

**THE SITING OF HOG CAFOS IN EASTERN NORTH CAROLINA:
A CASE OF ENVIRONMENTAL INJUSTICE?**

By

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Abstract

The eastern region of North Carolina is home to over 2,500 active hog farms. These hog farms are referred to as confined animal feeding operations (CAFOs) because hogs are densely crowded into small areas. In the field of environmental justice, there have been a number of studies relating environmental justice implications to the siting of CAFO. This study spatially examines the location of the CAFOs in eastern North Carolina to determine if higher percentages of disadvantaged populations live near these polluting facilities. Two sets of analyses were conducted for this study. The first analysis compares the demographics around CAFOs sited within the 100-year flood zone with CAFOs sited outside the 100-year flood zone. The findings from this analysis suggest that comparing the mean demographics around CAFOs in the 100-year flood zone, compared to the mean demographics around CAFOs not located in the 100-year flood zone, does not provide statistically significant results supporting the hypothesis that more minority, low-income, and lower education groups will live near CAFOs within the vulnerable 100-year flood zone. The second analysis is a longitudinal analysis that spatially examines the siting of CAFOs in eastern North Carolina, and then statistically analyzes the demographics of census tracts within one and three miles of these facilities in 1990 and 2000. In general, the longitudinal analysis finds that greater percentages of Hispanic, low-education, and low-income populations live near CAFOs in Eastern North Carolina as compared to random points within the same region. Also, between 1990 and 2000, the disparities between CAFO locations and random locations widened for a number of key demographics, such as percent Hispanic and average housing value.

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CHAPTER ONE – INTRODUCTION

The production of livestock in the United States occurs most often in confined industrial spaces known as concentrated animal feeding operations (CAFOs). CAFOs are commonly characterized as having large numbers of livestock confined into a small space, which results in large quantities of fecal waste in a small area. Since CAFOs often generate millions of tons of manure each year, substantial risks to the environment and public health exist (National Research Council, 2003). The pollution from CAFOs has documented health effects and impacts on quality of life for farmworkers and populations living near CAFOs (Wing et al., 2008). A number of research studies have found that hog CAFOs are disproportionately located in minority and low-income communities (Edwards and Ladd, 2000; Wilson et al., 2002, Wing et al., 1996, 2002, 2008). These findings support the growing body of research, by environmental justice scholars, that minority and low-income groups bear the disparate burden of living near locally unwanted land uses (LULUs) in many parts of the United States.

The eastern region of eastern North Carolina is host to over 2,500 active swine CAFOs. This region is the second most densely populated area with CAFOs in the United States. It is second only to the state of Illinois. A number of researchers have analyzed the environmental, public health, and environmental justice implications of the concentration of CAFOs in eastern North Carolina. Building on

past environmental justice research concerning LULUs, and more explicitly CAFOs, two sets of analyses were conducted in this study to understand the demographics of populations living near CAFOs. The first analysis combines floodplain, census, and CAFO data to analyze if marginalized populations are more likely to live near CAFOs sited in the vulnerable 100-year floodplain zones. The 100-year flood zone is designated as an area that has a one percent chance of flooding in any given year. It is referred to as the 100-year flood because its annual risk is the same as “one in 100”. The term is somewhat misleading because a 100-year flood can occur any year, but the name itself is only based on the statistical designation. A 100-year flood, although less frequent than a 10-year or 20-year flood, is far more destructive due to projected flooding depths. An analysis of the 100-year flood zone with CAFO sites is also a new contribution to the growing body of environmental justice research on CAFOs.

The second form of analysis also assesses if there are more minority, low-income, or lower-education populations living near hog CAFOs in eastern North Carolina. Although researchers have examined CAFOs in eastern North Carolina and found race and income disparities related to CAFO siting, no current research has analyzed these demographics longitudinally to analyze how these disparities have changed over time. To do this, race, class, and education variables on the census tract level were analyzed, from 1990-2000, to explore the overall demographic patterns and changes occurring within one and three-miles of a hog CAFO. To better

elaborate the research goals for this thesis, the main research questions are provided below.

Research Questions

- What is the geographic distribution of CAFOs in eastern North Carolina?
- What is the geographic distribution of CAFOs sited inside the 100-year flood zones in Eastern North Carolina?
- Does the geographic distribution of all CAFOs in eastern North Carolina and/or the CAFOs sited inside the 100-year flood zone in eastern North Carolina correlate with demographic characteristics of race, economic status, and educational attainment?
- Are there a greater percentage of minorities, low-income and low-education peoples living within a fixed distance from a CAFO site as compared to those same radii around randomly generated points in eastern North Carolina?
- Is there a greater percentage of minorities, low-income, and low-education peoples living within a fixed distance from a CAFO sited inside the 100-year flood zone as compared to those same radii around CAFOs not inside the 100-year flood zone?
- Of these demographic characteristics, which are statistically significant when using independent samples t-tests and multivariate models?

- What is the relative importance of race variables versus socioeconomic variables regarding where CAFO locations are sited?¹
- How have the demographic characteristics related to race, income, and income changed between 1990 and 2000?

Based on a number of research findings summarized in Chapter 2 of this study, the main hypothesis for this research posits that more minority, low-income, and low-education populations live near CAFOs, as opposed to the whiter, richer, more-educated populations in eastern North Carolina. Relating to the floodplain analysis, it is also hypothesized that greater percentages of minority, low-income, and low-education populations live near CAFOs sited inside the 100-year flood zone, as opposed to those CAFOs not sited inside 100-year flood zone.

The thesis provides a number of new contributions to the growing body of environmental justice research relating to CAFOs. First of all, this research is the first of its kind to longitudinally compare the demographics of populations living in proximity to a CAFO sited in eastern North Carolina. The longitudinal analysis indicates how demographic changes have occurred in eastern North Carolina, and can offer insights for how these changes relate to CAFO locations. Second, no other environmental justice analyses of CAFOs in eastern North Carolina examine educational attainment variables. Instead, a number of past studies examine race and income variables. The new focus on educational attainment adds a more

¹ This question relates to the “race versus class debate” in environmental justice research (Mohai and Pellow and Roberts, 2004).

comprehensive investigation of the demographics near CAFOs that has not been conveyed in past studies. Measuring a population's educational attainment can also provide insights into their overall social status, political clout, and access to resources that could potentially affect their inclusion in decision-making processes regarding CAFO locations. Third, this research utilizes a new methodology, suggested by Mohai and Saha (2007), of comparing populations living near CAFOs to those populations not living near CAFOs. To make this comparison, latitude and longitude points were randomly generated in eastern North Carolina. These points were then compared to CAFO points using bivariate and multivariate analyses. This specific methodology for cross-comparison was not found in past research studies analyzing the location of CAFOs, and it follows the approach by Mohai and Saha (2007) in their analysis of hazardous waste site locations. This approach offers a more precise method for comparison across populations. Fourth, although past research has questioned the siting of CAFOs within floodplain regions, this research is the first of its kind to analyze the siting of CAFOs in the 100-year floodplain. This particular research interest is based on the assumption that the siting of industrial facilities inside the vulnerable 100-year flood zone will increase the chance of environmental and public health risks for those living within these vulnerable areas.

To better aid and guide the reader, the rest of this document is organized into specific chapters. Chapter Two provides a literature review that gives a historical summary of CAFO production in eastern North Carolina, and outlines past environmental justice and CAFO research that helped guide the research questions and methodology for this study. Chapter Three describes the data and methods of

the floodplain analysis, and Chapter Four presents the results of the floodplain analysis. Similarly, Chapter Five describes the data and methods of the longitudinal analysis of CAFO locations, with Chapter Six then summarizing the longitudinal analysis results. Finally, Chapter Seven is dedicated to the discussion of the results for both analyses, with a conclusion that sums up the thesis research with recommendations for future research.

CHAPTER TWO – LITERATURE REVIEW

The literature review for this thesis is separated into sections. The first section offers the reader a brief overview of the environmental justice movement paying attention to seminal environmental justice research and events that have formulated this study's research questions and methodology. The second section provides background research pertaining to CAFOs along with the historical and political events that led to the industrialization and concentration of hog farms in eastern North Carolina. The third section provides an overview of the public health issues surrounding the siting of CAFOs for communities. The fourth section explores the main research studies and methodologies that directly contribute to the overall methodology and research questions for this study. The fifth section of the literature review explores the new contributions this study offers to the growing body of research exploring environmental justice issues relating to CAFOs.

Section 1: The Environmental Justice Movement

In the 1980s, new questions emerged within the environmental movement about the relationship between environmental quality and racial inequalities. This new focus on environmental injustices started to gain momentum in the 1980s with community organizing to protest the placement of polluting facilities and waste sites in minority communities (Bryant and Mohai, 1992). The use of the term 'environmental justice' first appeared in national discussion in 1982 when civil

rights activists organized to pressure North Carolina about the dumping of 120 pounds of contaminated soils in Warren County, the county with the highest proportion of African Americans in North Carolina (Bullard, 1994). These new developments created a new focus on the intersection of environmental issues and social justice (Mohai and Pellow and Timmons and Roberts, 2009). At this time, scholars, activists, and agencies began to formulate definitions for environmental justice. Robert Bullard defined environmental injustice as “the disproportionate exposure of communities of color and the poor to pollution, and its negative effects and health and the environment, as well as the unequal environmental protection and environmental quality provided through laws, regulations, governmental programs, enforcement, and policies” (Bullard, 1994). Further, the Environmental Protection Agency (EPA) describes environmental justice as the “fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies” (EPA, 2011).

The environmental justice movement continued to gain momentum into the 1990s with mounting concern and protest about the placement of waste sites and polluting facilities in minority and low-income communities (Bryant and Mohai, 1992). In 1983, the U.S. General Accounting Office conducted the first study to focus on the locations of hazardous waste sites and those demographics of the communities living near them. The study found that African American communities in parts of the southern region of the United States were living disproportionately

closer to hazardous waste sites (GAO, 1983). In 1987, The United Church of Christ Commission for Racial Justice wrote a report entitled *Toxic Wastes and Race in the United States*, which was the first study of its kind to find the disproportionate siting of toxic waste facilities in minority and low-income communities (Saha and Mohai, 2005; Mohai and Pellow and Timmons Roberts, 2009). In 1990, Robert Bullard published his first book, entitled *Dumping in Dixie*, which was the first major study of environmental racism finding that communities of color were being targeted for the country's LULUs (Brulle and Pellow, 2006). In the same year, Bunyan Bryant and Paul Mohai, the first researchers to systematically review and evaluate evidence from prior research on race and class disparities in the distribution of environmental hazards, organized the Conference on Race and the Incidence of Environmental Hazards, which took place at The University of Michigan. The conference brought together academics, activists, and researchers from across the country that were studying racial and socioeconomic disparities in the distribution of environmental contaminants (Mohai and Pellow and Roberts, 2009). The conference proceedings were sent to the United States Environmental Protection Agency (EPA), directly influencing the federal agency to begin its own assessment of environmental inequalities and its influence on new policy directions. In 1992, The EPA offered its own findings and recommendations in a report entitled *Environmental Equity: Reducing Risks for all Communities* (Brulle and Pellow, 2006). In 1994, a Presidential Executive Order issued an order that all federal agencies needed to take into account the potential for disproportionate burdens of pollution

existing in minority communities in the United States (Pastor and Sadd and Hipp, 2002). The issues important to the environmental justice movement have now spread to research in a number of academic disciplines including sociology, public health, and urban and regional planning (Mohai and Saha, 2006, 2007).

A number of quantitative studies within many academic disciplines have researched racial and socioeconomic disparities in the distribution of environmentally hazardous sites (Mohai and Saha, 2006, 2007). Most of these studies have found such disparities to be statistically significant. Despite these findings, there still remains considerable variation in the magnitude of the disparities found in environmental justice research. The most common factors used to explain these disparities are termed 'economic', 'sociopolitical', and 'racial' (Mohai and Saha, 1994; Saha and Mohai, 2005). An example of an economic factor is an industry's desire to build facilities in areas where land values and operation costs are low, and due to cheaper property values, these areas may also be where minorities and low-income populations are settling (Daniel and Friedman, 1999). Conversely, the siting of industrial facilities may cause property values and overall quality of life to diminish, resulting in more affluent and white populations to move away from the area, with the less affluent and the racial minorities moving into the area because of decreased housing and living costs. An example of a sociopolitical factor involves the unequal social capital and political power among communities. As a result, disproportionate access to environmental problems may occur due to the inability of poor, minority populations who have limited access to social and

political resources, to successfully lobby or organize against LULUs. Racial factors can also play a role in explaining the occurrence of environmental inequalities. Examples of these factors include housing segregation and racial inequalities in employment, healthcare, and education and the roles these inequalities play in the ability of minorities to move away from polluting sites (Mohai and Saha, 2006, 2007).

Although a number of studies have found that LULUs tend to be located in vulnerable communities with race being a strong factor, some studies have found that race is not a significant factor when controlling for other variables (Anderton et al., 1994; Davidson and Anderton, 2000). The debate over the degree to which environmental disparities are a function of race or class-based market dynamics has popularly been termed, 'the race versus class debate'. This debate has also ignited newer methodologies when researching environmental injustices (Brulle and Pellow, 2006; Mohai and Pellow and Roberts, 2009). One of these particular methodologies conducts research of demographics around LULUs over time. A notable study using this type of longitudinal analysis was conducted by Pastor, Sadd, and Hipp (2002) to analyze the demographic changes in Los Angeles County over three decades, as a result of the siting of toxic storage and disposal facilities. Their analysis found that the siting of these hazardous facilities was related to the concentration of minority and low-income populations located within the sample area. By conducting a longitudinal analysis, the researchers were able to move beyond a cross-sectional analysis that amounts to a "snap shot in time," and instead

develop a deeper understanding of the popular question of who came first, the polluting facility, or the marginalized community (Pastor and Sadd and Hip, 2002).

One of the main analyses in this study develops a longitudinal analysis of demographics around CAFOs in 1990 and 2000. This analysis is the first of its kind pertaining to CAFOs sited in eastern North Carolina. The longitudinal approach has not been used in CAFO research, and it can more effectively highlight demographic and siting trends in a specific region, and by doing so can offer deeper insights into the roles for future policy and research.

The environmental justice research highlighted in this section helped form this study's research questions regarding environmental injustices related to the siting of CAFOs in eastern North Carolina. CAFOs also present an environmental hazard and the thesis' research methodology seeks to determine whether they are distributed inequitably. Section 2 of the literature review provides the reader with the historical, political, and economic context for the concentration of CAFOs in the eastern North Carolina region.

Section 2: CAFOs and Eastern North Carolina

For most of the 20th century conventional hog farming in North Carolina was a small-scale family operation with few social or environmental impacts. Hog farming was also distributed throughout the entire state of North Carolina, with 11,400 farms producing hogs, with almost 60 percent having fewer than 25 hogs per farm (Furuseth, 1997). Now over 95 percent of hog operations occur in CAFOs,

operating with at least 2000 pigs on each site (Ladd and Edward, 2000). Hogs can produce as much as two-to-five times as much waste as humans, while a CAFO of 10,000 mature pigs can produce amounts of fecal waste that is comparable to a city of 20,000 people (Ladd and Edward, 2002). CAFOs in eastern North Carolina commonly store hog wastes in fecal cesspools, and are eventually used as fertilizer for agricultural fields (Wing and Wolf, 2000; Mirabelli, et al., 2006). These cesspools, most commonly referred to as 'lagoons', pose environmental concerns due to their potential for rupturing during periods of flood or other environmental stress. North Carolina has approximately 4,000 active and 650 abandoned waste lagoons tied to hog production (Ladd and Edward, 2002).

Since the 1990s, North Carolina has been the fastest growing swine producing state in the United States, with number of hogs increasing from 3.7 million in 1991 to almost 10 million by 1997. Currently, in some eastern North Carolina counties, the hog population outnumbers the human population by more than 50 to one (Ladd and Edward, 2002).

Many factors led to the increase of industrial hog farming in eastern North Carolina. In the past, hog production facilities were sited throughout the entire state of North Carolina. However, in order to consolidate wastes and environmental damage throughout the entire state, hog farming became mainly concentrated in North Carolina's eastern coastal region (Wing and Cole and Grant, 2000; Wing and Wolf, 2000). This trend was not a result of a law or statute, but instead was an obvious choice for industrial agricultural corporations to locate their facilities in

eastern North Carolina, since it was already known for its history as an agricultural region. Another factor leading to the concentration of CAFOs in eastern North Carolina was the declining revenues in tobacco farming, so many farmers believed that hog farming was a lucrative next step for the state. Next, “Right-to-Farm” laws gave industrial farm operators many economic and operational protections that further incentivized the intensification and industrialization of hog farms (Ladd and Edward, 2002). Another impetus for hog farm growth was a 1991 state legislation that exempted hog CAFOs from local zoning legislation, providing lenient environmental and zoning regulations across eastern North Carolina (Factory Farm Map, 2010). As a result of these lenient regulations, a number of community organizations, environmentalists, and social activists pushed North Carolina legislators to enforce harsher environmental regulations on hog CAFOs.

The economic and political factors explaining why CAFOs became increasingly concentrated in eastern North Carolina also offers an explanation for why more minority and low-income populations live near CAFOs. Given eastern North Carolina’s history as a predominately African American farming area, it is safe to assume that despite the intensification and industrialization of farming operations, these minority populations continued to live throughout the region. Also, with the leniency in zoning and environmental regulations throughout the region, it is assumed that one result of this would be declining property values in areas around CAFOs. This outcome would make it cheaper for low-income families to afford housing.

As a result of the new concentration of CAFOs in eastern North Carolina, a number of grassroots and community groups began to collectively organize around opposition to these hog operations. These early groups claimed that neighborhoods near hog CAFOs in eastern North Carolina were being directly affected by malodor on a daily basis (Ladd and Edward, 2002). One of the most notable grassroots organizations to form as a result of hog CAFOs in eastern North Carolina was the Citizens for Clean Industry. The main motivation for their organization was the announcement in 1990 that Smithfield Foods would construct the world's largest meat processing plant in Bladen County, North Carolina on the banks of the Cape Fear River (Hog Farming Overview, 2004). Citizens for Clean Industry petitioned elected officials, spoke against the site at public hearings, and filed numerous lawsuits against the construction. Although Citizens for Clean Industry's actions did not cancel or even delay construction of the slaughterhouse, they did generate a new concern across North Carolina that directly resulted in the creation of a broader coalition group called the Halifax Environmental Loss Prevention organization (Ladd and Edward, 2002). The organization was most interested in protecting vulnerable communities from the effects of large-scale industrial agricultural operations in their communities. Most notably, the Halifax Environmental Loss Prevention organization was the first organization to draw attention to the broader trend of industries singling out minority, low-income, and rural communities to construct polluting and dangerous facilities. The Halifax Environmental Loss Prevention organization, while also working with the larger

organization, Concerned Citizens of Tillery, worked to formally introduce industrial hog farms as a valid environmental justice issue in North Carolina. Concerned Citizens of Tillery, the grassroots organization in southeast Halifax County, North Carolina was initially created because of growing concerns about the air and water pollution, and malodor associated with hog farming. With so many county citizens relying on well water as a predominant drinking water source, they worried about groundwater contamination in such a low-lying region of North Carolina. They were also concerned about the loss of family owned and operated farms in eastern North Carolina (Wing and Freedman and Band, 2002). Above all, a growing number of citizens believed they were experiencing disproportionate environmental and social burdens because they were primarily African American and low-income communities lacking social, political, and economic power (Ladd and Edward, 2002). During this time, Concerned Citizens of Tillery sought support from environmentalists, social activists, political leaders, and academic scholars (Wing and Freedman and Band, 2002). These community and academic collaborations in research and awareness directly affected the passing of new CAFO regulations in North Carolina. As a result, this was one of the first times that linkages were made between racial and class injustices relating to large-scale industrial agricultural operations in rural communities.

In 1995, collective opposition expanded even more after the rupturing of several hog waste lagoons, which spilled over 40 million gallons of swine feces and urine into streams and rivers in eastern North Carolina's Coastal Plain (Wing and

Cole and Grant, 2000). The spill created nutrient loads that are attributed to the estimated death of 10 to 15 million fish and cost the state thousands of dollars in cleanup (Wing and Cole and Grant, 2000). It is important to note here that the eastern region of North Carolina is particularly vulnerable to environmental damage because of its susceptibility to flooding in this low-lying region (Setzer, 2004; Wing and Freedman and Band, 2002). Particularly in this region, the water tables are high and many wells are shallow or unlined (Setzer, 2004). Also, many CAFOs in North Carolina are primarily located in areas where a large proportion of neighboring households depend on well water for drinking water (Wing and Freedman and Band, 2002). In 1995, as these vulnerabilities were starting to become clearer, the North Carolina Senate passed the Swine Farm Siting Bill, which required new hog CAFOs and lagoons to be sited at least 1,500 feet from occupied homes, 2,500 feet from schools, hospitals, and churches, and at least 100 feet from property boundaries in general. Then in 1996, Hurricanes Bertha and Fran brought tremendous flooding to eastern North Carolina, which resulted in more incidences of swine waste lagoon overflows and water pollution events (Setzer, 2004). These events galvanized even more public protest, and in August 1997, the North Carolina General Assembly passed the "Clean Water Responsibility Act". The act created new measures to control malodor, protect water quality, and gave local governments the zoning authority to regulate the siting of large-scale hog operations in the eastern North Carolina region. Also, the act placed a moratorium on any new construction of hog farms housing more than 250 hogs starting in 1997 and ending in 2007. While no

new CAFOs were built during this ten-year period, a lot of the already existing CAFOs only grew larger. In 2007, the average CAFO in eastern North Carolina was 6,276 hogs each (Wing and Freedman and Band, 2002; Factory Farm Map, 2010; Hog Farming Overview, 2004; Environmental Defense, 2007).

As a result of added attention and legislation measures, the national environmental movement became more attentive to hog farming concerns in eastern North Carolina. In 1998, the Clinton Administration called for new controls on waste from CAFO operations, and more EPA protection of minority neighborhoods from pollution sources. In North Carolina, Governor Jim Hunt announced a plan to phase out waste lagoons and spray fields by 2009 by implementing higher farming performance standards and new regulatory incentives. Despite mounting opposition hog CAFOs on the local, state, and national level, the North Carolina General Assembly did not support Hunt's plan (Ladd and Edward, 2002).

Later in 1999, Hurricane Floyd travelled across eastern North Carolina dropping over 20 inches of rain, which flooded over 6,000 homes, displaced 48,000 residents from their homes, killed 48 people, and destroyed 2.3 million acres of croplands in the region (Wing and Freedman and Band, 2002). More than 50 swine lagoons ruptured, 250 CAFOs were entirely flooded, and 30,000 hogs were killed. These effects led to the inundation of wells and land with sewage, pesticides, and bacteria (Wing and Freedman and Band, 2002). The political result of this devastation following Hurricane Floyd was the creation of a \$75 million agreement

with Smithfield Foods by the North Carolina Attorney General, Mike Easley, to develop new swine waste disposal technologies to replace existing lagoons (Ladd and Edward, 2002).

Moving forward to the 2000s, local and national organizations have been teaming up with universities such as The University of North Carolina-Chapel Hill and North Carolina State to devote research studies to shedding light on the adverse health and environmental effects of the large concentration of CAFOs in the eastern North Carolina region. For example, The Waterkeeper Alliance, presided by President Robert F. Kennedy Junior, has worked on a “Pure Farms, Pure Water” campaign against the siting of CAFOs and its danger to local waterways and family farms. The Waterkeeper Alliance has brought a successful lawsuit against Perdue Farms, an industrial agriculture conglomerate, and the trial is set for April 16, 2012 (Ladd and Edward, 2002).

The environmental and public health concern regarding the siting of CAFOs in eastern North Carolina has led to a number of public health research studies on this topic. Section 3 offers a synopsis of some of the most popularized studies on CAFOs and public health issues.

Section 3: Past CAFOs Research in Public Health

It is important to understand the vulnerability of populations near swine CAFOs to hazardous water and air pollutants emitted from these facilities affecting both adults and children (Mirabelli, et al., 2006). The research outlined in this

section of the literature review offers the reader a background of the main contributors in research pertaining to public health and CAFOs. Although the methodologies used in much of these studies are outside the scope of this thesis' main research questions, it was important to review this past work to understand just how populations are affected by living near CAFOs.

CAFOs pose environmental health dangers because of their high volume of waste, the content of the waste, and the lack of isolation from liquid waste management practices. Because wastes are stored in lagoons, leakage can seep into groundwater and contaminate it with nitrates and pathogens, contributing to increased nutrient pollution and oxygen depletion of ground and surface waters, local aquifers, and private wells (Wing and Cole and Grant 2000; Wing and Freedman and Band, 2002; Ladd and Edward, 2002). Consequently, the North Carolina State Health Department's well-testing program has documented elevated nitrates in neighboring groundwater around hog production plants (Wing and Cole and Grant, 2000). Hog operations can also contaminate surface waters, leading to high pathogen and nitrate loads in the nearby water features.

Along with water pollution, CAFOs can also contribute to harmful airborne emissions from confinement houses, cesspools, and spray fields that contain elevated amounts of ammonia, hydrogen sulfide, endotoxins, and hundreds of organic compounds. Steve Wing and Susanne Wolf (2000) completed the first population-based research of physical health symptoms and quality of life, along with the possible health effects of airborne emissions from swine CAFOs. Their

research compared health symptoms of three neighborhoods in eastern North Carolina, where two of the neighborhoods were within a 2-mile radius of a CAFO, while the third was in a rural location not proximate to a CAFO. All three neighborhoods had similar economic and demographic characteristics. Trained interviewees collected survey data over a six-month period, with 155 interviews completed. The results found that incidence of many symptoms were consistent among the three groups, however, respiratory and gastrointestinal, along with mucous membrane irritation, were elevated for residents living near a swine CAFO (Wing and Wolf, 2000).

A research study by Susan Bullers (2005) looked at the differing health symptoms, physiological distress, and perceived control between a group of 48 residents near a swine CAFO and a control group of 34 residents with no exposure to swine CAFOs. Bullers matched the groups based on socioeconomic characteristics. Twelve of the 22 reported symptoms of the swine CAFO residents were related to respiratory sinus, and nausea problems; also they reported increased physiological distress and decreased perceptions of control over their environmental health. Residents near a swine CAFO cited increased physiological distress over physical health symptoms (Bullers, 2005).

Another research study on air pollution and malodor from swine CAFOs (Wing, et al., 2008) examined 101 nonsmoking volunteers living within 1.5 miles of swine CAFOs in eastern North Carolina. The respondents completed twice daily diaries reporting odor from the swine CAFOs. Further, monitors were placed in the

16 neighborhoods of the 101 respondents measuring hydrogen sulfide (a product of anaerobic decomposition of hog waste) and particulate matter levels. 1,655 episodes of swine odor were reported during the study. Further, in nine neighborhoods, odor was reported on more than half of the designated study days. This research indicates that swine odor is commonly present in neighborhoods near swine CAFOs, and that these odors are related to environmental measurements of ambient levels of hydrogen sulfide and particulate matter within the surveyed neighborhoods (Wing, et al., 2008).

As mentioned, these public health studies, although outside the scope of this thesis' research methodology, offered a look into how industrial hog farming in eastern North Carolina relates to public health concerns for its local neighbors. Some researchers interested in CAFOs research were not only interested in growing public health concerns related to industrial farming, but they also wanted to analyze what groups were actually being affected. More specifically, a number of researchers began to ask questions about environmental justice concerns related to the siting of CAFOs in the southern and midwestern regions of the United States. Section 4 highlights environmental justice research findings that relate to the siting of CAFOs.

Section 4: Environmental Justice and CAFOs

The siting of CAFOs in eastern North Carolina has emerged as North Carolina's most acknowledged environmental justice issue since the landmark

conflict in Warren County against a PCB landfill being sited in a residential community in 1982 (Ladd and Edward, 2002). Some environmental justice issues related to CAFOs include, endangerment of the future for small independent farms, the public and economic health of rural and minority communities, the commercial fishing and tourist industries, lowered property values, and air and water quality (Cecelski and Kerr, 1992; Ladd and Edward, 2002).

Outlined below are a number of environmental justice studies relating to CAFOs. These past studies directly contributed to the methodology and research questions of this thesis. As a result, this thesis contributes new methodological approaches and research questions to the growing body of research exploring the intersection of environmental justice and CAFOs. Outlined below are the main studies that guided the research questions and methodology for this thesis.

Environmental injustices brought about by swine CAFO operations are not just relevant in eastern North Carolina. In “Environmental Injustice and the Mississippi Hog Industry” (Wilson, et al., 2002), 67 Mississippi neighborhoods near swine CAFOs were spatially examined based on race and income levels. The goal of this research was to determine if African American and low-income communities, at the census block group level, tend to live near industrial hog CAFOs. The research established that the majority of Mississippi’s industrial swine operations are located in block groups with high percentages of African Americans and persons of poverty status. At the highest three quintiles of percentage of African Americans and persons in poverty, there were 2.4-3.6 times more swine CAFOs located within a county with

at least one industrial hog operation. This research further confirms a commonly found trend in environmental justice research that highly industrialized polluting sites are disproportionately located in proximity to non-white and low-income areas (Wilson, et al., 2002). The methodology used in the research to spatially examine the percentage of African American and low-income populations, on the census block group level, living near CAFOs in Mississippi guided my own interest in developing a similar methodology for the eastern North Carolina region.

In a similar study, Yeboah, et al. (2009) applied statistical and geographic information system (GIS) analyses to determine whether poor, non-white populations in eastern North Carolina are adversely exposed to industrial wastes from swine CAFOs. Using regression analysis, the study found that minorities might not have been directly targeted for exposure to hog locations, and that their exposure might be based on their association with poverty and designation as rural dwellers (Yeboah, et al., 2009). This research found that poverty and proportion of rural population are the most important factors explaining hog waste on the zip code level. Although Yeboah, et al. (2009) considered race and class, no education variables were applied to the analysis. This limitation in the research suggests that other variables, such as level of educational attainment, could help better explain disproportionate exposure to hog CAFOs. This interest in incorporating educational attainment into the thesis analyses is based on research linking lack of education to inability to prevent the siting of polluting facilities such as CAFOs (Mohai and Saha,

2007). Also, past research suggests that educational attainment is a good predictor of political resources and social capital (Mohai and Saha, 2007).

In 1999-2000 Mirabelli and Wing (2006) conducted research analyzing 226 middle schools within or beyond 3 miles of a swine CAFO. The goal of the research was to assess the environmental health conditions inside and surrounding the school buildings. A 21-item survey was distributed to school employees to assess these conditions. The research also used data from the State of North Carolina National Center for Education Statistics to assess the racial and ethnic composition of the schools, along with enrollment in the National School Lunch Program; all were used as a proxy for socio-economic status. The research found that schools with less than 63% enrollment of white students and greater than or equal to 47% of students receiving subsidized lunches were located closer to swine CAFOs than were the remaining schools (Mirabelli and Wing, 2006). These schools were also more likely to be located within three miles of a hog CAFO than schools with an increased socio-economic status. However, the survey of employees assessing environmental health in and around the 226 schools did not directly correlate according to the socio-economic status of its enrolled students. This study guided this thesis' methodology for testing the means of populations near CAFOs against populations not near CAFOs. However, Mirabelli and Wing only analyzed school demographics, and this thesis will instead analyze neighborhood demographics on the block group and census tract levels.

In 2000, Wing, Cole, and Grant (2000) analyzed the location and characteristics of 2,514 intensive hog operations in eastern North Carolina in relation to racial, economic, and water source variables on the census block group level. The researchers used Poisson regression models to understand the extent to which socio-economic and race variables predict the number of CAFOs located within an area. The researchers found that there are 18.9 times as many hog operations in the highest quintile of the poverty variable as compared to the lowest quintile for poverty. However, when adjusting for population density, the researchers found a 7.2 times difference (Wing and Cole and Grant, 2000). Further, the research shows that the excess of hog operations was greatest in areas with both high poverty and high percentages of nonwhites. Also, the research findings suggest that hog operations that use waste pits are located in areas with high dependence on well water for drinking. One limitation from this study that guided this thesis' methodology is that the researchers only compared demographic variables for populations in block groups containing CAFOs and excluded block groups that did not contain CAFOs. This research methodology inspired my own research question concerning the difference in socioeconomic, race, and education levels for populations living near CAFOs compared to a random sample of areas not located near CAFOs in eastern North Carolina.

Flooding and Hurricane Impacts

As mentioned in Section 2, hog CAFOs are mostly concentrated in the coastal plain region of North Carolina, featuring low-lying flood plains and high water tables (Wing and Cole and Grant, 2000). A substantial number of CAFOs in North Carolina are at risk of experiencing offsite discharge of waste from frequent flooding in the state's floodplain region (Schmidt, 2000). Groundwater contamination is also a particular problem in eastern North Carolina because high water tables and many shallow and unlined wells (Wing and Cole and Grant, 2000).

In a research study pertaining to the potential impact of flooding on CAFOs in eastern North Carolina, Steve Wing, et al. (2002) compared the geographic coordinates of 2,286 CAFOs in eastern North Carolina with the estimated flooding one week after Hurricane Floyd inundated this particular region with 15-20 inches of rain in September 1999. The research used digital satellite images to spatially define the flooded areas within this region. The analysis shows that 241 of the 2,286 CAFOs had geographic coordinates within the area of inundation one week after Hurricane Floyd hit eastern North Carolina. These areas of inundation with CAFOs sited within them were inhabited by 171,498 people, with more than one-third of that population being African American according to the 2000 census. According to their research using satellite images of flood inundation, African Americans were disproportionately located in areas with flooded CAFOs compared to whites (Wing, et al., 2002). This research was the first of its kind to analyze flooding, census, and CAFO data together. The research questions asked in this study concerning what populations are most vulnerable to the siting of CAFOs in flood-prone areas helped

guide my own research question of whether there are larger percentages of minority, low-income, and lower education populations near CAFOs sited inside the 100-year flood zone than near CAFOs sited not inside the 100-year flood zone. Building on the research methodology of this Wing, et al (2002) study, this thesis goes a step further to use flood zone designation data, provided by the Federal Emergency Management Agency, instead of satellite images showing flood inundation. Using flood zone designations, instead of satellite images after a flood, offers a more accurate measure of where vulnerable flood zone regions are located in eastern North Carolina.

Section Five - Main Thesis Contributions

This study provides a number of new contributions to the growing body of research pertaining to the environmental justice implications of the siting of CAFOs. As mentioned, a number of past research studies guided the creation of this thesis' main research questions and its methodology. Below are the new contributions this study provides for the growing body of environmental justice research pertaining to CAFOs.

Longitudinal Analysis

This study contributes a newer methodology that analyzes the siting of CAFOs and the change in demographics over time in these areas. Although a number of environmental justice researchers have performed longitudinal analyses of

demographics around toxic waste sites and LULUs, a review of the literature on environmental justice research pertaining to CAFOs suggests that a longitudinal analysis has not been conducted. This implies that the longitudinal analysis applied to my thesis' research design is original to CAFOs research in eastern North Carolina, and fills a gap in the lack of longitudinal analysis in the body of research concerning environmental justice and CAFOs. This type of analysis is important in assessing how demographic disparities change over time as a result of LULU sitings in particular areas.

Analyzing Socio-economic, Race, and Education Variables

Most of the research studies offered in this literature review analyze socio-economic and race variables relating to CAFOs sitings. However, no other research providing an environmental justice analysis of CAFOs in eastern North Carolina provides analysis of educational attainment variables. An analysis of educational attainment can help predict the level of political and social clout in an area, which can indicate a community's ability to combat LULUs (Mohai and Saha, 2007). As a result, inclusion of educational attainment variables fills a gap in the current environmental justice research pertaining to CAFOs.

Comparing CAFO Communities to Non-CAFO Communities

The methodology of this study compares the populations near CAFOs with a random sample of geographic points in eastern North Carolina that are not located

near CAFOs. Although Mohai and Saha (2007) developed this approach for analyzing demographic disparities around hazardous waste sites, there is no other CAFO research that utilizes this comparison model. It is assumed that using this type of method will offer a clear comparison of socioeconomic, racial, and educational differences between CAFO communities and non-CAFO communities in eastern North Carolina.

Emphasis on the 100-year floodplain

In 2002, Steve Wing et al. used digital satellite images to map the inundation of flooding from the September 1999 Hurricane Floyd. The flooding images were used to find the spatial distribution of CAFOs that were located within the flooded areas (Wing, et al., 2002). Although similar in scope, this study offers a new contribution to the body of research interested in the siting of CAFOs in low-lying floodplain regions. This study is the first of its kind to spatially analyze block group census data, CAFO points in eastern North Carolina, along with flood zone designations. Further, no other studies have analyzed the demographics of those populations around CAFOs that are within the vulnerable 100-year flood zone region. This particular analysis is relevant to other states and nations where CAFOs are sited in vulnerable flood zones.

Moving forward, Chapter Three, the following chapter, describes the floodplain analysis, with descriptions of the data, methodology, and analyses conducted. Then Chapter Four describes the results of the floodplain analysis.

CHAPTER THREE – FLOODPLAIN ANALYSIS

Data and Methods

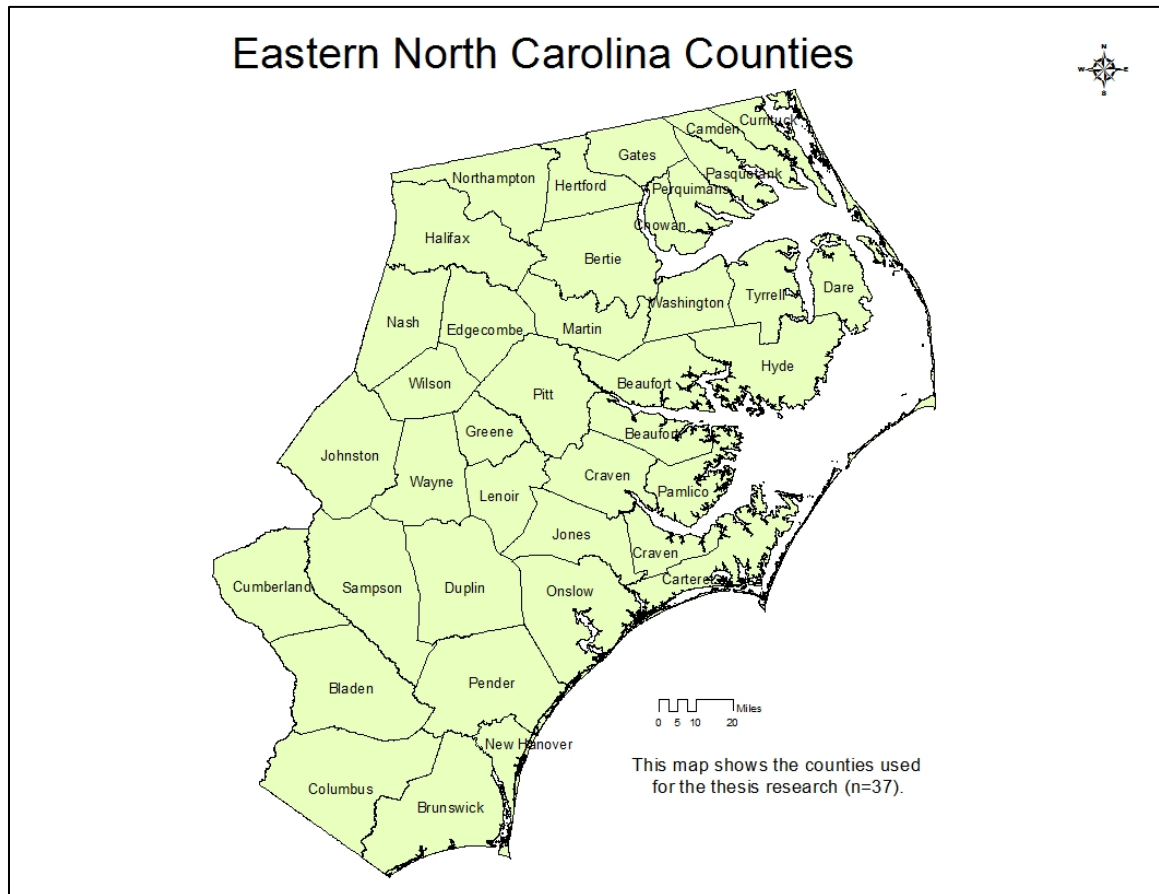
This portion of the thesis examines the demographic differences of those living near CAFOs in the 100-year flood zone versus those living not inside the 100-year flood zone. As mentioned in Chapter 1, the 100-year flood zone has the potential to be far more dangerous and destructive than other flood zones based on the projected flood depths the 100-year flood zone produces. Grounded in environmental justice theory, the main hypothesis is that higher proportions of minority and low-income residents, with a more limited educational background live near CAFOs that are located in the more dangerous 100-year flood zone. A general assumption is that populations living near CAFOs sited inside the 100-year floodplain will be more susceptible to more severe flooding and weather events, which has the potential to lead to increased environmental problems such as water and soil pollution.

Research Setting

The eastern region of North Carolina, shown in Figure 1, was chosen as the research location because more than 75% of the CAFOs in North Carolina are located in this region. Further, the eastern region of North Carolina is the second largest area in the United States for hog production. Figure 1 also highlights the

eastern North Carolina counties chosen for the research project. In all, 37 counties were included in the analysis. Oftentimes, the eastern North Carolina region is roughly denoted as the counties that are east of Interstate 95, and this distinction was the basis for the inclusion of these particular counties.

Figure 1 - Map of Eastern North Carolina Counties



Data

The data set used in this research was assembled from three sources: 2000 U.S. Census Bureau² data at the block group level; The North Carolina Division of Water Quality³ 2009 data on the state's hog operations, and The Office of Geospatial and Technology Management at the North Carolina Division of Emergency Management⁴ state floodplain data. The hog operation database was updated in May of 2009 with entries for the point locations for the 4,039 CAFOs located within the state of North Carolina. The point locations are based on the farm's centralized latitude and longitude location. The database also includes the name and address of each hog CAFO.

Those permitted CAFOs not located in the eastern North Carolina region were not used for the research project. In all, 2,183 permitted CAFOs were used in the analysis. The floodplain data provides all of the floodplain designations for the state, the only data used for this research were floodplains designated as '100-year' within the eastern North Carolina region. The actual number of 100-year flood zones located in eastern North Carolina was not made explicit in the raster dataset.

Eight socioeconomic status (SES) variables were chosen for the research based on past environmental justice studies that have analyzed the siting of LULUs

² The US Census Bureau provides downloadable census data that can be uploaded via the website. See www.census.gov for more information.

³ Database can be obtained by contacting the Animal Feeding Operations Unit within the NC Division of Water Quality – website: <http://www.ncwaterquality.org> – Phone Number: (919) 715-6697.

⁴ Database can be obtained by contacting the NC Floodplain Mapping Program – Address: 1812. Tillery Place Suite 105 4719 Mail Service Center Raleigh, NC 27669 Phone Number: (919) 715-5711.

in disadvantaged communities (Been 1995; Mohai and Saha 2006; Oakes and Anderton and Anderson, 1996). Table 1 provides descriptions of all the variables used in the floodplain analysis. Three variables relating to race and ethnicity were chosen for the research. Percent black refers to the percentage of each block group's population consisting of African Americans in 2000. Percent Hispanic refers to the percent of each block group's population who identified as non-white Hispanics. Percent minority is the percent of nonwhite residents in each block group. One educational attainment variable was also chosen for the research, which was the percent with less than high school diploma. This variable refers to the block group's population that is 25 and older that has not completed high school. Also, four variables served as indicators for income. Per capita income refers to the 1999 income of each working person in each block group. Average household income refers to the 1999 entire household income for each household in each block group. Average housing value refers to the 1999 assessed value of each home in each block group. Lastly, percent working in a manufacturing occupation refers to the percent of the population in each block group ages 16 and older that are employed in a manufacturing occupation in 2000.

Table 1 - Variables used for floodplain analysis

Variable	Definition
CAFOs	Hog confined animal feeding operations (CAFOS) registered with the state of North Carolina
% Minority	Percent of nonwhite residents in a census block group. This was calculated by subtracting non-Hispanic whites from total persons and dividing by total persons (from 2000 Census)
% African American	Percent of block group residents identified as non-Hispanic black in 2000
% Hispanic	Percent of block group residents identified as Hispanic in 2000
Percent with less than high school diploma	Percent of population 25 years and over that did not complete high school by block group in 2000
Per capita income	Per Capita Income of Persons in 1999
Average household income	Average household income by block group in 1999
Average housing value	Average housing value by block group in 1999
Percent with manufacturing occupation	Percent of population 16 years and over that are employed in a manufacturing occupation in 2000

Analysis

Comparison of State and County-Level Demographics

The first step of the floodplain analysis was to find the demographic information for the eight variables of interest for the state of North Carolina, the eastern North Carolina counties, and the counties located inside the 100-year flood zone. This information was helpful to understand the demographics of the region of

eastern North Carolina in comparison to the state figures. The percentages for each variable were calculated using the website, Social Explorer, a site with multiple reports and maps of census data. The North Carolina state percentages were calculated using statewide percentages for North Carolina. Thirty-seven counties were designated as the eastern North Carolina region. Of those counties, 20 were found to have CAFOs sited in the 100-year flood zone, and the other 17 did not have CAFOs sited inside the 100-year flood zone. The three categories were eastern North Carolina region (n=37), counties with CAFOs sited in the 100-year floodplain (N=20), and counties without CAFOs sited in the 100-year floodplain (n=17). The aggregate value was found for each variable of interest in each category.

Spatial Analysis of Distribution of CAFOs

The floodplain and CAFO databases, along with census block group data for each of the eight explanatory variables was imported into ArcGIS 10 for spatial and statistical analyses. The data were clipped only to the eastern North Carolina geographic region. As mentioned earlier, the CAFO database presents the locations of each CAFO in eastern North Carolina as a point, which represents the CAFO's centroid; therefore these points were easy to upload for spatial analysis into ArcGIS. In order to observe the distribution of CAFOs inside the 100-year floodplain and those CAFOs not inside the 100-year floodplain, two criteria were chosen in ArcGIS of 'inside' and 'not inside'. The ArcGIS function 'select by location' was used to select those CAFOs located inside the 100-year flood zone (see Figure 2), and then again

selected those located not inside the 100-year flood zone (see Figure 3). A total of 81 CAFOs were located 'inside' and 1,864 CAFOs were located 'not inside'.

Figure 2 - Map of Hog CAFOs Located in the 100-year Flood Zone

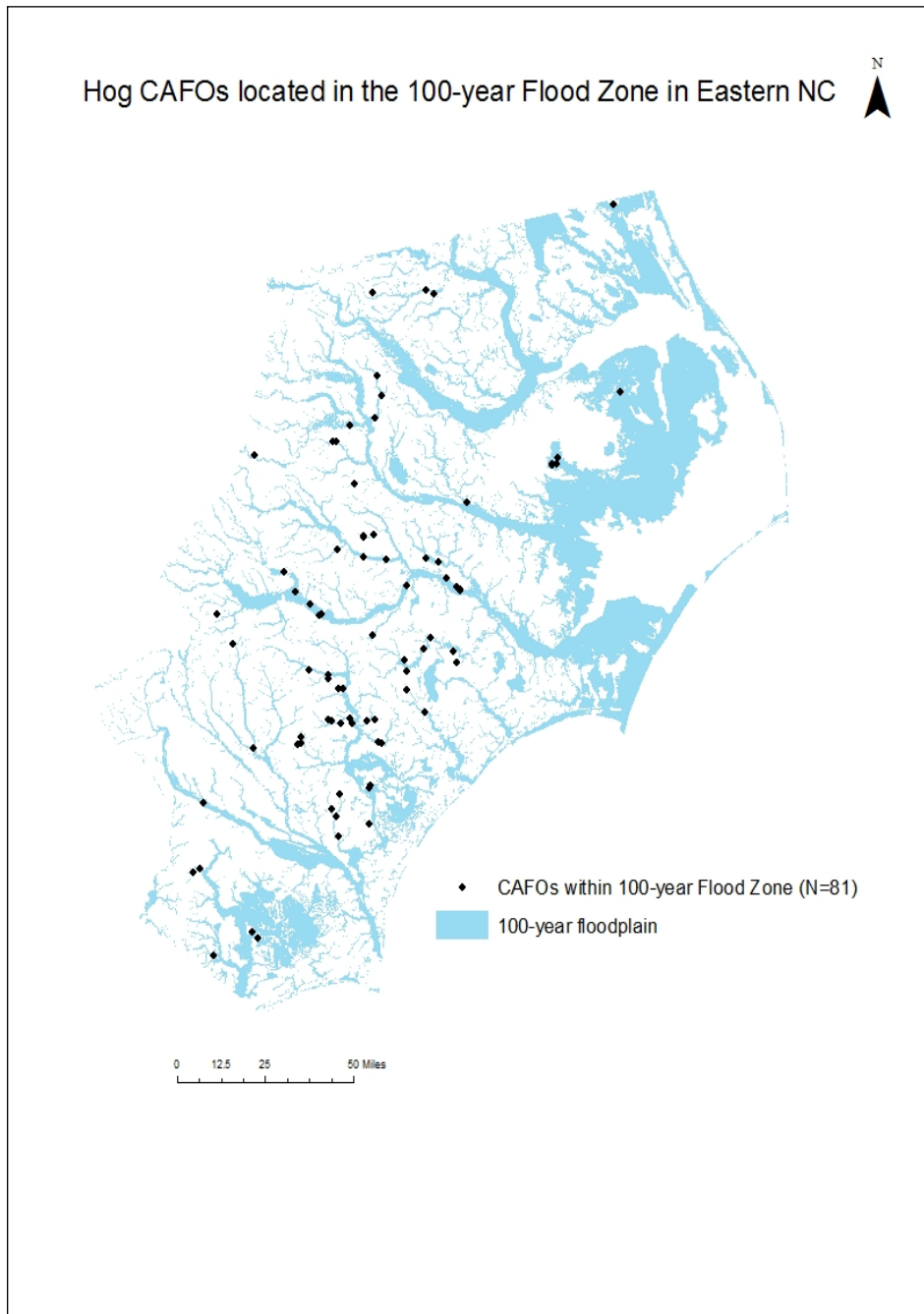
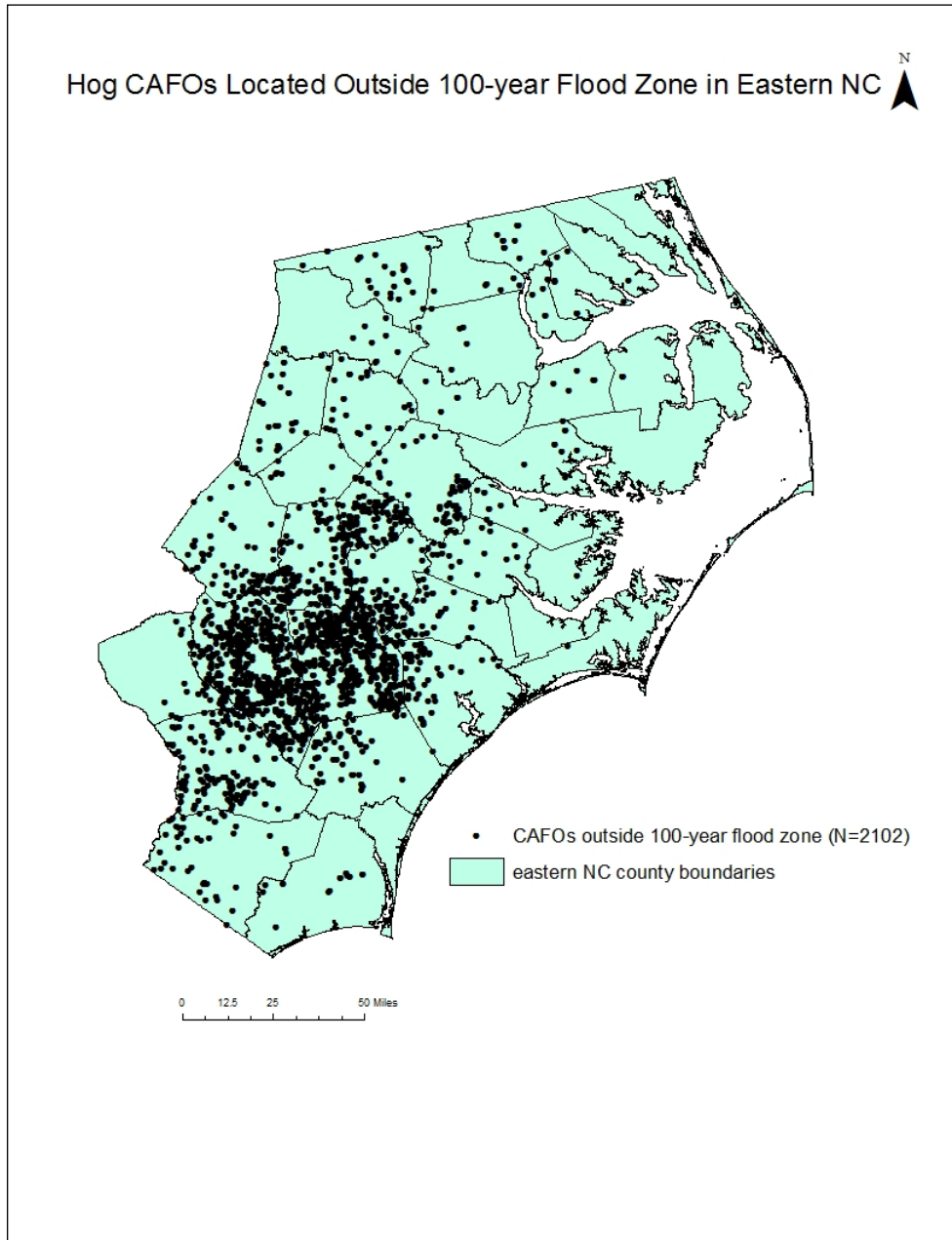


Figure 3 - Map of Hog CAFOs Located Not Inside the 100-year Flood Zone



Hot Spot Analyses

After importing the data into ArcGIS, the first statistical analysis performed on the data involved utilizing the Hot Spot Analysis tool for each of the eight variables in each 2000 block group in eastern North Carolina. Performing a Hot Spot Analysis calculates the Getis-Ord G_i^* statistic for a feature in a dataset. A Z score is the result, and it indicates whether high or low values cluster spatially. Those areas with a variable having > 2.58 standard deviations above the mean are color-coded in red, and those areas with a variable having < -2.58 standard deviations above the mean are color-coded in blue. These findings were then geographically displayed on a map with the CAFO location file overlaid on top of this output. As the name suggests, this analysis tool was helpful to spatially indicate areas where greater or lesser percentages of the variables of interest congregated throughout eastern North Carolina. Further, it was also helpful to distinguish any patterns of CAFO sites in “hot spot” areas for each of the variables of interest.

Comparative Demographic Analyses

Circular buffers were drawn around each of the ‘inside’ and ‘not inside’ the 100-year flood zone CAFOs in order to perform a distance-based analysis of the chosen census variables. These radii were chosen based on prior environmental justice research using buffers at the one and three-mile levels for assessing demographic disparities of LULUs (Mohai and Saha, 2006). By using this type of

methodology, one can analyze how the overall demographics around CAFOs change with varying distances.

Areal Apportionment Method

Census data research performed in the field of environmental justice sometimes applies the areal apportionment method to calculate population characteristics within certain distances of hazardous sites (Mohai and Saha, 2006). Using this method, every block group that was at least partially inside the specified one and three-mile circular radii was given weight in the analysis. For example, if a three-mile circular buffer around a CAFO captured 30 percent of a census block, then only 30 percent of its population is used for the analysis. This reduces the risk that any unit over or under influences the estimated demographic characteristics within a given distance of a CAFO.

After defining the block groups contained by the one- and three-mile buffers around the two groups of CAFOs, the next step was to compare the demographic characteristics of populations living within these distances of a CAFO. In order to make these comparisons, the zonal statistics function in ArcGIS was utilized, which calculates many common statistics for designated zones of a raster grid. In this case, the term 'zone' refers to the block groups located within the circular buffers. Zonal statistics was used to calculate the means of the eight variables of interest in each block group contained in the circular buffers. The zonal statistics function created

output tables of the means for each of the variables in each buffer. These output tables were created for 'inside' and 'not inside'.

The zonal statistics tables were used to generate independent samples t-tests to compare the means of the census variables for inside the 100-year flood zone and not inside the 100-year flood zone. These comparisons were made for each of the circular buffer radii of one and three-miles. All of the statistical analysis for the research was calculated using the statistical software, SPSS.

CHAPTER 4 – FLOODPLAIN ANALYSIS RESULTS

This section details the results of the floodplain analysis for the demographics comparing the state of North Carolina and eastern North Carolina counties, hot spot analysis, and independent samples t-tests. These analyses were performed in order to answer the research question: are there more low-income, minority, low-education groups living near CAFOs sited inside the 100-year flood zone as compared to those demographics near CAFOs not inside of the 100-year flood zone?

Data were collected for the census variables of interest on the state level, eastern North Carolina county level, eastern North Carolina counties with CAFOs sited in the 100-year flood zone, and the eastern North Carolina counties with CAFOS not inside the 100-year flood zone (see Table 2).

Table 2 - Demographics on State, County, and Flood Zone Level

Variables	State of North Carolina	Eastern NC Counties (Aggregated)	Eastern NC Counties hosting CAFOs inside the 100-year flood zone (Aggregated)	Eastern NC Counties with no CAFOs sited inside the 100-year flood zone (Aggregated)
Total Population	8,049,313	2,105,217	1,265,691	839,526
Percent White	70.2%	62.7%	62.8%	62.4%
Percent Black	21.4%	29.9%	29.7%	30.3%
Percent Hispanic	4.7%	4.5%	4.9%	4.0%
American Indian/Alaska Native	1.2%	0.7%	0.7%	0.8%
Asian	1.4%	0.8%	0.7%	1.0%
Native Hawaiian/Pacific Islander	0.1%	0.1%	0.1%	0.1%
Some other Race Alone	0.0%	0.1%	0.1%	0.1%
Two or more Races	1.0%	1.2%	1.0%	1.4%
Percent with less than high school diploma	21.9%	22.8%	24.8%	19.9%
Average Household Income (in 1999)	\$51,224	\$44,458	\$42,959	\$46,667
Per capita income	\$20,307	\$17,481	\$16,771	\$18,551
Average housing Value	\$95,800	\$81,633	\$76,818	\$88,445
Percent working in manufacturing occupation	19.80%	15.2%	16.40%	13.40%

The data suggests there are lower percentages of whites for the three eastern North Carolina categories compared to the overall state percentage. Also, the average household income and per capita income levels are lower in the three

eastern North Carolina categories compared to the state percentage. The percent black is also higher in the three eastern North Carolina categories compared to the state percentage. Next, the property values for the state are higher than any of the three eastern North Carolina categories. Compared to the statewide percentages, there are higher percentages of black and those with less than a high school diploma in the eastern North Carolina region. Further, there are lower percentages for white, those employed in a manufacturing occupation, and lower income levels in eastern North Carolina as compared to the statewide percentages. There are few differences in variables' percentages for eastern North Carolina counties with CAFOs inside the 100-year flood zone compared to eastern North Carolina counties with CAFOs not inside the 100-year flood zone. However, on the whole, counties with CAFOs in the 100-year flood zone comprise a lower household income, per capita income, and overall housing value. Also there is a higher percentage of those who did not complete high school in counties with CAFOs inside the 100-year flood zone when compared to those counties with CAFOs not inside the 100-year flood zone.

Hot Spot Analysis

The Hot Spot Analysis function in ArcGIS was used to calculate the standard deviation above and below the mean for each of the variables used in the analysis for 1990 and 2000 (see Figure 4 through Figure 19). Other methods of ranging the data might produce different results; that is a topic for future consideration. Maps were created to show the CAFO points located inside the 100-year flood zone, and

also to show the CAFOs not inside the 100-year flood zone. The percent minority, percent Hispanic, percent with less than high school diploma, and percent employed in a manufacturing occupation seemed to show a pattern of increased percentages (those areas in red) spatially corresponding to the CAFO points sited inside the 100-year flood zone. Per capita income and average housing value seemed to show a pattern of decreased percentages/values (those areas in blue) spatially corresponding to the CAFO points sited inside the 100-year flood zone.

Figure 4 - Hot Spot Analysis - Percent Black Inside the 100-year Flood Zone

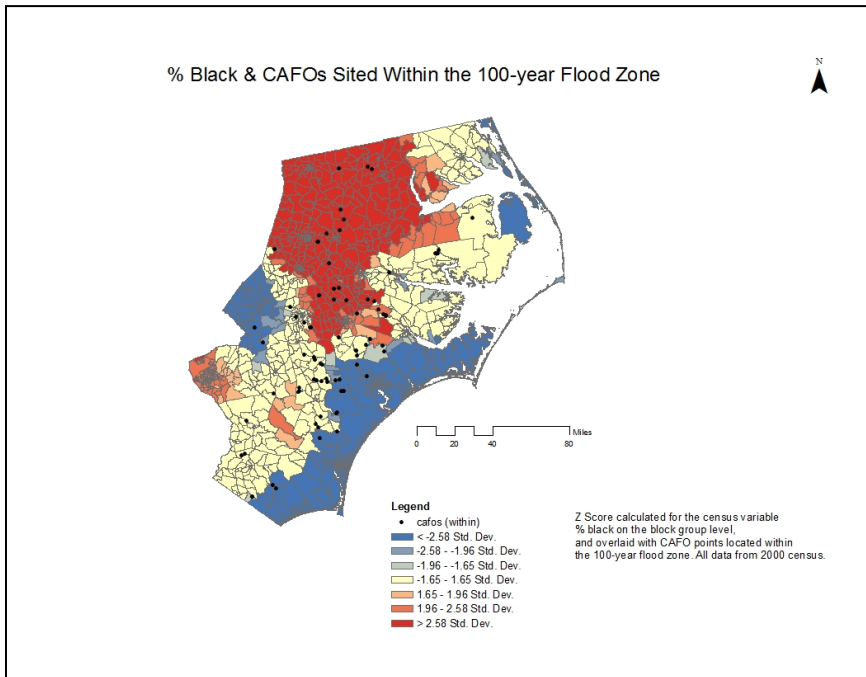


Figure 5 - Hot Spot Analysis - Percent Black Not-Inside the 100-year Flood Zone

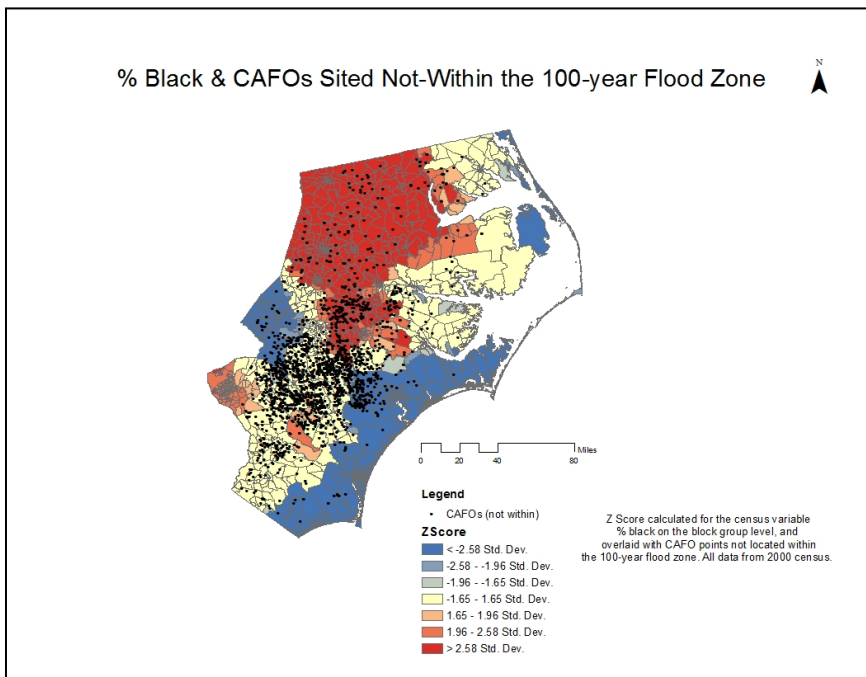


Figure 6 - Hot Spot Analysis - Percent Hispanic Inside the 100-year Flood Zone

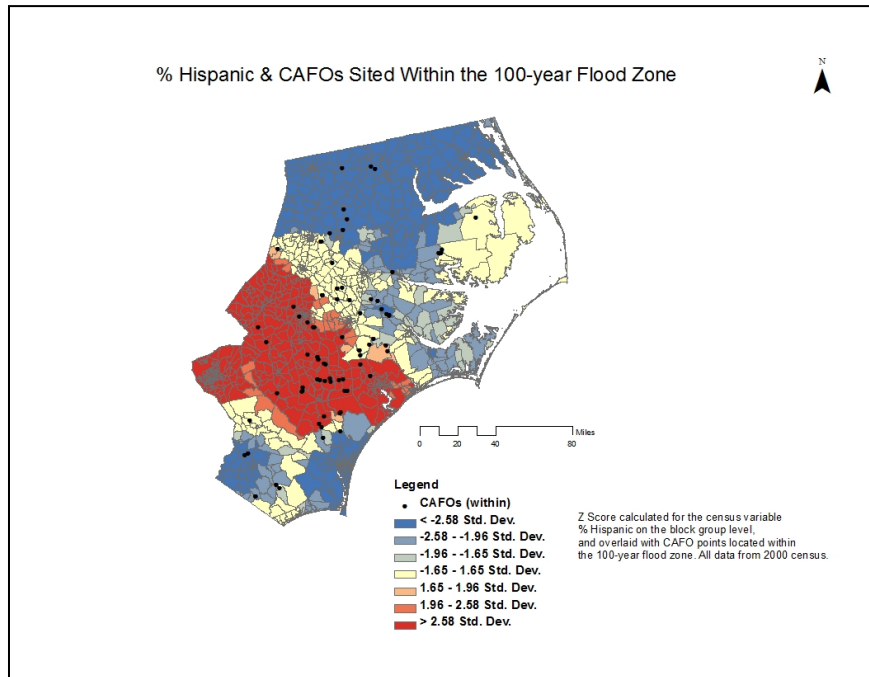


Figure 7 - Hot Spot Analysis - Percent Hispanic Not-Inside the 100-year Flood Zone

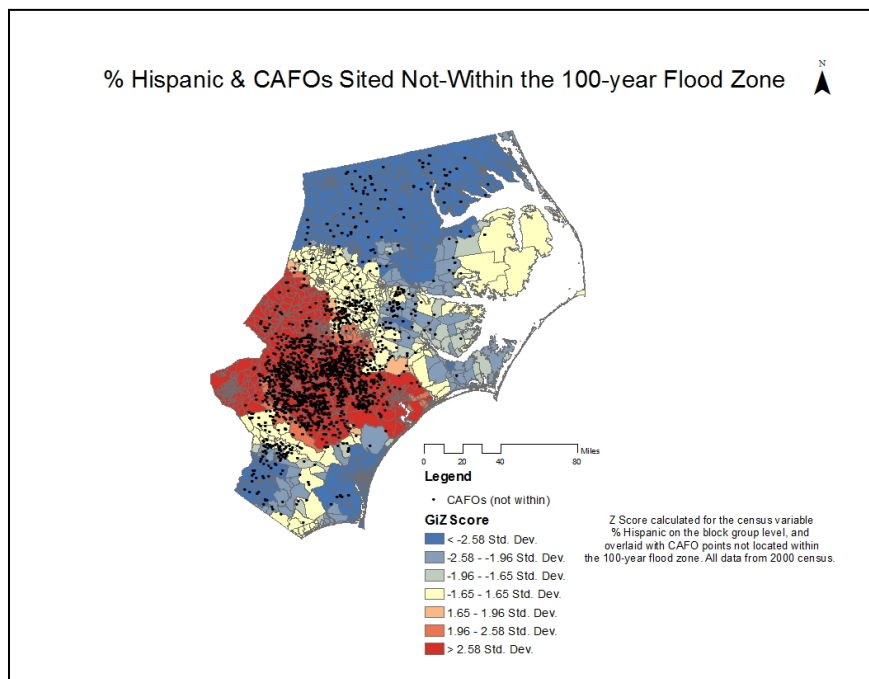


Figure 8 - Hot Spot Analysis - Percent Minority Inside the 100-year Flood Zone

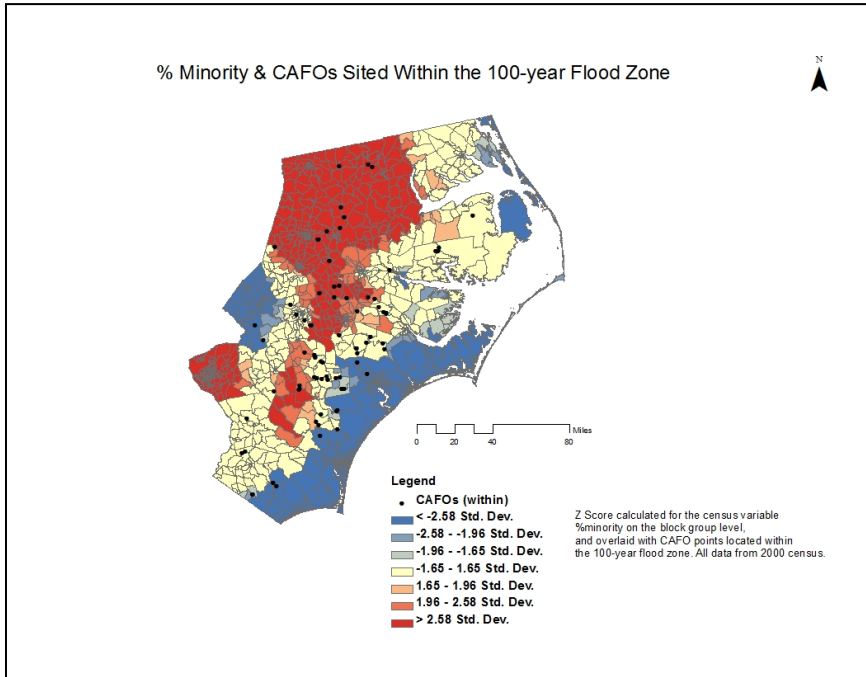


Figure 9 - Hot Spot Analysis - Percent Minority Not-Inside the 100-year Flood Zone

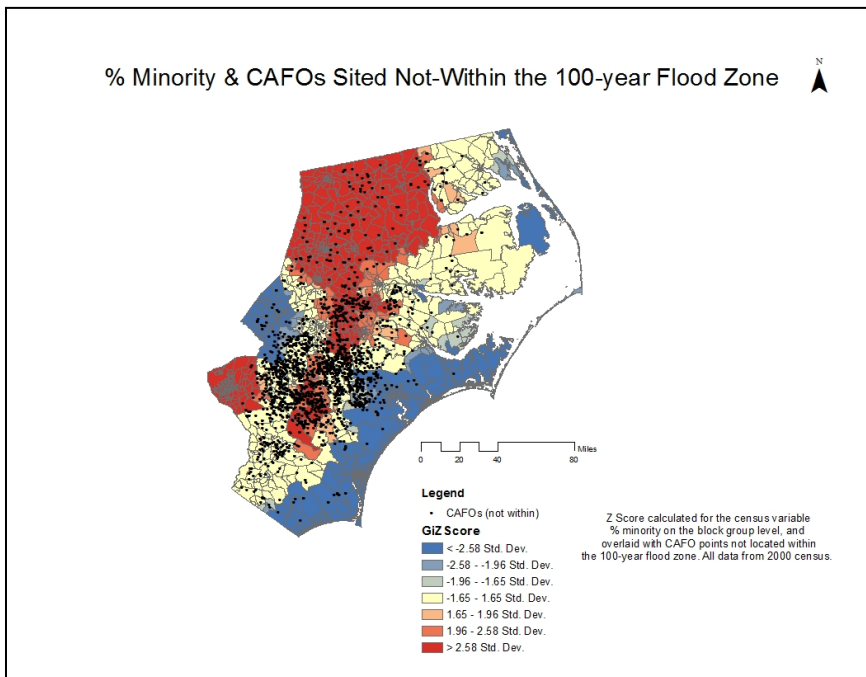


Figure 10 - Hot Spot Analysis - Percent Receiving Less than High School Diploma Sited Inside the 100-year Flood Zone

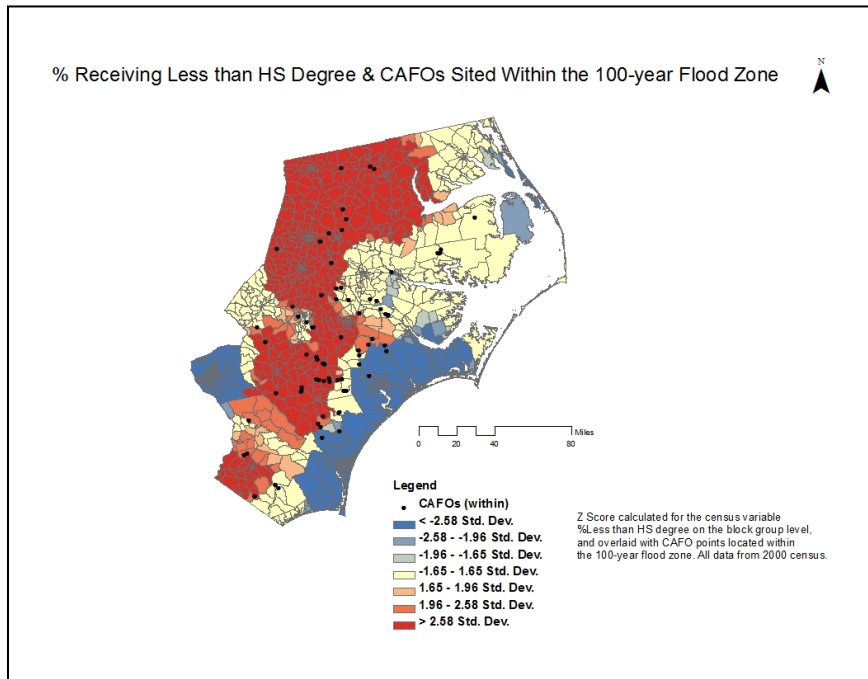


Figure 11 - Hot Spot Analysis - Percent Receiving Less than High School Diploma Sited Not-Inside the 100-year Flood Zone

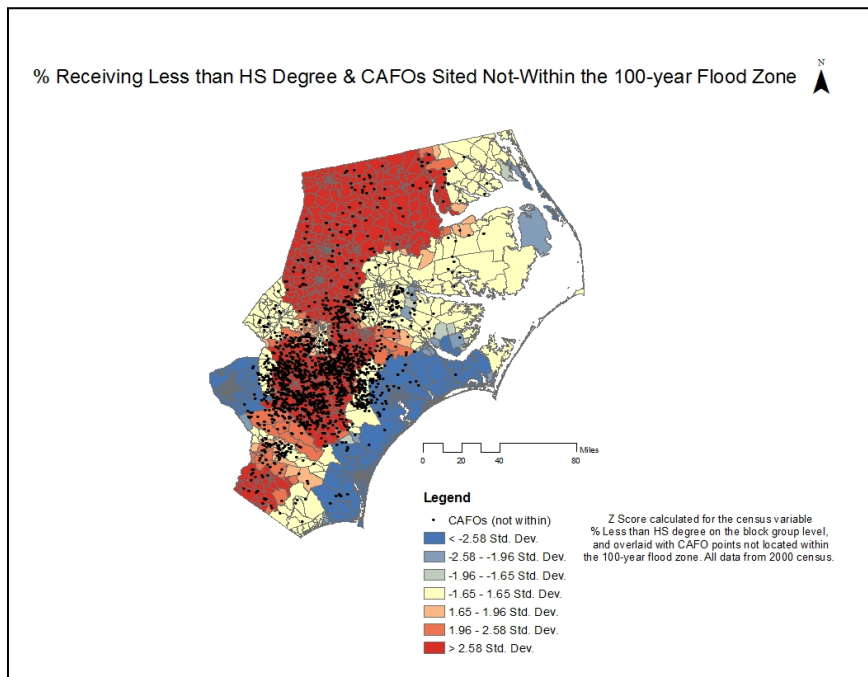


Figure 12 - Hot Spot Analysis - Percent Manufacturing Occupation Inside the 100-year Flood Zone

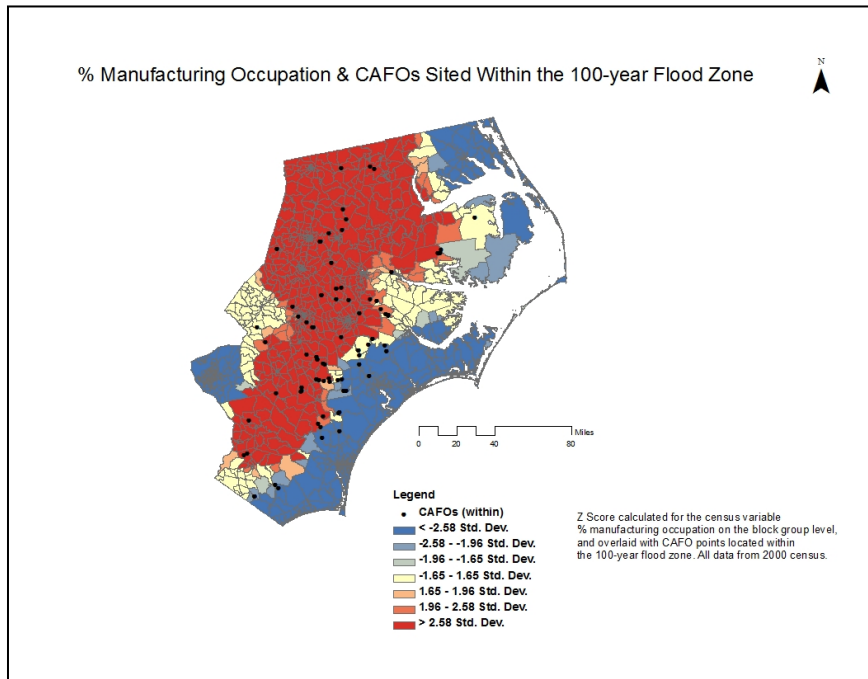


Figure 13 - Hot Spot Analysis - Percent Manufacturing Occupation Not-Inside the 100-year Flood Zone

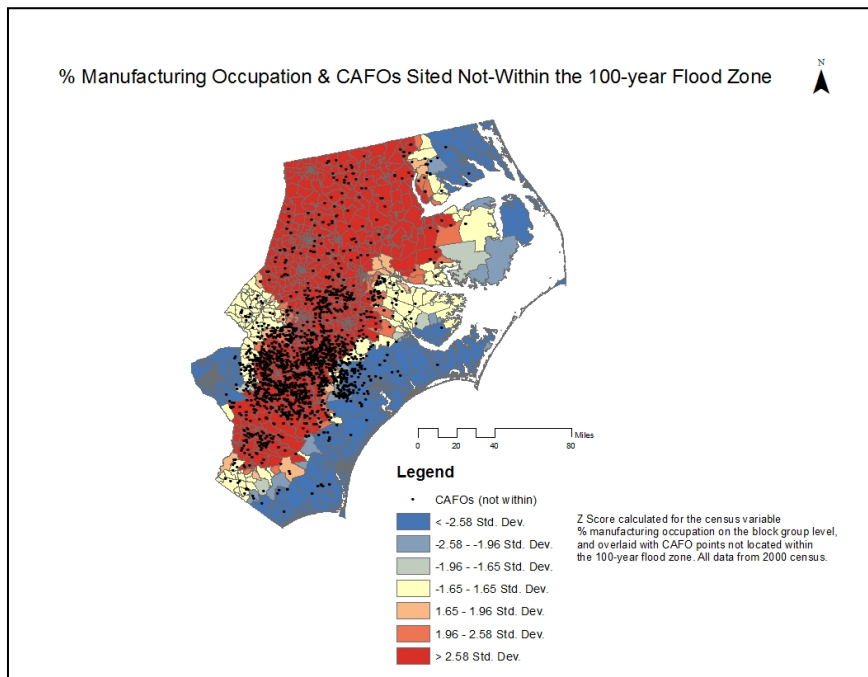


Figure 14 - Hot Spot Analysis - Per Capita Income Inside the 100-year Flood Zone

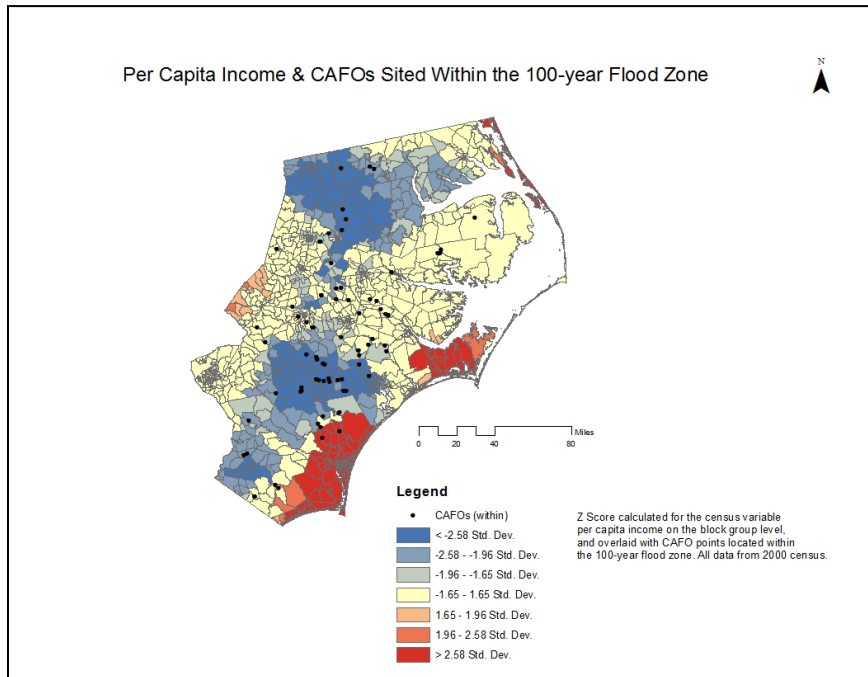


Figure 15 - Hot Spot Analysis - Per Capita Income Sited Not-Inside the 100-year Flood Zone

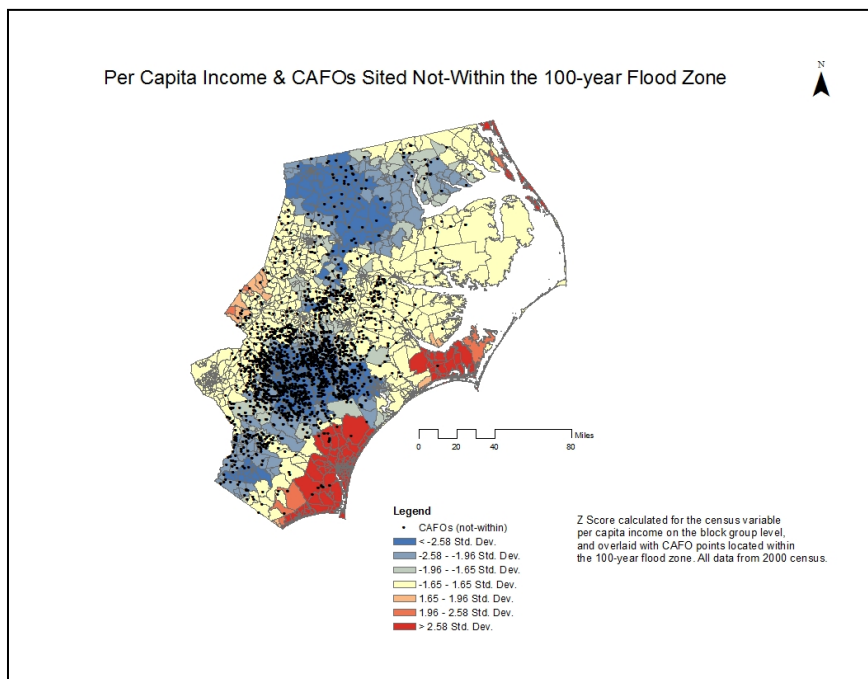


Figure 16 - Hot Spot Analysis - Average Household Income Inside the 100-year Flood Zone

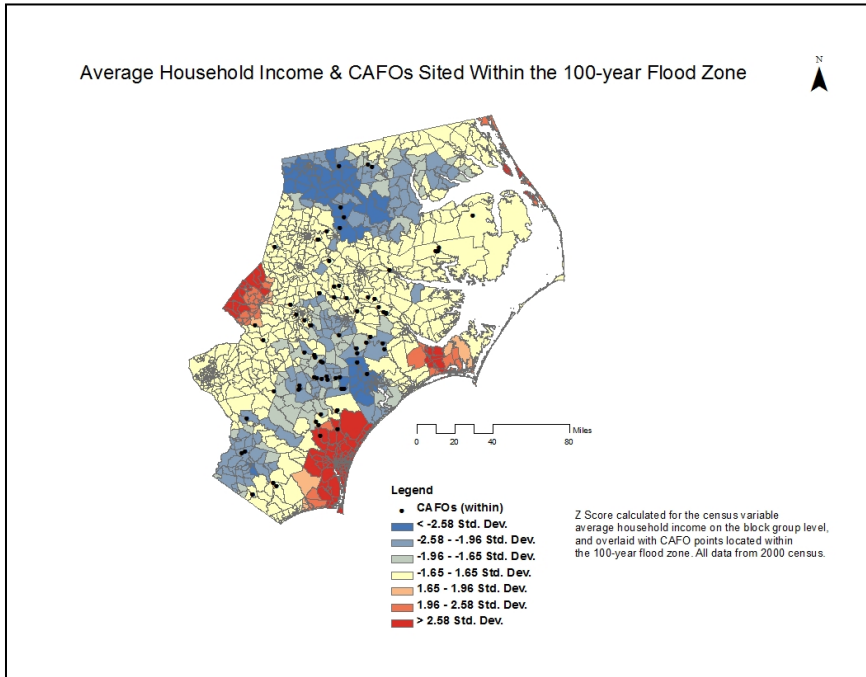


Figure 17 - Hot Spot Analysis - Average Household Income Not-Inside the 100-year Flood Zone

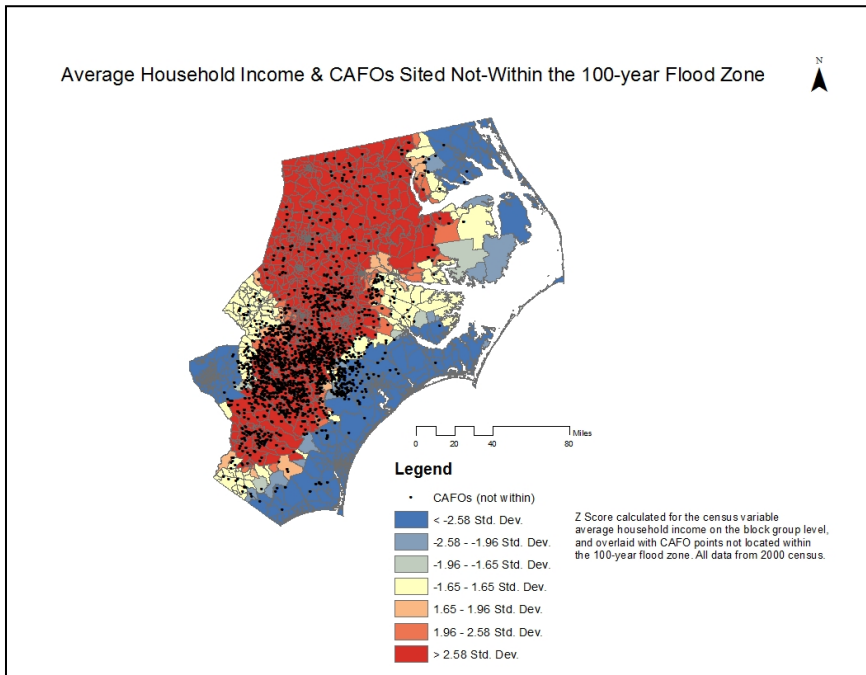


Figure 18 - Hot Spot Analysis - Average Household Value Inside the 100-year Flood Zone

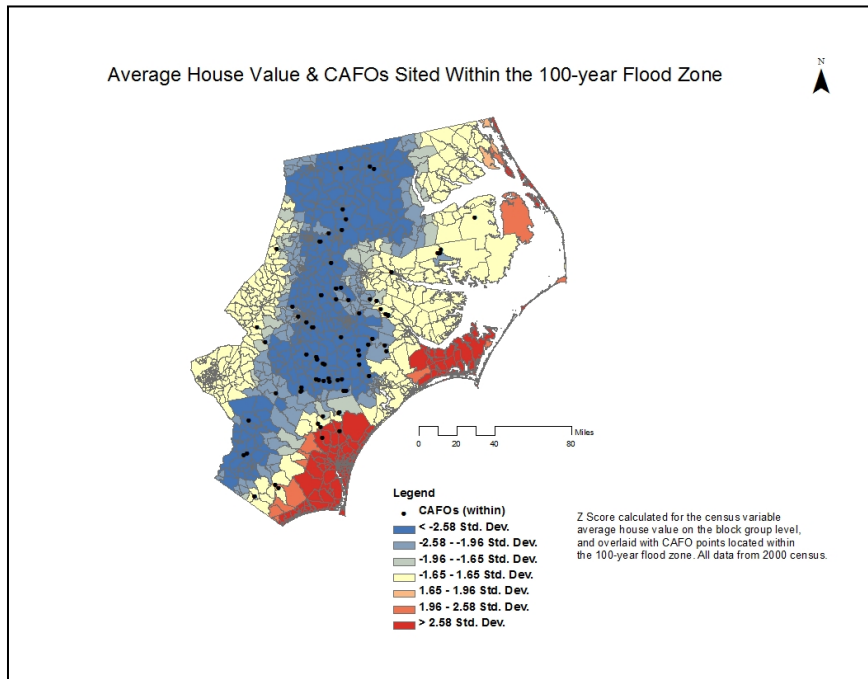
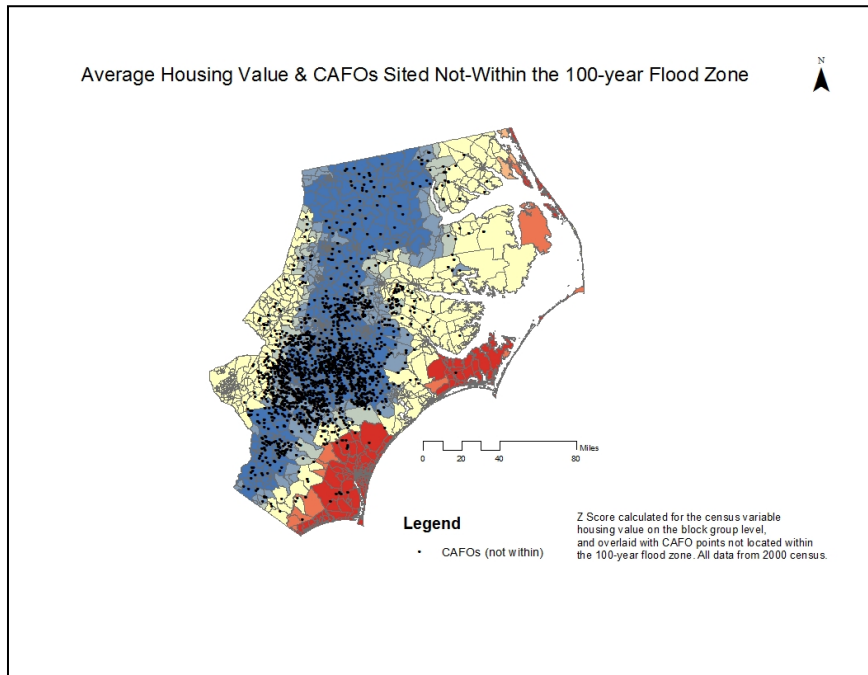


Figure 19 - Hot Spot Analysis - Average Household Value Not-Inside the 100-year Flood Zone



T-Test Results

Independent samples t-tests were conducted to compare the means of the eight census variables within a one-mile radius of the CAFOs inside the 100-year flood zones and not inside the 100-year flood zones (see Table 3). T-tests were similarly conducted for the areas within a three-mile radius around the CAFOS inside and not inside the 100-year flood zones (see Table 4).

For the one-mile radii, the t-test results only show statistically significant differing means for percent Hispanic (see Table 3). However, the mean for percentage Hispanic in the one-mile buffer around CAFOs not inside the 100-year flood zone was greater than the one-mile buffer around CAFOs inside the 100-year flood zones. These findings do not support the original hypothesis that increased percentages of minority populations will be found near CAFOs inside the 100-year flood zone as compared to minority populations around CAFOs not inside the 100-year flood zone. At the three-mile radius, t-test results also show statistically significant differing means for percent Hispanic (see Table 4). The percent Hispanic mean was greater within the three-mile buffers around the CAFOs not inside the 100-year flood zones than within the three-mile buffers around the CAFOs. As a result, this does not support the original hypothesis that greater percentages of minority populations would live near CAFOs inside the 100-year flood zone.

Table 3 - Flood Zone T-Test Results Comparing One Mile Buffer

Variable	Mean of One Mile Buffer Inside 100- year Flood Zone	Mean One Mile Buffer Not Inside 100-Year Flood Zone	Mean Percent Difference	t stat	Sig.
Percent black	32.259	28.861	3.398	1.662	.237
Percent Hispanic	5.260	9.219	-3.959	-39.8	.000
Percent minority	37.223	37.217	.006	.003	.913
Percent with less than high school diploma	29.812	30.992	-1.18	-1.567	.744
Percent manufacturing occupation	18.436	20.664	-2.228	-2.791	.922
Per capita income	\$15,373.35	\$15,163.55	\$209.80	.682	.129
Average household income	\$45,215.96	\$45,194.41	\$21.55	.024	.418
Average housing value	\$74,990.79	\$75,101.31	\$-110.52	-.063	.905

Table 4 - Flood Zone T-Test Results Comparing Three Mile Buffer

Variable	Mean Three Mile Within 100-year Flood Zone	Mean Three Mile Not inside 100- Year Flood Zone	Mean Percent Difference	t stat	Sig.
Percent black	32.128	28.843	3.285	1.798	.090
Percent Hispanic	5.614	9.280	-3.666	-5.623	.000
Percent minority	37.280	37.052	0.228	.126	.440
Percent with less than high school diploma	30.191	30.960	-0.769	-1.275	.880
Percent manufacturing occupation	18.523	20.595	-2.072	-3.049	.897
Per capita income	\$15,232.52	\$15,193.62	\$38.90	.164	.911
Average household income	\$44,730.50	\$45,281.35	\$-550.85	-.783	.391
Average household value	\$75,247.27	\$75,219.06	\$28.21	.020	.786

CHAPTER FIVE – LONGITUDINAL ANALYSIS

Data and Methods

This portion of the thesis analyzes demographics of race, income, and education variables near CAFOs in eastern North Carolina on the census tract level for the years 1990 and 2000. These demographics are then compared to the same demographic variables located around randomly generated points in eastern North Carolina. To do this, census tracts within a one and three-mile radii of CAFOs are compared to one and three-mile radii around randomly generated points.

Research Setting

The research setting used for the longitudinal analysis was the same for the floodplain analysis. Please refer back to page 31 for a description of the research setting.

Data

The CAFOs database used in the floodplain analysis was also used for this longitudinal analysis. Please refer back to page 33 for a description of this data. 1990 and 2000 tract level census data was collected from Social Explorer⁵ for eight socioeconomic variables based on race, income, and education. These variables

⁵ Social Explorer is a web application that offers reports based on census data from 1790-2010. Website: <http://www.socialexplorer.com/pub/home/home.aspx>

were chosen based on prior studies in environmental justice research assessing demographic disparities in conjunction with the siting of LULUs. Please refer back to page 33 for a more detailed description of this information. The reader should note that all of the variables used in the floodplain analysis were used for the longitudinal analysis except for the omission of percent manufacturing occupation and the addition of percent receiving public assistance income (see Table 5). Both of these variables serve as an indicator for socioeconomic status, but the author was more interested in analyzing percent receiving public assistance income for the longitudinal analysis because it offers more of an explanation about overall poverty, and by extension, a census tract's overall income level.

Analyses

The first step of the longitudinal analysis was to collect data for the variables of interests on the state and county levels in 1990 and 2000. These percentages were calculated using the website, Social Explorer, to aggregate the state and eastern North Carolina county percentages and values for race, income, and education variables of interest. The variables were calculated for the county category by aggregating the percentage or value for the 37 counties used in the analysis to represent the eastern North Carolina region.

The second step of the longitudinal analysis was importing the CAFOs database into ArcGIS 10 and converting it into a file that showed the CAFOs as point locations. Please refer back to page 36 for more information about this process. A

number of CAFOs were located within three miles of the edges of the eastern North Carolina polygon, and those CAFOs were excluded from the analysis because census data was only collected for the eastern North Carolina region and not outlying regions. Due to this constraint, 1,898 CAFOs were used for the analysis and 285 CAFOs were excluded from the longitudinal analysis (see Figure 20). In order to compare the demographics in areas near CAFOs to the demographics of areas not located near CAFOs, 2,000 random points were generated within eastern North Carolina using ArcGIS software (see Figure 21). Similarly, 106 random points were located on the edge of the eastern North Carolina polygon, so they were excluded from the analysis. In all 1,894 random points were generated for comparison with the CAFO points.

Census tract data for 1990 and 2000 were then imported into ArcGIS and appended to a boundary map file of the 1990 and 2000 census tract boundaries in eastern North Carolina. The variables were then converted to raster⁶ data, and the CAFO points and random points were layered over the rastered variables. Circular buffers of one- and three-mile radii were then drawn around the CAFO and random points.

Hot Spot Analyses

⁶ Raster data consists of a grid of rows and columns with each cell containing a value representing information.

The first statistical analysis performed on the data involved generating hot spot analyses, on the census tract level for both 1990 and 2000, for the eight variables of interest. The results were then mapped with the CAFO location file and the eastern North Carolina boundary file. For a more detailed description of the Hot Spot Analysis process refer to page 39.

Table 5 - Demographic Variables Used in Longitudinal Analysis

Variable	Definition
CAFOs	hog confined animal feeding operations (CAFOS) registered with the state of North Carolina
Percent minority	Percent of nonwhite residents in a census tract. Calculated by subtracting non-Hispanic whites from total persons and dividing by total persons (in 1990 and 2000)
Percent black	Percent of block group residents identified as non-Hispanic black in 1990 and 2000
Percent Hispanic	Percent of block group residents identified as Hispanic in 1990 and 2000
Average household income	Average household income by census tract in 1990 and 2000
Percent with high school diploma	Percent of population 25 years and over that completed only high school (including equivalency) by census tract in 1990 and 2000
Per capita income	Per Capita Income of Persons in 1990 and 2000
Percent receiving public assistance income	Percent of households receiving public assistance in 1989 and 1999
Average housing value	Average value for all owner-occupied housing units

Comparative Demographic Analysis

Please refer to page 40 of the thesis for a detailed overview of how areal apportionment and zonal statistical methods were used to compare the buffered

radii around the CAFO points and the buffered radii around the randomly generated points.

Independent samples t-tests were generated to compare the means of the variables located within the one-mile and three-mile circular buffers around the CAFOs to the means of the variables located with the one-mile and three-mile circular buffers around the randomly generated points. Grouping variables of '1' (CAFO point) and '0' (random point) were assigned to each of the variables. T-tests were conducted to identify if there is a statistically significant difference between demographics located near CAFOs and the demographics of those not located near CAFOs. Logistic regression models were also developed to weigh the relative importance of variables in predicting the occurrence of living near a CAFO. All of the statistical analysis for the research was performed using SPSS and ArcGIS.

Figure 20 - Map of Hog CAFOs in Eastern North Carolina

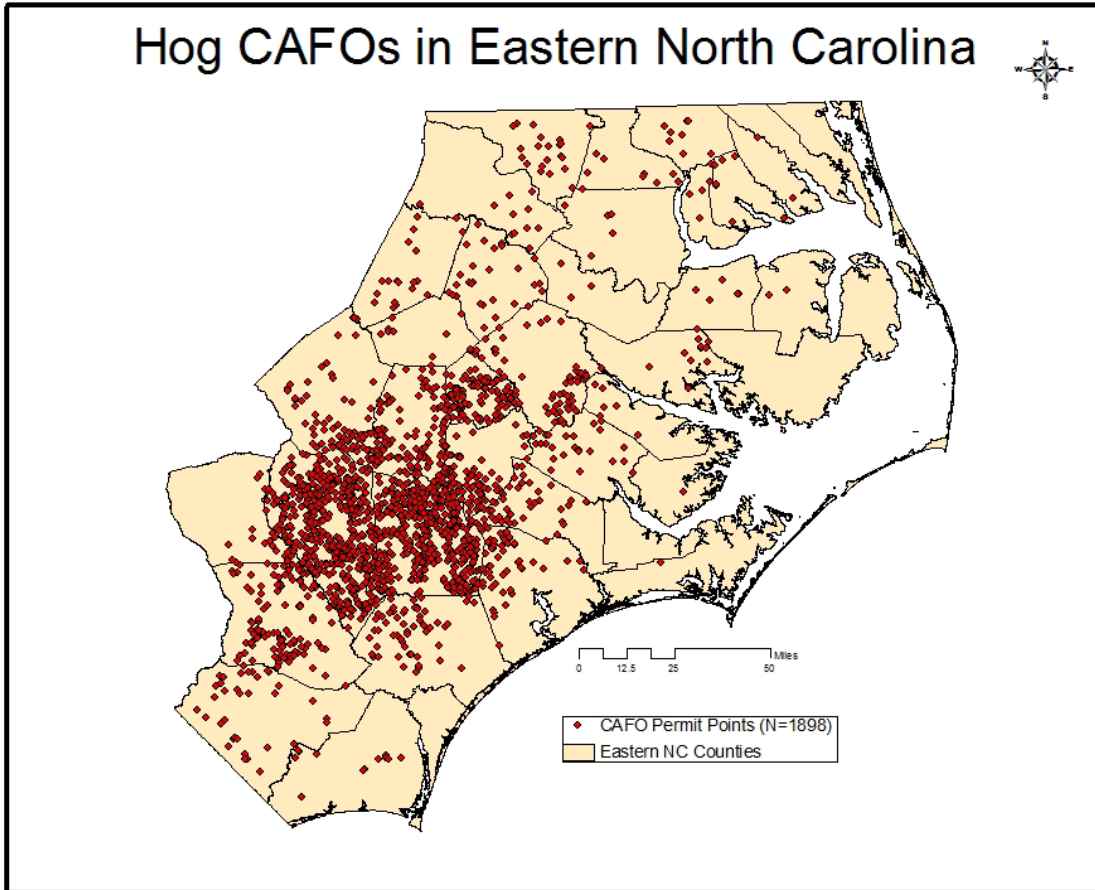
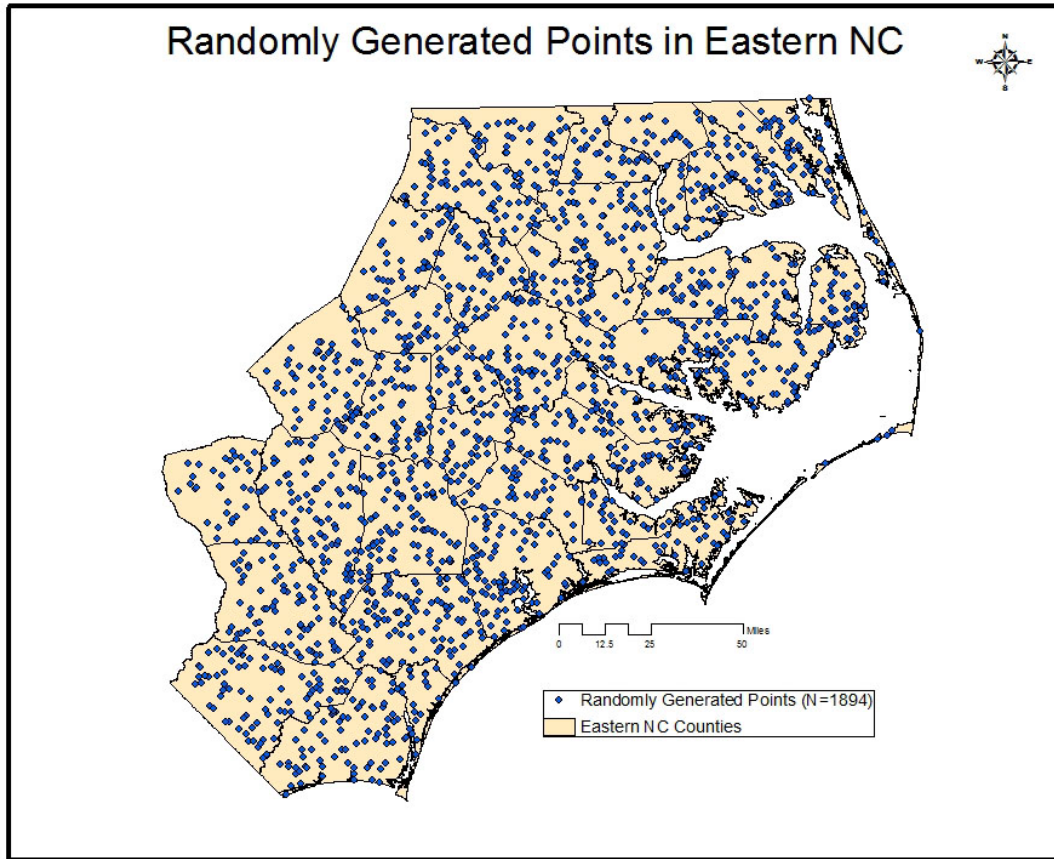


Figure 21 - Map of Randomly Generated Points in Eastern North Carolina



CHAPTER SIX – LONGITUDINAL ANALYSIS RESULTS

Values for each of the variables were calculated for both 1990 and 2000 for the state of North Carolina and the 37 eastern North Carolina counties (see Table 6 and Table 7). In 1990, the percent white, average household income, per capita income, and average housing value were all lower for the eastern North Carolina counties aggregate than for the corresponding 1990 state level average. The percent black and percent Hispanic were all higher for the eastern North Carolina counties aggregates than for the corresponding 1990 state level averages. In 2000, as shown in Table 7, the percent white, average household income, per capita income, and average housing value were all lower for the eastern North Carolina counties aggregates than for the corresponding 2000 state level averages. The percent black and percent receiving less than high school diploma were all higher for the eastern North Carolina counties aggregates than for the corresponding 1990 state level aggregates.

Table 6 - 1990 Demographic Data for North Carolina and Eastern North Carolina Counties

Variables	North Carolina State Level Aggregates	Eastern North Carolina Counties Aggregates
Total Population	6,628,637	1,827,667
Percent white	75.0%	65.80%
Percent black	21.9%	30.90%
Percent Hispanic	1.2%	1.90%
American Indian/Alaska Native	1.2%	0.70%
Asian	0.8%	0.70%
Some other Race Alone	0.0%	0.10%
Percent with less than high school diploma	30.0%	30.90%
Average household income	\$33,242.00	\$29,166.00
Per capita income	\$12,885.00	\$11,084.00
Percent receiving public assistance	13.0%	13.10%
Average housing value	\$65,300	\$58,497

Table 7 - 2000 Demographic Data for North Carolina and Eastern North Carolina

Variables	North Carolina State Level Aggregates	Eastern North Carolina Counties Aggregates
Total Population	8,049,313	2,105,217
Percent white	70.2%	62.7%
Percent black	21.4%	29.9%
Percent Hispanic	4.7%	4.5%
American Indian/Alaska Native	1.2%	0.7%
Asian	1.4%	0.8%
Some other Race Alone	0.1%	0.1%
Percent with less than high school diploma	0.0%	0.1%
Average household income	28.5%	27.2%
Per capita income	15.3%	17.1%
Percent receiving public assistance	\$51,224.00	\$44,458.00
Average housing value	\$20,307.00	\$17,481.00

Hot Spot Analysis

The Hot Spot Analysis function in ArcGIS was used to calculate the standard deviation above and below the mean, on the census tract level, for each of the variables used in the analysis for 1990 and 2000 (see Figure 22 to Figure 35). These standard deviation scores were then overlaid with CAFO points. This exploratory analysis suggests that in 2000, the variables for percent Hispanic and percent receiving less than high school diploma seem to correlate in the hypothesized direction, with the most concentrated siting of CAFOs in the southwest portion of eastern North Carolina. In 1990, the variables of percent receiving less than high school diploma, average household income, and per capita income seem to also correlate, in the hypothesized direction, with the largest concentration of CAFOs in eastern North Carolina. The findings also suggest that by 2000, the percentages of Hispanics living near high concentrations of hog CAFOs had also increased. Although this portion of the analysis only served as an exploratory assessment of spatial demographic and CAFO trends, the findings indicate that the bivariate analysis will present statistically significant outcomes in the hypothesized direction.

Figure 22 - Hot Spot Analysis of 1990 Average Family Income and CAFOs

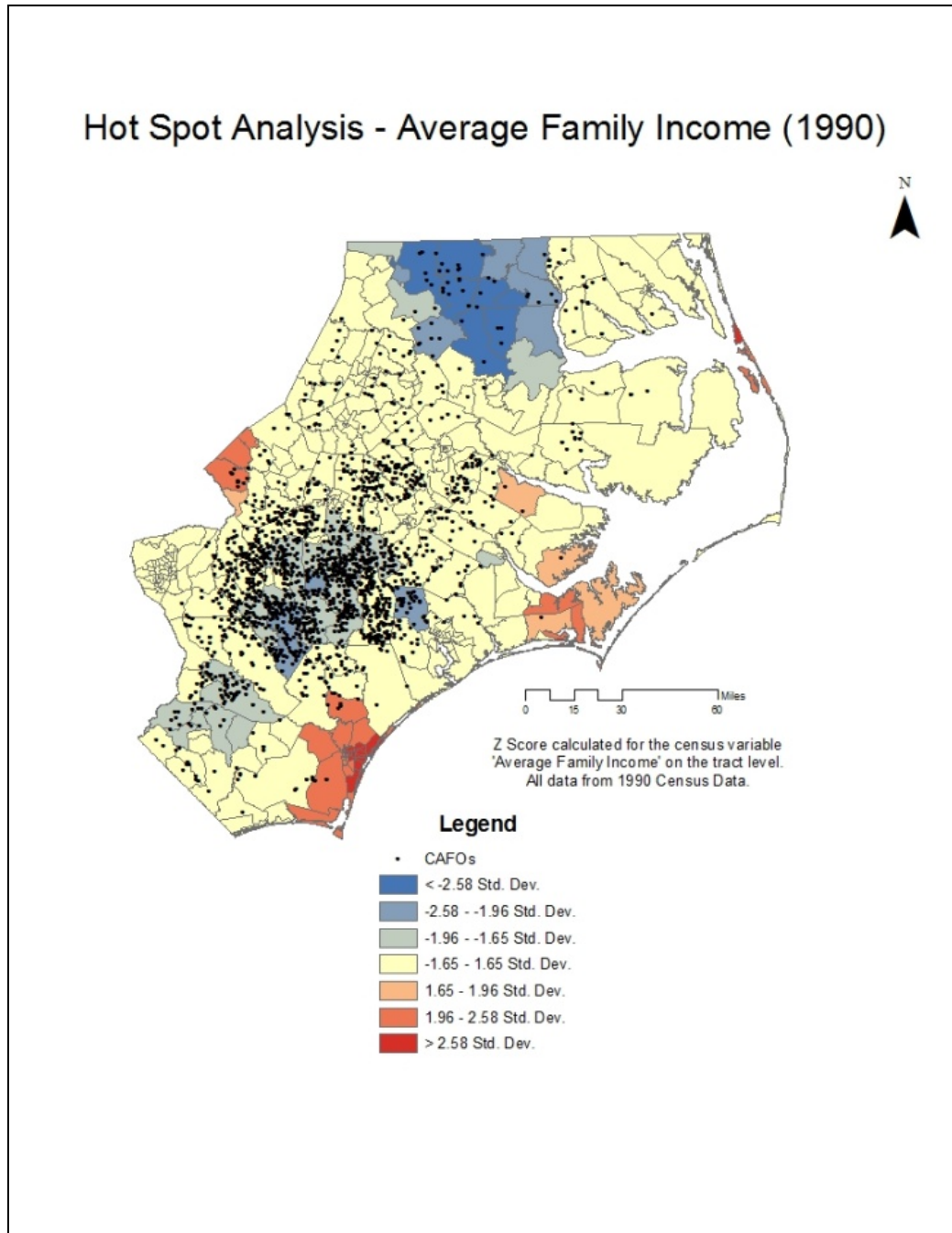


Figure 23 - Hot Spot Analysis of 2000 Average Family Income and CAFOs

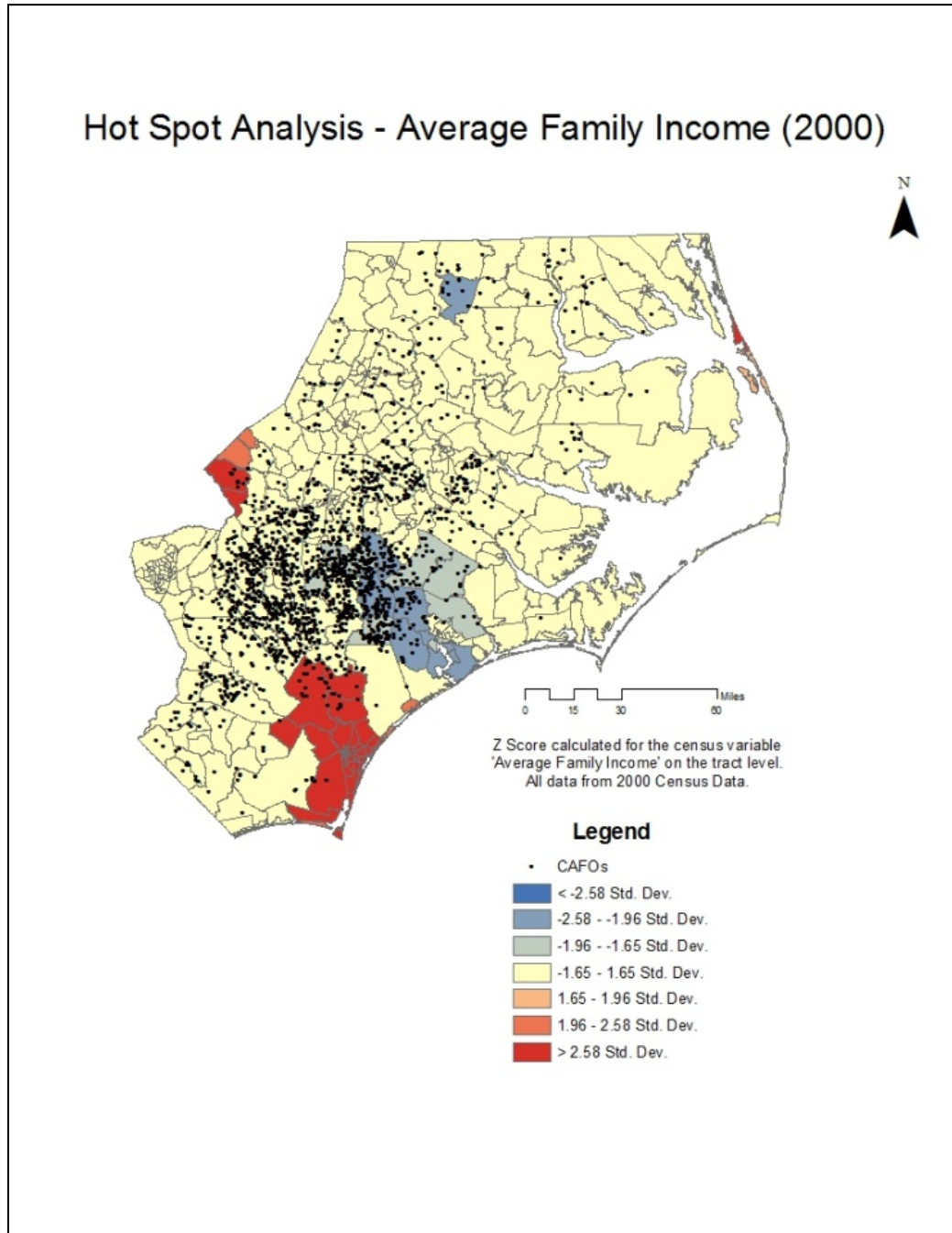


Figure 24 - Hot Spot Analysis of 1990 Percent Black and CAFOs

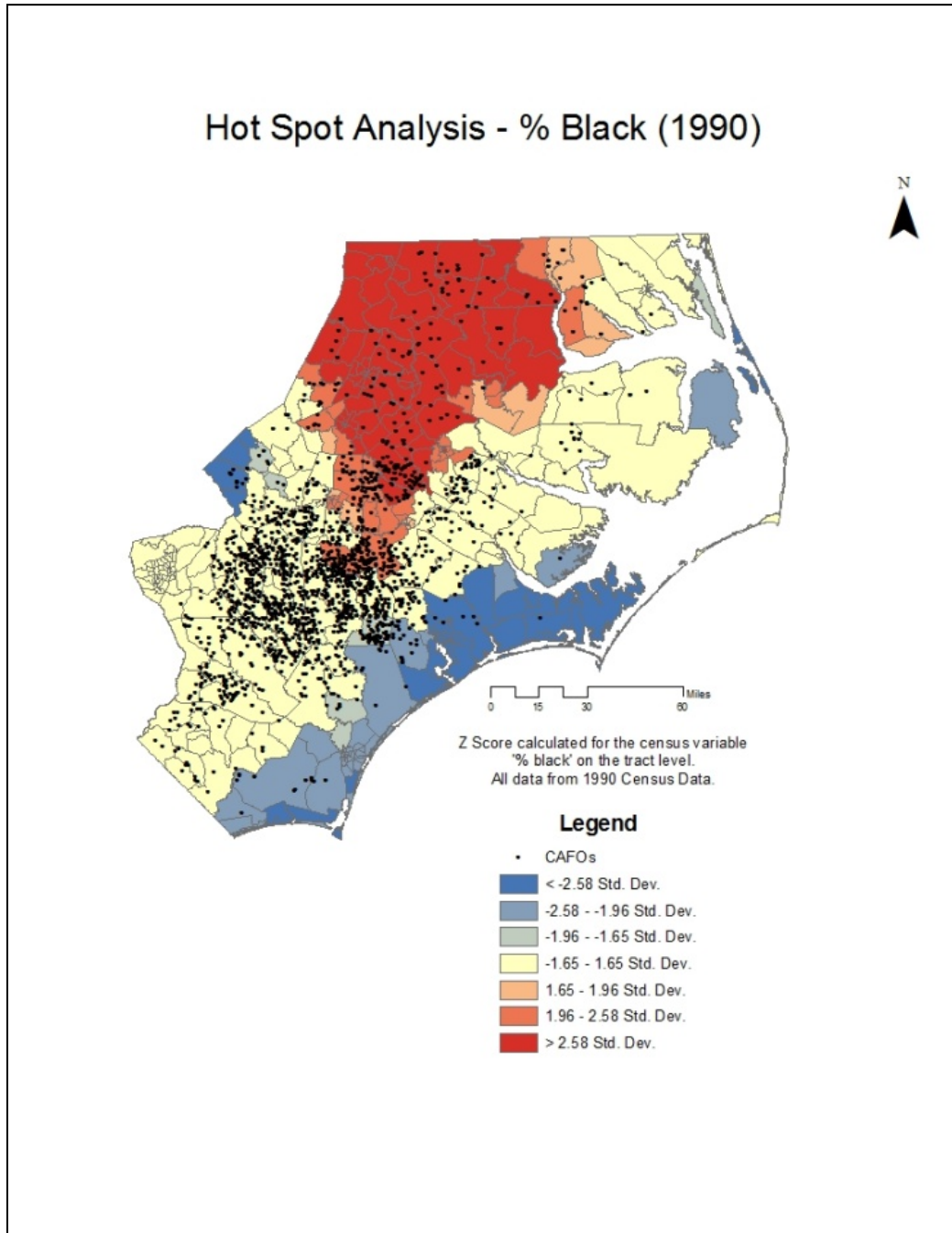


Figure 25 - Hot Spot Analysis of 2000 Percent Black and CAFOs

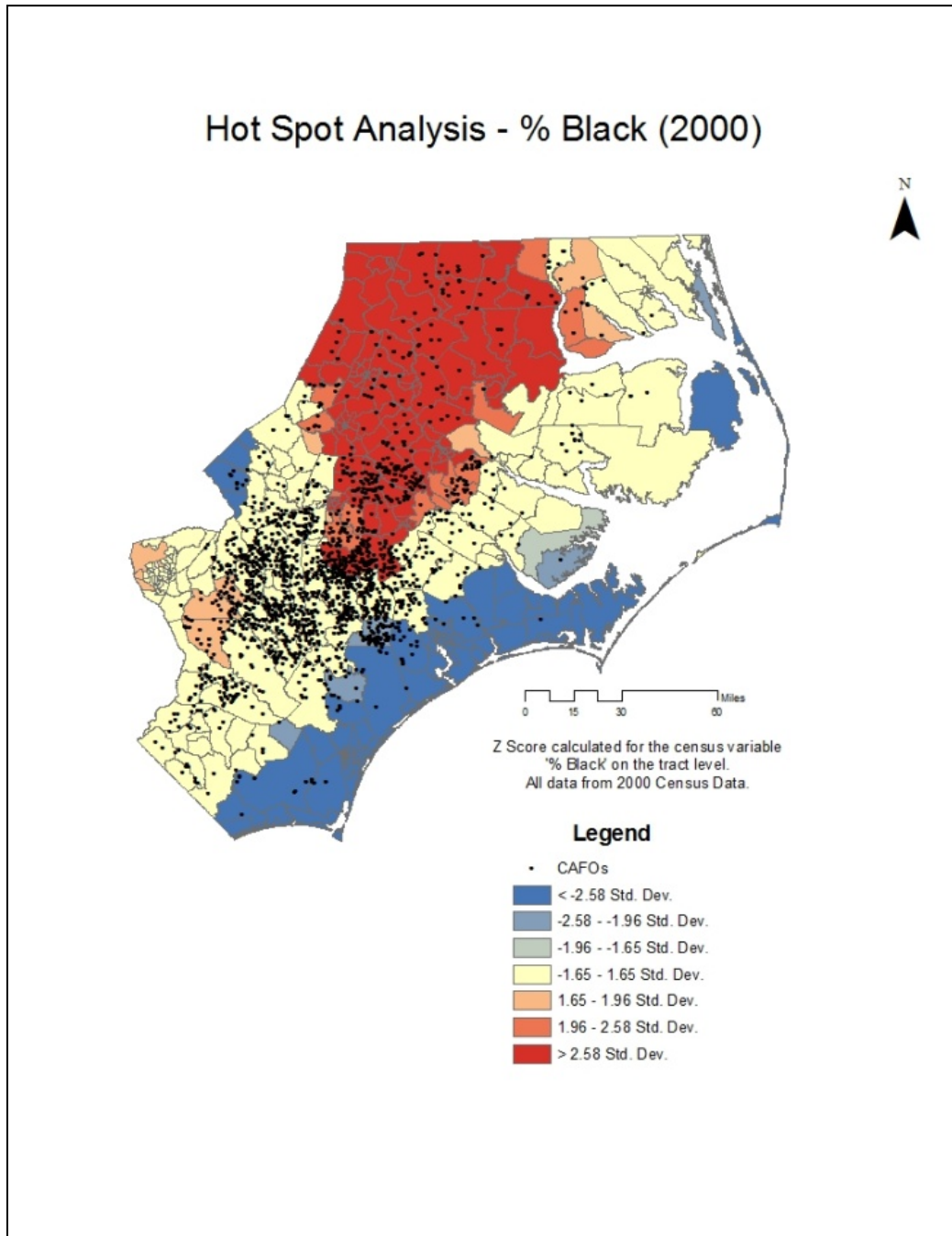


Figure 26 - Hot Spot Analysis of 1990 Percent Hispanic and CAFOs

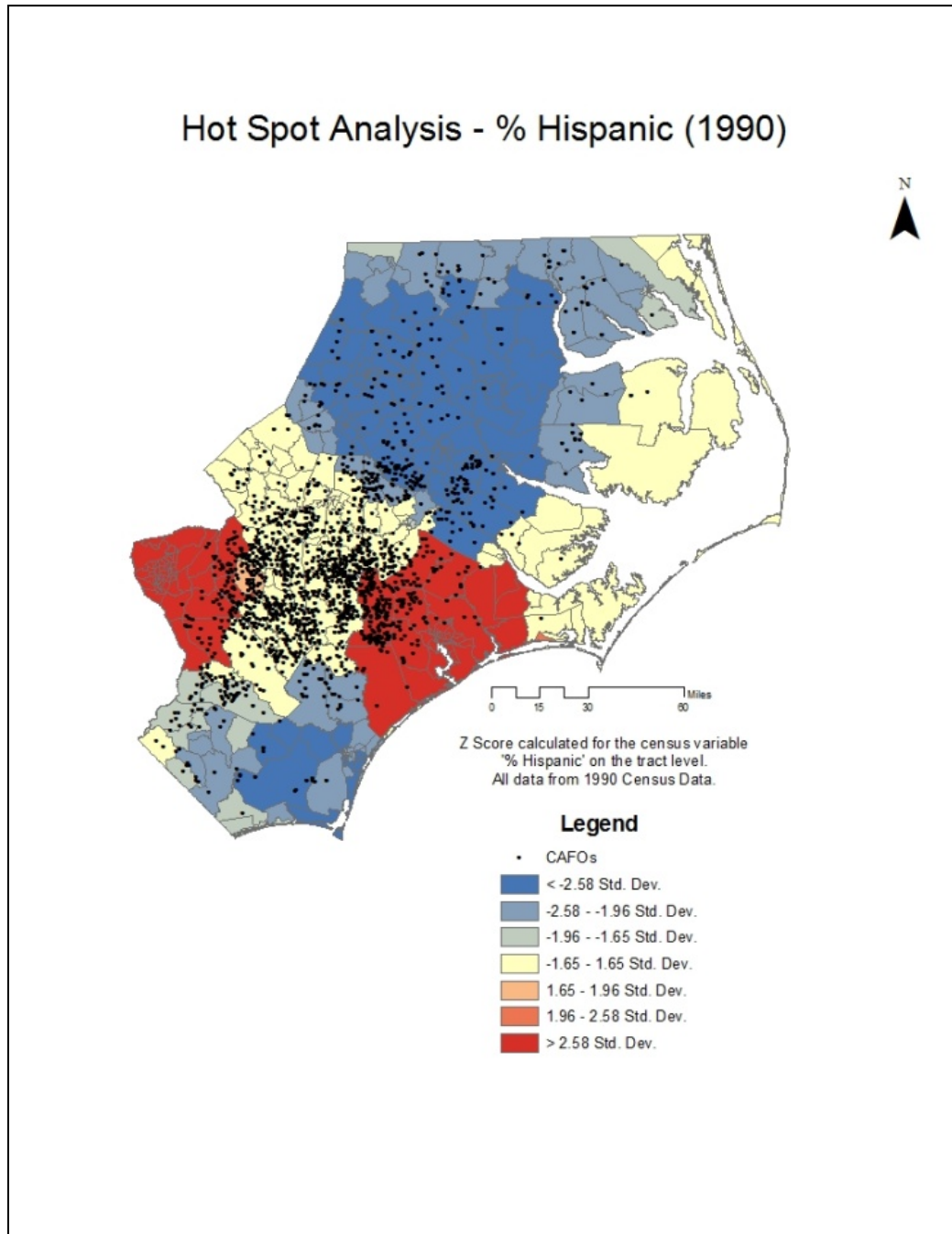


Figure 27 - Hot Spot Analysis of 2000 Percent Hispanic and CAFOs

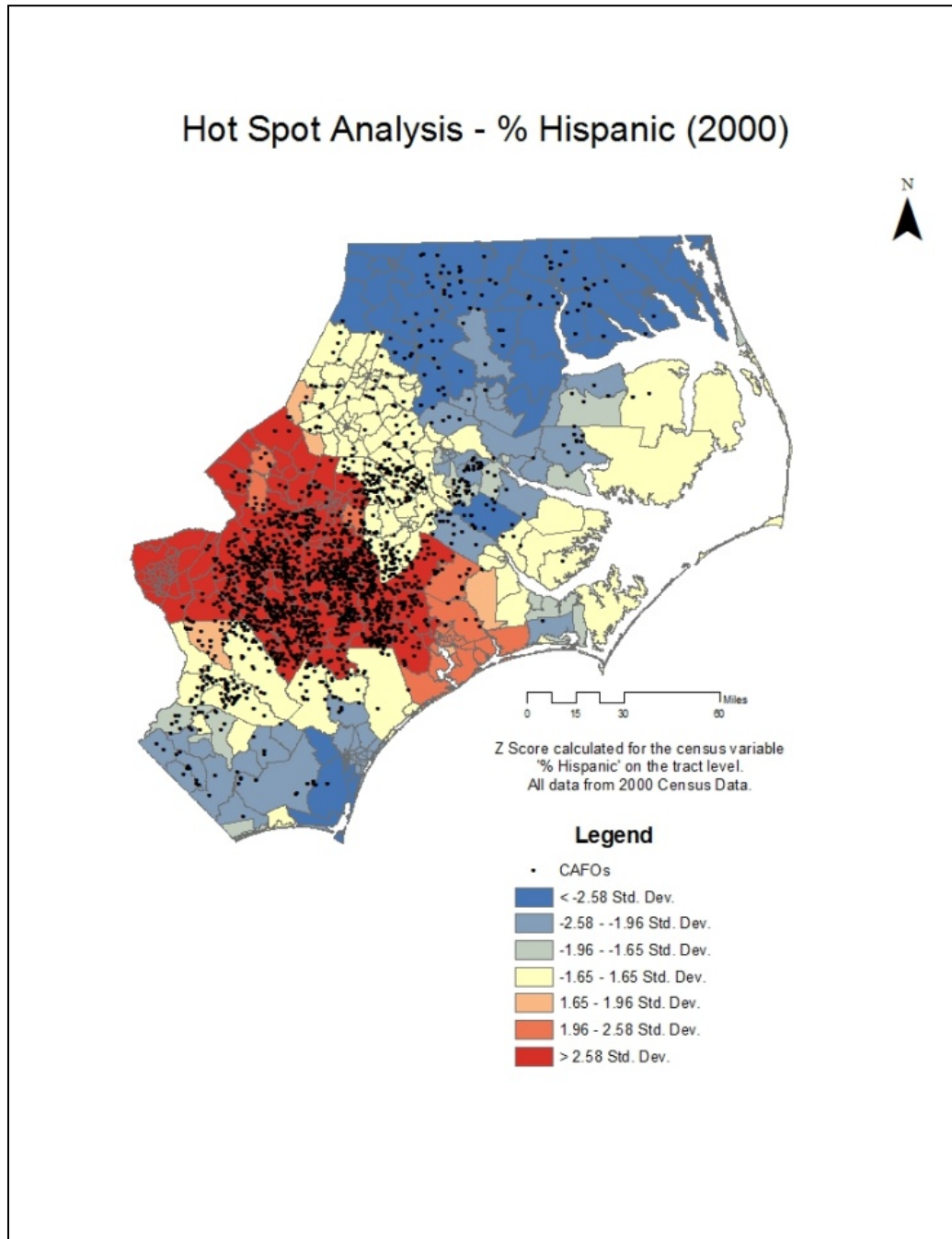


Figure 28 - Hot Spot Analysis of 1990 Percent With Less Than High School Diploma and CAFOs

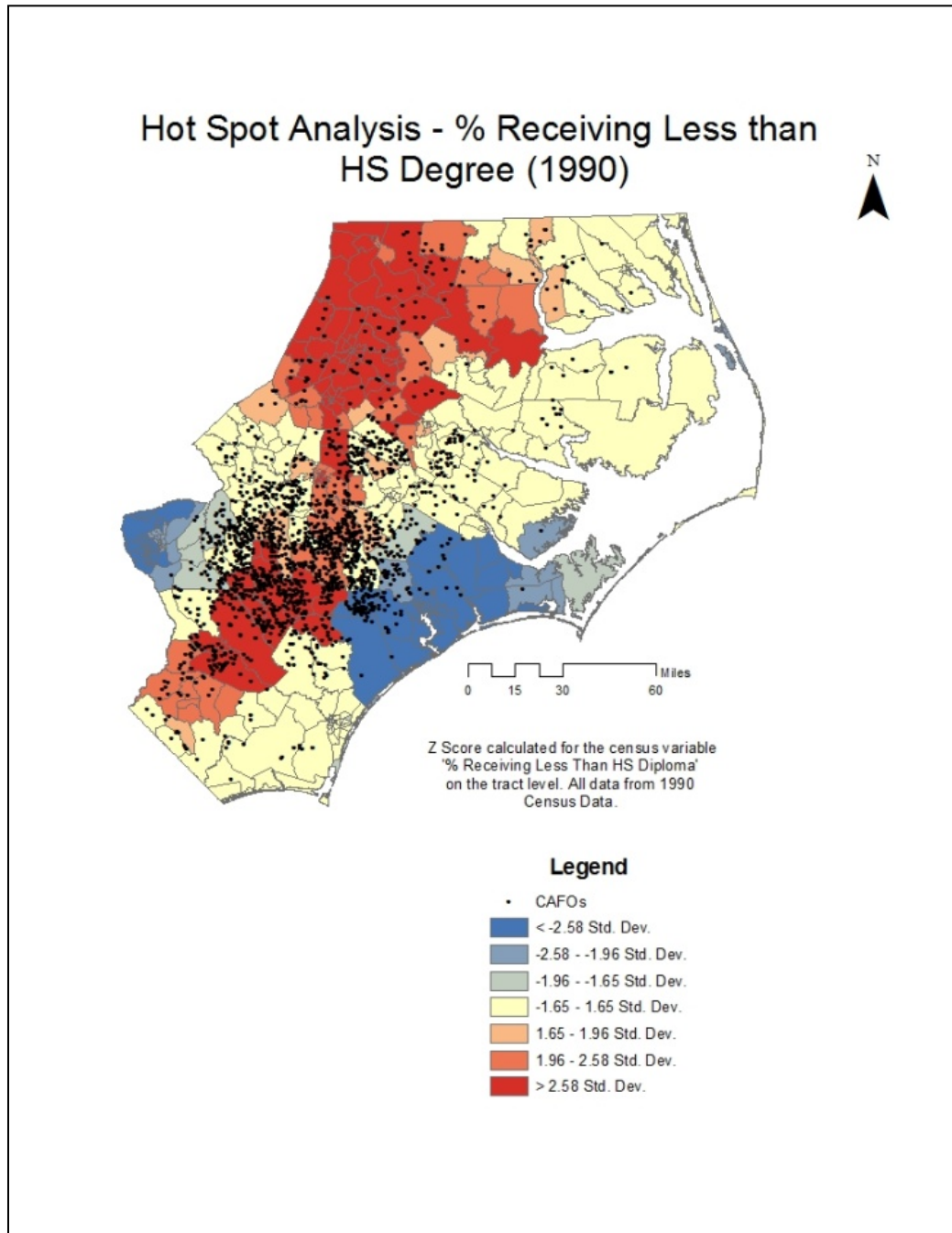


Figure 29 - Hot Spot Analysis of 2000 Percent With Less Than High School Diploma and CAFOs

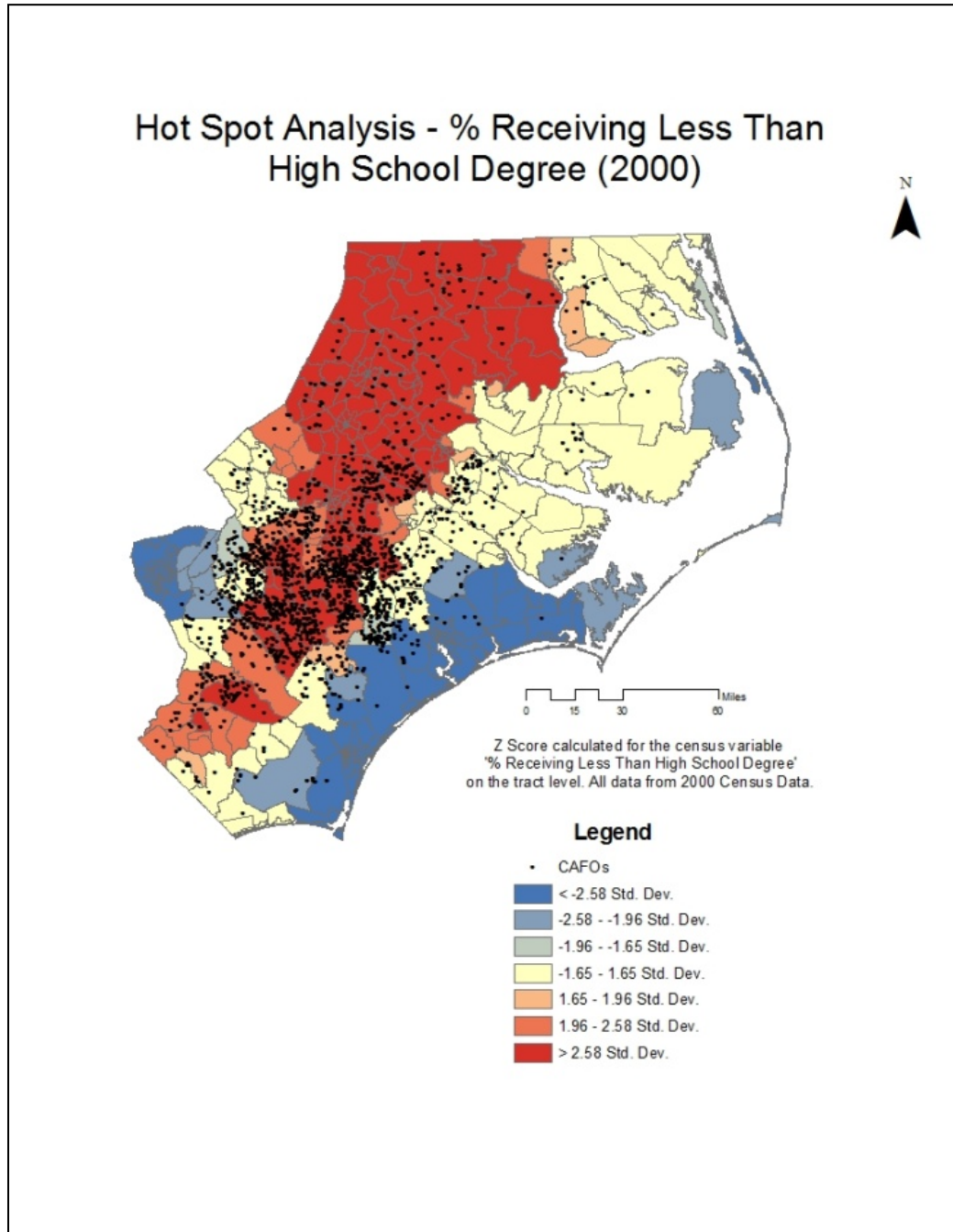


Figure 30 - Hot Spot Analysis of 1990 Percent Minority and CAFOs

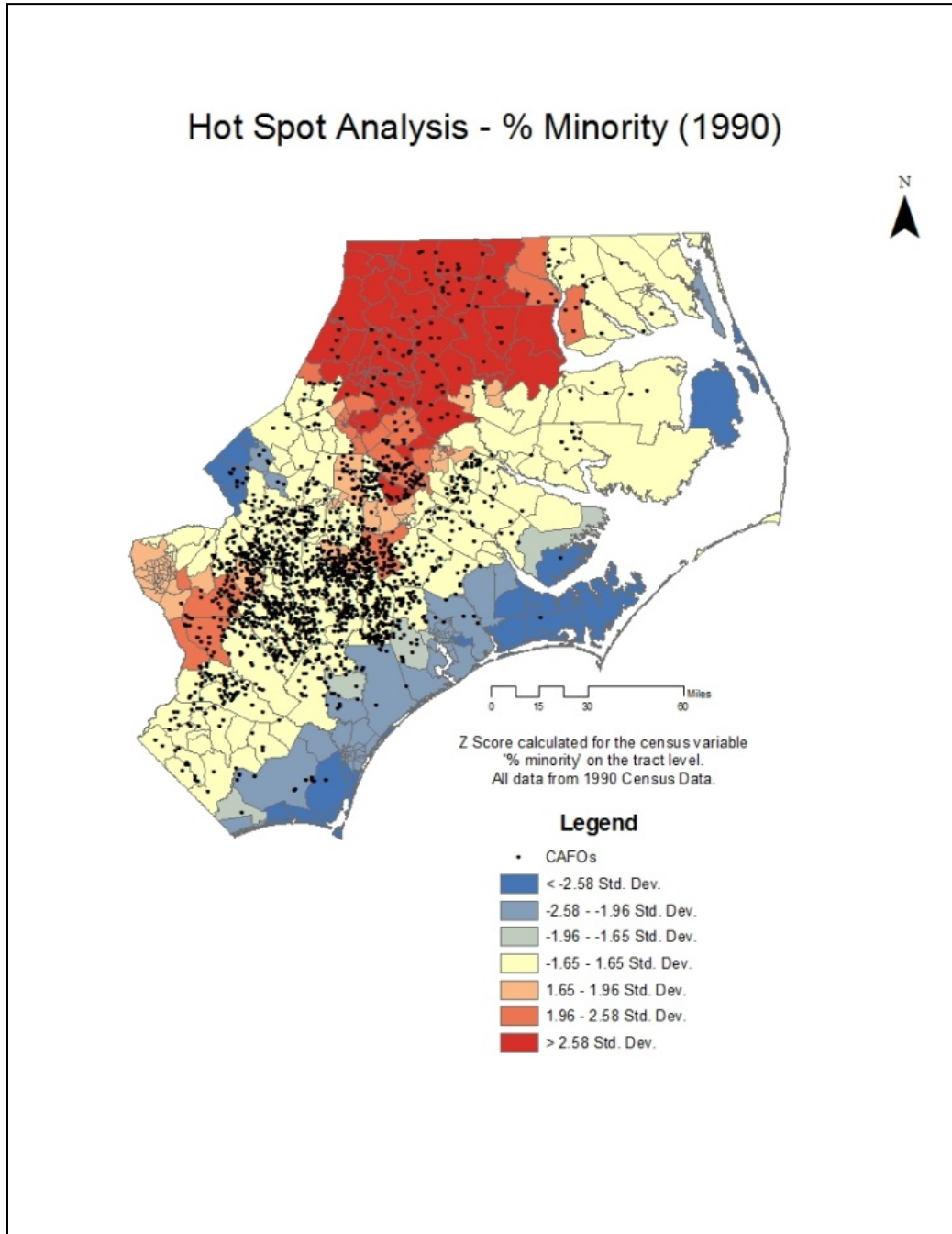


Figure 31 - Hot Spot Analysis of 2000 Percent Minority and CAFOs

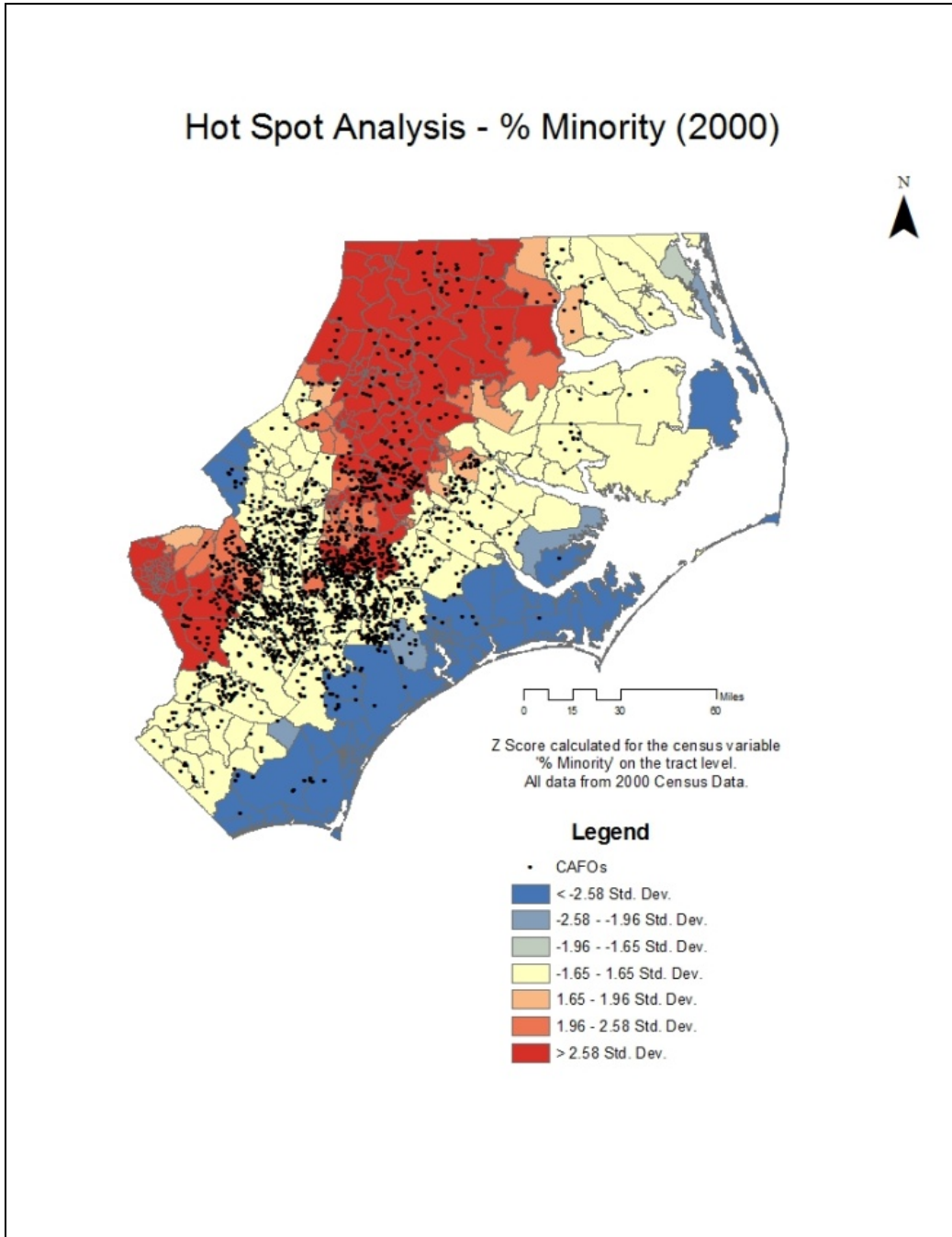


Figure 32 - Hot Spot Analysis of 1990 Per Capita Income and CAFOs

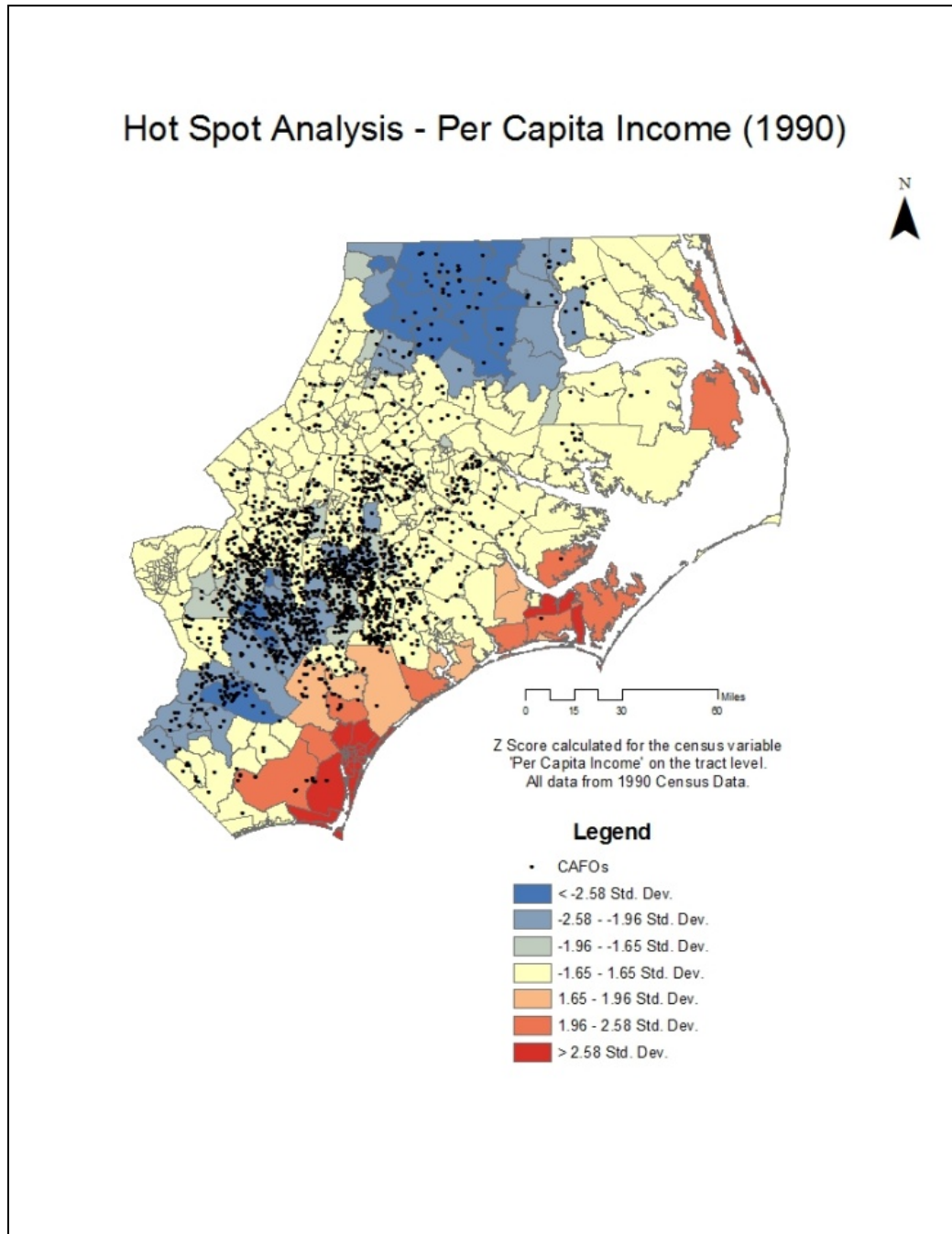


Figure 33 - Hot Spot Analysis of 2000 Per Capita Income and CAFOs

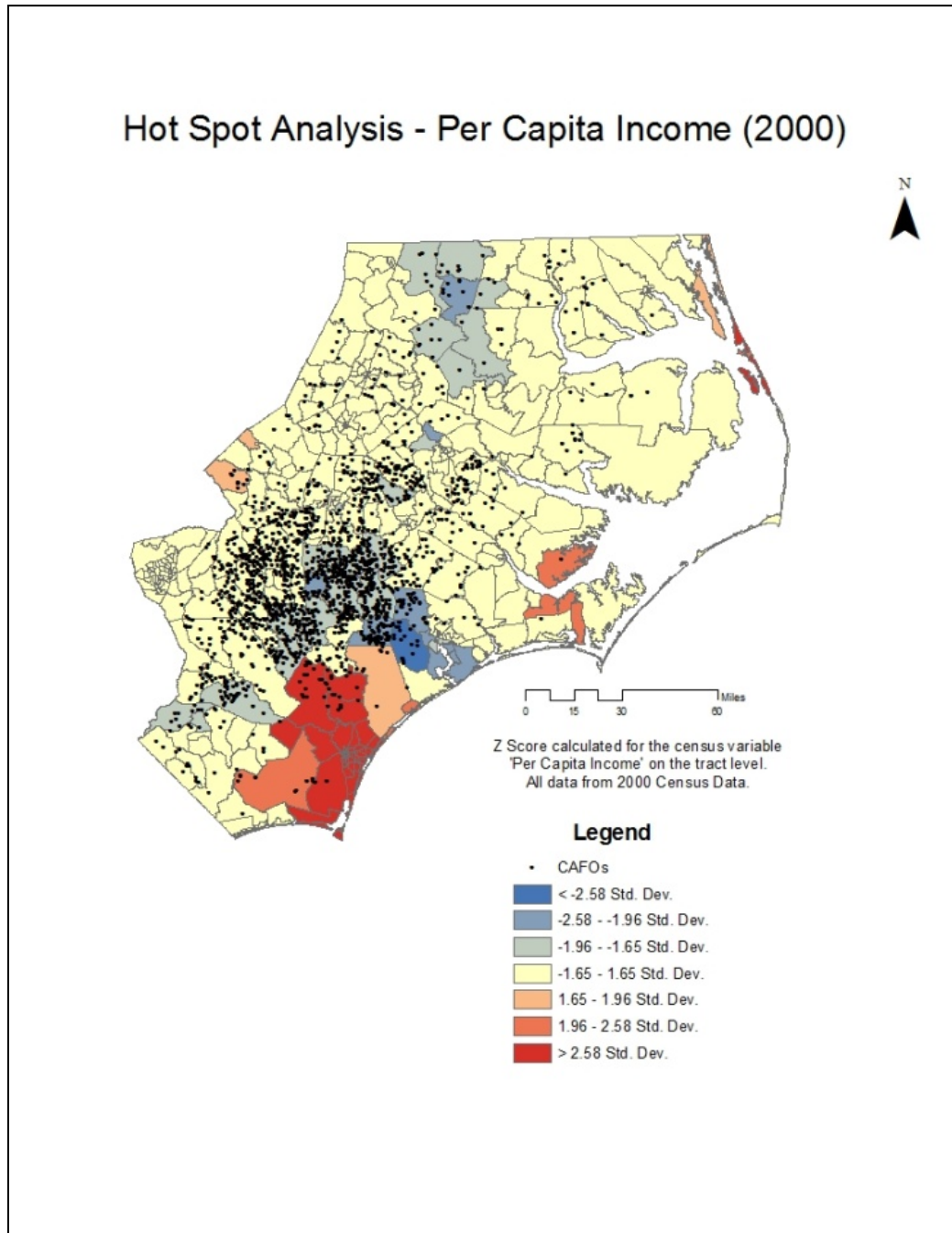


Figure 34 - Hot Spot Analysis of 1990 Percent Receiving Public Assistance and CAFOs

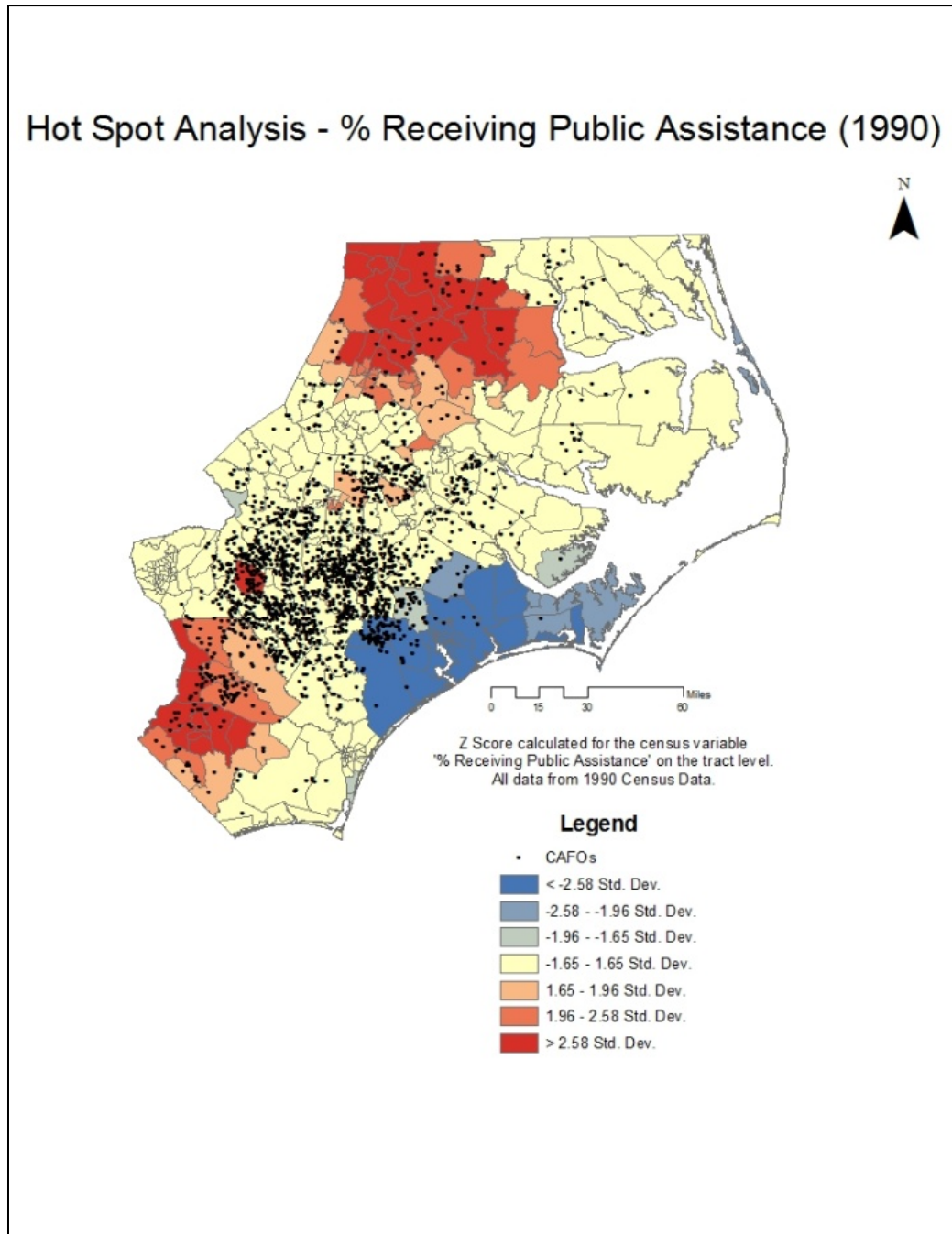
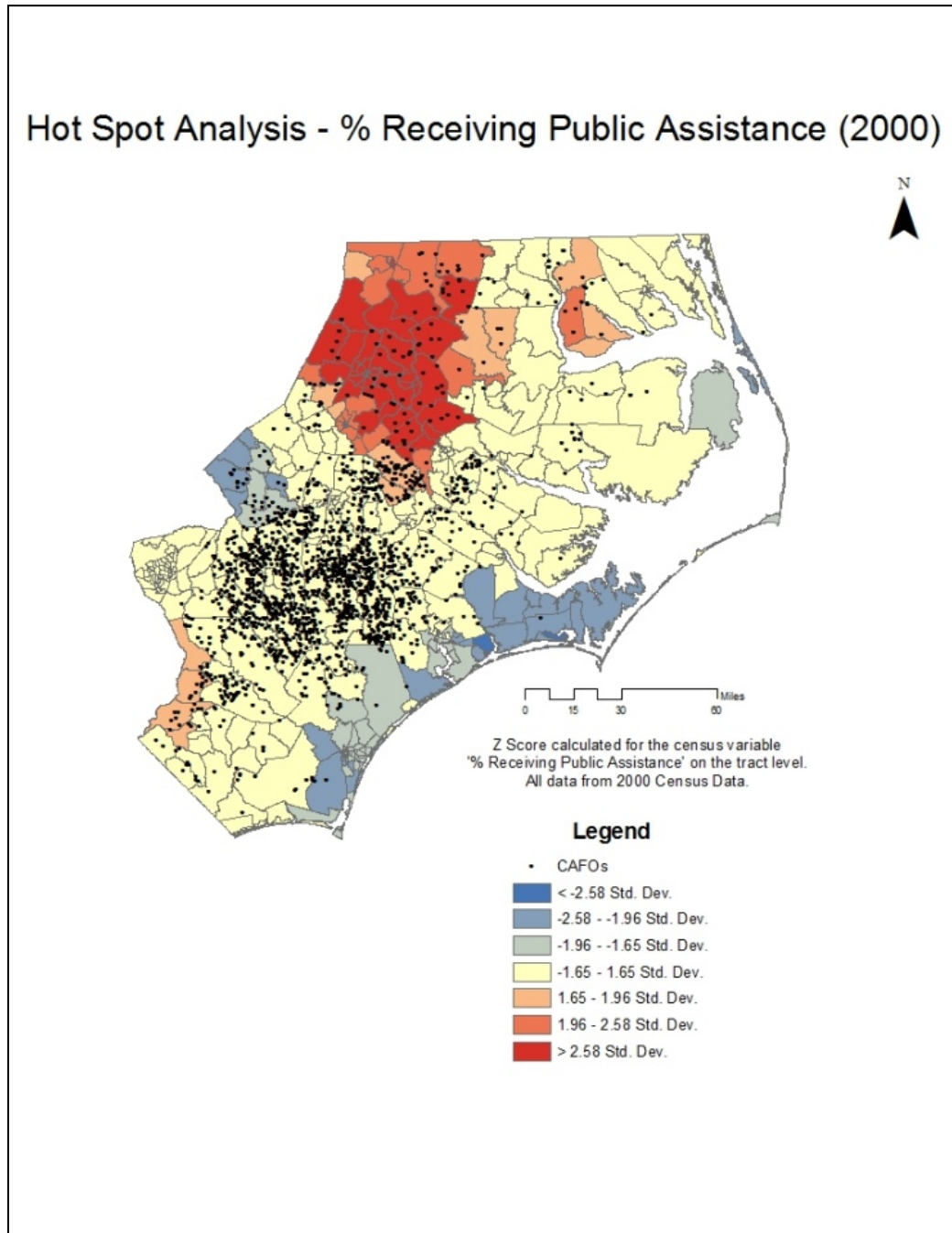


Figure 35 - Hot Spot Analysis of 2000 Percent Receiving Public Assistance and CAFOs



T-Test Results

Four independent samples t-tests were performed to test the original hypothesis that greater percentages of minority, low-income, and low-education populations live near CAFOs compared to random points not near CAFOs. The first t-test was performed for the 1990 census tracts within a one-mile radius of CAFOs in eastern North Carolina. The means of each variable were compared to the means of each variable within a one-mile radius of randomly generated points in eastern North Carolina (see Table 8). The results of the test found statistical significance for all of the variables except the percent receiving public assistance. Of the seven variables that were found to be statistically significant, the variables supporting the original hypothesis, that higher percentages of low-income, low-education, and minority populations are living near CAFOs, were percent Hispanic, percent receiving less than a high school diploma, per capita income, average household income, and average housing value. The percent Hispanic and percent receiving less than high school diploma both had higher means compared to the randomly generated points. The income variables had lower mean scores on the one-mile and three-mile buffers near CAFOs. Further, the independent samples t-test performed for the 1990 census tracts comparing CAFOs and random points within a three-mile radius also showed the same results (see Table 9).

An independent samples t-test was also performed for the 2000 census tracts within a one and three-mile radius of CAFOs in eastern North Carolina compared to

census tracts within a one and three-mile radius of randomly generated points in eastern North Carolina (see Table 10 and Table 11). The results of the tests both found significance for all of the variables, with percent Hispanic, percent minority, percent receiving less than high school diploma, per capita income, average household income, and average housing value supporting the original hypothesis. This hypothesis assumes that there will be a higher incidence of minority, low-income, and low education populations living near CAFOs compared to randomly generated points in eastern North Carolina.

Demographic Changes Between 1990 – 2000

Line graphs were created to show the mean difference for each variable by year for the CAFO points and the random points (see Figure 36 – Figure 43) in order to compare mean demographic changes over time. The CAFO means from 1990 to 2000 are depicted in dark grey, and the random point means from 1990 to 2000 are depicted in light grey. These graphs serve the function of providing a more visual depiction of the longitudinal mean change between 1990 and 2000 for the radii of one and three miles around the CAFO points and the random points.

The graphs indicate that little to no percent differences exist when comparing the one and three-mile buffers around CAFOs. This finding does not support the original hypothesis that increased percentages of low-income, minority, and lower education populations will live nearer to CAFOs, in the one-mile buffer, as compared to the three-mile buffer around CAFO locations.

The percent black and percent with public assistance variables all decreased from 1990 to 2000 (see Figure 36 and Figure 40). These were the only variables with declining percentages between 1990 and 2000. The income variables of per capita income and average house income both increased between 1990 and 2000 around CAFOs and random points. Per capita income rose by around \$5,000 between 1990 and 2000 around CAFO and random points (see Figure 41), while average house income rose by \$11,000 around CAFO and random points (see Figure 42).

The findings from the graphs indicate a large increase in percentage Hispanic from 1990-2000 around the CAFO points for both the one-mile and three-mile radii, but not as great an increase for the random points one and three-mile radii (see Figure 37). In 1990, within both buffered distances, the percent Hispanic around the CAFO points was two percent, and around the random points it was one percent. Then in 2000, the percent Hispanic around the CAFOs soared to ten percent, with the percent Hispanic around the random points rising to four percent. These results indicate that the disparities in the Hispanic percentages around CAFO and random point locations widened between 1990 and 2000. The percent minority increased from 34% in 1990 to 38% in 2000 around CAFOs, and from 34% in 1990 to 36% in 2000 around random points (see Figure 38). However, the minority percentage increases were largely the result of the increases in the Hispanic population.

Next, percent receiving less than high school diploma increased around both CAFOs and random points from 1990 to 2000 (see Figure 39). This variable's

percent in 1990 was 23%, and rose to 31% in 2000 around CAFO points. Around the random points, the percent receiving less than high school diploma in 1990 was 21%, and rose to 28% in 2000 (see Figure 39).

Finally, the average housing value rose from \$58,644.98 to \$86,377.19 between 1990 and 2000 within the one-mile buffered radii of the random points (See Figure 43). However, the average housing value only rose from \$50,693.58 to \$76,457.11 between 1990 and 2000 within the one-mile buffered radii of the CAFO points. A similar observation also occurred for the three-mile buffered radii of the random points and CAFO points. These findings suggest that the average housing value rose between 1990 and 2000 around CAFOs and random points, but the disparities in housing values between CAFO and random point locations also widened in that time period. In 1990 and 2000, the average housing value around random points was around \$8,000 more than the average housing value around the CAFO points (see Figure 43).

Table 8 - T-Test Results Comparing the One-mile Buffers Around CAFOs and One-mile Buffers around Random Points from 1990

Variable	Mean of One Mile Buffers around CAFOs	Mean Within One Mile Buffers Around Random Points	Mean Percent Difference	t stat	Sig.
Percent black	31.988	32.586	-0.598	-1.137	.000
Percent Hispanic	1.525	0.884	0.641	14.155	.000
Percent minority	33.923	34.210	-0.287	-0.544	.000
Percent with less than high school diploma	23.117	21.181	1.936	13.843	.000
Percent receiving public assistance	10.694	10.746	-0.052	.185	.853
Per capita income	\$9,431.58	\$10,138.53	-\$706.95	-12.951	.000
Average household income	\$28,834.39	\$30,283.12	-\$1,448.73	-10.922	.000
Average housing value	\$50,459.75	\$58,748.99	-\$8,289.24	-16.187	.000

Table 9 - T-Test Results Comparing the Three-mile Buffers Around CAFOs and Three-mile Buffers Around Random Points from 1990

Variable	Mean of Three Mile Buffers around CAFOs	Mean of Three Mile Buffers Around Random Points	Mean Percent Difference	t stat	Sig.
Percent black	31.971	32.581	-0.61	-1.239	.000
Percent Hispanic	1.507	0.897	0.61	14.548	.000
Percent minority	33.892	34.201	-3.309	-0.624	.000
Percent with less than high school diploma	23.040	21.194	1.846	14.458	.000
Percent receiving public assistance	10.693	10.625	0.068	.562	.574
Per capita income	\$9,458.34	\$10,136.48	\$-678.14	-13.863	.000
Average household income	\$28,894.90	\$30,241.22	\$-1,346.32	-11.434	.000
Average housing value	\$50,693.58	\$58,644.98	\$-7,951.40	-16.756	.000

Table 10 - Results from Independent Samples T-Tests Comparing the One-mile Buffers Around CAFOs and One-mile Buffers around Random Points from 2000

Variable	Mean of One Mile Buffers around CAFOs	Mean of One Mile Buffers Around Random Points	Mean Percent Difference	t stat	Sig.
Percent black	29.111	30.806	-1.695	-3.192	.000
Percent Hispanic	9.525	4.103	5.422	25.383	.000
Percent minority	37.798	35.684	2.114	3.891	.000
Percent with less than high school diploma	31.146	27.911	3.235	15.116	.000
Percent receiving public assistance	3.774	4.025	-0.251	-4.968	.000
Per capita income	\$15,172.29	\$15,744.40	\$-572.11	-5.011	.000
Average household income	\$40,060.02	\$41,644.96	\$-1,584.94	-7.73	.000
Average housing value	\$76,113.60	\$86,617.34	\$-10,503.74	-13.847	.000

Table 11 - Results from Independent Samples T-Tests Comparing the Three-mile Buffers Around CAFOs and Three-mile Buffers around Random Points from 2000

Variable	Mean of Three Mile Buffers around CAFOs	Mean of Three Mile Buffers Around Random Points	Mean Percent Difference	t stat	Sig.
Percent black	29.168	30.729	-1.561	-3.113	.000
Percent Hispanic	9.386	4.120	5.266	26.496	.000
Percent minority	37.757	35.613	2.144	4.179	.000
Percent with less than high school diploma	31.024	27.933	3.091	15.544	.000
Percent receiving public assistance	3.769	4.020	-0.251	-5.531	.000
Per capita income	\$15,195.24	\$15,764.16	\$-568.92	-5.994	.000
Average household income	\$40,131.88	\$41,604.69	\$-1,472.81	-8.023	.000
Average housing value	\$76,457.11	\$86,377.19	\$-9,920.08	-14.721	.000

Figure 36 – Percent Black Mean Differences in 1990 and 2000

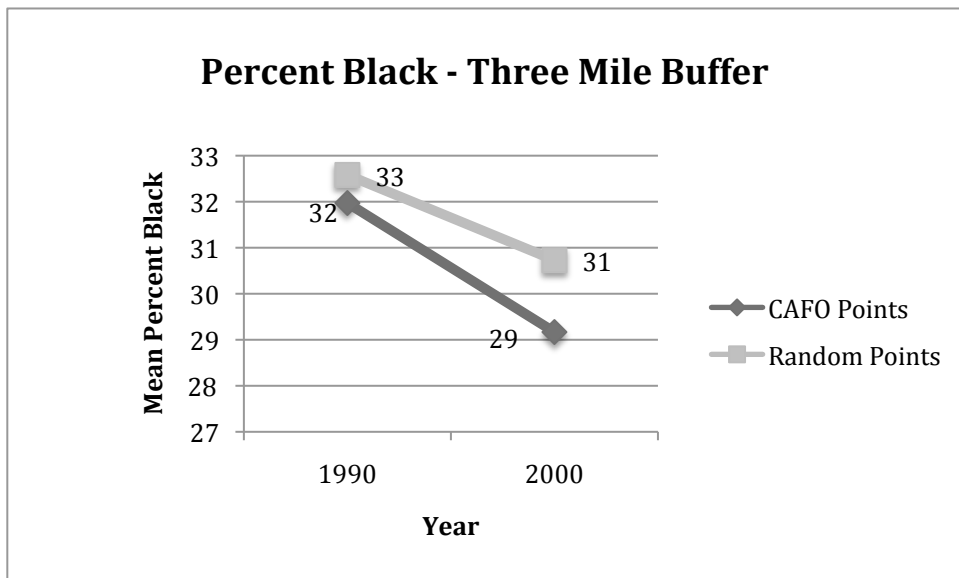
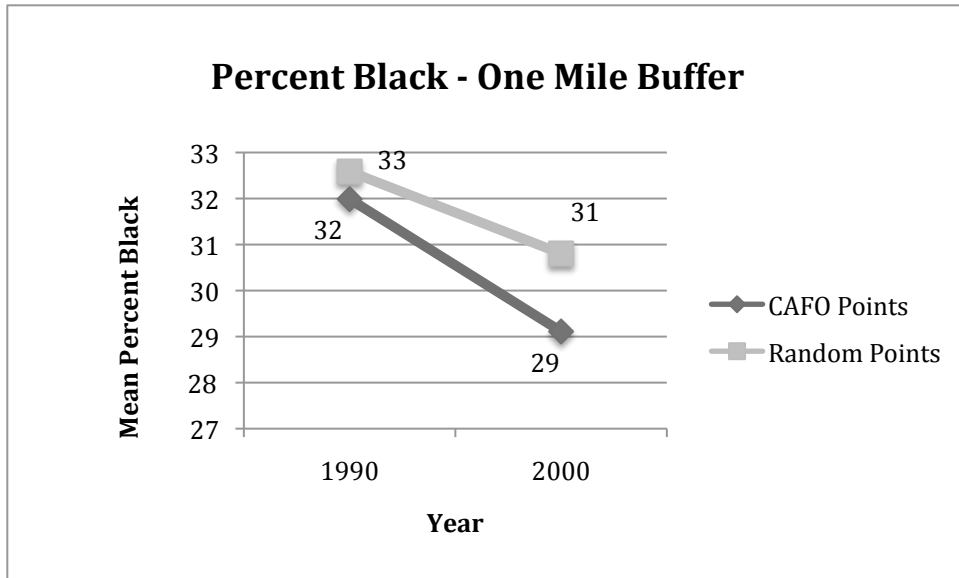


Figure 37 - Percent Hispanic Mean Differences in 1990 and 2000

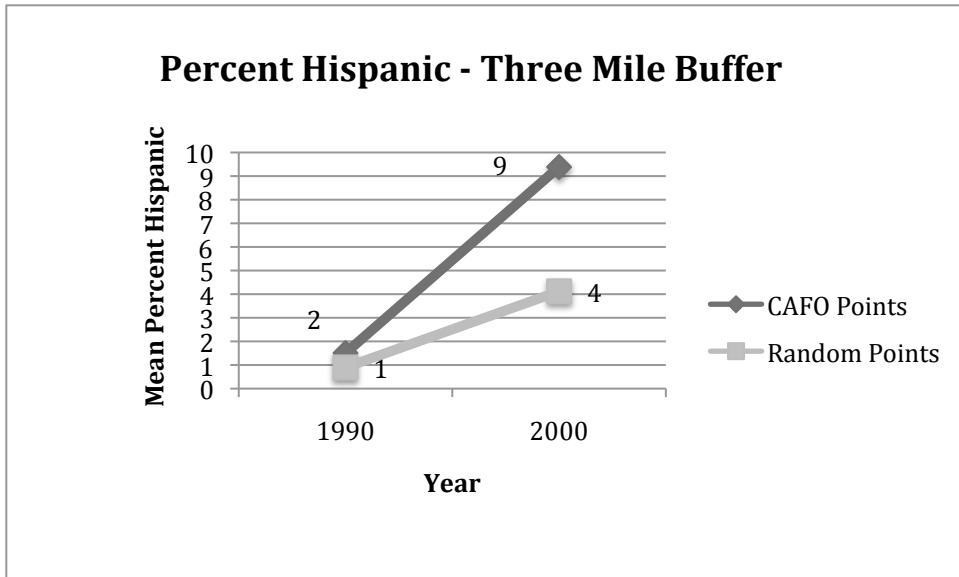
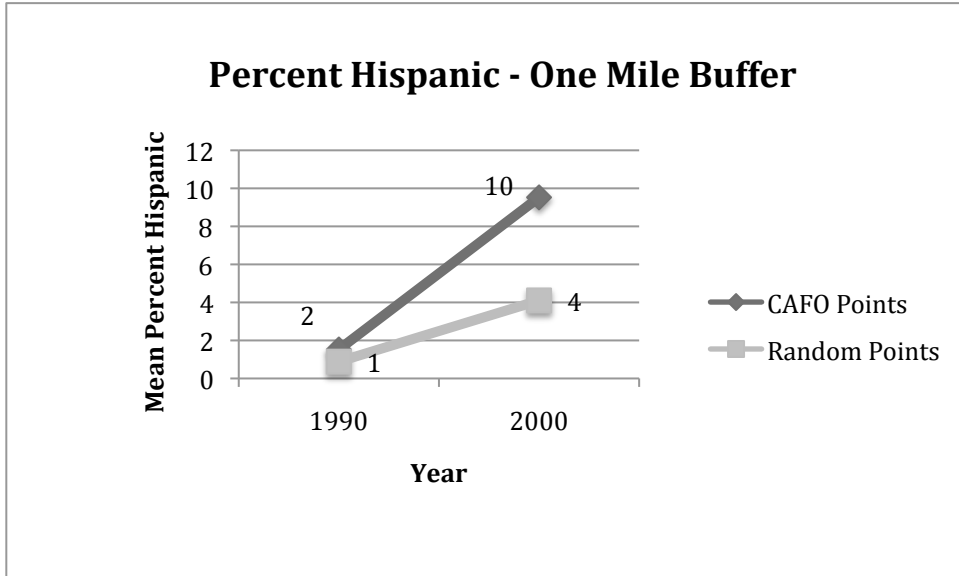


Figure 38 – Percent Minority Mean Differences in 1990 and 2000

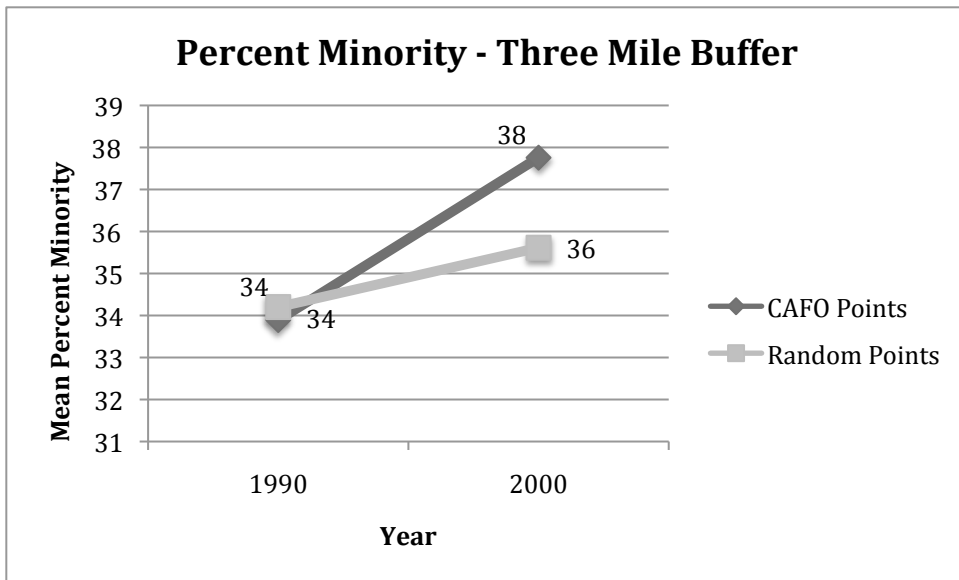
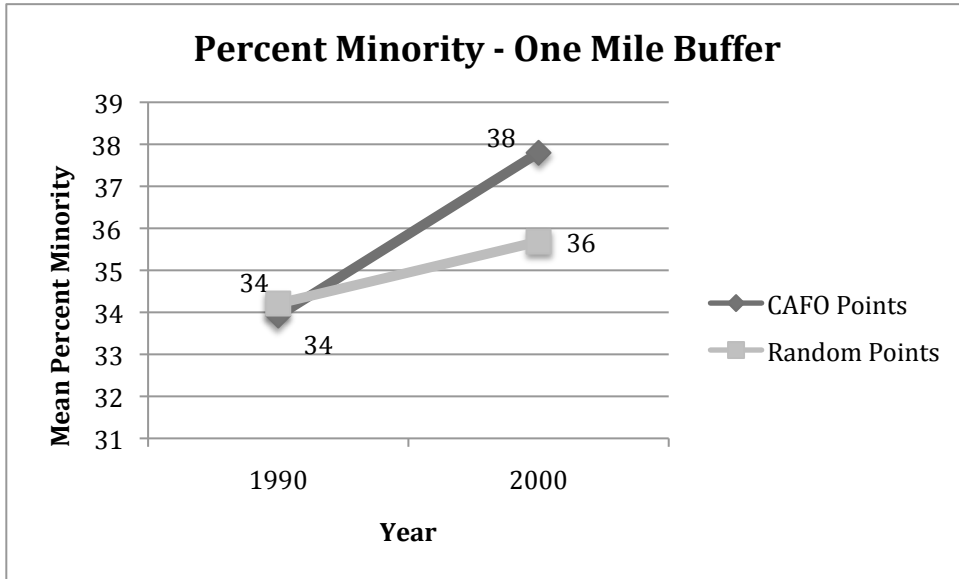


Figure 39 – Percent Receiving Less than High School Diploma Mean Differences in 1990 and 2000

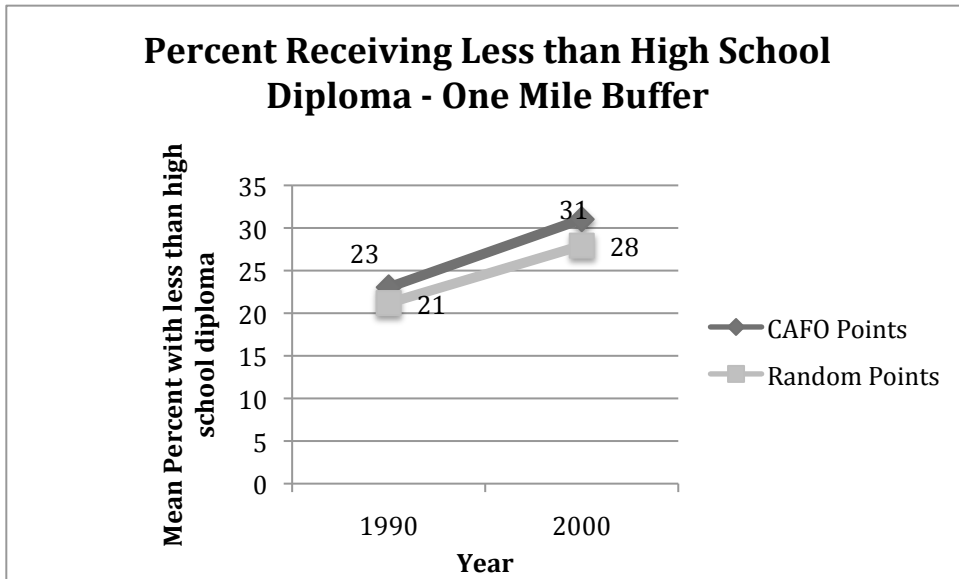
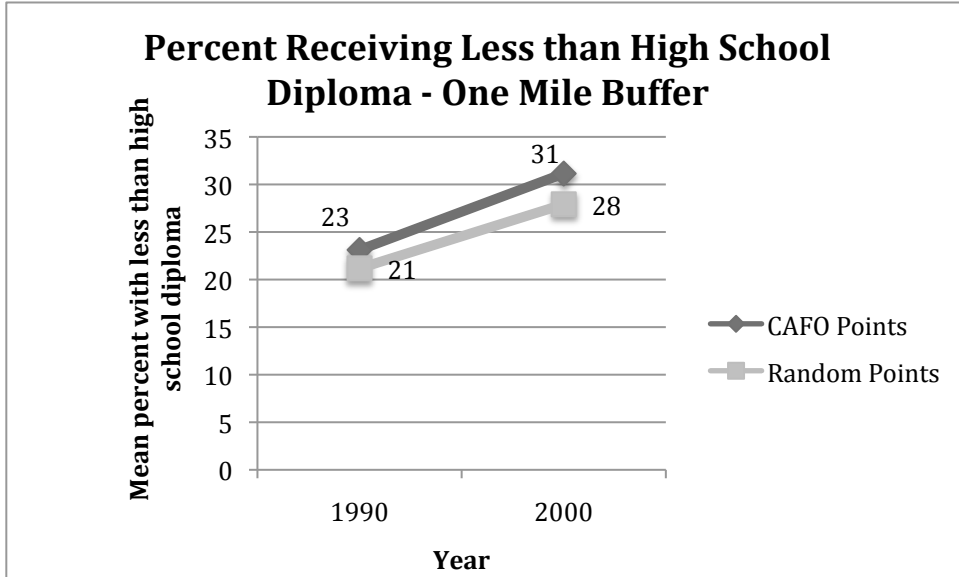


Figure 40 - Percent Receiving Public Assistance Mean Differences in 1990 and 2000

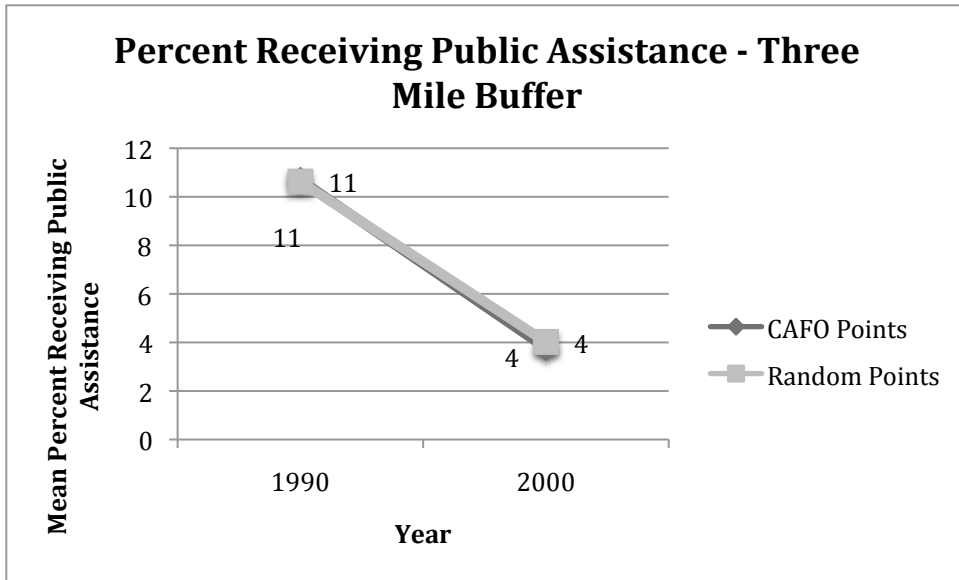
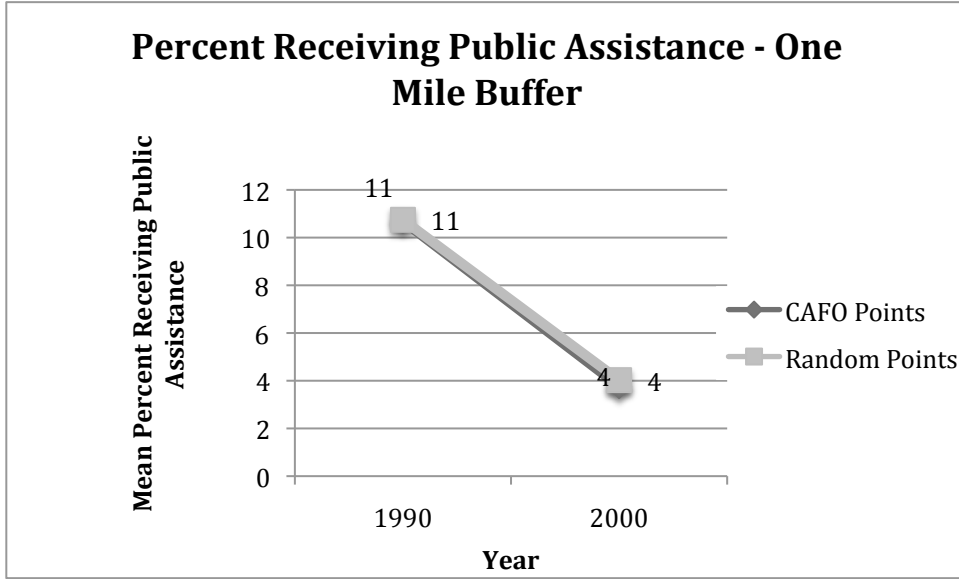


Figure 41 - Per Capita Income Mean Differences in 1990 and 2000

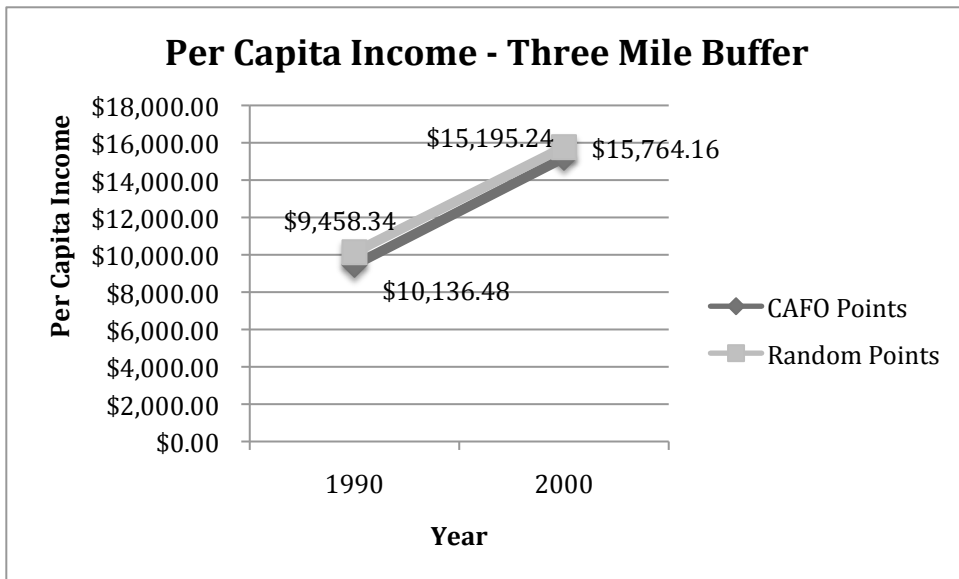
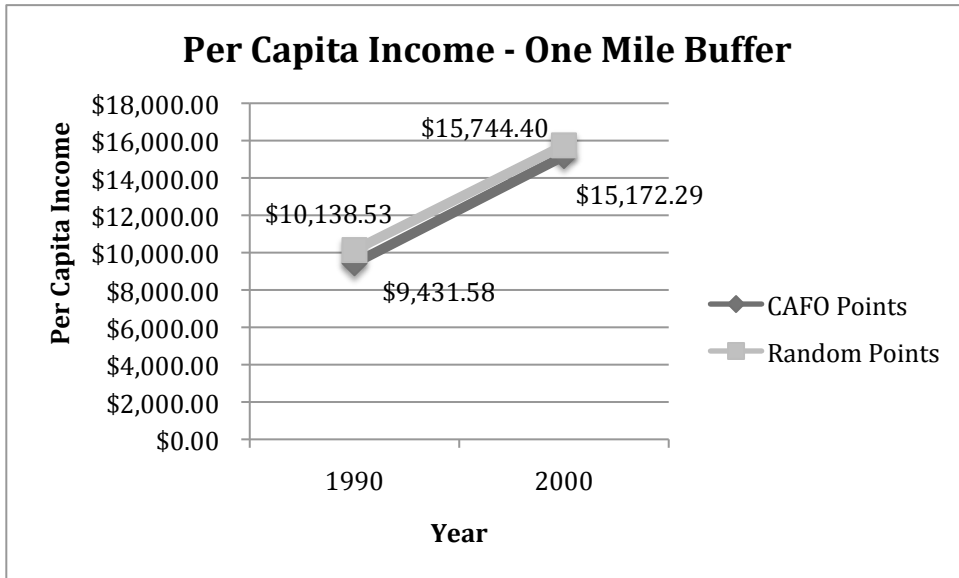


Figure 42 – Average Household Income Mean Differences in 1990 and 2000

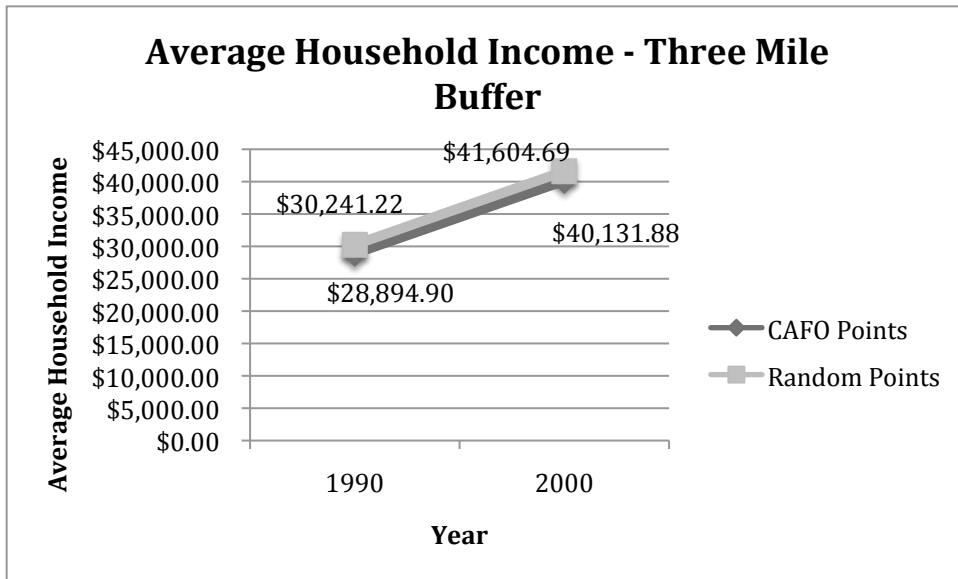
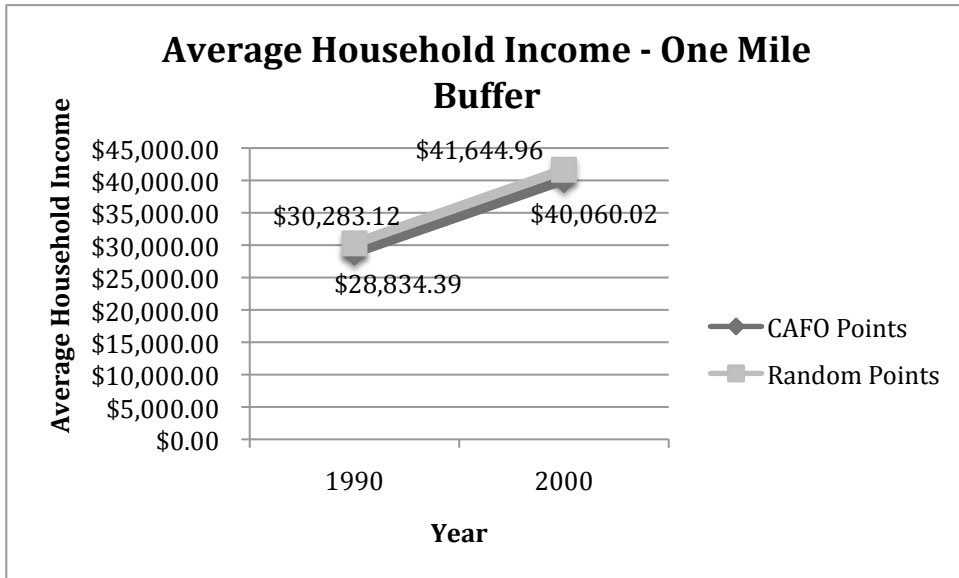
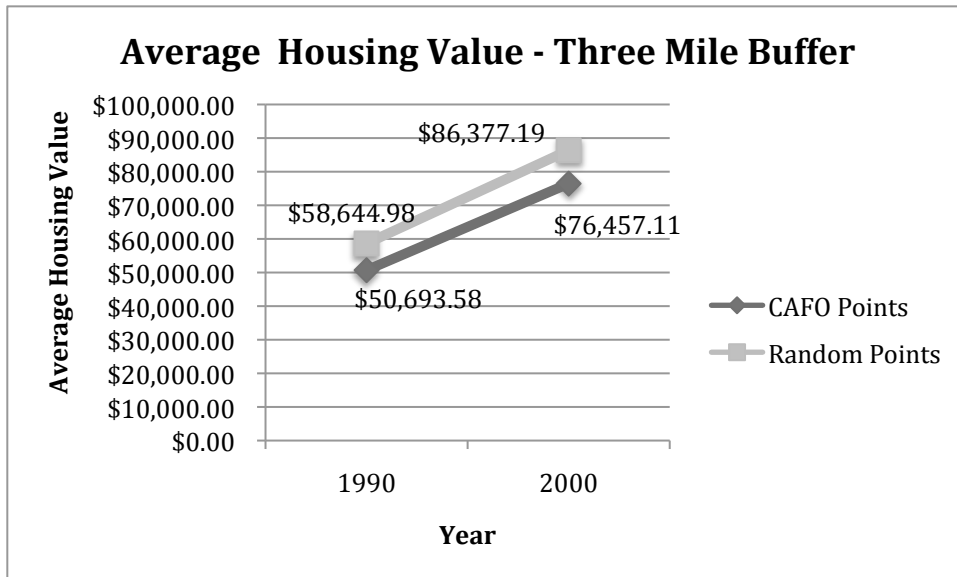
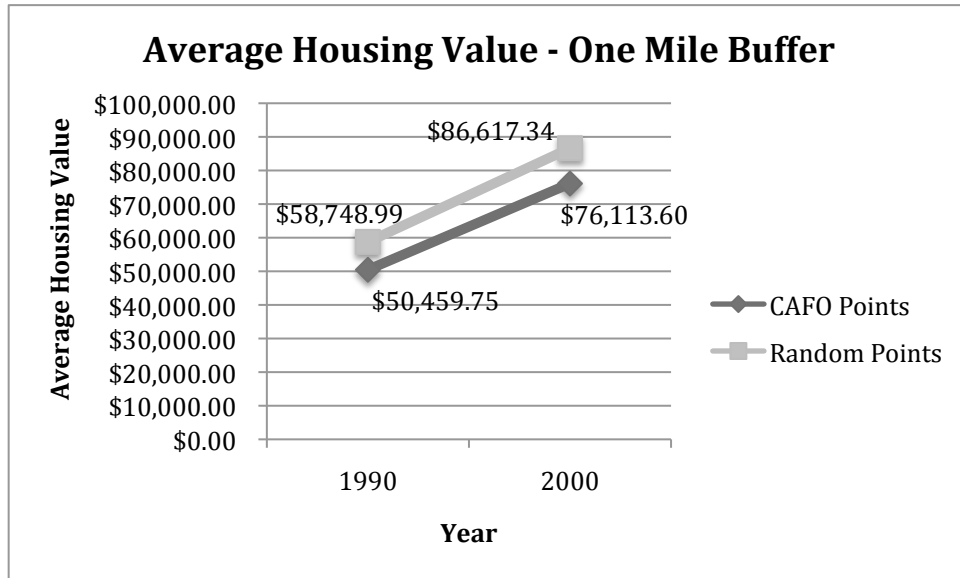


Figure 43 – Average Household Value Mean Differences in 1990 and 2000



Logistic Regression Results

Logistic regression models were used to estimate odds ratios and their 95 percent confidence intervals in order to assess the relative impact the independent variables of percent Hispanic, percent black, percent receiving less than high school diploma, average household income, and average housing value have on the presence of CAFOs. These specific variables were selected for the logistic regression models because they were not highly correlated, thus avoiding multi-collinearity among the independent variables. The dependent variable was the presence (coded as '1') or absence (coded as '0') of CAFOs. The logistic regression models were conducted for the one and three-mile buffers for 1990 and 2000. SPSS was used for all of the binary logistic regression analyses. Table 12 and Table 13 show odds ratios (ORs) from the logistic regression model of the census tracts living within one and three-miles of a CAFO in 1990 in eastern North Carolina. In this year, within the one-mile buffer, an increase in percent Hispanic (OR=1.439; CI = 1.349, 1.535) and increase in percent with less than high school diploma (OR=1.124; CI = 1.100, 1.148) increased the odds of being near a CAFO, as opposed to a random point not near a CAFO. Also, as the average household income (OR=.967; CI=.945, .989) and average property value (OR = .967; CI=.961, .972) decreased, the odds of being near a CAFO increased. The odds ratios from the logistic regression analysis of the samples living within three miles followed the same pattern (see Table 13), with percent Hispanic and percent with less than high school diploma having a statistically significant positive impact on the occurrence of CAFOs, and the average household income and

the average property value having a statistically significant negative impact on the occurrence of CAFOs. For both of the logistic regression models using the one and three-mile buffers, the percent black does not follow the original hypothesized direction. This finding suggests that as the percent black decreases the odds of being near a CAFO increases.

In 2000, percent Hispanic (OR=1.132; CI=1.114, 1.150) and percent receiving less than high school diploma (OR=1.061; CI=1.046, 1.077) were also both statistically significant predictors of proximity to a CAFO in eastern North Carolina (see Table 14 and Table 15). Both of these outcomes suggest that as the Hispanic and those with less than a high school degree increase so do the odds of living within one and three miles from a CAFO. Further, the average household income (OR=.967; CI=.963, .988) and average property value (OR=.990; CI=.987, .994) were both statistically significant predictors of CAFO location. As these income variables decrease, the odds of living within a mile and three miles of a CAFO increase. Just as the 1990 logistic regression models suggest, the percent black in 2000 using either the one or three mile buffers, does not follow the original hypothesized direction. This finding suggests that as the percent black decreases the odds of being near a CAFO increases.

Table 12 - Longitudinal Analysis Logistic Regression Results for One-Mile Radii in 1990

Variable	Model 1, OR (95% CI)
Percent Hispanic	1.439*** (1.349, 1.535)
Percent black	.981*** (.975, .986)
Percent with less than high school diploma	1.124*** (1.100, 1.148)
Average household income	.967** (.945, .989)
Average housing value	.967*** (.961, .972)
Constant	1.606
-2 Log Likelihood	4546.922
Model chi-square	658.166***
Sample size	3,792

Note. OR = odds ratio; CI = confidence interval.
* P≤.05; **P≤.01; ***P≤.001.

Table 13 - Longitudinal Analysis Logistic Regression Results for Three-Mile Radii in 1990

Variable	Model 1, OR (95% CI)
Percent Hispanic	1.527*** (1.422, 1.640)
Percent black	.977*** (.971, .983)
Percent with less than high school diploma	1.154*** (1.126, 1.182)
Average household income	.960** (.936, .985)
Average property value	.962*** (.956, .968)
Constant	1.560
-2 Log Likelihood	4392.570
Model chi-square	721.255***
Sample size	3,792

Note. OR = odds ratio; CI = confidence interval.
* P≤.05; **P≤.01; ***P≤.001.

Table 14 - Longitudinal Analysis Logistic Regression Results for One-Mile Radii in 2000

Variable	Model 1, OR (95% CI)
Percent Hispanic	1.132*** (1.114, 1.150)
Percent black	.984*** (.978, .989)
Percent with less than high school diploma	1.061*** (1.046, 1.077)
Average household income	.967*** (.963, .988)
Average property value	.990*** (.987, .994)
Constant	.801
-2 Log Likelihood	4422.691
Model chi-square	782.396***
Sample size	3,792

Note. OR = odds ratio; CI = confidence interval.

* P≤.05; **P≤.01; ***P≤.001.

Table 15 - Longitudinal Analysis Logistic Regression Results for Three-Mile Radii in 2000

Variable	Model 1, OR (95% CI)
Percent Hispanic	1.145*** (1.126, 1.165)
Percent black	.981*** (.974, .987)
Percent receiving less than high school diploma	1.074*** (1.056, 1.092)
Average household income	.968*** (.954, .983)
Average property value	.985*** (.981, .989)
Constant	1.276
-2 Log Likelihood	4258.611
Model chi-square	855.214***
Sample size	3,792

Note. OR = odds ratio; CI = confidence interval.

* P≤.05; **P≤.01; ***P≤.001.

CHAPTER SEVEN – DISCUSSION AND CONCLUSION

This section of the thesis restates the main objectives and findings in the research, and discusses the major trends and implications of these findings. The section is broken down into sections that discuss the floodplain analysis findings, following with the minority, education, and income findings for the longitudinal analysis comparing CAFOs and randomly generated points in 1990 and 2000 in eastern North Carolina.

Floodplain Analysis Discussion

One of the major research questions for the study asked if the geographic distribution of CAFOs sited within the 100-year flood zone correlate with greater percentages, compared to those CAFOs not inside the 100-year flood zone, of minority, low-income, and/or low-education populations. To answer this question, the geographic distributions of CAFOs sited within the 100-year flood zone and not inside the 100-year flood zone were mapped, and demographic information for income, race, and education variables on the one and three-mile buffers around these CAFOs were statistically analyzed using independent samples t-tests. The original hypothesis for this analysis assumed that greater mean percentages for percent minority, percent Hispanic, percent black, and percent with less than high school diploma would exist around the CAFOs sited within the 100-year flood zone. There was also an assumption that the income variables of average housing value,

per capita income, and average household income would have lower means for the sample population living near CAFOs sited inside the 100-year flood zones. This hypothesis is grounded in a growing body of research, outlined in Chapter 2, that finds more disadvantaged populations living near hazardous and polluting facilities; and since 100-year flood zones are the flood zones most vulnerable to flooding in heavy rains and extreme weather events, it was hypothesized that more disadvantaged populations would be living near CAFOs in these more environmentally at risk areas.

The floodplain analysis contributes to the body of research related to environmental justice and CAFOs because currently, no other research has paid attention to the siting of CAFOs in floodplain regions. The thesis' research methodology is the first of its kind to analyze the demographics of communities inside the 100-year flood zone and communities not inside the 100-year flood zone. This type of analysis introduces the assumption that communities living near to CAFOs in 100-year flood zones are more vulnerable as a result of increased occurrences of flooding and extreme weather events in these areas. This fulfills a gap in the current research because it also introduces other land use implications for increased vulnerability as a result of CAFO sitings. Further, the thesis is the first to analyze if this increased vulnerability is also a predictor of where minority, low-income, and low-education populations are concentrated.

Despite these new contributions, the results of the floodplain analysis did not support the hypothesis stated above. The only variable that was statistically

significant in the independent samples t-tests was percent Hispanic. However, the significance went in the unexpected direction such that there was a greater mean percentage of Hispanics living within a one and three-mile radii of CAFOs sited not inside the 100-year flood zones.

As a result of the insignificant results for the floodplain analysis comparing demographics near CAFOs sited inside the 100-year flood zone and not inside the 100-year flood zone, a number of possible scenarios to describe these results are theorized. The first possible explanation for the lack of significance is the possibility that most home owners might not consider what flood zone designation their property is sited within when considering where to buy or rent homes. If this is the case, then comparing demographics based on flood zone designations is not an effective level of analysis. The second possible explanation for the lack of significance involves the fact that all of the income variables and percent with less than high school diploma in eastern North Carolina are lower in the eastern North Carolina region compared to the overall averages for the state of North Carolina. Also, the percent minority, percent black, and percent receiving public assistance are higher in eastern North Carolina compared to the state averages. These facts might explain why the comparison of the variables' percent means for inside the 100-year flood zone and not inside the 100-year flood zone was insignificant, because the entire area of eastern North Carolina is overall poorer, less-educated, and more minority. As a result, there may not be enough statistical variation in the values of the demographic variables in eastern North Carolina, thus comparing the

demographics of floodplain zones in eastern North Carolina was an inconsequential level of analysis. A third possible explanation for why the hypotheses were not confirmed for this analysis involves the geographical location of the eastern North Carolina region being considered a coastal floodplain. In other words, all of eastern North Carolina is a low-lying region with an elevated water table. As a result of the entire region's location within a low-lying floodplain region, analyses that compare flood zone designations is likely trivial, and again this implies insufficient statistical variation in the data.

Longitudinal Analysis Discussion

The longitudinal analysis portion of this thesis compares the race, income, and education variables for populations living near CAFOs with populations not living near CAFOs in eastern North Carolina. The analysis was performed for both 1990 and 2000 to provide a cross-comparison analysis on a longitudinal scale. Currently, no other research pertaining to the environmental justice implications of the siting of CAFOs in eastern North Carolina has utilized a longitudinal approach. This approach helps to highlight any major demographic changes, resulting from the siting of CAFOs. Such demographic changes might be expected due to the potential effects industrial farming facilities have on property and housing values, along with the ability for more affluent populations to move away from LULUs such as CAFOs.

Bivariate Analysis Findings

The t-test results confirm that the means for percent with less than high school diploma and percent Hispanic were statistically significantly higher within the one- and three-mile buffers around CAFOs compared to those within the one- and three-mile buffers around randomly generated points. This was true in both 1990 and 2000. The t-tests also confirmed that the means for the income variables of per capita income, average household income, and average housing value were all significantly lower within one and three miles of a CAFO than within one and three miles of a random point.

Comparison of Mean Demographics from 1990 to 2000 Findings

The longitudinal analysis comparing the demographic changes from 1990 to 2000 was important for developing an understanding how the presence of CAFOs has the potential to result in overall population changes over time. A number of notable trends emerged when comparing the mean percentages of the eight variables between 1990 and 2000. First of all, when comparing the one and three-mile buffers around CAFO and random point locations, little to no differences existed when comparing these differing distances. As a result of this particular finding, the original hypothesis, assuming that the demographics within the one-mile radii around CAFOs, as opposed to the three-mile radii around CAFOs, would have higher percentages of minority, low-income, and lower education populations, was incorrect.

The second notable finding shows that housing values around CAFOs have increased over time, but are still consistently less than those housing values around the randomly generated points in Eastern North Carolina. This finding not only indicates the statistical significance of lower mean housing values around CAFOs, as compared to random points, but it also indicates that the disparities around CAFO and random point locations widened between 1990 and 2000.

The third notable finding relates to the percent Hispanic change from 1990 to 2000 around CAFO locations and random points. From 1990 to 2000, the mean for percent Hispanic rose by eight percent around CAFOs and only three percent around the random points. This indicates that the disparities in Hispanic percentages around CAFOs, when compared to the random points, widened over time.

The final important finding from the comparison of the mean demographics from 1990 to 2000 relates to the percent with less than a high school diploma. From 1990 to 2000, the mean percentages for this variable rose by around seven to eight percent around both CAFOs and random points. Although these percent increases did not widen between CAFO and random point locations, it is still important to note that the percent with less than a high school diploma was greater in both 1990 and 2000 around CAFOs as compared to random points in eastern North Carolina.

All of these findings indicate that not only are the mean percentages and values different when comparing populations around CAFO points and those around random points, but there are also noteworthy longitudinal demographic changes

that have occurred from 1990 to 2000. Most importantly, the longitudinal analysis offers that the percent Hispanic, percent minority, and percent with less than high school diploma has increased from 1990 to 2000 around CAFO locations relative to random point locations. That is, the disparities widened over time. However, the percent black and percent receiving public assistance has decreased around CAFOs from 1990 to 2000, which was also similar to the percent decrease of these variables around the random points during this time period. Also, the per capita income, average household income, and average housing value have all increased from 1990 to 2000, and this is more than likely due to inflationary changes over this ten year period. However, the important finding for this study suggests that the average housing values around CAFOs is around \$10,000 less than the average housing values around the random points, and this finding occurred in both 1990 and 2000. This particular disparity widened over time because the mean difference in 1990 was roughly \$8,000 dollars, while in 2000 the mean difference for average housing value increased to roughly \$10,000.

Multivariate Analysis Findings

The multivariate analysis findings show that even when controlling for socioeconomic variables, as the percents for Hispanic and people less than high school diploma increase, the odds of being near a CAFO, as opposed to a randomly generated point in eastern North Carolina, also increases. Also, as the income

variables of average house income, and average housing value decrease, the odds of being near a CAFO increase.

Discussion of Income Findings

All of the income variables including, per capita income, average household income, and average housing value, had lower mean scores around CAFOs within the one- and three-mile buffer when compared to within the one- and three-miles of the randomly generated points. Further, the multivariate analyses indicate that declining average household incomes and average housing values increase the likelihood of living near CAFOs when compared to the randomly generated points. Also, when comparing income variable changes between 1990 and 2000, the average housing values increased around CAFOs and random points during this time, but housing values around the random points increased more than \$10,000 compared to housing values around the CAFO points. All of these findings suggest that income variables are statistically related to the siting of CAFOs in eastern North Carolina. More specifically, lower income populations are more likely to live near CAFOs when compared to random points in eastern North Carolina not located near CAFOs. All of the income variable values similarly increased from 1990 to 2000 around CAFOs and random points. However, it is interesting to note that between 1990 and 2000, the difference in average housing values for CAFO locations versus random points spread from around an \$8,000 dollar difference to a \$10,000 dollar difference, with random point locations comprising a higher housing value. This

finding suggests that the disparity in average housing values is widening over time around CAFOs when compared to random points.

Discussion of Race and Ethnicity Findings

In all, the means for percent Hispanic were greater around CAFOs than random points in eastern North Carolina. Also, when controlling for socioeconomic variables, the multivariate analysis indicated that increased percentages of Hispanic populations increased the odds of the presence of a CAFO. Further, in 2000, the mean percent Hispanic within a one and three-mile radii of CAFOs in eastern North Carolina was above nine percent, while the mean percent Hispanic within a one and three-mile radii of the randomly generated points in eastern North Carolina was only slightly above four percent. This demonstrates that disparities widened over time around CAFO sites. It is also astonishing to see that the percent Hispanic within the buffers around the CAFOs rose by more than six times from 1990 to 2000. These findings do parallel with the overall state and eastern North Carolina county population increase of Hispanic percentages. However, the percentage of Hispanics living near CAFOs is still consistently greater when compared to the random points in eastern North Carolina.

One possible explanation for these findings is that growing populations of Hispanic workers are attracted to job opportunities as farmworkers on CAFO sites. This assumption would imply that Hispanic populations are moving near CAFOs to seek out job opportunities. This explanation is an example of indirect

institutionalized discrimination (Feagin, 1987). Indirect institutionalized discrimination is the negative or differential impact that minority groups can experience as a result of practices by organizations or communities without necessarily being motivated by racial prejudices (Feagin, 1987). Although Hispanic groups are not forced to work at CAFOs, the industrial agriculture industry relies heavily on cheap labor that Hispanic workers potentially rely as an income source. As a result, greater percentages of Hispanics are bearing a disproportionate burden by living near CAFOs. One could also argue, however, that this example is indeed a form of direct institutionalized discrimination also. As the name suggests, this form of discrimination intentionally places negative impacts on minority groups (Feagin, 1987). Under this scenario, Hispanic populations could be intentionally targeted by farming companies to work in dangerous and polluting CAFO facilities for less pay than their white counterparts.

Although the Hispanic variable overwhelmingly supported the original hypothesis that greater percentages of minority populations live near CAFOs in eastern North Carolina, the statistical findings for the variables of minority and black did not fully support the original hypothesis. The t-test results found that the minority means were only greater near CAFOs on the one and three-mile buffers in 2000, but this finding was not the case in 1990. This finding suggests that over the ten-year period, from 1990 to 2000, the minority population living near CAFOs increased. This particular finding could be linked to the earlier discussion of the Hispanic population increase in the areas near CAFOs between 1990 and 2000.

Also, the hypothesis that the percent black would be greater near CAFOs, when compared to the random points, was not confirmed by the t-test findings. Instead, the percent black was higher around randomly generated points. Also, the logistic regression results were not statistically significant for percent black, suggesting that an increase in percent black does not correlate with increased odds of being near a CAFO. In all, the research findings suggest that there is a larger percent of African Americans living in eastern North Carolina than the state levels for percent black, but the siting of CAFOs does not implicate greater percentages of African Americans, at least on the census tract level in 1990 and 2000.

Overall, the race and ethnicity variable findings suggest that CAFO sites are mainly attracting Hispanic populations, and this could be related to the availability of jobs at local hog CAFOs for Hispanic farmworkers. Further, this particular premise could be an example of indirect and/or direct institutionalized discrimination on the part of CAFOs hiring Hispanic workers.

Discussion of Educational Attainment Findings

All of the statistical findings suggest that there is an increased percentage of people with less than a high school diploma living within one and three-mile radii of CAFOs in eastern North Carolina. Further, the multivariate analysis findings suggest that as the percent with less than high school diploma increases so do the odds of being near a CAFO. Lastly, the percent with less than high school diploma increased by eight percent from 1990 to 2000 around CAFO points, which suggests the

percent with less than a high school diploma will continue to increase in the future around CAFOs. All of these findings indicate that there is a disproportionate amount of people without a high school diploma living near CAFOs in eastern North Carolina. Further, the findings point out that the percent of people without a high school diploma is widening over time around both CAFO locations and random points. However, this disparity has widened around CAFO locations from 1990 to 2000 as compared to the random points during this same time period.

This particular finding provides support of a sociopolitical explanation for the disproportionate incidence of polluting hog CAFOs in locations where lower education populations exist. Past research indicates that low educational attainment for a census tract or block group is a good predictor of a lack of political and social resources available to people within that geographic unit (Mohai and Saha, 2007). Thus, the lack of resources available to these particular census tracts around CAFOs with greater percentages of people without a high school diploma makes it far more difficult to effectively oppose the siting of CAFOs in these areas.

Conclusion

There has been a growing body of research related to the environmental justice implications concerning the siting of CAFOs. This study produced new contributions to this past research by examining educational attainment, introducing the first longitudinal analysis relating to CAFO sitings, and including a

methodology that spatially and statistically analyzed the presence of CAFOs within the 100-year flood zone.

There were two forms of analyses conducted for this study. The first analysis spatially examined the siting of CAFOs within the 100-year flood zone. T-tests were conducted in order to evaluate the means of eight race, income and education variables around CAFOs located in the 100-year flood zone compared to the same variables around CAFOs located not within the 100-year flood zone. The original hypothesis assumed that more marginalized populations live near CAFOs within the 100-year flood zone, and this is based on the fact that the 100-year flood zone is more vulnerable to flooding and extreme weather events as opposed to less destructive flood zones. However, the findings of the t-test analysis do not support this hypothesis. This finding implies that using flood zone designations is an inconsequential category of analysis when analyzing CAFOs in eastern North Carolina. Despite this, the methodology used in the floodplain analysis for this study might provide statistically significant results for regions with CAFO concentrations outside of eastern North Carolina.

The second analysis spatially and statistically examined the locations and demographics around all CAFOs in the eastern North Carolina region and compared these results to randomly generated points in the same region. Further, this analysis was the first of its kind to provide a longitudinal analysis of demographic changes around CAFOs. To do this, race, income, and demographic characteristics around

CAFOs and random points in 1990 and 2000 were analyzed using bivariate and multivariate analyses.

The results of the t-tests and logistic regression models indicate that greater percentages of Hispanic people and those without a high school diploma live near CAFOs and increase the odds of a CAFO location. Next, the results also suggest that tracts with lower mean values of per capita income, average household income, and average housing value live near CAFOs and these particular income variables increase the odds of a CAFO location. Further, the percent Hispanic and percent with less than high school diploma around CAFOs increased from 1990 and 2000. All of these findings imply that census tracts with the increased presence of Hispanic, low income, and lower-education populations are more likely to live near a CAFO in eastern North Carolina. This indicates that these populations are disproportionately burdened by the adverse impacts related to living near CAFOs in eastern North Carolina. Further, the disparities widened between 1990 and 2000 for percent Hispanic, percent minority, percent receiving less than a high school diploma, and average housing value.

Directions for Future Research

A number of new directions for future research appear as a result of the data and research limitations in this thesis and the study's research findings. These new recommendations for future research are highlighted below:

- **Include 2010 census data in the longitudinal research:** During the period of time that I was conducting my data collection, 2010 census data was not currently available. Including that data in the longitudinal analysis would offer a much more comprehensive analysis of the demographic trends and patterns that have occurred in the past 20 years as a result of CAFO sitings in eastern North Carolina.
- **Incorporate survey analysis into research methodology:** Although the study did not have the funds or timeline to conduct survey research in eastern North Carolina CAFO communities, this method could potentially shed light on how environmental justice communities are being affected by CAFOs in their community. This method would also add to the robustness of the study by not just focusing on quantitative research. One example of how survey data could help better develop the study would be interviewing Hispanic populations living near CAFOs. Important survey questions might include if they sought employment at local CAFOs, and any other reasons for why they located near CAFOs, such as lower property and housing values in the area. These surveys could better define the reasons why there is a disproportionate amount of Hispanics living near CAFOs.
- **Access the exact years that CAFOs were sited to support a more accurate longitudinal analysis:** Although it is known that most of the CAFOs in eastern North Carolina were sited in the early 1990s, I did not have direct access to the years each of the CAFOs were sited in the region. If a

researcher knew the exact siting dates of the CAFOs, they could determine more conclusively whether there was a pattern of disproportionately placing CAFOs in areas where minority and poor communities live, or if instead, the CAFOs attract minorities and poor people after their siting. However, both processes could also occur.

- **Incorporate climate change models to predict the future vulnerability for low-lying communities with CAFOs:** One of the original research questions I developed for this thesis was whether or not climate change was going to severely impact eastern North Carolina's coastal region, and lead to increased occurrences of water and air pollution resulting from CAFOs being sited in this already at risk area. Although the scope of this research question fell outside of my financial resources and thesis timeline, this is an important direction for future research because of the mounting body of research demonstrating that climate change effects are going to drastically impact low-lying coastal regions. It can also provide future explanations for the consequence of pollution and land use degradation resulting from industrial agriculture operations such as CAFOs.

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