.

RESULTS: Bivariate correlation analysis show a strong association between the UHI and age-adjusted mortality rate of cardiovascular disease across all selected timeframes. The spatial distribution of county-level UHI values visualized for the CSRA reflect an improvement observed from 2010-2014. Overall, from 2000 to 2019, there is a decrease in mortality for cardiovascular disease and increase in population health and equity.

DISCUSSION: Although statistically significant correlations were identified with the bivariate analyses, further investigation is necessary due to limitations in data for the indicators of interest. Despite this drawback, the study established the feasibility of using the UHI calculation to visualize and measure health inequities in the CSRA and associations with cardiovascular disease.

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APPROVAL PAGE

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Author's Statement Page

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Introduction

Recent projections predict that 68% of the global population, i.e., an additional 2.5 billion people, will reside in current urban environments by the year 2050 when compared to previous figures from 2015 (United Nations, 2018). This urbanization trend demonstrates the need for increased data collection, analysis, and visualization to accurately determine the potential health impacts stemming from the positive correlation between urbanization and increased health risks (Weiss et al., 2020). The association between health and urbanization stems from two factors. First, negative lifestyle changes allow for the development of health issues (Li et al., 2016; Reddy & Yusuf, 1998). Changes in an individual's diet and physical activity would raise the risk of health problems and susceptibility to disease (Li et al., 2016; Reddy & Yusuf, 1998). Second, an urban environmental change characterized by an increased exposure to pollution could result in disease onset (Li et al., 2016). As such, there is a need for an increased understanding of the burden of disease to better target communities at greatest risk.

A disease of particular importance is cardiovascular heart disease (CVD). Already the leading cause of death globally, models estimate the effects of urbanization, population growth, and aging may more than double the current incidence rate of cardiovascular disease in urban areas (Chan et al., 2012; World Health Organization, 2021). This stems from an increased exposure to risk factors of CVD (Reddy & Yusuf, 1998). Economic development and effective public health responses allow for increased life expectancies (Reddy & Yusuf, 1998). An increased longevity creates a longer period of exposure to risk factors of CVD, which increases the probability of the development of a CVD event (Reddy & Yusuf, 1998). However, not all individuals are equally exposed to risk factors of CVD (Reddy & Yusuf, 1998; Psaltopoulou et

al., 2017). The burdens of CVD may exacerbate the current health inequities within low- and middle-income individuals, introducing a socioeconomic risk element (WHO, 2021).

Lower socioeconomic status is a major risk factor of cardiovascular disease (Lemstra, Rogers & Moraros, 2015; Weiss et al., 2020; Utzinger & Keiser, 2006). The concept of socioeconomic status is an amalgamation of several interconnected factors (Schultz et al., 2018). These factors are generally grouped into income level, educational attainment, environmental factors, and employment status (Schultz et al., 2018). First, increases of $10,000 in the median income of a community correlates with a reduction in mortality risk of 10% (Schultz et al., 2018). Second, there exists an inverse relationship between educational attainment and CVD (Schultz et al., 2018; Psaltopoulou et al., 2017). Third, disadvantaged neighborhoods provide poor dietary options and increase food costs (Schultz et al., 2018; Psaltopoulou et al., 2017). Fourth, unemployment increases the likelihood of a CVD event by 20% (Schultz et al., 2018). Disadvantaged from a socioeconomic viewpoint, individuals with fewer means are unable to sufficiently prevent and treat cardiovascular heart disease.

In the United States, there exists a geographic region experiencing an intersection of urbanization and low socioeconomic status. Comprised of 21 counties, 13 in Georgia and 8 in South Carolina, approximately 700,000 individuals reside within the boundaries of the Central Savannah River Area (CSRA) (Stone, Chung & Ansa, 2018; Hamilton et al., 2022). The CSRA has experienced disparate health outcomes despite containing Georgia's second largest metropolitan area (Moore et al., 2021; Stone, Chung & Ansa, 2018; Hamilton et al., 2022). Furthermore, the total population of counties within Georgia are projected to increase to 575,304 by 2035, representing a 26.5% increase from 2010 or a 67.4% increase from 1980 (Georgia Department of Community Affairs, 2012).

As the CSRA already lacks the structural support necessary to increase health outcomes, the projected growth will only further health disparities and poor health outcomes within the area (Moore et al., 2021). The lack of health care resource, lower socioeconomic status, food insecurity, and healthy food access magnifies the proportion of population at risk for infectious and chronic diseases (AHA, 2022; Stone, Chung & Ansa, 2018; Moore et al., 2021). Compared to national averages, the CSRA has a higher proportion of indigent and uninsured individuals (Stone, Chung & Ansa, 2018). Despite being served by two public health districts, 58% of the population in the region have high blood pressure (AHA, 2022). These figures serve as a warning of the disproportionate effect CVD may have in the area.

Previous studies confirm the effectiveness of behavioral changes necessary in the CSRA, such as normalization of blood pressure and healthy diets, to prevent the likelihood of a negative health event (Guttmacher & Collins, 2003; Lu et al., 2015; Schultz et al., 2018). Such lifestyle modifications are typically delivered through community intervention programs (Puska et al., 1983; McLeroy et al., 2003; Cutler, 2004; Winkleby, Feldman & Murray, 1997; Jacob et al., 2022). These methods typically involve lifestyle changes aimed to decrease cigarette smoking, blood pressure, cholesterol level, and body mass index or to increase the ability to manage adherence to prescribed medication (Puska et al., 1983; Winkleby, Feldman & Murray, 1997; Jacob et al., 2022). The identification of risk factors for the disease theoretically allows for precise interventions to mitigate and decrease occurrences of cardiovascular disease. However, in practice, differences observed between implementing and not implementing a community intervention program are statistically insignificant, suggesting smaller than expected differences (Winkleby, Feldman & Murray, 1997). A potential solution to mitigate this challenge is the development of a more robust intervention program design focused on small subgroups and

longitudinal follow-ups (Winkleby, Feldman & Murray, 1997). Changing the program design would require the utilization of a tool to allow for policy and program changes to better target the communities with the greatest burden of disease.

The gap between theory and implementation necessitates the utilization of a tool, the Urban Health Index (UHI), to allow for policy and program changes to better target the communities with the greatest burden of disease. The Urban Health Index allows for an increased understanding of the burden of disease due to a higher level of visualization on a selected geographic scale. A composite score of health determinants taken in isolation would not provide sufficient understanding of the scope of disease (Weaver et al., 2014). Instead, the utilization of a measure of health that allows for the ranking of urban areas and geographic visualization would be more advantageous (Rothenberg et al., 2014; Weaver et al., 2014). The ability to select a specific geographic location allows for a greater flexibility and understanding of health indicators and determinants in the community (Dai et al., 2017; Rothenberg et al., 2014; Weaver et al., 2014). Focusing on a particular location would allow policymakers and stakeholders to understand the progression of disparity reduction and to plan program changes allowing for further improvement (Dai et al., 2017). Furthermore, the temporal aspect of the Urban Health Index allows for a comparison between current and previous health trends, allowing for the identification of historical "hot spots" that require attention (Dai et al., 2017; Rothenberg et al., 2014). Incorporating both a spatial and temporal aspect to the visualization allows for a deeper understanding for stakeholders when planning the program (Dai et al., 2017). These factors make the UHI a viable tool to assist in the development of powerful intervention programs.

In this study, cardiovascular disease is quantified and compared across a geographic region, known as the Central Savannah River Area (CSRA), using four health indicators. An association is explored on the county level across a 20-year timeframe, 2000 to 2019, thus, allowing for the observation of geographical trends. The resultant analysis will illustrate variances in cardiovascular disease across counties and provide insight on the determinants of urban health.

Literature Review

Cardiovascular Disease

Cardiovascular heart disease (CVD) is the leading cause of death and illness in the United States and globally (Schultz et al., 2018; Guttmacher & Collins, 2003; WHO, 2021). This umbrella term encompasses all conditions, direct and indirect, that affects the heart or blood vessels (WHO, 2021). In addition to heart attack and stroke, this group also includes congenital heart disease, deep vein thrombosis, and pulmonary embolism (WHO, 2021).

In 2019, approximately 17.9 million deaths, representing 32% of all global deaths, were attributable to cardiovascular heart disease (WHO, 2021). Although encompassing all disorders that impact the blood vessels or heart, the overall burden is primarily generated by the acute events of heart attack or stroke (WHO, 2021). Of the deaths associated with CVD, approximately 85% were attributable to heart attack or stroke (WHO, 2021).

The primary cause of these medical emergencies is the inability of blood to flow to the brain or heart (WHO, 2021). This blockage is due to increased levels of fatty deposits on the inner walls of blood vessels (WHO, 2021). This restriction of blood flow may double the likelihood of a cardiovascular event, such as a heart attack (Gruzdeva, 2018). The formation of plaque may also damage heart muscles due to a lack of oxygen (Lu et al., 2015). This increases the likelihood of cardiovascular disease, such as heart failure (Lu et al., 2015).

Interconnectivity of risk factors

Health is influenced by a myriad of factors. In the framework of cardiovascular disease (CVD), behavioral risk factors are the most important and easily modified (WHO, 2021; Berry et al., 2012). There exists ample evidence linking unhealthy behaviors, such as an unhealthy diet,

physical inactivity, tobacco use, and excessive alcohol use, to an increased propensity for a cardiovascular event (WHO, 2021; Berry et al., 2012). The difference is most pronounced amongst individuals who smoke (Yusuf et al., 2004). The odds of developing cardiovascular disease were 2.87 times higher among individuals who smoke compared to non-smoking individuals (Yusuf et al., 2004). Adherence to other healthy behaviors have been shown to decrease risk of cardiovascular disease (Yusuf et al., 2014; Zhang et al., 2020). The odds ratio for the daily consumption of fruits and vegetables and regular physical activity were 0.7 or 0.86 respectively (Yusuf et al., 2004).

Although not strictly a behavioral risk factor, other factors positively correlated with increased risk include diabetes and elevated levels of cholesterol and blood pressure (Berry et al., 2012). The odds of developing cardiovascular disease were 3.25 times higher among individuals within the top quintile for cholesterol level compared to the lowest quintile (Yusuf et al., 2004). The odds ratio falls to 2.37 and 1.91 for diabetes and hypertension respectively (Yusuf et al., 2004). An improved understanding of risk factors allows for the development of robust policies and focused intervention programs to reduce the likelihood of cardiovascular disease.

The targeting of health policies and interventions on identified risk factors have proven to be effective in decreasing cardiovascular disease incidence rates. Providing a conducive environment allows for the adoption and maintenance of a healthy lifestyle. Observed in multiple studies, the cessation of tobacco usage, reduction of salt intake, increase in physical activity, increased consumption of fruits and vegetables, and avoidance of excessive alcohol consumption have been proven to decrease the possibility of a cardiovascular event (WHO, 2021). The odds of an individual regularly engaging in physical activity developing a cardiovascular disease is 0.86 times that of an individual with no physical activity (Yusuf et al., 2004). This figure

decreases with dietary changes. The odds of an individual with daily consumption of fruits and vegetables are 0.7 times that of an individual with no incorporation of fruits and vegetables (Yusuf et al., 2004). Lifestyle changes allow for the minimal amount of invasiveness in an individual's physical body and maximize the potential future upkeep.

The benefits provided in a lifestyle change will only be realized through proper implementation of the proposed interventions. This poses a challenge as the unequal distribution of burden on low and middle-income individuals introduces a socioeconomic risk element (WHO, 2021; Worrall-Carter, Edward & Page, 2012; Karan, Engelgau & Mahal, 2014). Cardiovascular disease disproportionately affects individuals with lower socioeconomic status (WHO, 2021). An estimated three-quarters of global occurrences happen in low and middle-income countries (WHO, 2021). Already disadvantaged from a socioeconomic viewpoint, individuals with fewer means are unable to sufficiently detect, prevent, and treat cardiovascular heart disease. For example, a lower purchasing power limits dietary change (Psaltopoulou et al., 2017; Worrall-Carter, Edward & Page, 2012). The decreased options lead to consumption of items with high saturated fat, sweets, and sweetened beverages, increasing the risk of a CVD event (Psaltopoulou et al., 2017). Cost conscious individuals are unable to disregard perceived costs of food items, such as fruits and vegetables (Psaltopoulou et al., 2017). The average monetary difference between a healthy and unhealthy diet is 600 British pounds (Psaltopoulou et al., 2017). Furthermore, increasing socioeconomic status is correlated with increased physical activity (Psaltopoulou et al., 2017). Individuals with lower socioeconomic status are less likely to exercise (Psaltopoulou et al., 2017). The inability to access healthy foods compounded with the lack of physical exercise result in increased levels of hypertension and obesity causing

individuals and communities with a lower socioeconomic status to more deeply be impacted by cardiovascular heart disease (Psaltopoulou et al., 2017).

The observed differences in socioeconomic status are further exacerbated by gender related disadvantages (Worrall-Carter, Edward & Page, 2012; O'Neil, Scovelle, Milner & Kavanagh, 2018). Compared to men, females are undertreated and have worse health outcomes (Woodward, 2019; Worrall-Carter, Edward & Page, 2012). This issue is due to three main factors. First, manifestation of inherent bias in society has conditioned a difference of perception on cardiovascular diseases between males and females (Woodward, 2019). Women are less familiar with potential risk factors than men (Woodward, 2019). This incognizance creates a misconception of risk. Of women at an increased risk, approximately 62% perceived personal risk to be low or mild (Woodward, 2019). Of the surveyed women, only 38% correctly understood their risk level (Woodward, 2019). Unfortunately, this understanding translates over to the professional setting. Medical practitioners are liable to incorrectly perceiving cardiovascular disease as a male problem (Woodward, 2019). This oversight results in a difference of 12% between the odds of being screened for cardiovascular health disease as a woman when compared to a man (Woodward, 2019; Worrall-Carter, Edward & Page, 2012; O'Neil et al., 2018). The failure to screen for CVD is exacerbated by the failure to detect heart attacks and the inadequacy of treatment provided to women (Woodward, 2019; Worrall-Carter, Edward & Page, 2012; O'Neil et al., 2018). Second, biological differences between males and females create risk factors unique to women. Women have a greater cardiovascular risk from diabetes (Woodward, 2019). Being diabetic confers an additional 44% risk to women compared to men (Woodward, 2019). In addition, the female reproductive cycle creates more vulnerabilities for women (Woodward, 2019). An adverse pregnancy would increase the

likelihood of a cardiovascular event (Woodward, 2019). As previously mentioned, women with diabetes are at an increased risk of experiencing a cardiovascular disease in the future (Woodward, 2019). This translates to a hazard ratio of 1.43 amongst individuals with gestational diabetes (Woodward, 2019). The relative risks are 2.33, 2.03, and 2.29 for individuals developing pre-eclampsia for cardiovascular heart disease, stroke, and cardiovascular mortality respectively (Woodward, 2019). Third, there exists a psychological component to cardiovascular disease (O'Neil et al., 2018; Xia & Li, 2018). A previous meta-analysis found a large effect size for cardiovascular disease attributable to sexual and physical abuse an individual suffered during childhood (O'Neil et al., 2018). This mirrors the understanding that intimate partner violence during late adolescence and early adulthood increases the risk of cardiovascular disease over the next 7 to 14 years (O'Neil et al., 2018). Such psychological stressors may disproportionately impact women. An example of the increased propensity is shown in differences between genders when coping with loneliness. Hazard models developed to understand the relationship between loneliness and incidence of cardiovascular disease failed to show a significant association for men (Thurston & Kubzansky, 2009). However, among women, high levels of loneliness were associated with an increased incidence of cardiovascular disease (Thurston & Kubzansky, 2009).

Impact of urbanization

The global impact of cardiovascular disease on health outcomes is not expected to abate in the foreseeable future. Advancements in medical treatment and pharmaceutical drugs have reduced the mortality rate of coronary heart disease in the United States and Europe since the mid-1990's (Bansilal, Castellano & Fuster, 2015; Pearson-Stuttard et al., 2016). This trend is expected to continue with mortality rates decreasing by approximately 27% by 2030 (Pearson-

Stuttard et al., 2016). However, this outlook on cardiovascular disease is not replicated in other countries. Instead, the burden is projected to increase in low and middle-income countries (WHO, 2021; Moran et al., 2010; Karan, Engelgau & Mahal, 2014; Reddy & Yusuf, 1998).

As individuals in developing countries experience the benefits attributed to the establishment of market economies, the increasing life expectancy poses new challenges to health (Reddy & Yusuf, 1998; Weiss et al., 2020). This longevity creates a longer stage of exposure to risk factors associated with cardiovascular disease (Reddy & Yusuf, 1998). The increased lifespan would be inconsequential on cardiovascular disease rates if appropriate lifestyle changes were implemented. However, further impacting the increased likelihood of cardiovascular disease is the adverse environmental and lifestyle changes that accompany urbanization and industrialization (Reddy & Yusuf, 1998; Li et al., 2016; Eckert & Kohler, 014). In China, urbanization increases incidence rates of coronary heart disease by 13-16% and stroke by 17% (Chan et al., 2012). Seemingly small, this translates to an increased incidence rate of 164.4 to 244.9 per 100,000 and 790.1 to 830.9 per 100,000 for coronary heart disease and stroke respectively (Chan et al., 2012). While urbanization creates unique opportunities, it is imperative to address challenges to health alongside economic growth (Vlahov & Galea, 2002).

Community intervention

Community intervention programs can result in positive outcomes with participants experiencing a reduction in cardiovascular disease risk (Winkleby, Feldman & Murray, 1997; Tan et al., 2019; Chiazor et al., 2015). These interventions may provide favorable returns, as in the case of medical adherence where the averted healthcare costs exceeded the cost of implementation (Jacob et al., 2022). However, community interventions are difficult to evaluate

and implement (Kraemer & Winkleby, 1997, Chiazor et al., 2015). Although results generally indicate a decrease in risk factors, the program retention rates are inconsistent. Lifestyle targets are only achieved by 34% of men and 32% of women (Woodward, 2019). This figure decreases when quantifying effectiveness (Woodward, 2019). The treatment targets for blood pressure control are only reached by 8% of men and 6% of women (Woodward, 2019). These low figures are concerning as effective interventions are expected to attain a 70% retention rate (Amico, 2009). Although community intervention programs may assist in decreasing risk factors for cardiovascular disease there exists a need to improve the program design and implementation to achieve widespread success.

Urban Health Index

Following the Human Development Index (HDI), the methodology for creating an Urban Health Index (UHI) for health determinants allows for flexibility in selecting and presenting public health data (Weaver et al., 2014). Previous studies suggest the utilization of a UHI approach may allow stakeholders to plan more effective community intervention programs and develop effective health policies (Dai et al., 2017; Rothenberg et al., 2014; De Lima, Kruger & Tennant, 2022). This increased effectiveness is due to two factors. First, the UHI allows for the selection of the scale of interest (Weaver et al., 2014). The geographical unit of measure may range from small area estimates to global comparisons (Weaver et al., 2014). Data permitting, it is possible to create UHI scores observing census level health disparities (Dai et al., 2017; Rothenberg et al., 2014; De Lima, Kruger & Tennant, 2022). The ability to select a specific geographic unit allows for a greater understanding of health indicators and determinants in communities within a geographic location of interest (Dai et al., 2017; Rothenberg et al., 2014). Furthermore, the inclusion of a temporal aspect allows for a comparison between current and

previous health trends (Dai et al., 2017). Incorporating both a spatial and temporal aspect to the visualization allows for a deeper understanding for stakeholders when planning the program (Dai et al., 2017). Second, the flexibility of UHI may allow for utility in a variety of situations (Weaver et al., 2014). Researchers utilizing the UHI approach may select a narrow or broad range of indicators (Weaver et al., 2014). This may create a composite score influenced by a single domain of interest or a broad range of domains (Weaver et al., 2014). Curating the UHI for specific needs is a viable option to guide health policy and intervention program development.

Methods

Geographic Area of Interest

The selected area of interest for this study is the Central Savannah River Area (CSRA). Comprised of 21 counties, 13 within Georgia and 8 within South Carolina, all measures were obtained at the county level. The 13 counties within Georgia are Burke, Columbia, Glascock, Hancock, Jefferson, Jenkins, Lincoln, McDuffie, Richmond, Screven, Taliaferro, Warren, Washington, and Wilkes. The 8 counties within South Carolina are Aiken, Allendale, Bamberg, Edgefield, McCormick, and Saluda. Figure 13 details the location of these counties within their respective states.

Data source for health indicators

For this study, four indicators based on the 2000 Decennial Census Summary File 3 (SF3) and the 2010-2015 American Community Survey (ACS) were utilized. As the US Census Bureau archived all ACS data for the years 2000, 2001, 2002, 2003, and 2004 in 2008, data from the SF3 was used to surrogate the 2000 and 2005 social determinants. These four indicators are the proportion of non-female head of households, proportion of employed, proportion that are above the poverty line, and proportion of individuals with an educational attainment at the Bachelor’s degree or higher. The inverse proportion of female head of household and unemployment were obtained to orient the variables in the same direction as the other selected variables of interest. This was to create a positive association between the four variables and improved health outcomes. These indicators were selected as they reflect social stress and socioeconomic depravation in the community setting (Lemstra, Rogers & Moraros, 2015; Davari, Maracy & Khorasani, 2019; Thurston & Kubzansky, 2009). The increase in

socioeconomic status is likely to decrease the cumulative cardiovascular disease mortality rate (Davari, Maracy & Khorasani, 2019). 1-year estimates were obtained for the year 2000 from SF3. 1-year estimates for 2010 and 5-year estimates for 2010 and 2015 were obtained from the ACS.

Data source for cardiovascular disease mortality rate

The mortality data utilized in this study were obtained from the CDC's Wide-ranging ONline Date for Epidemiologic Research (WONDER) database. All categories of data were selected: all levels of urbanization, race, age, gender, as well as place and time of death. The final datasets were divided in 5-year timeframes: 2000-2004, 2005-2009, 2010-2014, and 2015-2019 and 10-year timeframes: 2000-2009 and 2010-2019. The database provided age-adjusted cardiovascular disease mortality rates per 100,000. These rates were calculated utilizing a direct method, where the age-specific death rate is applied to the U.S. standard population age distribution. The age-adjusted mortality rates are shown by timeframe in Table 4.

Methodology for the evaluation of health disparities

Calculation of the Urban Health Index of health determinants

The methodology for the calculation consisted of a two-part process. First, the indicators of interest were standardized (Weaver et al., 2014). Converting the indicators to a proportion of the respective range allows for the normalization of the metrics and scales of the indicators (Weaver et al., 2014). Second, the geometric mean of the standardized indicators was calculated. This allows for a composite score detailing the level of health disparities at a geographic unit of interest (Weaver et al., 2014).

Using four indicators and six timeframes, a total of six Urban Health Indexes (UHI) scores were generated at the county-tract level using the World Health Organization Urban Health Index Calculation tool. All indicators were adjusted to ensure that variables were oriented in the same direction. SF3 was utilized to create a UHI score for the timeframes: 2000-2004, 2005-2009, and 2000-2009. ACS was utilized to create a UHI score for the timeframes: 2005-2009, 2010-2019, and 2005-2019. Table 5 details the UHI score for each county by rank in their respective timeframes of interest.

Correlation calculation

The statistical software SAS was utilized to construct a Pearson correlation matrix to observe the association between cardiovascular disease mortality rates and calculated Urban Health Index scores for each county during the various time periods.

Assessing disparities

The counties of the CSRA were ordered according to the corresponding UHI rank. The UHI ranks were then plotted against the UHI scores to create an index plot. This allowed for a visualization of the two methods for assessing disparity. First, a disparity ratio was calculated. The disparity ratio is the ratio of the mean of the 10^{th} percentile to the mean of the 90^{th} percentile. Second, the slope of the eight middle deciles were calculated. This allows for an understanding of the disparity between the best and worst county in the CSRA.

Creating a visualization

ArcGIS (ArcMap 10.7.1, Redlands, California) was utilized to display the UHI outcomes with a gradient color scheme and mortality rates with graduated symbols. Each UHI and mortality rate were attributed to the corresponding county. This created a visualization of the dispersion in the CSRA. The county shapefiles were obtained from the US Census Bureau.

Results

Assessing the mortality rate

The average mortality rate for cardiovascular disease within the CSRA was observed to decrease from 2000-2019 (Table 2). The mean mortality rate decreased from 364.55 per 100,000 in 2000-2009 to 281.79 per 100,000 in 2010-2019 (Table 2). This trend remained constant even when the timeframe was divided in 5-year increments. The average mortality rate was reduced from a high of 397.78 in 2000-2004 to a low of 274.40 in 2015-2019 (Table 2).

Overall, county specific mortality rates for both the 5-year and 10-year increments follow the decreasing trend exhibited in the average calculations. However, instances exist within the 5-year periods that suggest this decline observed in the overall trend may not be as ubiquitous. CVD mortality rates increased in Warren County, Georgia and Allendale County, South Carolina from 352.2 and 416.1 in 2000-2004 to 355.2 and 436 in 2005-2009 respectively (Table 4). The mortality rates experience a subsequent decrease, consistent across 2010-2014 and 2015-2019 (Table 4). The observed decrease in Warren and Allendale in 2010-2014 and 2015-2019 is contrasted by an increase in mortality rate observed in eight counties: Glascock, Hancock, Jefferson, McDuffie, Richmond, and Wilkes in Georgia and Bamberg and McCormick in South Carolina (Table 4).

Assessing the Urban Health Index Distribution

The distribution of county-level Urban Health Index (UHI) values ordered by rank resembles a sigmoid growth curve. The removal of the tails on both ends suggests a linear relationship between rank and score (Figures 1, 3, 5, 7, 9, and 11). An analysis of the calculated disparity ratios shows a low of 10.505, during 2010-2019 and a high of 16.309, between 2000-

2009 (Table 1). This indicated a decrease in disparity over time. This trend is mirrored by an increase in the average UHI score. The mean score of 2010-2019 was 0.419, an increase from 0.382 during 2000-2009 (Table 1). Further investigation of the slope reveals an estimate of the extent of heterogeneity (Weaver et al., 2014). A moderate slope of 0.348 was observed for 2010-2014 (Table 1). However, the disparity slopes for all other timeframes suggest high levels of heterogeneity of risk. Unlike the disparity ratios, the slope increases from 0.348 in 2010-2014 to 0.451 2015-2019 (Table 1; Figures 5 and 7). This trend is mirrored in the 10-year increment period of 2000-2009 and 2010-2019 as the slope increased from 0.487 to 0.516 (Table 1; Figures 9 and 11). The contrast between disparity ratio and slope suggests a decrease in inequality among the outer quantiles, but an increase among counties in the middle ranges.

The decrease in disparity observed during the 10-year increments is not replicated when analyzing the timeframe with 5-year increments. While there is a decrease in disparity during 2010-2014 when compared to 2000-2004 and 2005-2009, the trend is reversed in 2015-2019 (Table 1). The disparity ratio increased from 13.293 in 2010-2014 to 15.563 in 2015-2019 (Table 1). While not to levels observed in 2000-2004 and 2005-2009, the increase signifies potential changes within the CSRA unaccounted for in the study.

During the 5-year timeframes of 2000-2004 and 2005-2009 and the 10-year period of 2000-2009, Glascock County and Columbia County ranked last and first respectively. Columbia County maintained the highest UHI rank during the 5-year timeframes of 2010-2014 and 2015-2019, as well as, the 10-year period of 2010-2019. Conversely, Allendale County ranked last during the same periods, replacing Glascock County (Table 1).

Correlation between Urban Health Index and Mortality Rate

The calculated Pearson correlation coefficients demonstrated a significant correlation during all timeframes between the calculated Urban Health Indexes (UHI) and cardiovascular disease mortality rates. This establishes an association between the UHI scores and mortality rates. The Pearson correlation coefficients ranged from 0.54 (2000-2004) to 0.81 (2015-2019) (Table 3). The strongest measure of linear trend between the two variables occurred for 2015-2019. All correlations are statistically significant with a p-value of 0.05.

The indicators of interest utilized in the UHI calculations were hypothesized to be inversely related with cardiovascular disease mortality rate. This assumption was affirmed during the correlation calculations. All Pearson correlation coefficients were negative. This inverse association between the UHI and morality rate was replicated on the geographic visuals. Lower mortality rates were overlayed on counties with higher UHI scores.

The correlation between mortality rate and UHI score decreased when utilizing 10-year increments. The correlation for 2000-2009 was 0.74 but decreased to 0.68 for 2010-2019. Conversely, overall, the correlations increased when calculations are based on a 5-year timeframe.

Discussion

Feasibility of Geographic Visualizations with County Level Data

Cartographic visualization is an important tool in public health as it may assist in policy and program development. The entire subject of public health developed as a result of mapping the geographic spread of a disease to understand a cholera outbreak (Jeffery, Ozonoff & Pagano, 2014). Over time, the increased availability of spatial data allowed for the development of various methods of visualization (Jeffery, Ozonoff & Pagano, 2014). Health determinants are monitored within census tracts or compared between nations (Gupta et al., 2003; Nagasako et al., 2018). Regardless of scale, all levels of visualization provide insight and allow for the planning of strategies, whether through policy, intervention program, or health care, to improve health (Jonnalagadda et al., 2022; Pricope et al., 2019; Hamilton et al., 2021).

In this study, county level estimates were utilized to calculate an Urban Health Index (UHI) for health determinants and age-adjusted cardiovascular disease mortality rates within the Central Savannah River Area (CSRA). Unlike previous studies where the UHI approach was conducted for census tract level administrative regions, county level estimates were utilized (Dai et al., 2017; de Lima, Kruger & Tennant, 2022; Rothenberg et al., 2014). Census data allows for the development of detailed statistics within a small region (Gupta et al., 2003). In contrast, county level data may not be as sensitive as the census data (Hamilton et al., 2021). This uniformity may affect the observed differences and hide the true scale of health disparities within the CSRA (Hamilton et al., 2021). However, this does not impact the potential for visualizations on a county scale to direct policy and program creation (Hamilton et al., 2021; Cahill, Kutac & Rider, 2021; Yi et al., 2008). This study highlights the feasibility of county level visualizations to guide policy and health care. The instances where CVD mortality rates or UHI scores for health

determinants increase following a period of reduction suggest a need to reevaluate or reexamine existing policies and intervention programs for effectiveness. Furthermore, understanding the public health situation on a macro level may allow for the allocation of time and resource to areas of the greatest need. Visualizing public health data on a count level is a feasible and valuable method.

Limitations

The temporal aspect of the study is subject to limitations. Despite best efforts, survey availability proved challenging to overcome. The observed differences during the 5-year and 10-year periods may not be reflective of the true population experience. This is due to the issues in obtaining county level data for the selected timeframe. Data from 2001 to 2009 is not available on the US Census Bureau database. Instead, 1-year estimate data from 2000 from the US Decennial Census was utilized to calculate the UHI scores for 2000-2004 and 2005-2009. The repeated sampling of health determinants resulted in the same UHI composite scores. This decreases the value of a comparison between 2000 to 2019 binned in 5-year estimates. This inability to accurately observe health disparities within the CSRA from 2005-2009 may impact the development of effective health policies and intervention programs. In addition, observed rates of health disparities may been influenced by outside factors, such as the 2008 recession and COVID-19 pandemic. These elements occurred during the timeframe of interest, 2000-2019, and may provide a rationale for observed increases of health disparities within the CSRA.

Even when information on the indicators of interest is readily available, there exists reliability issues with the data source, the American Community Survey (ACS). The inclusion of information from the ACS may complicates any attempts to obtain coherent results. Previous

studies have established the existence of large margins of error within the small area estimates obtained from the ACS (Spielman, Folch & Nagle, 2014; Dai et al., 2017; Spielman & Folch, 2015). Differences between estimates obtained from the ACS and the US population may be heightened among the minority community (Siorda & Le, 2013). Results of any analysis based on estimates obtained from the ACS may be less reliable (Folch et al., 2016). Further validation of comparisons within the UHI may be necessary to understand disparity within the CSRA. However, this would require the availability of a reliable source of data for indicators at the county level.

Furthermore, the study did not account for demographic change due to the displacement and migration within the CSRA. Although population levels are projected to increase with the Georgia area, South Carolina faces a reduction in population (Georgia Department of Community Affairs, 2012; South Carolina Revenue and Fiscal Affairs Office, 2019). The change in demographics may influence the observed composite scores for the UHI of health determinants and CVD mortality rate.

Conclusion

Using a 10-year period during the timeframe 2000-2019, this study revealed that the CSRA has experienced an improvement in the overall risk factors of cardiovascular disease, evidenced by the narrowing disparity ratio and increasing mean UHI score of health determinants. This improvement does not signify a permanent trend. When a 5-year time period is utilized, the UHI disparity ratio increased from 13.293 in 2010-2014 to 15.563 in 2015-2019. While still a decrease compared to the earlier increments of 2000-2004 and 2005-2009, the rise signifies a potential external factor uncontrolled for in the scope of this study.

Contrasting the rebound of health disparities, the mean rate of cardiovascular disease was constantly decreasing during the timeframe. This proved true when observed with 5-year and 10-year increments. The reduction in mortality rate but increase in disparity may require further examination. It would be worthwhile to examine the deterioration of previously improving areas to identify persistent and new challenges to the reduction of health disparities. Stakeholders involved in the development of community intervention programs may be interested in understanding external factors unaccounted for in this study.

This study provides a visual representation that incorporates a temporal aspect of disparities in risk factors of cardiovascular disease in the CSRA. This may be beneficial to policymakers and stakeholders interested in addressing cardiovascular disease. The ability to locate differences between counties may guide public health workers develop policies and community intervention programs aimed to address cardiovascular disease. Furthermore, the incorporation of multiyear measures of mortality rate and health determinants allows for the improvement of existing programs.

Table 1: UHI Summary Statistics by Period

Urban Health Index Score Statistics by Period

	2000-2004	2005-2009	2010-2014	2015-2019	2000-2009	2010-2019
Mean	0.382	0.382	0.438	0.371	0.382	0.419
Standard Deviation	0.227	0.227	0.207	0.221	0.227	0.233
Minimum	0.047	0.047	0.008	0.022	0.047	0.064
10th Percentile	0.069	0.069	0.163	0.160	0.069	0.143
Median	0.369	0.369	0.429	0.352	0.369	0.450
90th percentile	0.586	0.586	0.590	0.649	0.586	0.636
Maximum	0.986	0.986	0.997	0.971	0.986	1.000
Selected Proportion (Extreme Areas)	0.200	0.200	0.200	0.200	0.200	0.200
10th percentile	0.069	0.069	0.163	0.160	0.069	0.143
90th percentile	0.586	0.586	0.590	0.649	0.586	0.636
Mean UHI for bottom extreme group	0.052	0.052	0.064	0.053	0.052	0.084
Mean UHI for top extreme group	0.841	0.841	0.852	0.830	0.841	0.881
UHI Health Disparities Ratio	16.309	16.309	13.293	15.563	16.309	10.505
UHI Health Disparities Difference	0.790	0.790	0.788	0.776	0.790	0.797
Slope	0.487	0.487	0.348	0.451	0.487	0.516

Table 2: Cardiovascular Disease Mean Mortality Rate

Mean Cardiovascular Disease Mortality Rate by Period	
Year	Rate (per 100,000)
2000-2004	397.87
2005-2009	334.02
2010-2014	289.63
2015-2019	275.4
2000-2009	364.55
2010-2019	281.79

Table 3: Pearson Correlation Coefficient Matrix by Periods

	Cardiovascular Disease Mortality Rate by Time Period					
UHI Score by Time Period	2000-2004	2005-2009	2010-2014	2015-2019	2000-2009	2010-2019
2000-2004 Prob > |r| under H0; Rho=0	-0.54378 0.0108					
2005-2009 Prob > |r| under H0; Rho=0		-0.77982 <0.0001				
2010-2014 Prob > |r| under H0; Rho=0			-0.72346 0.0002			
2015-2019 Prob > |r| under H0; Rho=0				-0.80758 <0.0001		
2000-2009 Prob > |r| under H0; Rho=0					-0.74026 0.0001	
2010-2019 Prob > |r| under H0; Rho=0						-0.68199 0.0007

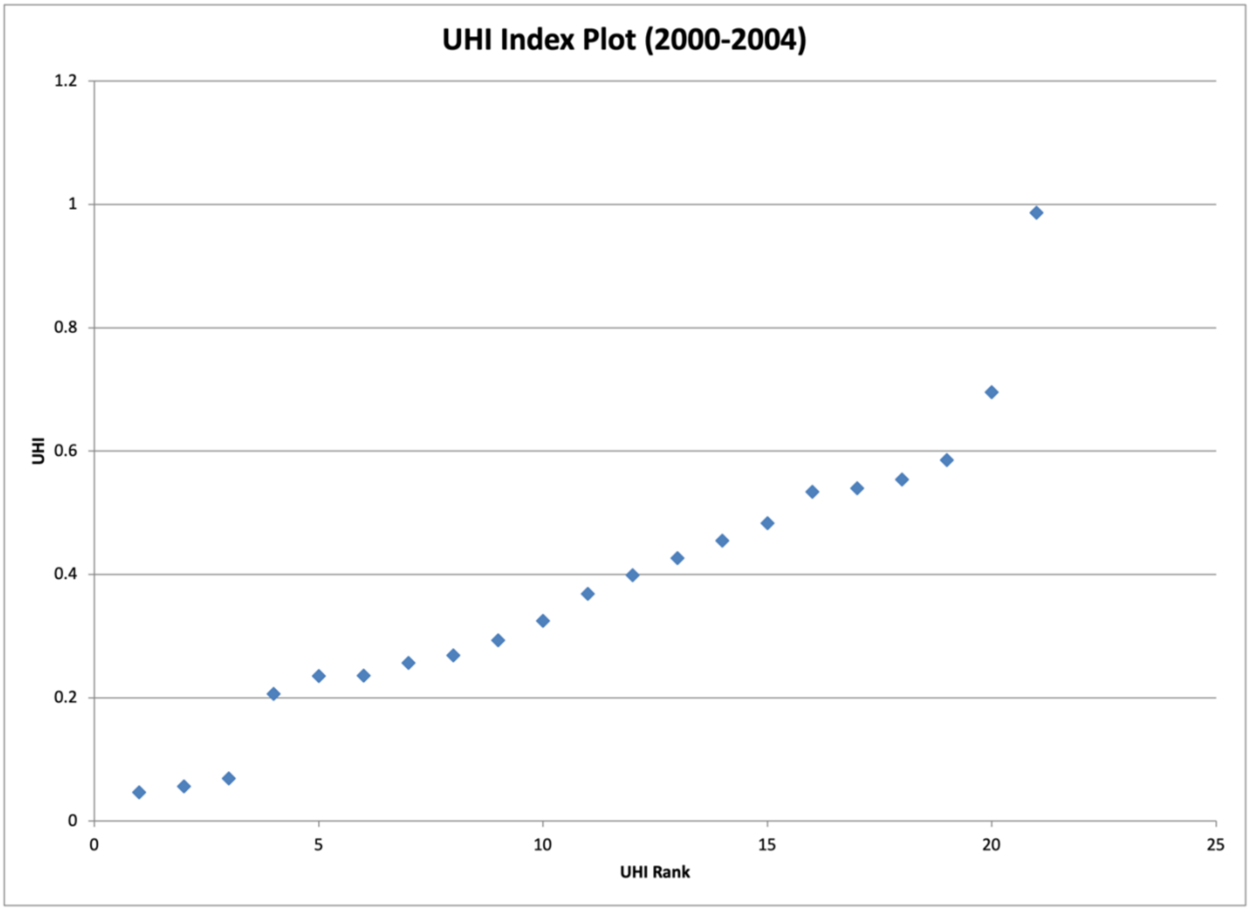

Figure 1: UHI Index Plot for 2000-2004

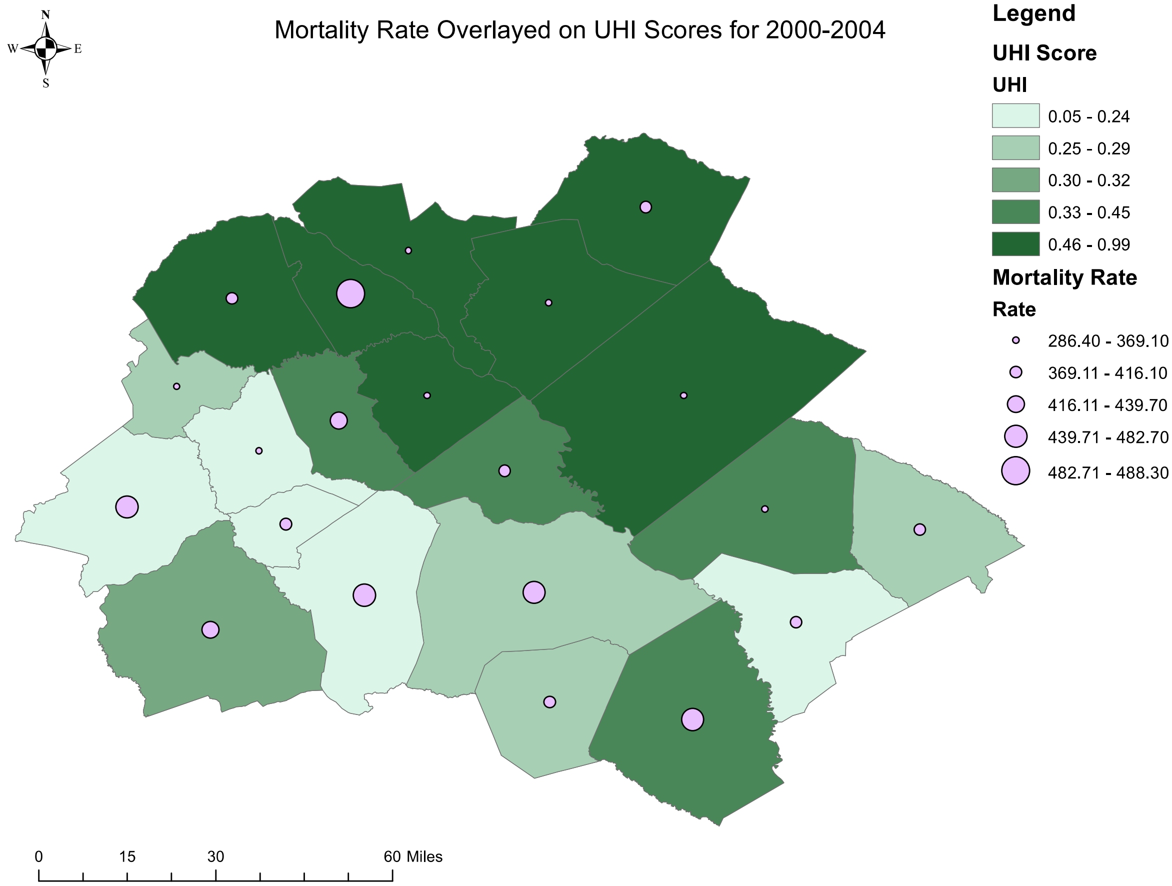

Figure 2: CSRA Map 2000-2004 Utilizing Quantiles for UHI and Mortality Rate

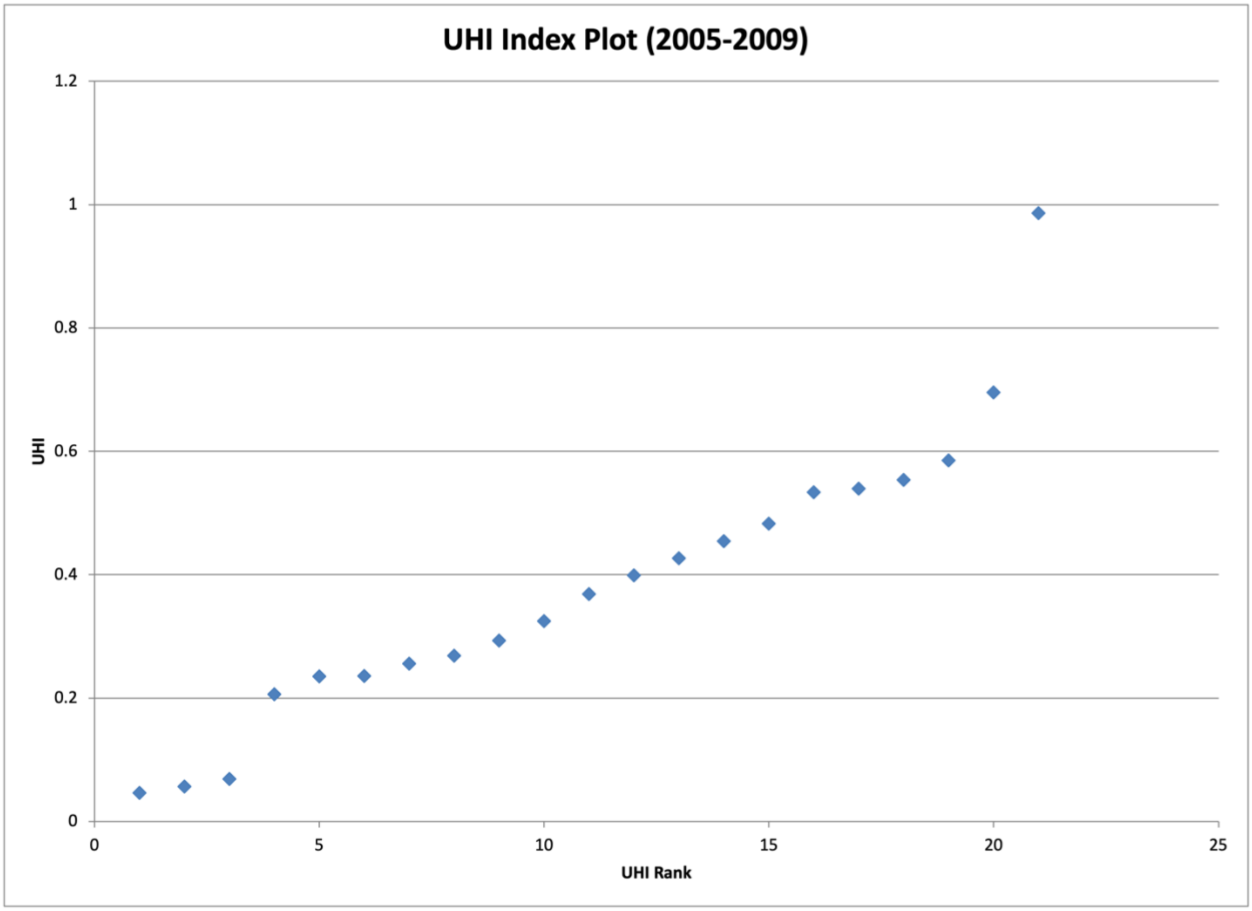

Figure 3: UHI Index Plot for 2005-2009

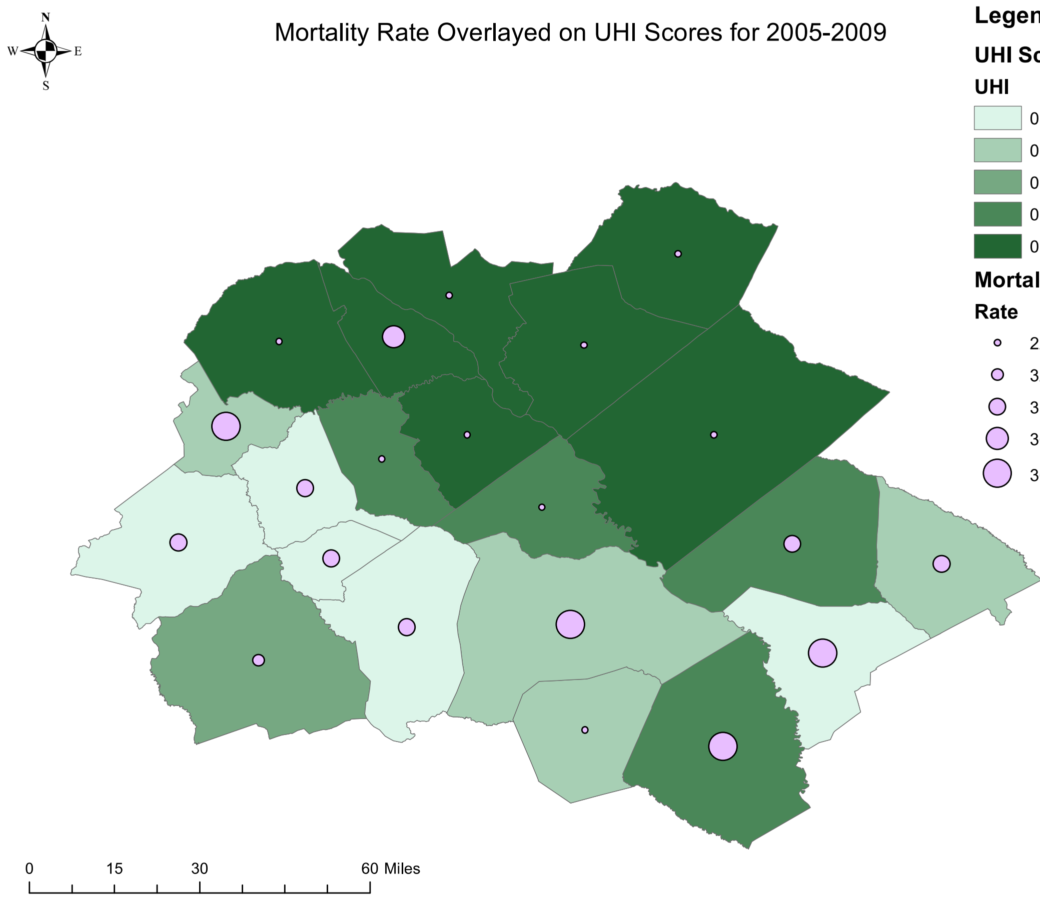

Figure 4: CSRA Map 2005-2009 Utilizing Quantiles for UHI and Mortality Rate

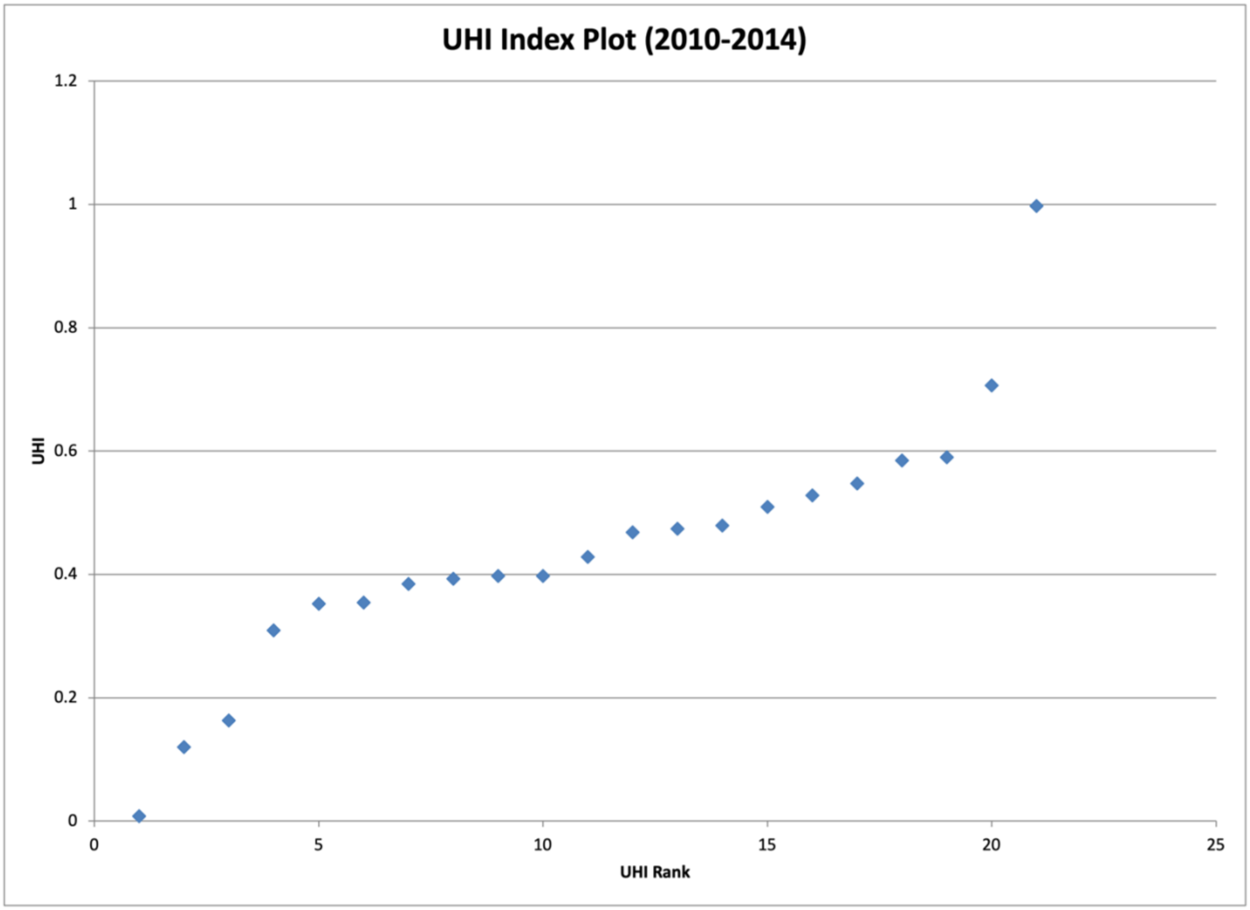

Figure 5: UHI Index Plot for 2010-2014

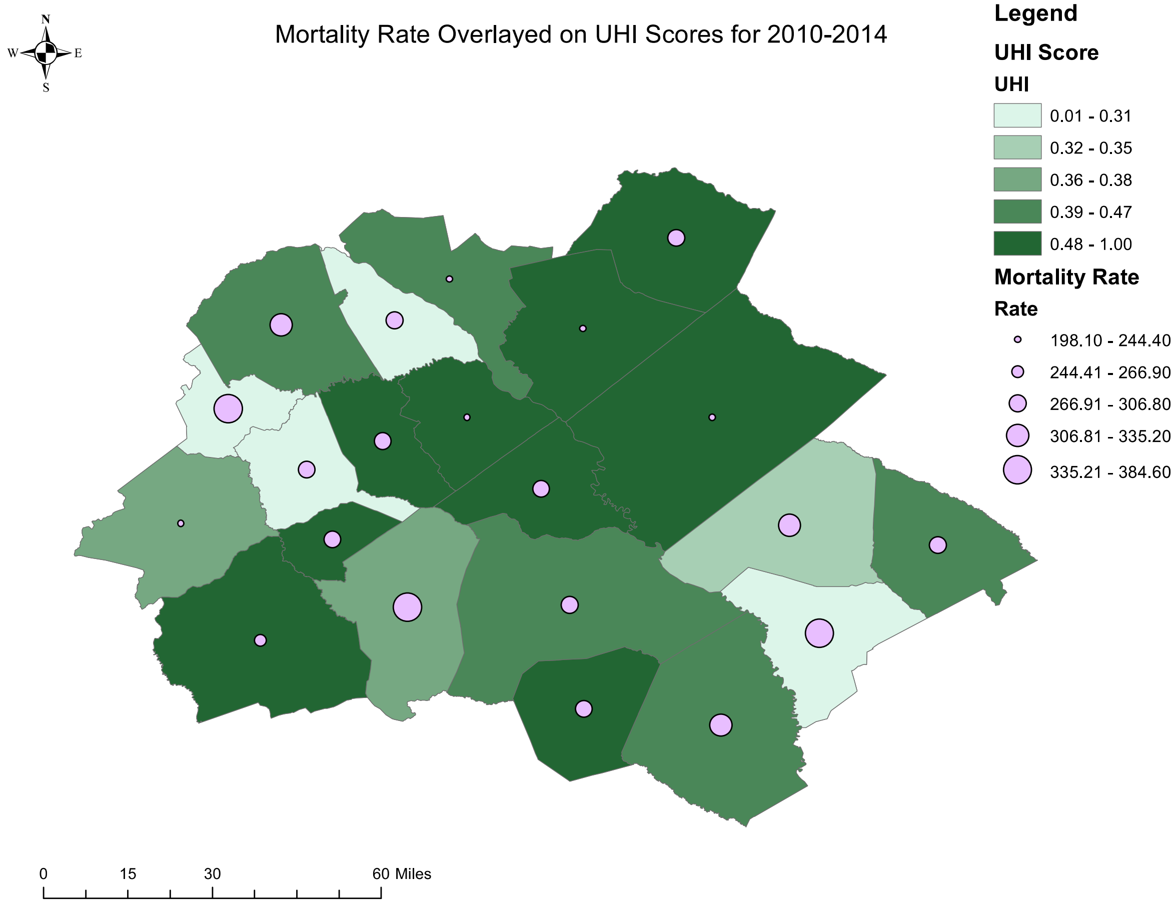

Figure 6: CSRA Map 2010-2014 Utilizing Quantiles for UHI and Mortality Rate

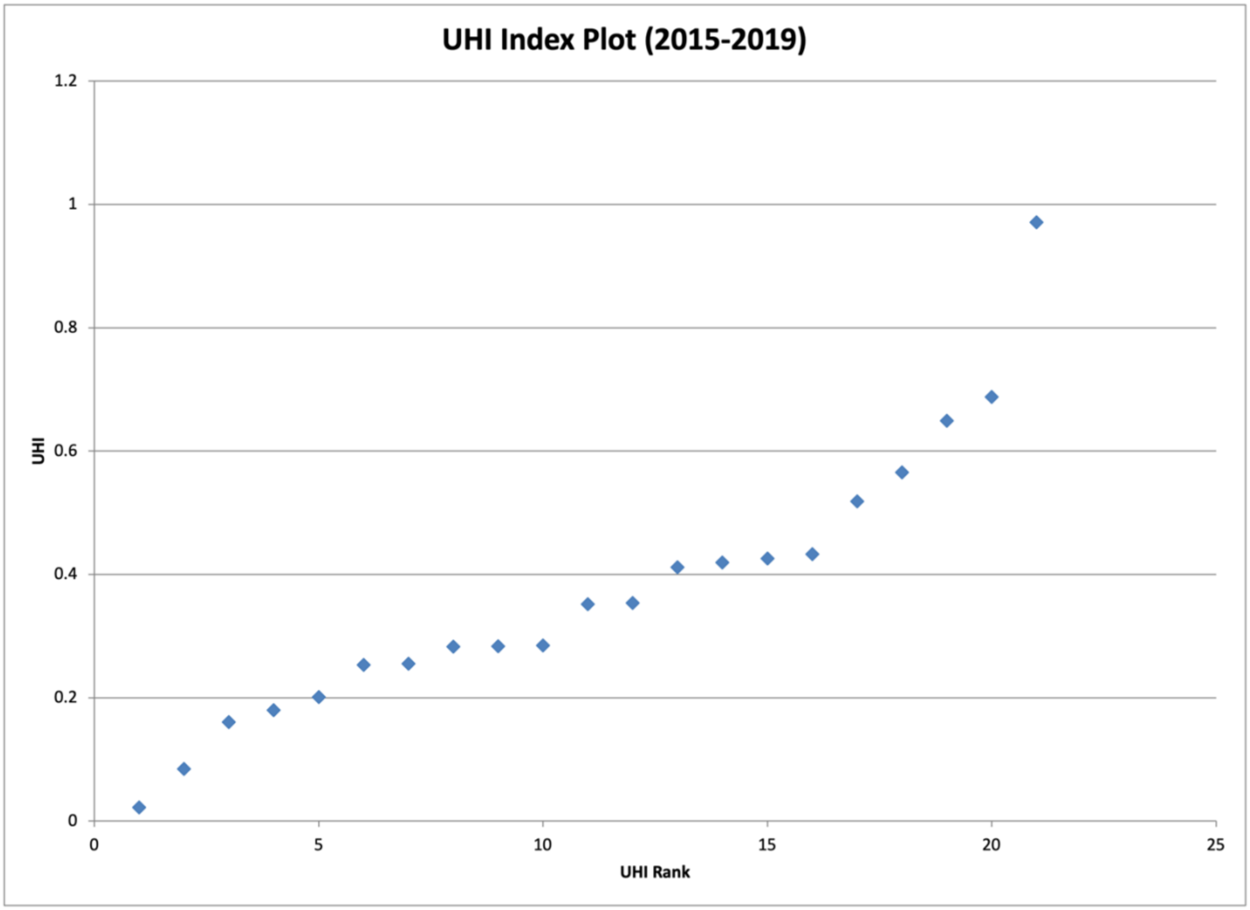

Figure 7: UHI Index Plot for 2015-2019

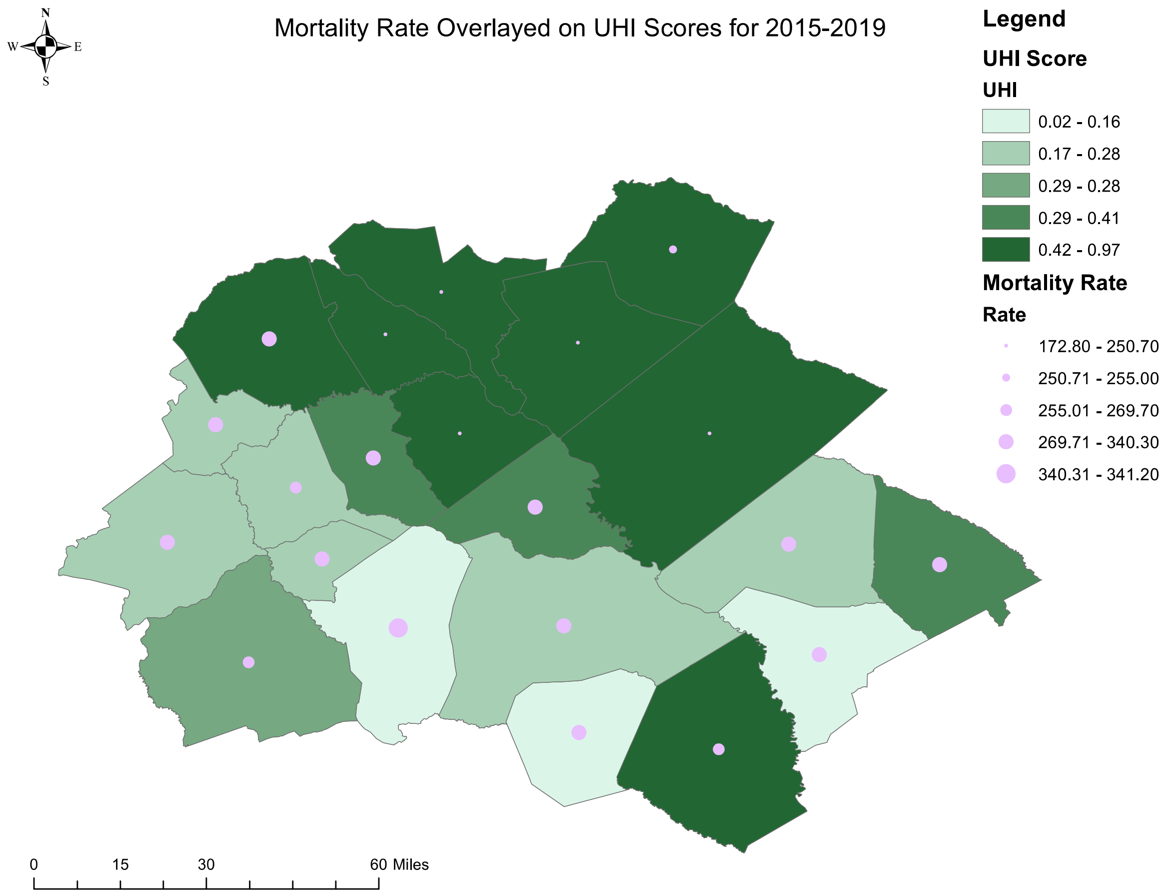

Figure 8: CSRA Map 2015-2019 Utilizing Quantiles for UHI and Mortality Rate

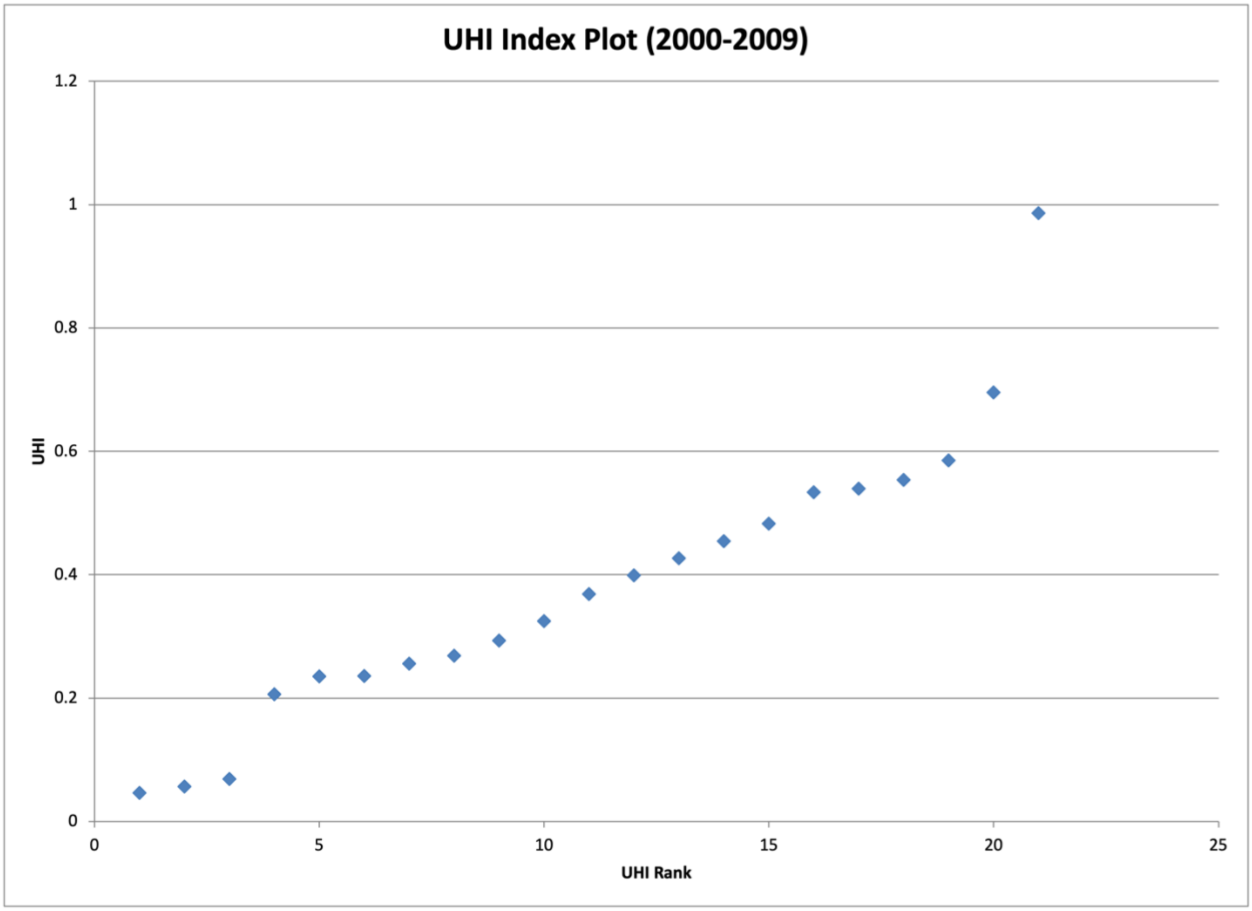

Figure 9: UHI Index Plot for 2000-2009

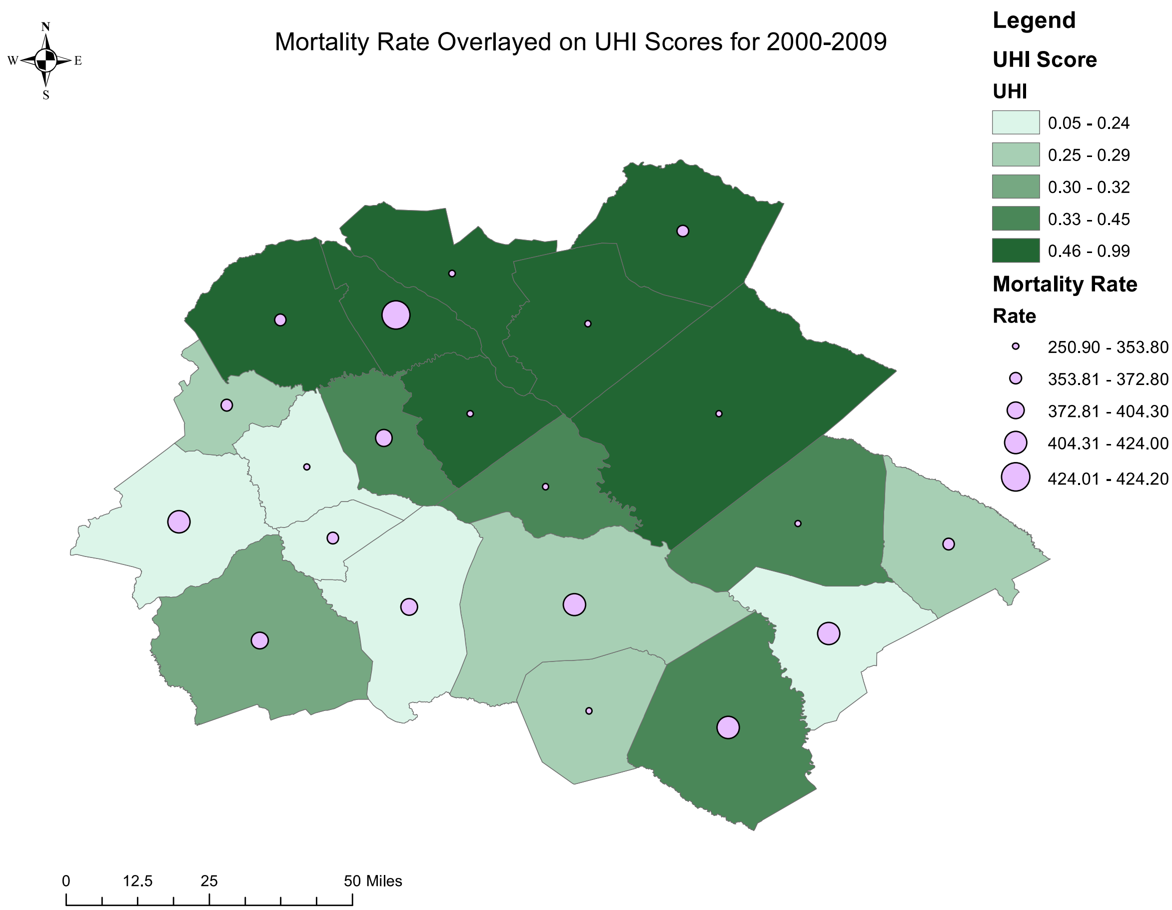

Figure 10: CSRA Map 2000-2009 Utilizing Quantiles for UHI and Mortality Rate

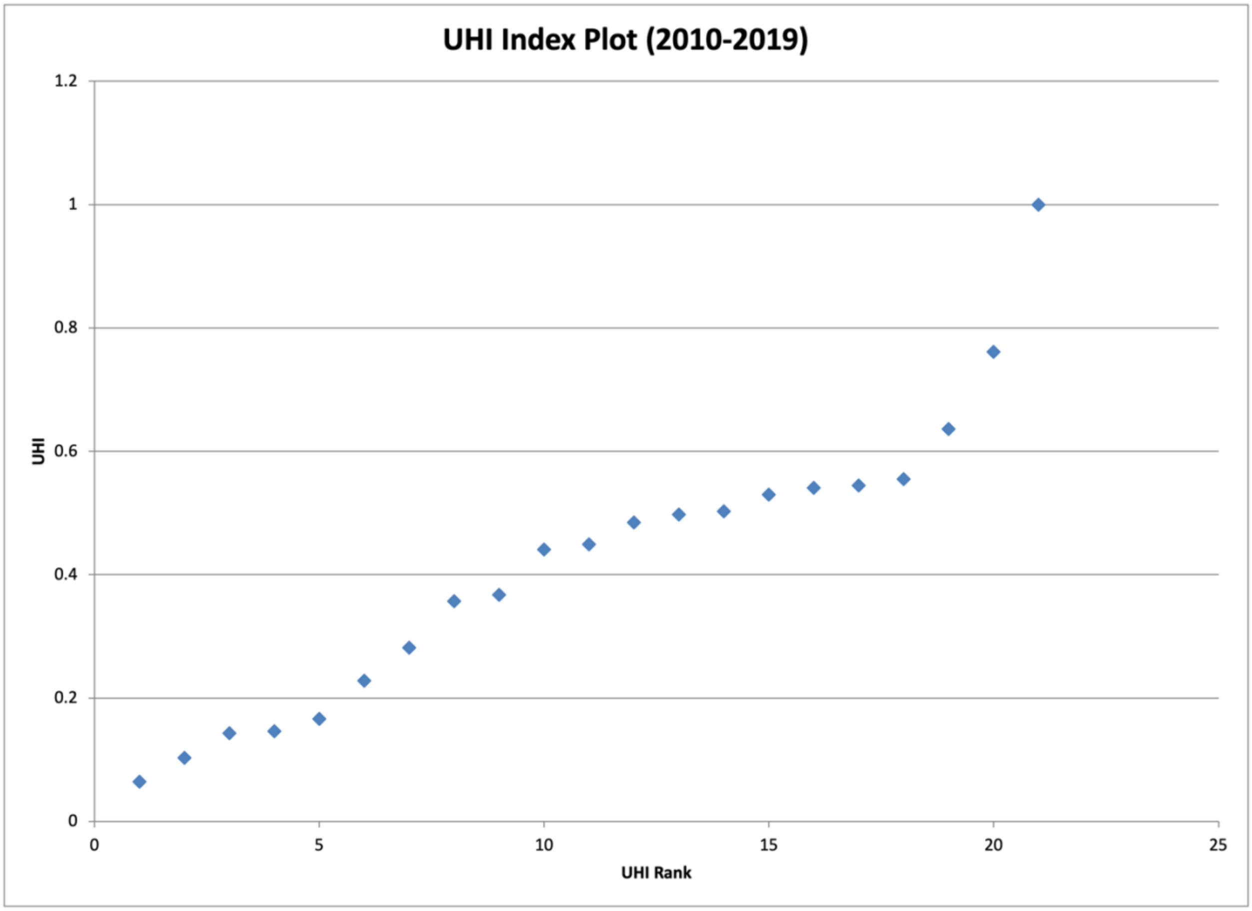

Figure 11: UHI Index Plot for 2010-2019

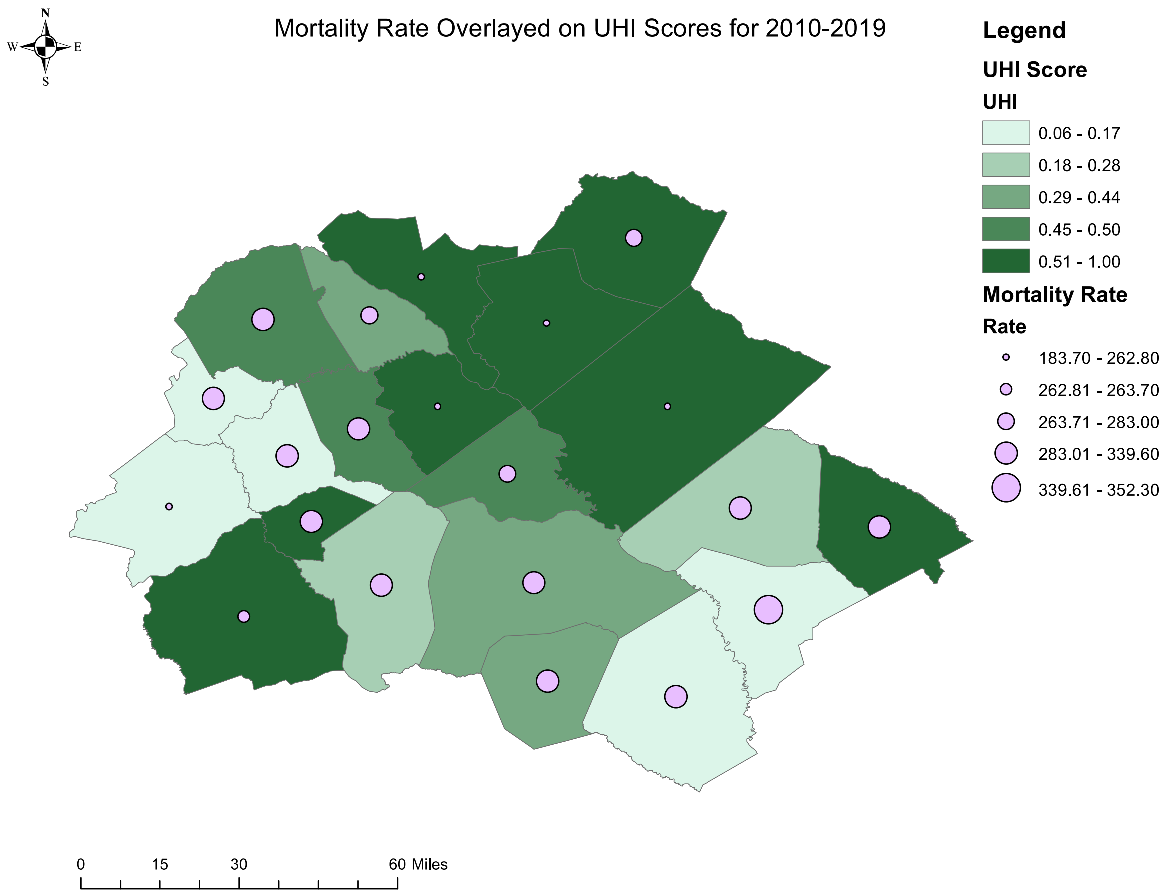

Figure 12: CSRA Map 2010-2019 Utilizing Quantiles for UHI and Mortality Rate

Table 4: Age-Adjusted Cardiovascular Disease Mortality Rate (per 100,000) by Timeframe

County	2000-2004	2005-2009	2010-2014	2015-2019	2000-2009	2010-2019
Burke County, GA	466.6	371.1	293.8	290.2	417.6	291.7
Columbia County, GA	286.4	224.1	198.1	172.8	250.9	183.7
Glascock County, GA	383.9	354.4	294.4	322.1	370.9	309.5
Hancock County, GA	482.7	335	243.4	284.3	404.8	262.8
Jefferson County, GA	446.4	363.4	339.3	341.2	404.3	339.6
Jenkins County, GA	395	292	300.6	292.7	342	297.6
Lincoln County, GA	488.3	365.5	306.8	250.7	424.2	273.5
McDuffie County, GA	439.7	326.7	277.1	297.7	381.6	287.4
Richmond County, GA	387	307.5	272.2	292.7	345.8	283
Screven County, GA	446.5	373.2	319.8	265.3	409.6	291.8
Taliaferro County, GA	365	381.3	357.5	286.3	372.8	319.2
Warren County, GA	352.2	355.2	300.5	269.7	353.8	285.6
Washington County, GA	420.8	330.6	266.9	261.8	375.8	263.7
Wilkes County, GA	410.2	326.8	335.2	340.3	367.9	336.5
Aiken County, SC	333.9	270.4	244.4	224.7	299.1	233.8
Allendale County, SC	416.1	436	384.6	318.4	424	352.3
Bamberg County, SC	385.1	356.6	288.7	303.8	369.8	296
Barnwell County, SC	369.1	337.7	311.5	285.7	352.7	297.9
Edgefield County, SC	347.8	305.6	239	213.1	324.4	225
McCormick County, SC	323.7	289.4	214.5	214.9	305.7	213.7
Saluda County, SC	407	312	293.9	255	357.9	273.2

Table 5: UHI Score by County by Timeframe

County	2000-2004	2005-2009	2010-2014	2015-2019	2000-2009	2010-2019
Burke County, GA	0.2359	0.2359	0.3927	0.1802	0.2359	0.4408
Columbia County, GA	0.9863	0.9863	0.9972	0.9711	0.9863	1.0000
Glascock County, GA	0.0467	0.0467	0.5899	0.2010	0.0467	0.5550
Hancock County, GA	0.0565	0.0565	0.3849	0.2555	0.0565	0.1033
Jefferson County, GA	0.2351	0.2351	0.3544	0.1605	0.2351	0.2817
Jenkins County, GA	0.2685	0.2685	0.4794	0.0843	0.2685	0.3573
Lincoln County, GA	0.4830	0.4830	0.3095	0.4194	0.4830	0.3673
McDuffie County, GA	0.4267	0.4267	0.5094	0.3519	0.4267	0.4977
Richmond County, GA	0.4547	0.4547	0.5472	0.3539	0.4547	0.4848
Screven County, GA	0.3688	0.3688	0.3973	0.4257	0.3688	0.1434
Taliaferro County, GA	0.2562	0.2562	0.1632	0.2831	0.2562	0.1662
Warren County, GA	0.2062	0.2062	0.1202	0.2832	0.2062	0.1461
Washington County, GA	0.3248	0.3248	0.4743	0.2846	0.3248	0.5028
Wilkes County, GA	0.5340	0.5340	0.4285	0.4328	0.5340	0.4495
Aiken County, SC	0.6958	0.6958	0.7064	0.6881	0.6958	0.7612
Allendale County, SC	0.0690	0.0690	0.0080	0.0223	0.0690	0.0644
Bamberg County, SC	0.2934	0.2934	0.4680	0.4116	0.2934	0.5301
Barnwell County, SC	0.3989	0.3989	0.3523	0.2535	0.3989	0.2279
Edgefield County, SC	0.5395	0.5395	0.5278	0.6494	0.5395	0.6360
McCormick County, SC	0.5856	0.5856	0.3973	0.5655	0.5856	0.5445
Saluda County, SC	0.5537	0.5537	0.5845	0.5187	0.5537	0.5409

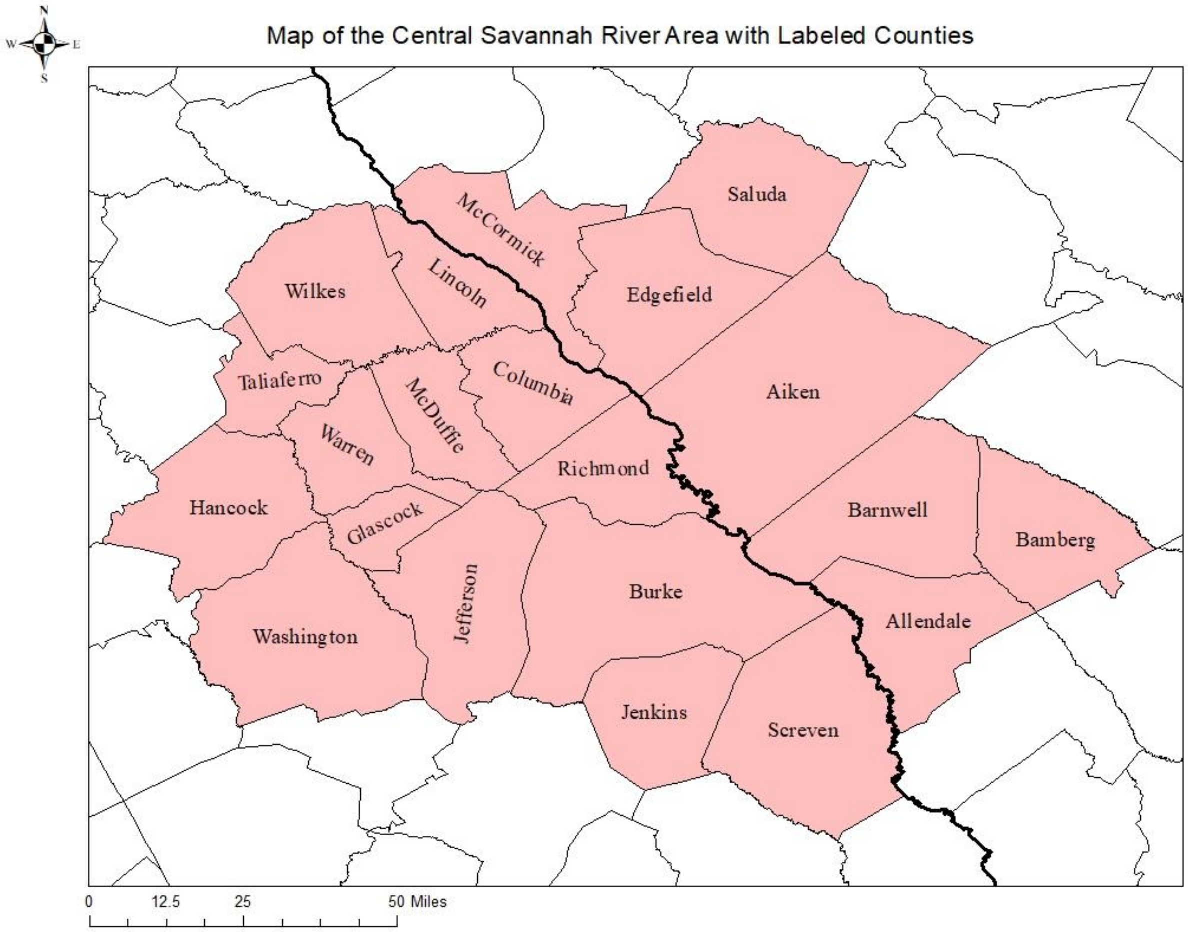

Figure 13: Labeled Map of the Central Savannah River Area

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