Projected urbanization in North Carolina's Piedmont-Triad Region; *the urban heat island effect and future consequences related to citizen health and deterioration of local ecosystems*

Samantha Gaillard

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Introduction

The North Carolina Piedmont-Triad Region is a 12-county and 62 municipality section of the state that features major highway systems such as I-40, I-85, and I-77 (PTRC 2020). Within this geographic region are three major metropolitan cities that are the main focus of this research: Greensboro, High Point, and Winston Salem. This small grouping of cities gets its name-sake, Piedmont Triad, from being situated within the state's larger geographical Piedmont region. The cities which I will study are not the largest in the state, but they are beginning to reflect similar climate consequences in comparison with their more populated neighbors: Durham and Charlotte. As of 2020, Greensboro now ranks as the third-largest city in the state. The Piedmont Triad region (PTR) covers about 5,900 of the 53,000 square miles the state offers. The region is expected to grow economically and in population annually (Stanford 2019). According to the North Carolina Census, the Triad's overall population density has increased consistently with a growth rate of 4.4% since 2010 (Stanford 2019). Thereby, the overall impacts on population, metropolitan, and economic growth will continue to have effects on local ecosystems, heat distribution, and citizen health.

The focus of this research will be analyzing how projected urbanization in the Piedmont Triad is contributing to city climate change impacts through the urban heat island effect. In addition, town solutions and citizens' health will be referenced to draw reliable conclusions on the importance of municipal and immediate action in the PTR. When comparing the demographics in the state from 2010 to 2020, the Piedmont Triad revealed higher levels of sprawl which have begun to impact many variables such as population increase and emissions output. In 2010, the total population of Greensboro, Winston Salem, and High Point consisted of about 603,000 people. By the end of 2019, that population had increased to 663,000 and

counting (U.S. Census Bureau 2018). The Triad as a whole has a growing population of 1.7 million people. Population growth without strategic planning will continue to put stress on energy demand and use, waste emissions, and future livelihood.

I will begin by introducing the history and science behind the urban heat island (UHI) effect with data from impacts on previously studied cities. The UHI is being exaggerated within more urbanized centers through the continued destruction of green, natural spaces by the development of asphalt and alternative heat-absorbing materials (Qian et al., 2016). The relationship between city and climate is dependent and has a direct impact on the amount of heat being trapped and/or reflected. Consequences of the UHI will be the most consistent through water body analysis, meteorological patterns, and being able to compare the cities to their rural outskirts. Then, I will be analyzing the Piedmont Triad's 2014 sustainability action plan and any further proposed municipal plans that attempt to combat any effects of the urban heat island effect. For example, the City of Greensboro released its action plan in 2011 (amended in 2020) that only mentions the urban heat island effect once (Landau and Powell 2020). Lastly, I will compare annual temperatures to any local health reports of heat-related illnesses as compared to previous years. The results of this paper are to conclude that the North Carolina Piedmont Triad region is experiencing a UHI that is threatening citizens and local ecosystem sustainability.

Urban Heat Island Determinants

The urban heat island is described as a kind of heat accumulation phenomenon within a concentrated metro area due to increases in construction and human traffic (Qian et al., 2016). The effects are considered by environmental scientists as one of the main causes of rural versus city temperature differences. One of the first cities to be recorded for a shift in inner city

warming was London, England by scholar, Lake Howard (Qian et al., 2016). Howard's research focused on the specific material use of asphalt and concrete in this city. His research around this issue of centralized heat in urban areas has infiltrated the realms of metropolitan planning and has catapulted a new field of climate science focusing on unequal heating absorption. Asphalt and concrete surfaces within the municipalities will continue to absorb the sun's heat, just as Howard theorized because they are so dark and do not have abilities to not reflect the sun's radiation (Qian et al., 2016). Since then, many efforts and pursuits have been demonstrated in the scientific community that supports the effects of centralized warming in most growing cities. It is important to recognize how significant the relationship between inner-city temperatures and specific ecological functions is. Many natural processes such as evapotranspiration, albedo effect, and greenhouse gas emissions are being impacted and changed by consistent, localized urban heating. These variables are factors that can be measured to determine the presence of an urban heat island effect.

Evapotranspiration is the reaction of the sun drawing moisture out through the soil in tandem with the plants absorbing and releasing vapor through transpiration. This action contributes to the overall cooling of the city because both parts of the natural process require heat from their surroundings. A direct relationship exists between increases in evapotranspiration and a decrease in city temperatures. As the water vapor is drawn up and released from these plants, other critical metabolic and physiological functions can occur that impact local ecosystems (Chen et al., 2013). As these cities continue to increase in population and as an economic sector, there will be more intense development and pollution concentrated within areas that already contribute to local heat absorption. A large factor indicating a loss of evapotranspiration is the loss of native plants and diversity due to development. Many studies have supported the idea that

urban greenery is beneficial in mitigating the levels of ambient air temperatures (Chiam et al., 2015).

In addition to evapotranspiration, more ecological functions will steadily decline without the presence of these natural, green spaces. Internal municipal temperatures will continue to rise when considering the lack of shade cover from trees and the persistent loss of natural cooling effects. Due to the lack of evapotranspiration and shaded areas, the cities are beginning to rely on energy-intensive cooling measures (Mayclin 2018). Following, usage of air conditioning (AC) is substantially increasing as citizens require additional unnatural cooling from the lack of heat reflection and shade within the city as a result of urban sprawl. According to the U.S. Energy Information Administration, North Carolina's climate is considered mixed humid and contributes to many decisions behind personal and commercial AC usage. Currently, air conditioning energy usage accounts for about 12% of US Southeast home energy expenditures (Mayclin 2018). This number will increase annually and continue to emit radiation while reflecting the public's response to the ongoing heating crisis through AC usage.

AC systems are also contributing to warming through the continued release of EMF radiation in the air and atmosphere. Not only are the systems warming the city, but contributing further to ozone impacts through pollution release (Landau and Powell 2020). In Greensboro's Sustainability Action Plan, the city is implementing the use of HVAC system upgrades both commercially and residentially. These changes are anticipated to conserve about 10% of energy over the upcoming years (Landau and Powell 2020). The natural process of evapotranspiration has impacts on many variables that are just as likely to trap heat within the city. Lastly, evapotranspiration is directly related to the reflection of specific gases and heat-known as the

albedo effect. This reflection is a broader issue that begins to reveal impacts to many natural cooling processes contributing to the UHI.

The albedo effect is a great determinant of how much of the surrounding environment is absorbing or reflecting the sun's radiation. In more populated cities, many calculated albedos tend towards levels of 0.00-0.10 due to the lack of greenery (Chiam et al., 2015). A lower albedo indicates that the surface does not have properties that allow for radiation reflection. Without the implementation of reflective materials and conservation of vegetative areas in city limits, there will be added contributions to the urban heat island effects. The PTR has a significant amount of natural space that helps the city naturally cool. But, these spaces are spread out and are being impacted by continued development that further impacts the evapotranspiration and albedo processes (Stober 2014). For example, the albedo of snow and ice masses tends to be around .80-.95, while the albedo of the ocean rests at about 0.02 and .10 (Climate Data 2020).

In the Piedmont Triad, using albedo values can help determine future city development strategies and decisions that should consider radiation reflective and heat absorptive products in structural uses. These two factors, evapotranspiration and albedo effect are interconnected variables that can help to determine the presence of an urban heat island effect. There is a dependent relationship between the two and the percentage of undeveloped land. If there are more instances in the Piedmont Triad with a lack of evapotranspiration and lower albedo results, then it can be concluded that a UHI is beginning to take effect in the city. Likewise, community response to these variables is essential because greenhouse gas emissions will continue to be emitted if ecological functions are interrupted and human activity is not mitigated.

Greenhouse Gas Emissions and Urban Heat Islands

Many of the problems exaggerating the urban heat island effect stem from human activity and the release of greenhouse gases (GHG). The emissions of these gases come from a variety of sources within the city, both commercial and residential. These are specific gases that absorb and emit energy back into the atmosphere. GHG emissions were once regulated through natural feedback processes, but human activity has heightened the unnatural release of pollutants that enhances their negative impacts (EPA 2019). GHG are important because their ability to penetrate and impact the ozone affects all living things on Earth. As a result, the ozone layer is thinning due to the prevalence and intensity of these gases. The lack of ozone protecting the Earth will result in higher temperatures and a change in ecological response (EPA 2019). Moreover, community responses towards mitigating the UHI effects should be met with strategic planning since GHG emissions in the Piedmont Triad have skyrocketed following the industrialization of these cities over the last decade. Through data in each city's sustainability plan, researchers can determine which activities result in more GHG emissions, how they have changed over the years, and the importance of heat reflection in metropolitan areas.

In a report released in 2016 by the city of Winston Salem, it was assumed that greenhouse gas emissions would increase as a result of project development and impact the total amount of natural land square footage (Hardin and Peplowski 2016). Many of the harmful emissions from the PTR come from the Department of Transportation and utility centers. In Winston Salem, these sites have been shown to release about 84% of the emissions (Hardin and Peplowski 2016). Upon further analysis, after 2011, Winston Salem has had periods of intense GHG release and relief. In Greensboro, their efforts to reduce emissions are stated within the goals of the sustainability action plan (Landau and Powell 2020). Both cities have high energy usage that

contributes to more warming within industrial limits. Nationally, the different gases that are released through natural gas and electricity usage make up about 27% of the emissions in the United States (EPA 2019). Gases such as carbon dioxide, methane, nitrous oxide, and fluorinated compounds are the largest threats contributing to ozone depletion and city warming (EPA 2019). The impacts of greenhouse gas emissions on the environment are substantial. Once the natural systems are impacted, the flux of ecosystems is affected. The urban heat islands are amplified by many factors in the city that have been discussed. Their effects have been correlated with far-reaching impacts such as droughts as well.

Urban Heat Islands and NC Water Bodies

Climate change in the Piedmont Triad will not only affect the way city ecosystems operate, but will also heavily impact local water bodies and drought effects. The U.S. Southeast already experiences many natural disasters in which federal aid is required for assistance (Stober 2014). Due to the UHI, drought resistance following the impacts on evapotranspiration, local rainfall, and temperature increase, is affecting the region. If the persistence of droughts continues, then the negative impacts of the urban heat island effect will only continue to be magnified by the expected increase in natural disasters. According to Piedmont's Climate Adaptation Plan, the Triad of North Carolina consists of many financially vulnerable communities that would be impacted the most by flash flooding or persistent droughts (Stober 2014). In 2019, drought had started impacting supply in at least thirty counties throughout the state. Klaus Albertin, the chairman of the North Carolina Drought Management Advisory Council made a statement that year, "...We are seeing impacts to streams, groundwater levels, and inflows to reservoirs across central and eastern North Carolina" (Perkins 2019). These

specific intervals that are monitored for drought are important because the determinants of whether current conditions range from abnormally dry to exceptionally dry will affect community response. The last drought that occurred in North Carolina before May of 2019 was May of 2018 (Perkins 2019). The beginning of these droughts in NC are around similar times annually, near the months of Spring transitioning into Summer. Not only should the time of year be monitored for differences in front activity, but so should streamflow, local climate patterns, and water body evaporation levels to determine possible solutions.

There is evidence to support how urbanization is affecting watersheds through the loss of forest land and sprawl. However, there is information lacking about the effects in the Piedmont regions. In North Carolina, studies have been conducted in Wake and Durham county that allude to differences in the land around forested watersheds versus urban watersheds (Boggs et al., 2012). Stream channel and elevation change from 2000-2007 were assessed within both the urbanized and the forested regions. The conducted analysis reveals that the impacted watershed has less capacity to hold water compared to the forested one (Boggs et al., 2012). Many studies were conducted through continued observations of these variables that provided reference data to impacts on evapotranspiration as a result of the UHI. There were differences in the soil series and impervious cover between these two locations which significantly affected the net water amount (Boggs et al., 2012). While these results are in neighboring counties, the city coordinators within the Piedmont Triad have begun to realize how significantly urbanization can impact the local natural resources. The ability of a city to hold water will contribute immensely to the ability of it to naturally cool itself. All of these factors are interconnected and continue to be depreciated by human activity.

City Materials Use and Urban Heat Islands

Structural materials used for building and the total percentage of heat-absorbing materials in the city is another factor that contributes to the exaggeration of urban heat island effects. The materials used for building can be permeable and impermeable; both of which significantly affect the amount of heat being absorbed. It was found in the comparison of permeable versus impermeable surfaces that heat retention is higher in the permeable materials. The shift to these more sustainable sources is one of the first steps to take towards future climate change impacts (Li 2016). About 90% of residual heat in a city is due to the inadequacy of materials used in buildings and pavements. The type of material used is critical in supporting a city that reflects more heat than it absorbs (Li 2016). Current environmental studies show that because of North Carolina's specific geography, there is a considerable amount of rural farmland that borders many cities. In these locations, the UHI will not be as much of an issue (Stober 2014). Asphalt and brick are darker materials that can absorb heat consistently throughout the day. In some cities, there have been mitigations to this issue through the use of high albedo materials on rooftops, building walls, and pavements (Li 2016). In a study done, it was found that when an albedo changes from 0.24 - 0.40, the likelihood of inner-city cooling is 40% higher compared to rural areas. With this in mind, it is crucial that the city plans for the change in materials for buildings towards those that will help to curb and reduce the heating effects (Akbari et al., 2000).

Current Piedmont Triad Solutions

In addition to shifting the materials used in construction to more heat-reflecting sources, another simple city solution is to paint rooftops and pavements white or use reflective colors. This transition would positively affect the city's albedo and the ratio of building to heat retention

(Stober 2014). Using lighter materials in the scenarios regarding city architecture can significantly decrease centralized heating if applied to most buildings in the PTR. Most rooftops get resurfaced or painted every decade anyways, thereby in the next cycle, this task could be easily done to pre-existing buildings. Any new structure to be made should intentionally choose materials that are better for the mitigation of the UHI (Akbari et al., 2000). Another recent implementation in some cities is the idea of green or cool roofs.

Green roofs are specific sites of vegetation on urban rooftops, whether this is commercial or residential in cities. They have been prevalent throughout Europe, but are beginning to be seen and in discussion throughout the U.S. According to the Environmental Protection Agency, green roofs can induce about 30-40% more cooling than conventional roofing (EPA 2019). In recent years, the market for green roofs has increased, even within the PTR. In High Point, a local company has pioneered itself through installing eco-friendly roofs called Green Roof Gals (Daniel 2019). In a news article posted about the group called in 2012, a natural resource agent for Forsyth County stated “We don’t have a lot of green roofs in North Carolina because we just don’t plan ahead for that type of thing structurally on a building” (Daniel 2019). Since then, there have been many initiatives to install green roofs within large sections of the Piedmont Triad as a supplemental long-term, structural solution. In 2011, a Winston Salem group called LiveRoof created a startup plan to install green roofs throughout the Triad. This group has a large scope of initiatives to create green architecture that is resilient to climate change impacts in addition to creating aesthetic building spaces (Storm Water Solutions 2011). Not only do green roofs help with the city albedo and evapotranspiration rates, but they also can absorb more stormwater which naturally cools the surroundings areas. Some of these locations in the PTR for future vegetated roof projects are at the Winston Salem Career Center, a Greensboro transit building,

and Walkertown middle/high school (StormWaterSolutions 2011). Since the idea is not only eco-friendly but aesthetically pleasing as well, many homeowners are beginning to consider vegetated rooftops for their homes.

The last option for metropolitan heat reflection is cool roofs. Cool roofs have been used commercially and residentially for over a decade, but their properties for mitigating the urban heat island effect still are constantly being updated (EPA 2016). Cool roofs have high solar reflectance and can transmit back sunlight efficiently. According to the EPA, the properties of cool roofs can alleviate temperatures of up to 50-60 degrees Fahrenheit cooler than other conventional materials (EPA 2016). Many cool roofs are a specific type of metal that has transient characteristics allowing for further opportunities for both commercial and residential locations to cool the city (EPA 2016). They are often used on both low and steep-sloped buildings, making them a great solution to conventional darker materials. In a recent analysis, the U.S. dominated the cool roofing market in 2019 through the increased commercial use of them in city hospitals, manufacturing plants, and universities (Watson 2020). Coupled with cool roofs is the use of awnings in cities to further protect the cooling ability of residential and commercial buildings. Awnings are an example of a low-technology solution that can dramatically increase the amount of cooling with homeworkers or commercial urban locations. Awnings can come in different forms but have overall proved to reduce the heat by up to 65% in south-facing windows and 77% in west-facing windows according to the government's energy efficiency research (Gunn 2019).

Awnings are an example of a low-cost solution that can prove to withstand additional environmental conditions compared to their uses in the past. Previously, awnings would consist of metal or canvas materials. More recently, their production is made from synthetic materials

that allow for better reflection (Gunn 2019). It is important when considering the use of awnings that their intention can be reversed and cause additional centralized warming when used improperly or they are left out during the wrong seasons. The market for retractable awnings has increased due to this reason, and the individual consumer solutions to city heating are beginning to create larger community efforts for future mitigations against the impacts of climate change.

Many factors are affecting the ability of the Piedmont Triad to reflect energy back into the atmosphere. Such factors mentioned such as evapotranspiration, albedo, and materials used are all parts of processes that are incredibly essential to many natural functions. Their fluctuations must be met with solutions and studied in regions with more retained heat. Each city has created a sustainability action plan that has been introduced briefly and will be addressed further in the next few pages. These action plans are crucial components of city solutions to the many factors that are impacted by unequal warming.

NC City Climate Plan Analysis

Each state plan included below outlines forward-thinking green solutions coupled with impending state and county effects of climate change. The plans recognize human and natural occurrences that are impacting local ecosystems and citizen health throughout the state (Stober 2014). Many variables such as the effects of the sun's intensity, changes in orbit, burning fossil fuels, and urbanization are addressed in some of them, specifically. The purpose of this section is to highlight the important elements of city response strategies mentioned in each independent action plan as related to the UHI and analyze the reliability of their solutions. The future of the Piedmont Triad can be best outlined by the recently released North Carolina's Climate Adaptation plan instituted in February of 2014. This action plan was created by a regional group

called “Piedmont Together” with the support of the U.S. Department of Housing and Urban Development and the Piedmont Triad Regional Council (Stober 2014). Greensboro and Winston Salem have both instituted their plans that are projected to be implemented towards overall state environmental efforts. High Point does not have its action plan but continues to follow the footsteps of its neighboring cities.

The NC Climate Adaptation plan analyzes meteorological changes and consequences such as droughts, extreme weather, heatwaves, and other identifiers of changing city patterns (Stober 2014). Each of these consequences directly relates to the urban heat island effect and what must be done in the future. According to this plan, the NC PTR is more vulnerable to “heat stresses due to its high level of traffic, reduced tree canopy, and large population of vulnerable individuals” (Stober 2014). These examinations are reliable with hotter temperatures and the outcomes demonstrate the presence of an urban heat island effect. A significant number of yearly studies have been carried out and the council has narrowed down issues concerning a shift in yearly precipitation, more supported dry spells, and heatwaves (Stober 2014). The National Oceanic and Atmospheric Administration (NOAA) released a nationwide temperature analysis from March-May 2012 that classifies North Carolina with record warming temperatures. Since then, new climate data has revealed 2019 to be North Carolina’s warmest year. This data joins a reserve of observations from the state that dates back to 1885 (Dello and Davis 2020). As mentioned previously, there will be more exaggerated consequences of the UHI if cities continue to retain heat. This plan substantially includes many features of consequences and adaptation strategies the Piedmont Triad must adopt with projected conditions. The Climate Adaptation plan easily displays critical meteorological and natural resource data with detailed graphics and information that the public can understand without much prior environmental science

knowledge. In addition, the Piedmont Action plan recognizes the urban heat island effect as one of the four major reasons for impacts due to climate change within the city (Stober 2014).

Piedmont Together and the other involved committees have compiled reliable and comprehensive data that details the regions' current and future ecological impacts. In regards to the UHI effect and this research, the data presented reflects the presence of active sustainability programs and different mitigation projects accompanied by future preparedness strategies to combat-related consequences. The solutions mentioned in this plan coalign with many active green initiatives that have begun within the last five years in the Piedmont. For example, the Piedmont Environmental Alliance oversees many community events throughout the triad focused on greening the city that aim to involve many people from different areas of the city. This initiative is helping community members make individual efforts as well as put pressure onto commercial businesses for systematic change.

The Piedmont Climate adaptation plan is the most consistent source of data for the Piedmont Triad available currently. At the end of their published report, there are credits given towards the North Carolina Interagency Council (NCIC). This group is another organization that works directly with political sectors to push the new and sustainable plan into action. Many of their strategies for greening the city have been used as the basis for the Piedmont Together compiled report (Stober 2014). I think it is important that these action reports address the influence that stakeholders hold in city decisions because of how critical their roles are. Lastly, the overarching benefits that this Climate Adaptation plan mentions are many of the bases that individual cities such as Greensboro, High Point, and Winston Salem are committing to efforts towards developing their unique plans.

Winston Salem has multiple plans, which limit their regard to mention the term “urban heat island”. Their original approved plan was released in 2008, with a significant focus on greenhouse gas emissions and plans to reduce city amounts. Many of the original 2008 goals had certain targets to meet by 2010 (City of Winston Salem 2008). Since over a decade has passed, an updated version with newer information can be used as the determinant if city strategies have been a success. The most recently compiled report was released by the city of Winston Salem in 2017. The Winston Salem Office of Sustainability Manager, Wendell Hardin, and Project Coordinator, Helen Peplowski, introduced these plans to the City of Winston in 2016. The plan has recently been amended with new statistics as of May 11, 2020, but it is yet to be released. This report's compilation of data does include many similarities to the region’s climate plan proposed by Piedmont Together, but with a reserved focus on city energy usage from electricity and natural gas (Hardin and Peplowski 2016). The focus of the updated report was to include the change in greenhouse gas emissions and updates in the future action plan. Importantly noted in the 2016 plan is that there are ongoing discussions and city meetings about a specific city action plan for Winston Salem going into effect within the upcoming years (Helen and Peplowski 2016). The basis for this plan will be focused on the overall sustainability goals for the state of North Carolina, but with application to the city of Winston Salem.

This third unreleased plan for Winston Salem has been developing over the last few years and is currently in the stages of passing through city sustainability committees (Young 2020). The coordination with city policymakers and stakeholders is critical because these positions influence municipal decisions due to the nature of the solutions requiring significant city planning and funding. Therefore, any information included in the plans that regard emissions or infrastructure must be considered for effects of urban heat island exaggeration since they are

interrelated. Impacts such as greenhouse gas emissions, energy usage, natural gas prices, and vehicle emissions are important factors mentioned in the amended Winston Salem action plan that will heighten the effects of an UHI (Young 2020).

In an objective reflection of the 2008 and revised 2016 plans that the city released to reduce emissions, many avenues are being addressed for their energy output and usage within the city. The larger concerns are focused on the city transportation fleets, utilities, and unsupported population increase within an increasingly stressed region (Hardin and Peplowski 2016). Surprisingly, there are solutions listed in the 2008 report- such as developing sustainability and conservation partnerships, expanding on land-use strategies, and establishing operative goals for the use of energy within the city- that have been met with positive results. In 2008, the city's greenhouse gas emissions for electricity were 86.2% (City of Winston Salem 2008). In 2017, these emissions decreased about 8.5% from this baseline to 81%. As the city's largest contributor to emissions, electricity output solutions are comprehensive datasets to monitor.

The relationship between electricity and the urban heat island effect was researched in a 2015 study done on the impact of the heat island on power usage. It was discovered that, on average, when there is an ambient temperature rise of one degree, electricity load can increase from 0.45% to around 4.6% (Lodi et al., 2015). Moreover, each household is releasing more electricity than they would originally because the city is trapping heat. In 2017, the most recent solutions to this problem are noted as implementing sustainability programs, corporate participation, and cutting overall GHG emissions. The electricity and natural gas output are further multipliers of heat being trapped within city limits. These interrelated variables are also present in the Greensboro plan, including similarities regarding the amount of heat trapped as a result of less green space.

Greensboro has two action plans consisting of solutions for the city to undertake and has compiled data of the climate change effects on natural ecosystems and citizens. The city's first sustainability action plan was instituted in 2011 and amended in 2020. It has separated city issues into eight important topics. Many of the topics such as adaptation, city operations, and green technologies directly relate to the urban heat island effect (Landau and Powell 2020). With that being said, it is essential to recognize the connection between developing solutions to the climate crisis and future city plans. This plan introduces many statistics supporting the Piedmont Triad's response to climate change. It provides data that impacts all sectors and urges immediate state environmental reform supporting recent suggestions of(Landau and Powell 2020). Following the City of Greensboro's passing of this amended plan, a new comprehensive action plan was released with long-term solutions for the years leading up to 2040. The Greensboro 2040 Comprehensive Plan was released in June of 2020 and acts as a planning document for future growth and changes the city will face (City of Greensboro 2020). More conservative strategies can be implemented with ongoing considerations given towards the use of natural resources and spaces within cities. Places such as parks, lakes, gardens, and local fauna/flora will greatly reduce the warming effects within cities because of their ecosystem services. The conservation of natural spaces is a large feature of this new plan. It is with the help of city planners that their conservation efforts are consistent with new data and protect natural green space within the city following more urban sprawl (City of Greensboro 2020).

One of the recommendations stated in this plan is focused on a project titled "Greening the Downtown Greenway" (City of Greensboro 2020). This project began in 2017 for crowdfunding through a conservation-based community group called Greensboro Beautiful. A 4.1-mile natural loop is planned to surround the city and include "solar panels, alternative

transportation methods, and agriculture" (City of Greensboro 2020). The Greensboro city action plan has significant solutions and propositions that impact current practices, those that can be developed better. The eight-category and twelve policy data compilation includes solutions under each category and is a great source of information on climate projects the city is currently undertaking along with those they plan to fund in the future.

Lastly, High Point does not have a specific action plan, but its minimal energy usage and city statistics are available on the regional website through annual community development and housing reports. Much of the High Point resides within Guilford county, which allows for a grouping of these two cities together in reports- Greensboro and High Point. The city of High Point is smaller in comparison and is only starting to urbanize more recently (Data USA 2020). High Point can be concluded as also having many of the problems associated with the urban heat island effect in Winston Salem and Greensboro, but on much less of a scale since the city is significantly smaller. High Point University (HPU) is a large economic and emissions flux for the city- noted as one of the larger private institutions within the state. It has been awarded, along with the University of North Carolina at Greensboro (UNCG) as being members of the Tree Campus USA. This program is a committed long-term project that is sustaining healthy forests on college campuses (Tree Campus USA 2020). At each university, there are available environmentally conscious resources, information centers, and active programming aimed at campus carbon footprint reduction as well as activism with goals of city conservation reflecting citizen and environmental needs. High Point is benefitting from Guilford county's climate response, but many of the same statistics that Greensboro and Winston Salem have are lacking because of the grouping together of the two neighboring cities. The rest of the city of High Point resides in Davidson and Randolph counties, a more rural outskirts in the twelve-part section of

the Piedmont Triad. There are no published reports of different environment data coming from this county because they are considered under Rockingham and Lexington city statistics in the overall Greensboro-High Point NC Metropolitan Statistical Area (Stober 2014). This area does not legally bind these cities nor relates them on any level except for high population density and economic outputs (Stober 2014). As a result, I think it would be beneficial for the city of High Point to create its personal sustainability action plan in response to the other plans following Greensboro and Winston Salem initiatives. The overall conclusions these plans must come to regarding solutions all center around the protection of the people and the environment. Citizens face many changes as a result of urban heating, but in the PTR heat-related illness is a large threat.

Citizen Health Impacts

Since the Piedmont Triad is the region in the state with the most elderly people, the reliability of climate adaptations must include aging citizens and the possibility of a vacuum to the economic stability in the future (City of Greensboro 2020). Research has shown that over the last decade the population breakdown of the Piedmont has revealed a trend in the age margins of homeowners. More young people are moving from the Triad and older generations are settling in the city and its rural outskirts (Stober 2014). According to the Centers for Disease Control, people ages 65 and older are more prone to react to heat via heat stroke and heat-related stress compared to other age groups (CDC 2018). Protections must be in place for the elderly community living in the PTR since the presence of the urban heat island is prevalent and becoming exaggerated more often. Another factor that can threaten citizens' health is that within the United States, one in five seniors over the age of 70 are experiencing financial hardship while

31% of those in the age group 60's are having the same problems (DCCA 2013). Age and the hardships of financial insecurities can result in the lack of initiative for older individuals to turn on their air conditioners or fix broken items. This position exacerbates the heat they are exposed to. The results of the urban heat island effect not only affect the elderly but those who are working outdoors and have intensive job requirements in the field.

In a news report released in July of 2020 by the North Carolina Department of Health and Human Services, from the time of May-July there had been 1,205 heat-related illnesses. Comparing those results to 2019, the warmest year on record in NC, reports show that there were 3,692 total heat-related illnesses from just May-August. Many of the reports were statistically men ages 45-64 that had been recently exposed to long periods in the outdoors and recreational activities during the summer months (NCDHHS 2020). A report that the North Carolina Disease Event Tracking and Epidemiologic Collection Tool (NC DETECT) released in 2019 regarding hospital-related environmental records revealed a higher number of hospital intakes during the months of May and July that year (NCDHHS 2019). Statewide in August 2019, NC DETECT analysis reported 34 heat exhaustion hospital visits from those in the recreational and outdoor fields. More importantly, the heat exhaustion phase of heat illness can lead quickly to a heat stroke which is a very concerning medical issue. Heat strokes are life-threatening developments of the body that can cause damage to a person's control system and lead to brain damage (CDC 2018).

City climate solutions must consider how to best manage individual impacts within city centers and in rural counterparts. More hospitalizations can also be attributed to higher pollen counts, ground level ozone ratios, and air quality degradation as respiratory-related illnesses will become more of an issue as ratios continue to degrade as a result of the UHI. As of 2013, North

Carolina has one of the highest rates of heat-related deaths in the United States (Arbury et al., 2014). Methods of transportation are important during the spring and summer because of the intensity of the stored heat during this time. Many citizens commute through public transportation and walking throughout the city, but will continue to be limited in these efforts as conditions get hotter (Arbury et al., 2014).

Many current studies show that most heat-related illnesses within the state are in rural areas surrounding the cities. Citizens health officials are most concerned with the risks of heat-related illnesses. As it has been concluded, urbanizing cities such as the Piedmont Triad are getting warmer annually and contributing significant amounts of greenhouse gases into the atmosphere as a result. It is beneficial that these cities have begun thinking about future metropolitan plans in terms of urbanization and how to be the most sustainable. Furthermore, these plans should continue to include health protections following city warming with created initiatives for community outreach and conservation strategies.

The last demographic of people within the Piedmont Triad region to experience more effects from the urban heat islands over time will be those in poverty. Living in impoverished conditions while operating daily life under the impacts of climate change will be a hardship for many city residents. In Greensboro in 2018, about 52,000 people lived below the poverty line. This number is dramatically higher than the same measurement in the year 2000: 26,000 people. In Winston Salem, the poverty levels are above the national average (Data USA). Due to the varying levels of poverty, many adults and children face a variety of consequences of the UHI. Many of those facing poverty are living in places that are more heat retaining and less impervious towards the water. These conditions will lead to higher rates of community needs as a result of the UHI.

There are racial disparities between white and black communities that lead to further division by the effects of urban heat islands in the state of North Carolina. Different items such as air conditioning, access to water, and stable transportation are many of the indifferences between those in poverty experiencing centralized heat effects and those above the poverty line (Gronlund 2015). If temperatures within the city are expected to increase with more urbanization and affect the health of citizens unequally, then it should be released in each regional location's climate plan how they are planning to address this in future changes. In the current plans released, there is minimal coverage given to a racial disparity in the region, but a few mentions of poverty and how to best implement solutions. Each plan has similar versions of community improvement programs, specific statistics taken on environmental injustices in the PTR, and an eager outlook on the community response to urban heating.

Discussion

Within the last decade, there have been more city council discussions about climate change which have led to city action becoming consistent and reliable. With a large focus on city emissions, the consequences of the urban heat island effect could remain stable or begin to lessen as a result of solutions being implemented. By referring to Figure 1, the three cities being analyzed for this research are outlined for geographical consideration. Furthermore, if no action is taken, the heat retaining effects will only continue to impact local environments and health. The importance of natural processes such as albedo, evapotranspiration, and city cooling have been mentioned due to the loss of green space for development in the cities. Figure 2 is a breakdown of the counties that have experienced the most forest loss contributing to the fluctuations in these levels. The Piedmont cities in the discussion are in the -17% to -14% loss

range. According to the published Climate Adaptation plan, 7.4% of the rural land has been lost from the years 1987-2007 in the PTR (Stober 2014). The exaggeration of the urban heat island in the city is demonstrated in Figure 3. The rural outskirts have more albedo and evapotranspiration contributing to their cooler temperatures. More of these albedo values are shown in Table 1 to compare their values with city recorded ones. Furthermore, Google Earth can provide critical imaging of these cities over the last decade which can begin to emphasize the rate of sprawl and loss of green spaces. The thermal imaging of the cities in addition to a timelapse of sprawl and growth are also key indicators towards the increasing concerns following an urban heat island presence. There is a lot of possibility for further research to continue on the urban heat island effects in the Triad.

Natural gas and electricity use are also catalysts towards greenhouse gases polluting these cities in NC. Figure 4 is a constructed analysis of the greenhouse gases emitted from 2008-2016. The report focuses on the difference between a reference base temperature and the average temperature of the day (Hardin and Peplowski 2016). In analyzing this data, there is a controlled base for heating and cooling intensive uses of energy creating GHG. The plans are crucial towards urging the city to take action and proper implementation strategies. As mentioned previously, albedo value is a significant tool when determining an overall environmental analysis of cities. After comparing the solutions mentioned previously within the reviewed action plans, it is obvious that there are important and committed groups of people that have been hired and positioned to manage the city's sustainability suggestions. There is now a large focus on sustainability in the cities of Winston Salem, Greensboro, and High Point that is positively contributing to the mitigations of climate change. The ongoing urban heating crisis has revealed many changes that need to be made to adjust in the long term. The results of each city's action

plans should be held with high regard as the contenders for this change are needed. Overall, the action plans have great potential for emissions reduction. Each of them has more ability to go into detail and adequately list human and ecological impacts versus only proposing solutions and generalizing the effects. It is important to understand the gravity of municipal response because cities themselves can impact the nature of harmful catalysts.

Conclusions

Climate change and the effects of the urban heat island will only continue to get worse annually. I recognize how important long-term outreach is when discussing climate because of how broad environmental conservation is. The support of the vitality of the Piedmont Triad in NC is a large factor in ongoing discussions. Although each city action plan seeks solutions by 2040, many of them are far-reaching and will not see immediate results. These are important to consider when talking about citizens' and environmental health as a top priority. There must be implementations in place that can lessen the effects in the short term and long term. As mentioned in previous paragraphs, the city can begin to install architectural changes such as cool roofs, rooftop gardens, or utilizing the ability to paint darker surfaces white. These mitigations and solutions will slowly begin to minimize the amount of heat retention in the Piedmont, but are also limiting to those in poverty and experiencing homelessness. Unless there is some safety net system installed which will provide aid relief to those most affected by climate change, there will continue to be a disparity between those who can protect themselves against the effects of climate change and those who can not. Nevertheless, the released action plans that Winston Salem, Greensboro, and High Point have released have many consistent and equitable solutions for conditions related to the urban heat island effect. I am sure that by the PTR regional goals of

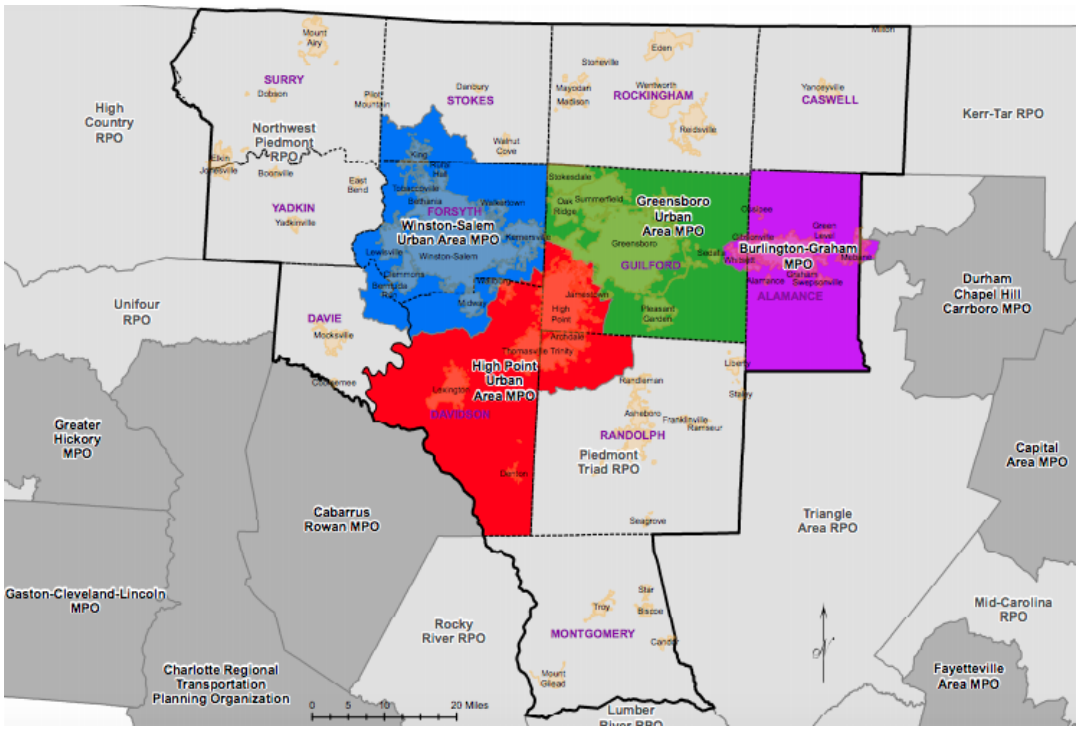
2040, many of these sustainability programs will be established if regional councils keep pressure on local government reliefs and policies to be passed. Otherwise, limits in these action plans will continue to exaggerate the UHI.

Nationwide urban heating impacts are threatening natural green coverage in states and how the population will respond. Factors such as evapotranspiration, albedo, and materials used have been revealed as interconnected with the effects of climate change and heat retention in a city. This report only focused on a couple that has possible outcomes in the future. North Carolina's Piedmont Triad is only beginning to urbanize and feel the effects of climate change, but the consequences can be mitigated if action and determination are prioritized by the city councils.

Graphs and Data

Figure 1

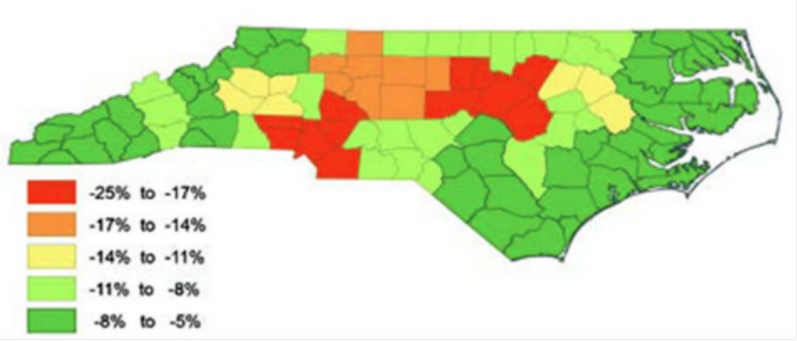
Piedmont Triad Metropolitan Planning Organizations (MPO's)



Note. Above are outlined three metropolitan planning organizations that are highlighted in this research- Winston Salem MPO, Greensboro MPO, and High Point MPO. Source: City of Winston Salem, 2017.

Figure 2

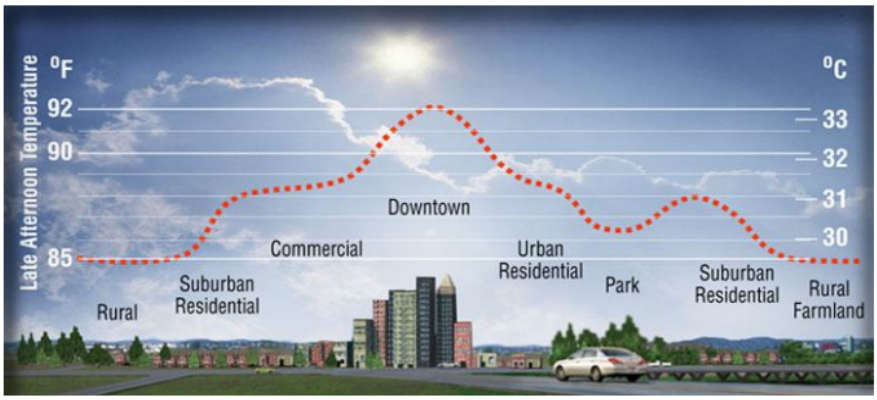
Percent Loss of Forest and Cropland, 1987-2007



Note. Seen in a sliding scale from most percent loss to least, there are many countries throughout central NC experiencing urbanization effects. Source: Stober, 2014.

Figure 3

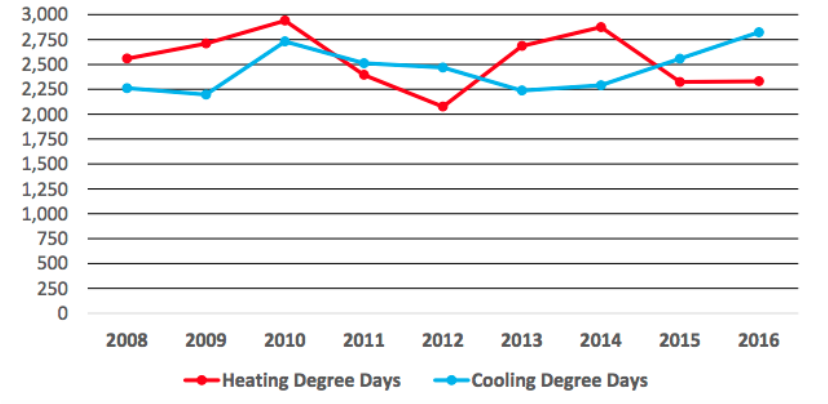
Urban Heat Island Effect



Note. The urban heat island effect is more directly related to metropolitan areas through their heat retention and level as compared to their rural counterparts. Source: Lawrence Livermore Laboratory, 2014.

Figure 4

Degree Days



Note. A compilation of the heating and cooling days within the city from 2008-2016 that have contributed to natural gas and electricity usage. Source: Hardin and Peplowski, 2016.

Table 1

Albedo References of Different Surface Materials

Surface	Range of Albedo
Fresh Snow	0.80 to 0.90
Old/Melting Snow	0.40 to 0.80
Desert Sand	0.40
Grassland	0.25
Deciduous Trees	0.15 to 0.18
Coniferous Forest	0.08 to 0.15
Tundra	0.2
Ocean	0.07 to 0.10

Note. Albedo ranges for different natural surfaces and environments to compare to the urban albedo of lower amounts. Source: Climate Data Information 2020.

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