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Climate Adaptation

IN NORTH CAROLINA'S PIEDMONT TRIAD REGION

Climate Adaptation in North Carolina's Piedmont Triad Region

PIEDMONT together

A Community Choices. Regional Solutions. Report

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PIEDMONT TRIAD REGIONAL COUNCIL

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INTRODUCTION

This climate adaptability report is based upon a wealth of information and data analysis that reflects "… [a] significant change in measures of climate (such as temperature, precipitation, or wind) lasting for an extended period (decades or longer)" (Ingram, *et al.*, 2013). The causes of this change in global climate and local weather patterns can include, "natural factors, such as changes in the sun's intensity or slow changes in the Earth's orbit around the sun; natural processes within the climate system (e.g. changes in ocean circulation); or human activities that change the atmosphere's composition (e.g. burning fossil fuels) and the land surface (e.g. deforestation, reforestation, or urbanization)" (US EPA 2012a). Much of the data indicates that the primary factor in altering the global climate is greenhouse gas emissions from human activities (Figure 1).

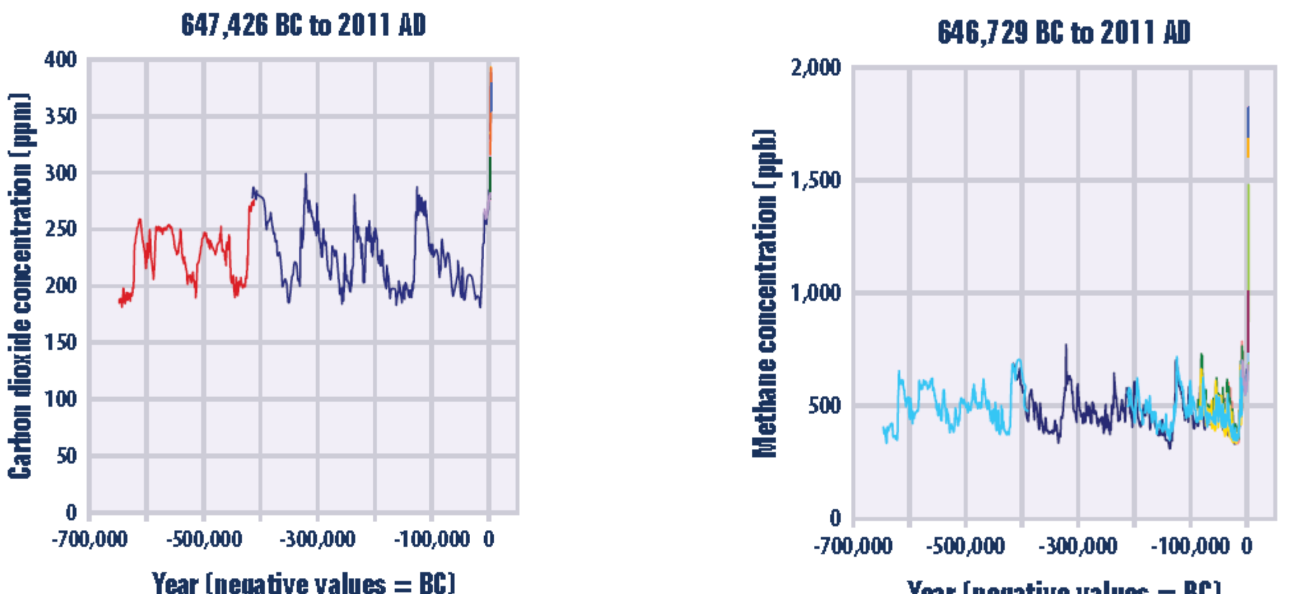


FIGURE 1: US EPA 2012

The Earth's global climate is changing due to emissions of enormous amounts of greenhouse gas to the atmosphere in the past one-hundred years (APHA, 2011; USDA 2012; IPCC 2012; Ingram, *et al.,* 2013). There is consensus among climate scientists that the global temperature has risen 1.4°F since 1900, with ten of the warmest years in recorded history occurring since 1997. The U.S. recorded its hottest year from August 2011 – July 2012, with a spring 5.2°F warmer than historic averages (Figure 2). These temperatures appear to be a continuing trend of record warmer averages in the past ten years (Figure 3). The scientific community estimates that a 50-85% reduction from 1990 levels of global greenhouse gas emissions will be required by 2050 to avoid catastrophic impacts to the world (Krause, 2011, NFWPCAP 2012).

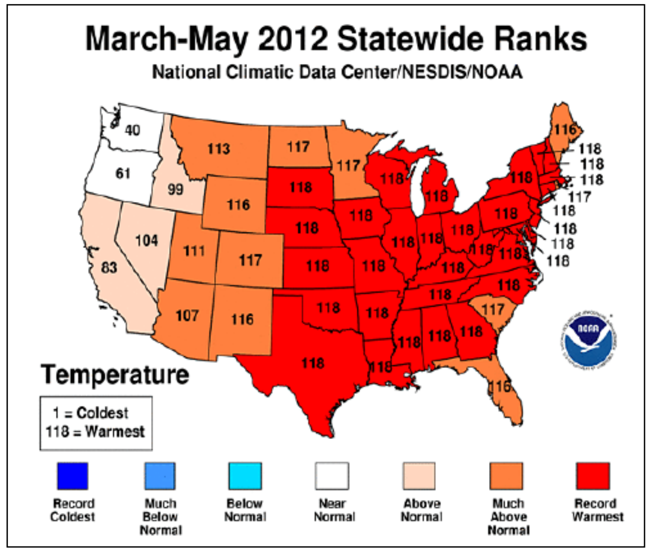


FIGURE 2: ***NOAA, 2012***

Costs in the United States from resulting extreme weather continue to increase with every year (Figures 4 & 5). 2012 was the year in which 64% of the continental U.S. experienced drought that directly led to over 100 deaths. Prior to October 2012, the U.S. had spent $22 billion on weather disasters, not accounting for the costs from caring for the injured, sick, or dead. The costs of the extraordinary weather event Superstorm Sandy are currently estimated at $60.2 billion, and do not account for the 146 American lives lost, health care costs, and businesses lost due to the storm (Figure 6; AP 2013).

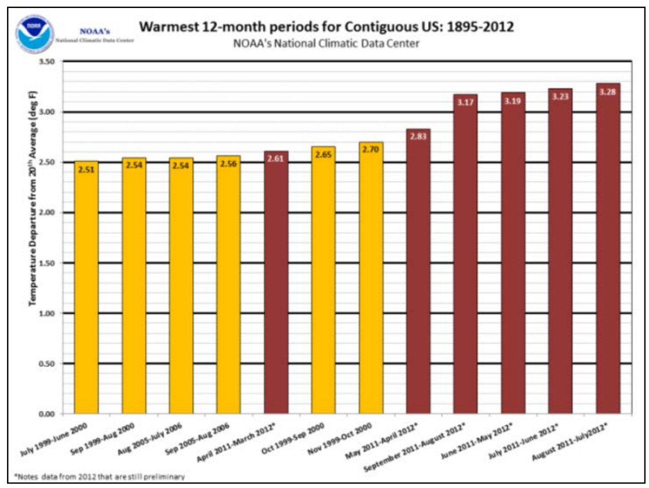
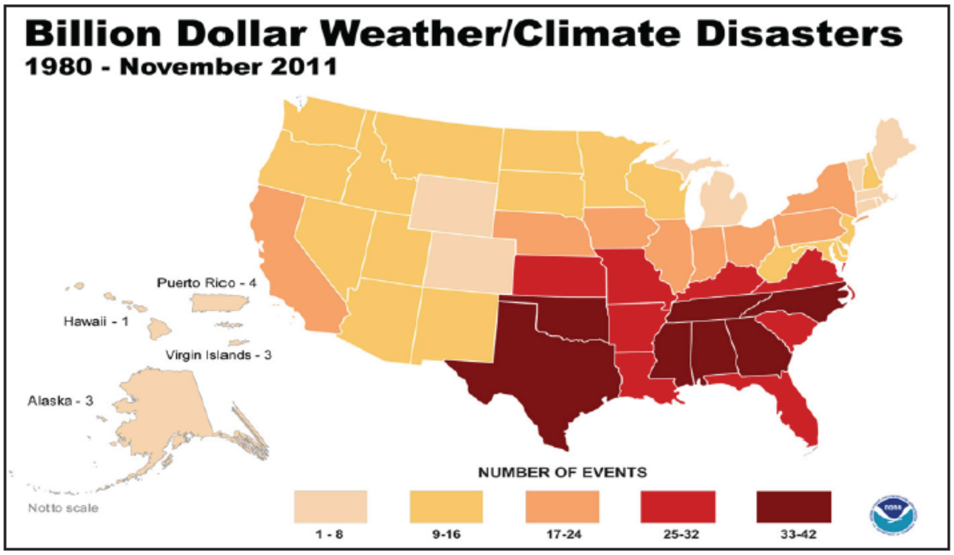


FIGURE 3: ***NOAA, 2012***



Disaster Type: Tropical Storms/Hurricanes; Severe Weather; Heatwaves/Droughts; Non-Tropical Floods; Fires; Freezes; Blizzards; Ice Storms; Noreaster

FIGURE 4: INGRAM, *ET AL*, 2013

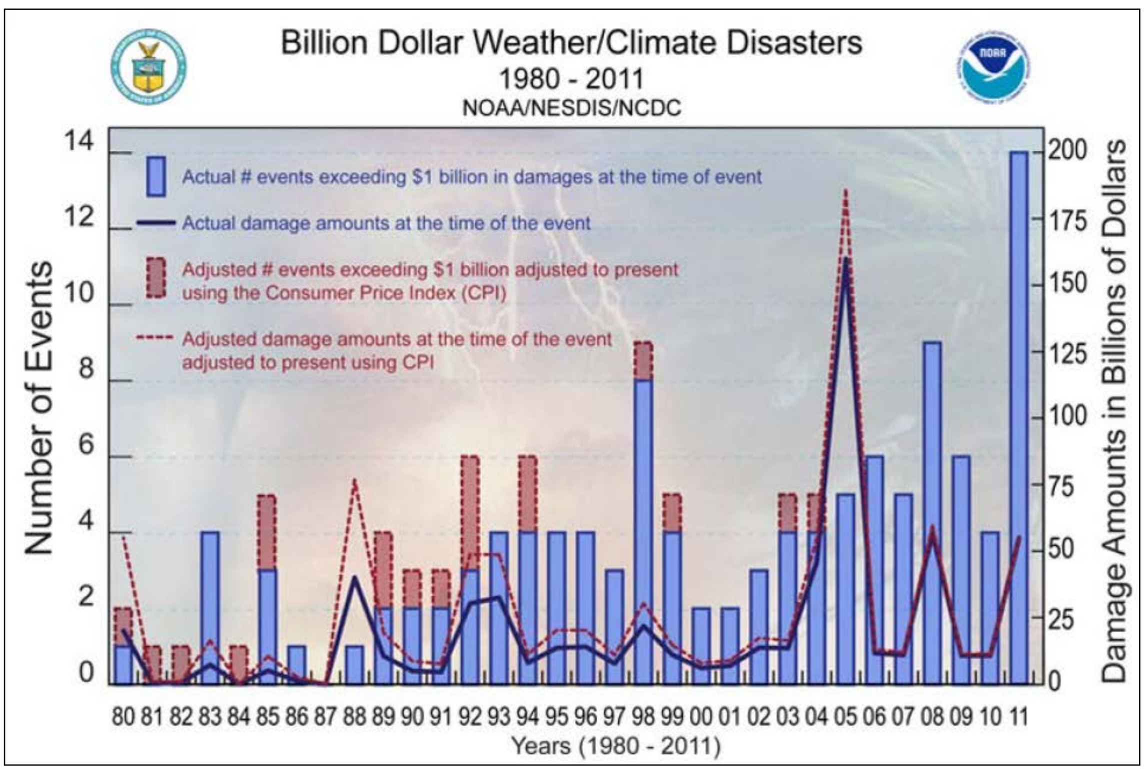


FIGURE 5: INGRAM, *ET AL, 2013*

FIGURE 6: SUPERSTORM SANDY IMPACTS TO THE NEW JERSEY SHORE; ***PHOTO CREDIT USEPA, RETRIEVED FROM WWW.DAILYMAIL.CO.UK/NEWS/ARTICLE-2225348/SUPERSTORM-SANDY-DEVASTATION-SEEN-OBAMA-FLIES-VISIT-NEW-JERSEY-VICTIMS.HTML***

CLIMATE CHANGE IN THE PIEDMONT TRIAD

The US Southeast appears to be fundamentally changing due to climate change in the forms of coastal flooding more violent thunderstorms higher temperatures increased drought risk and greater winter precipitation. Compared to other regions of the nation and the world, the impacts of climate change on the Triad may less dramatically alter lifestyles and the environment from today's "normal," but there will be fundamental changes to the region (Figures 7 & 8) (APHA 2011; USDA 2012).

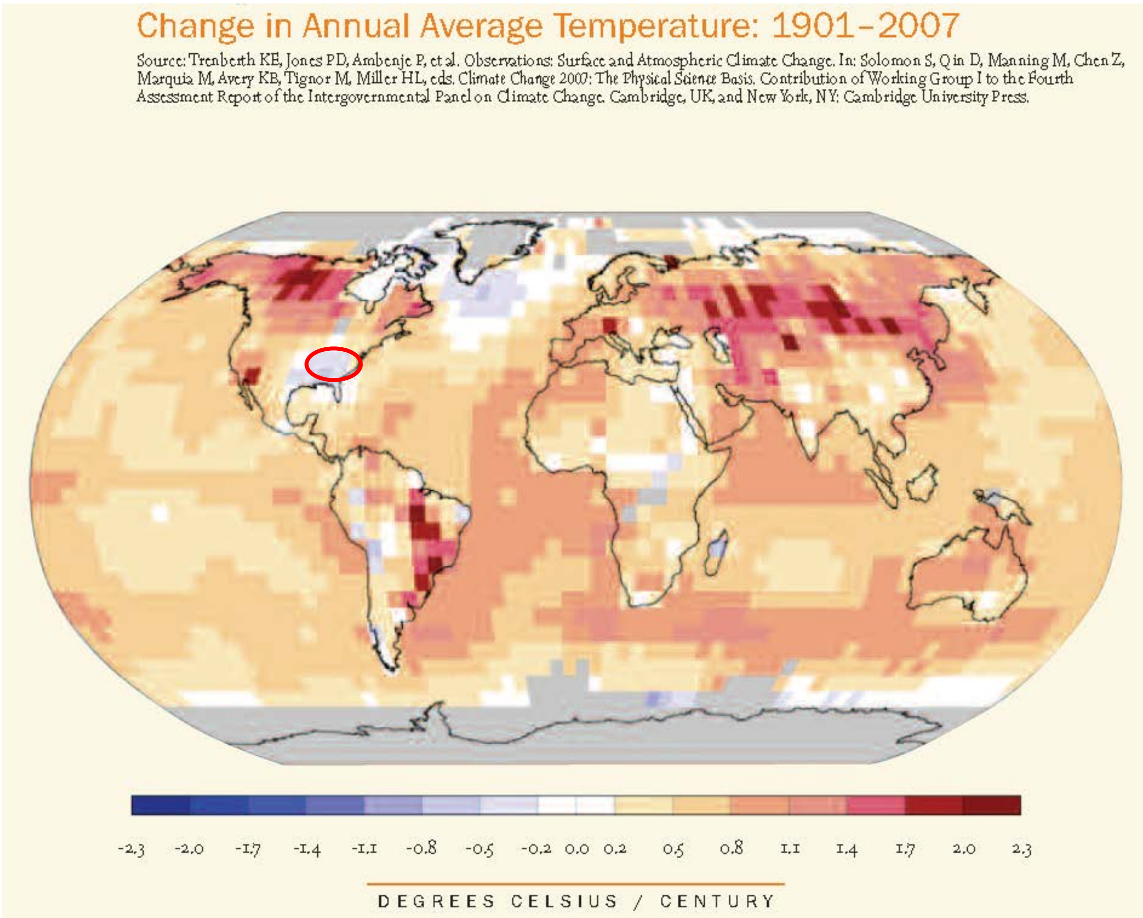


FIGURE 7: ***APHA 2011, CIRCLE ADDED FOR EMPHASIS***

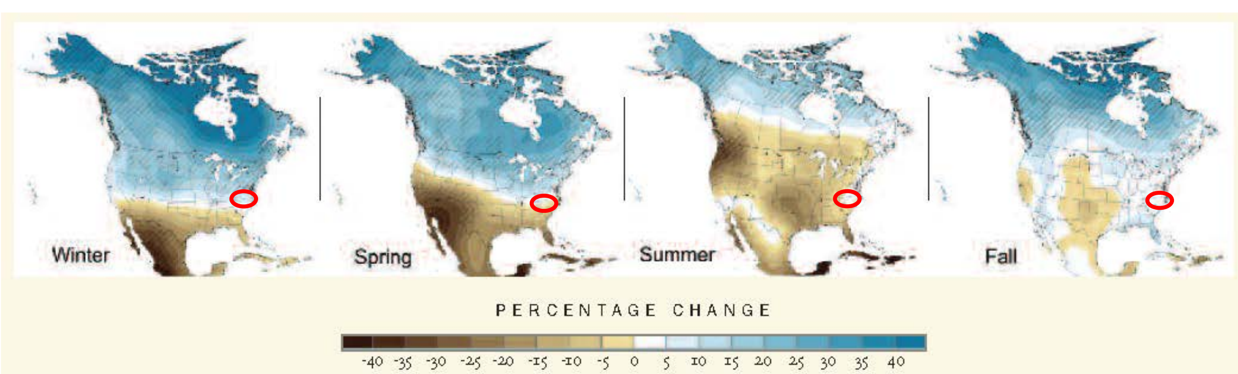


FIGURE 8: PREDICTED CHANGES IN PRECIPITATION LEVELS FROM CURRENT CONDITIONS, APHA 2011, *CIRCLES ADDED FOR EMPHASIS*

Before discussing the impacts of global climate changes upon weather, it is important to distinguish between the terms "climate" and "weather." "Climate is the long-term average of the weather in a given place," while "weather is the state of the atmosphere at any given time and place." The history of the Piedmont Triad's weather defines its climate; its current weather patterns may significantly deviate from this history, or may be the same. The sources of any changes to local weather patterns may be local to the region or may come from other places (NC ILT 2012).

Based upon these changes and historic trends, current data, and anticipated impacts, the US Southeast is forecasted to experience the following changes in regional weather:

- Sea level rise;
- Higher average annual temperatures;
- Fewer days with freezing temperatures;
- Greater heat stress to air and water;
- Less water due to higher evaporation rates;
- More intense hurricanes; and
- Fundamental changes in the native environment.

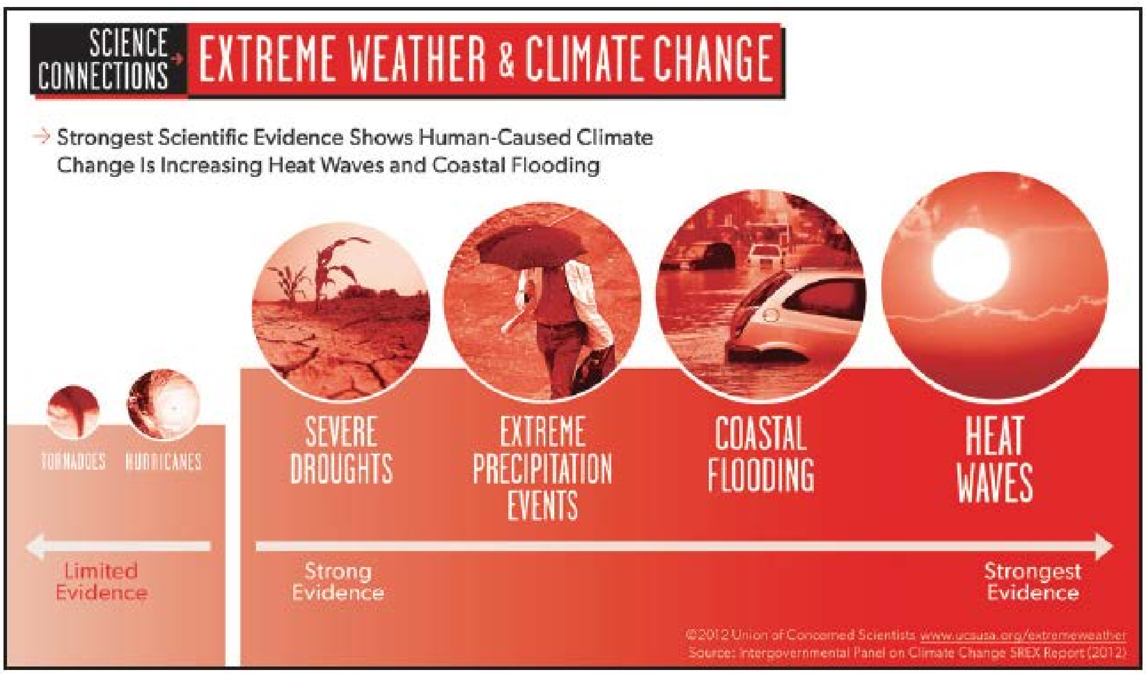


FIGURE 9: NORTH CAROLINA'S PROJECTED LIKELIER EXTREME WEATHER EVENTS DUE TO IMPACTS FROM GLOBAL CLIMATE CHANGE, *NC ILT 2012*

The US EPA's "strategic issues" for the US Southeast's weather are:

- Increased temperature;
- Increased evapotranspiration;
- Increased drought incidence;
- Increased hurricane intensity;
- Increased stresses to aquatic ecosystems;
- Decreased oxygen levels in waters; and
- Shifting ecological habitats (Figure 9).

All of these concerns affected the lives, economies, and environment of the Piedmont Triad already in the past ten years, and will have to be addressed if the region is to remain economically competitive, socially healthy, and environmentally resilient (US EPA 2012c). Already, North Carolina has one of the highest rates of natural disaster nationally, receiving more federal assistance for disaster recovery than most states in the U.S. Since 2006, North Carolina has experienced all-time records for warmest month (Aug. 2007), 1st (2010) and 2nd warmest summers (2011), worst drought in 100 years (2007), and the worst tornado outbreak in the modern record (April 2011) (NC ILT 2012). According to the US EPA, it needs to prepare for heat waves, extreme thunderstorms, severe droughts, and increased intensity and incidence of hurricanes and tornadoes (Figures 4 & 9).

The Piedmont Triad regularly experiences 7 of the 8 recognized natural disasters, and is already one of the nation's top recipients of federal disaster assistance. The incidence of extreme weather is anticipated to

While the anticipated intensification of the Triad's weather may be less extreme than elsewhere, in North America, they will strain an already-stressed community. Some impacts from extreme weather such as flash flooding are not well recorded, so patterns of their incidence and intensity are difficult to track. Basing the region's preparedness on its response to recent extreme weather events, the Piedmont Triad is not ready to address more of the same events, let alone the more intense "new normal" anticipated by the National Oceanic and Atmospheric Association (NOAA) in which extreme weather events are twenty times likelier to occur than they were fifty years ago (Ingram, *et al.,* 2013; NC ILT, 2012).

FIGURE 10: FALLS LAKE, RTP, NC, IN 2008; WWW.SERCC.COM/DROUGHT

The Piedmont Together team is planning for a future that best ensures the health of the region's economy, communities, and environment. To do so, we must account for the anticipated increases in heat, drought, seasonal precipitation, and hurricane intensity. The NC Piedmont is seen as being vulnerable to heat stresses due to its high level of urbanization, reduced tree canopy, and large population of vulnerable individuals (Figure 21, 23, & 24). Some climate change impacts may bring benefits to the region; all climate change impacts will require adjustments in the way we interact with our environment. Direct impacts, such as lower crop productivity due to higher drought risks, are often addressed through existing programs and agencies, but they will need to refocus their efforts to absorb the anticipated changes and become more resilient.

EXTREME WEATHER IN THE PIEDMONT TRIAD

The Piedmont Together project has recognized the need to prepare for impacts from climate change to ensure a resilient and healthy regional economy, community, and environment. To this end, it dedicated staff to support a work group of stakeholders from the private sector, non-profit organizations, and federal, state, local governments to assess the likely impacts to the Piedmont Triad region, provide guidance, and set priority actions for the region (Table 1).

Climate Adaptability Work Group Member	Representative Organization
Angela Parrish	Alamance County Community College
Jack Martin	Appalachian State University, Alamance County Community College
Jenny Edwards	Dan River Basin Association
Jimmy Flythe	Duke Power
Michelle Brock	Forsyth County Emergency Management Service
Tyler Meyer	Greensboro Department of Transportation
Zach Smith	Guilford County Emergency Management Service
Graham Kelly	League of Conservation Voters
Jim Rogers	NC DENR, Div. Air Quality
Anne Tazewell	NC State University Solar Center
Mark Megalos	NC State University Cooperative Extension
Kyle Laird	Piedmont Authority for Regional Transportation, *staff*
Elizabeth Jernigan	Piedmont Triad Regional Council, *staff*
Cy Stober	Piedmont Triad Regional Council, *staff*
Charles Konrad	Southeast Regional Climate Center
Ryan Boyles	State Climate Office of North Carolina
Ken Mitchell	US Environmental Protection Agency
Linda Rimer	US Environmental Protection Agency
Matthew Rushing	

An adaptive management approach has been employed when assessing current conditions, including strengths and vulnerabilities, and recommending strategies and actions to engage projected changes to local weather. The efforts thus far only address the needs for "Identifying Risks and Vulnerabilities" and "Planning, Assessing and Selecting Options," with the goal of transiting into an "Implementation" stage by the end of the project (Figure 11).

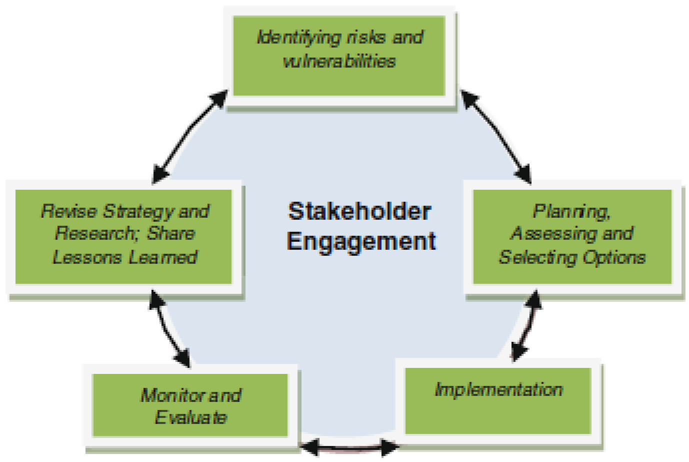


FIGURE 11: ***BIERBAUM, ET AL., 2007***

This work group has met quarterly throughout the project, and arrived at a consensus that the leading impacts to the Piedmont Triad will be greater annual precipitation with warmer and drier summer and fall seasons, accompanied by more sustained drought, more intense heat waves, and likelier violent thunderstorms. Other, extreme weather events such as ice storms will also become more regular as the weather systems that determine the Triad's weather change over time.

FIGURE 12: AUGUST 2013, FLASH FLOOD IN RALEIGH, NC; WWW.WUNDERGROUND.COM/WXIMAGE/MMB/22?GALLERY=

The Piedmont Triad will likely experience an annual 6% increase in precipitation. Based upon rising global ocean temperatures, rainfall volumes are estimated to increase and storm wind speeds are estimated to increase at a proportional rate of 1 – 3% and 1-8%, respectively (Ingram, *et al.,* 2013). This is expected to lead to more common violent storms and more intense hurricanes, with accompanying flash flooding and other threats to human safety (APHA 2011; NC ILT 2012). Recent history has shown that the distribution of precipitation events – especially violent thunderstorms – can be difficult to predict, but the interplay of coastal and inland weather systems should make conditions in the Piedmont Triad drier and hotter in the summer and wetter in the winters (Figures 13 & 14). These changes – especially the warmer and wetter winters – will create a longer growing season and affect agriculture, perhaps altering the types of crops grown and the times of year they are able to grow in the region.

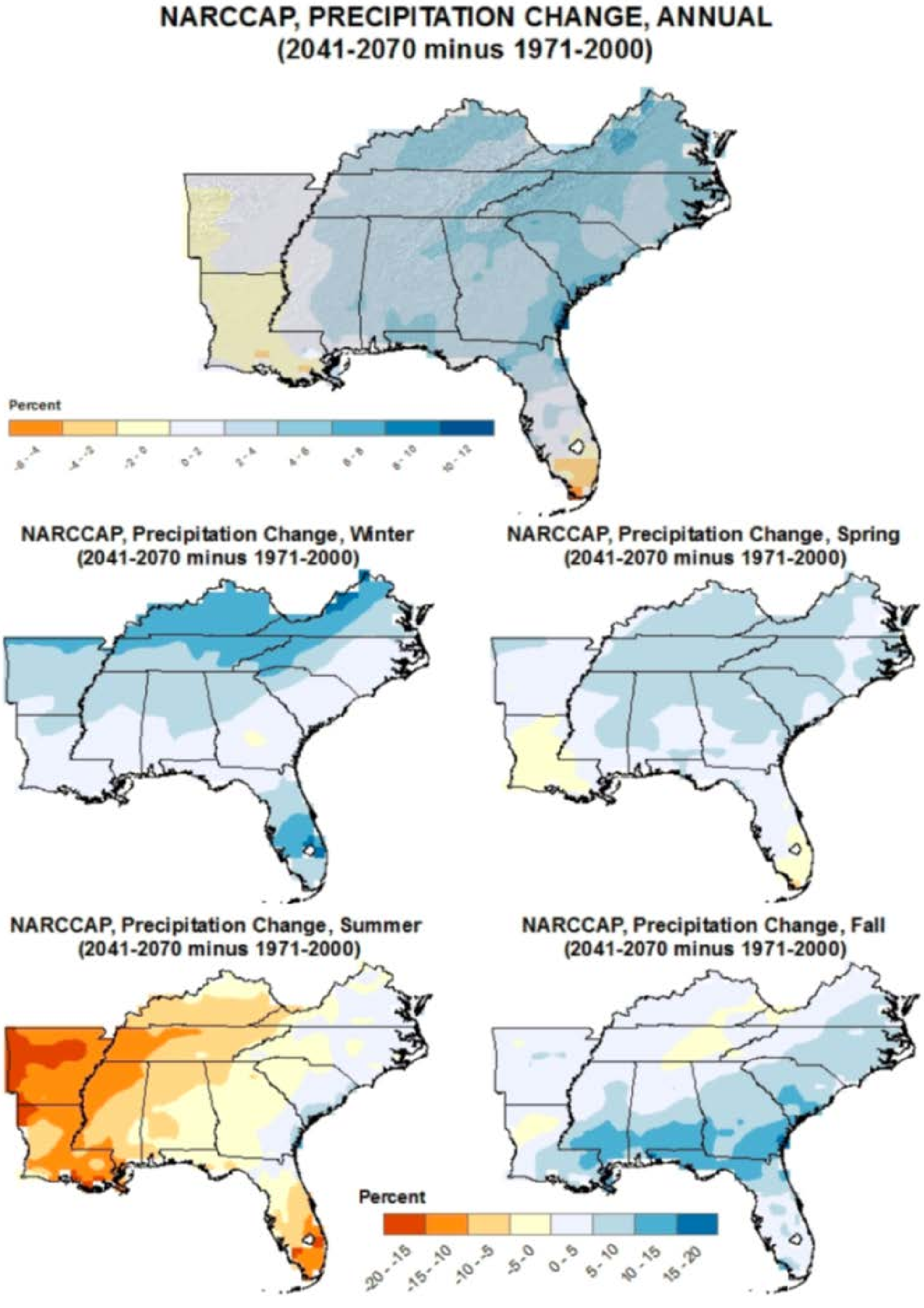


FIGURE 13: PROJECTED CHANGES IN SEASONAL PRECIPITATION FOR THE SOUTHEAST US, INGRAM, *ET AL.*, 2013

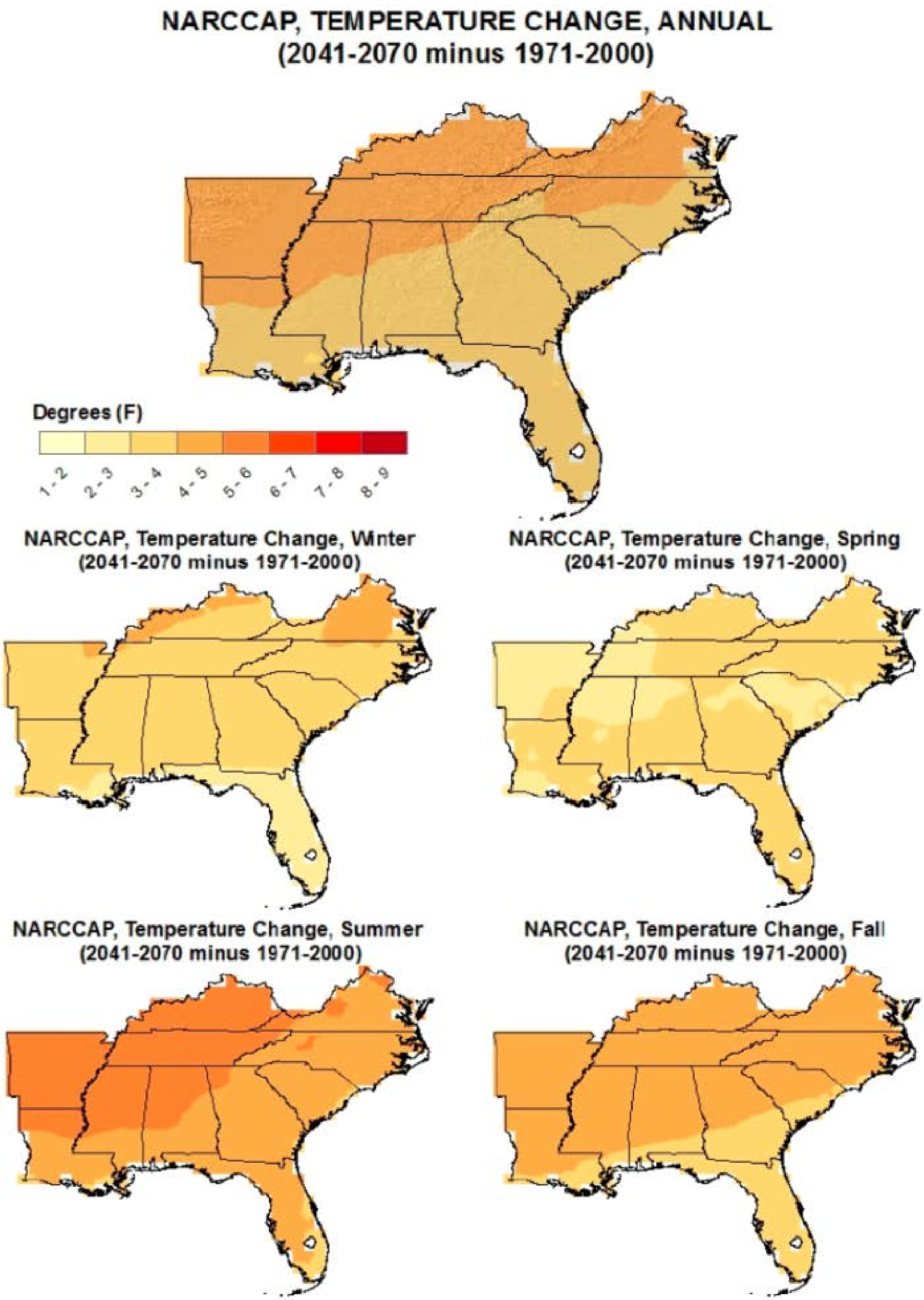


FIGURE 14: PROJECTED CHANGES IN SEASONAL TEMPERATURES FOR THE SOUTHEAST US, INGRAM, *ET AL.*, 2013

The region is likely to get warmer year-round, with hotter summers and falls and fewer days with freezing temperatures. The average increase in annual temperatures for the Piedmont Triad is estimated to be 5°F. However, these impacts are already being experienced in North Carolina, which has had 15 – 35 more days per year with temperatures over 95°F since 1972 (Figure 14).

When accounting for the human and ecological demands of water resources, the US Forest Service (USFS) forecasts a stressed future, in which natural landscapes, agriculture, the human population, energy utilities, and industry are all competing for increasingly limited water resources (Figure 15). Similarly, the US Department of Commerce (DOC) lists declining water supplies as a leading concern for the US Southeast. Energy generation requires large amounts of cool water in order to keep up with demand. During summer months, when air conditioning is used more often, energy production is also taxed due to higher surface water temperatures, which raises evaporation rates, losing available water and increasing the risk for brownouts. This seasonal demand is incompatible with the cyclical regeneration provided by weather, when most of the precipitation will occur in the cooler months. The energy plant on the Dan River seems to be especially vulnerable to overconsumption of available water supplies (Figure 16).

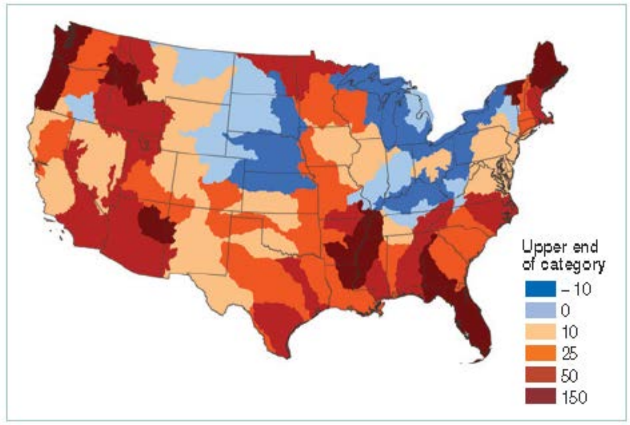


FIGURE 15: PROJECTED ECOLOGICAL WATER STRESS, BASED UPON CURRENT WATER CONSUMPTION RATES, ***USDA 2012***

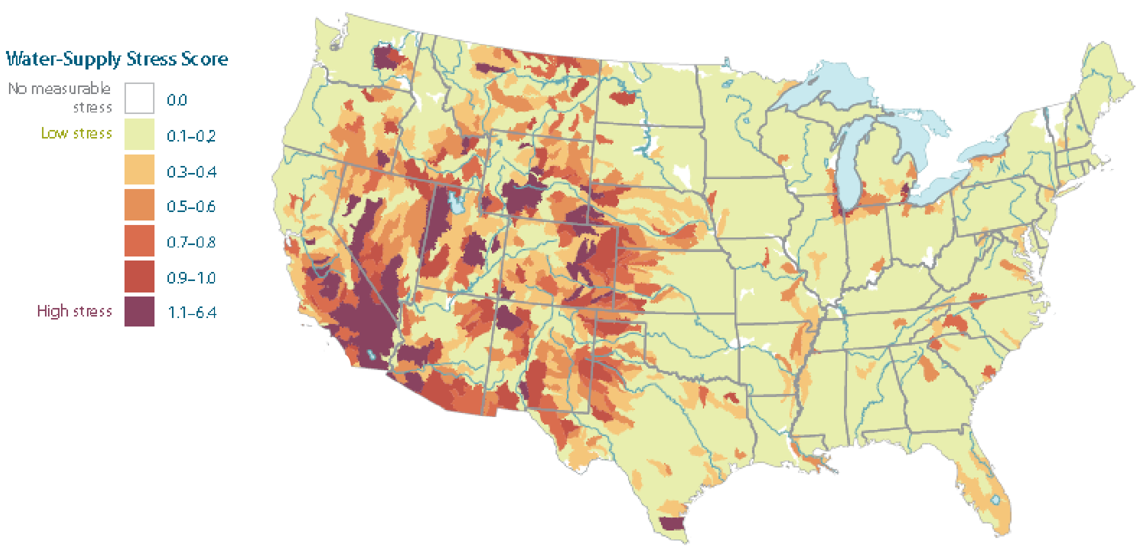


FIGURE 16: PROJECT WATER SUPPLY STRESS, BASED UPON CURRENT CONSUMPTION RATES, ***EWWWI 2011***

NC has yet to adopt water conservation measures like those that are much more common in the US West, where limited water supplies are common. Some leaders such as the City of Raleigh are reusing treated wastewater in supplying non-potable water for its residents, but such practices are still uncommon in NC. In addition to pursuing such new strategies, there is a more immediate need for North Carolina communities to invest in their existing water and sewer infrastructure, which is aging and, increasingly, failing throughout the state (ASCE 2013). To optimize its profile to the private sector and retain and attract residents, the Piedmont Triad will need to ensure clean, plentiful water supplies for the foreseeable future. Such a goal will require a significant change in the level of investments the region makes in maintaining existing infrastructure and adopting new practices that minimize consumption rates and ensure high quality.

Powerful private sector groups such as the CERES partnership clearly state that infrastructure maintenance and conservative natural resources management are attributes they are reviewing when considering investments. Because the Piedmont Triad is unprepared for the existing extreme weather events, the region is forecasted to be unable to absorb the greater costs projected to affect the state. The costs of extreme weather events can affect all sectors of the state, damaging crops and crop productivity, sending more people to the hospital, causing rolling brownouts, and destroying or damaging critical infrastructure (US DOC 2011; NC ILT 2012). The following report attempts to address these impacts of climate change by general topic: Public Health, Agriculture, and Ecology.

In an effort to anticipate and prepare for these challenges, the Piedmont Together wok group partnered with the emergency management services of Guilford and Forsyth Counties to hold a day-long workshop on the "Impacts of Extreme Weather in the Piedmont Triad." Speakers from throughout the region, as well as the US EPA, the NC State Climate Office and the NC chapter of the American Planning Association spoke at the event. Many of the presentations detailed the causes and impacts of climate change and extreme weather that are summarized in this document. Additionally, the attendees broke into small groups to discuss and highlight the priority concerns presently and potentially affecting the quality of life and safety of the region's residents. These priority concerns are detailed in Table 2.

Weather Event Concern	Impacts	Short Term Response	Long Term Response
Ice Storms	1. Increase in Cases of Hypothermia 2. People using Grills indoors 3. Increase in Cases of Hypothermia 4. Automobile Accidents (injuries fatalities and traffic jams) 5. Increase Use of Kerosene Heaters 6. School/Business Closings (loss of productivity) 7. Downed Trees 8. Downed Power Lines 9. Lower Indoor Air Quality 10. Loss of Transpiration 11. Power Outages	1. Stay at home 2. Driver Education 3. Firewood Distribution	1. Bury Utility Lines 2. Better Road Design
Tropical Cyclones	1. Mold 2. Loss of Transportation 3. Power Outages 4. Wind Damage 5. Water Quality 6. Flooding 7. Mosquitos	1. Engineering 2. Education About Evacuation/Shelteri ng in Place 3. Buffers and Wetland Restoration 4. Neighborhood Based Cooling Shelters 5. Fan Distribution 6. Increase Surge Capacity 7. Education 8. Ozone Alerts 9. Fill Gas Tanks and Mow Lawn in Evening 10. Run Existing PSAs from EPA NWS and County EM Depts.	1. Low Impact Development (in safe places) 2. Walkable Places 3. Underground Power Cables 4. Building Code Improvements/Enforcement 5. Buffers and Wetland Restoration
Drought	1. Food Safety 2. Air Quality 3. Jobs (agriculture and other) 4. Agricultural Losses 5. Livestock and Wildlife 6. Water Supply (shortages) 7. Water Quality 8. Recreation	1. Water Reuse 2. Conservation Efforts	1. Planning, Mitigation, education 2. Storage

	9. Economic Impact		
Wildfires	1. Pine Tree Reproduction (positive: 2. Limited Resources (depletes resources across jurisdictions) 3. Structural/Property Damage 4. Air Quality 5. Health Systems 6. Ecosystems 7. Agricultural Losses 8. Wildlife and Environmental Losses	1. Encourage Fire Insurance 2. Local Ordinances 3. Education	1. Implement Firewise (community wildfire protection plans) 2. Planning, Mitigation, Education 3. Enforcing Building Codes 4. Forest Mitigation
Heat Waves	1. Crop Damage/Dairy Cows 2. Increased Fire Danger 3. Train Derailment 4. Rolling Brown/Blackouts 5. Pavement Buckling 6. Water Mains Bursting 7. Increased ER Visits 8. Increased Domestic Violence/Crime 9. Risks to Homeless Population 10. Increased Demand on Emergency Services 11. Air Quality 12. Water Shortage	1. Neighborhood Based Cooling Shelters 2. Fan Distribution 3. Increase Surge Capacity 4. Education 5. Ozone Alerts 6. Fill Gas Tanks and Mow Lawn in Evening 7. Run Existing PSAs from EPA NWS and County EM Depts.	1. Increased Investment in Power Grid 2. Diversity/Local/Renewable Energy 3. Distributive Power Generation 4. Green Roofs 5. White/Reflective Roofs/Roads 6. Tree Canopy 7. Weatherization Programs 8. Heat Resistant Crops 9. Education 10. Infrastructure Retrofit
Extreme Precipitation Events	1. Residential, Commercial and Governmental 2. Flooding 3. Health Issues 4. Mold 5. Displacement 6. Need for Shelters 7. Limited Resources (depletes resources across jurisdictions) 8. Damage to Infrastructure 9. Stormwater Runoff (human and environmental health)	1. Manage Stormwater On-site 2. Better Floodplain Management 3. Best Management Practices 4. Encourage Flood Insurance 5. Public Outreach	1. Manage Stormwater On-site 2. Better Floodplain Management Practices 3. Best Management Practices 4. Location Relative to Floodplain 5. Better Designed Infrastructure 6. Map Hazard Areas and Vulnerable Populations

PUBLIC HEALTH IMPACTS

The impacts of climate change upon the Triad's public health are both direct and indirect (Figure 17). The American Public Health Association and researchers at UNC-Chapel Hill have concluded that the primary public health concerns due to climate change impacts in the Piedmont Triad are the:

- impacts of the urban heat island effect upon city residents and outdoor workers;
- impacts to rural workers, primarily farmworkers;
- health of elderly in both rural and urban communities; and
- impacts to local ecosystems.

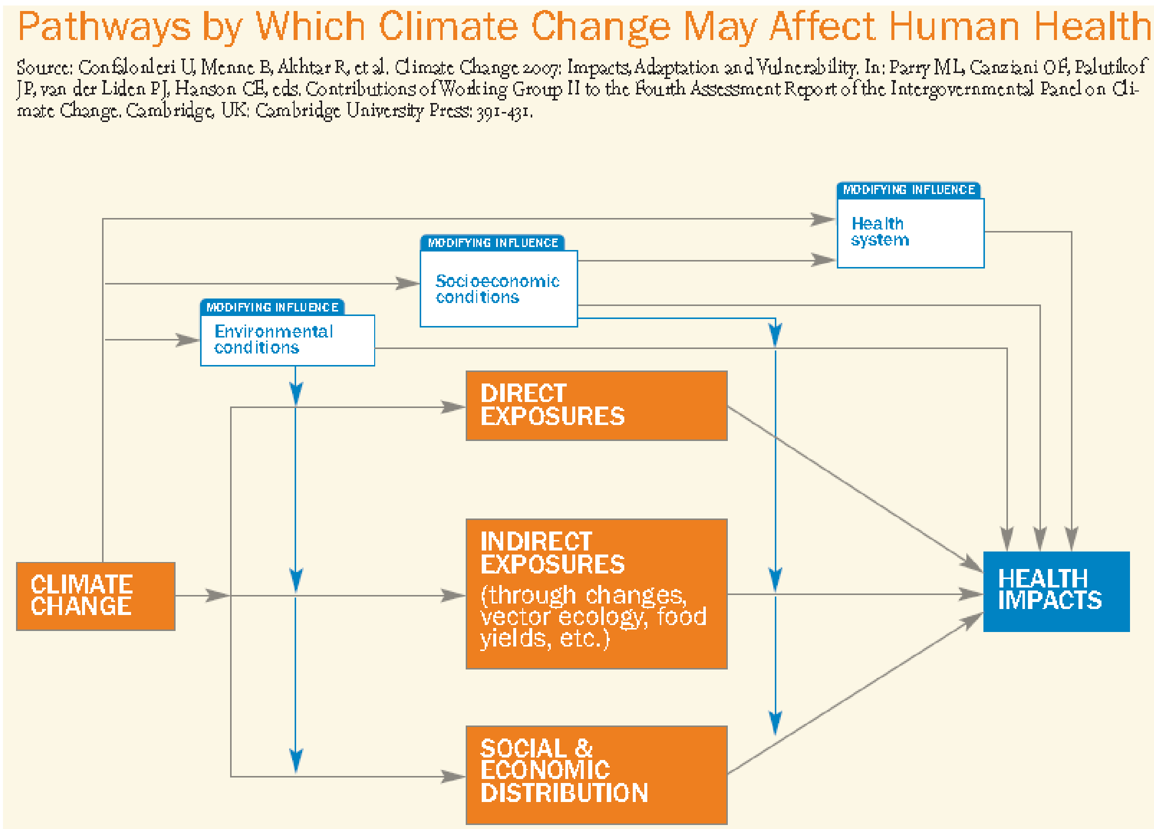


FIGURE 17: ***APHA 2011***

Currently, neither the state nor the Piedmont Triad region is adequately prepared to accommodate more regular and intense droughts or heat waves predicted, as evidenced by the costs and reactionary measures taken during the droughts of 2002 and 2007 (Figure 4 & 25; APHA 2012; NC ILT 2012).

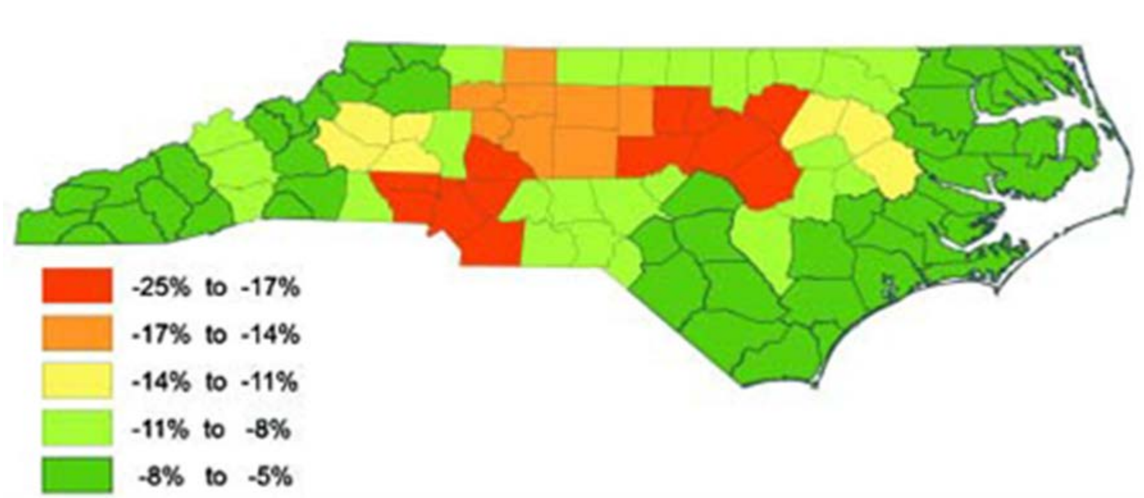


FIGURE 18: PERCENT LOSS OF FOREST & CROP LAND, 1987 - 2007, ENC, 2007

Fundamental to the conversation on climate change impacts in the Triad is the role of urbanization and the urban heat island effect. The US Southeast and North Carolina in particular have urbanized at unprecedented rates in the last two decades, losing open space at an average rate of 7.5% per year (Figure 18). With urbanization comes the urban heat island effect, which results from the concentration of paved surfaces in towns and cities. This is due both to the lack of shade cover from trees, but also the loss of evapotranspiration (EVT), which all plants use for cooling (Figure 21). EVT is the plant equivalent of sweating, allowing them to release hot air and water vapor through the stoma on the underside of their leaves. As these temperatures rise, urban residents turn to air conditioning, which adds heat to a city and increases energy consumption, stressing regional supplies and degrading air quality conditions (Figure 22; American Rivers, 2009; CA DPH, 2007; Ingram, *et al.,* 2013).

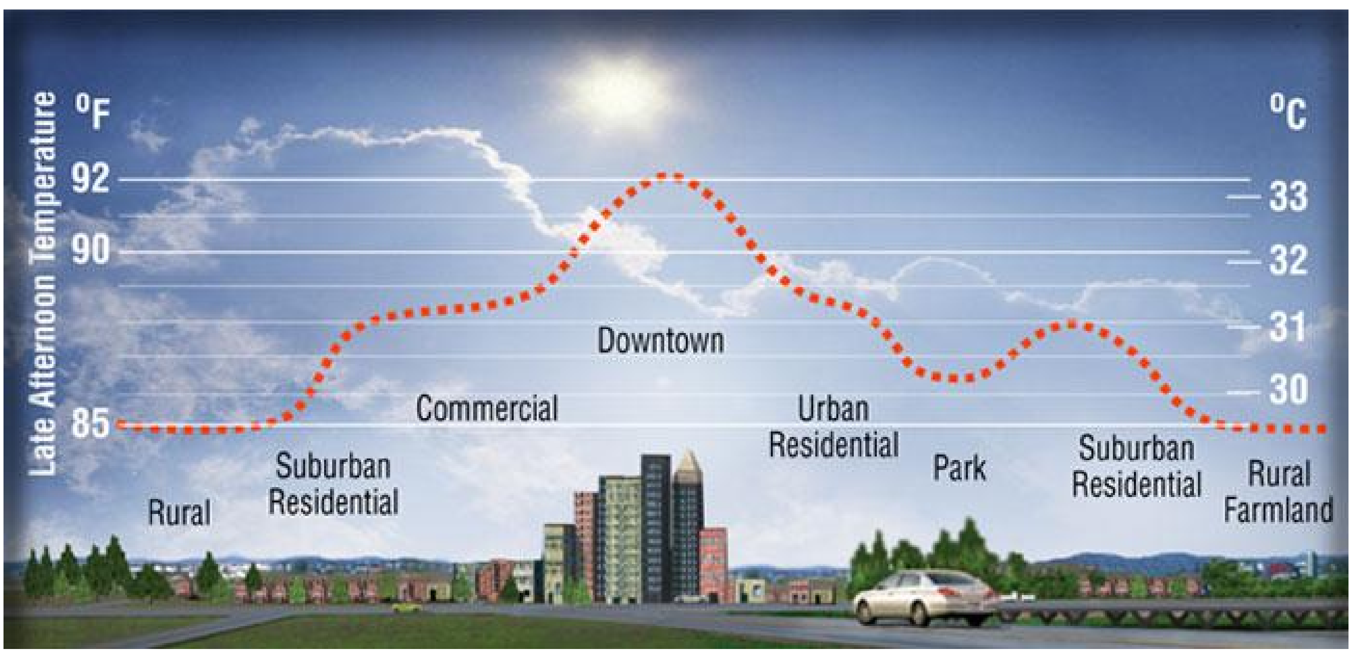


FIGURE 19: URBAN HEAT ISLAND EFFECT; LAWRENCE LIVERMORE LABORATORY, 2014 HTTP://HEATISLAND.LBL.GOV/

The urban heat island effect will also lead to sustained hotter temperatures through the night, indirectly adding to the burden of heat stress, especially for the elderly. The health impacts of higher temperatures and drier conditions can take the form of heat cramps, which are due to electrolyte imbalances; heat exhaustion, which is due to a depletion of blood plasma and requires shelter and salts for recovery; or heat stroke, in which the body's core temperature rises above 104°F, which can lead to brain damage or death and requires hospitalization for recovery. Furthermore, higher humidity levels and temperatures are directly related to ground-level ozone levels and higher pollen counts, which are both tied to higher rates of respiratory stresses like asthma (Figure 20).

FIGURE 21: THERMAL IMAGE OF URBAN HEAT ISLAND IN ATLANTA, GA; LAWRENCE LIVERMORE LABORATORY, 2014

The Piedmont Triad region has been identified as a particularly vulnerable area of the United States for these anticipated stresses solely due to increased local temperature and humidity levels (Figure 21 & 23). When considering the changing demographics of the region, especially the aging of the average Triad resident, these concerns are even greater. The elderly are especially vulnerable to these impacts, due to their isolation from others, physical weaknesses that make them more vulnerable to heat stress, and a lack of connection to media (CA DPH, 2007; Ingram, *et al.,* 2013; US EPA 2012b).

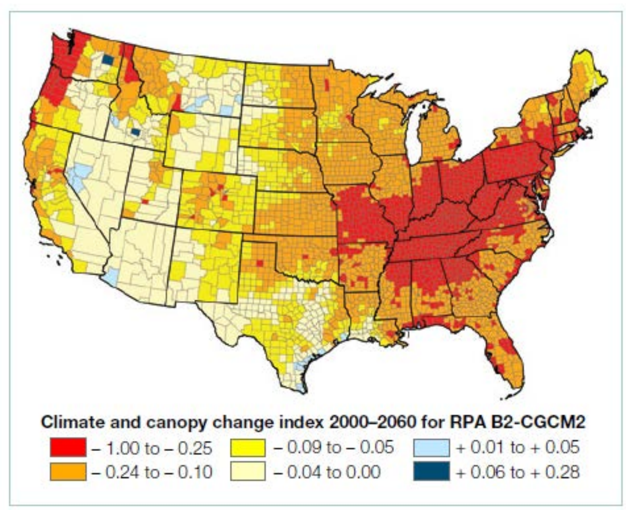


FIGURE 20: PROJECTED DRYNESS DUE TO CHANGES IN TEMPERATURE AND FOREST CANOPY COVER; *USDA 2012*

The Piedmont Triad has the state's largest elderly and aging populations – the fastest growing age demographic both nationally and regionally – making heat stress one of the leading climate adaptability priorities for the region and its communities (Figure 23). However, proactive programs to mitigate these risks do not exist, and significant investments in outreach and collaboration will be necessary to ensure the resiliency to address these concerns. The regional and local emergency management service programs have not fully integrated heat response plans that reflect this new, more stressful scenario into their efforts, and have not been directed to as yet by their constituencies.

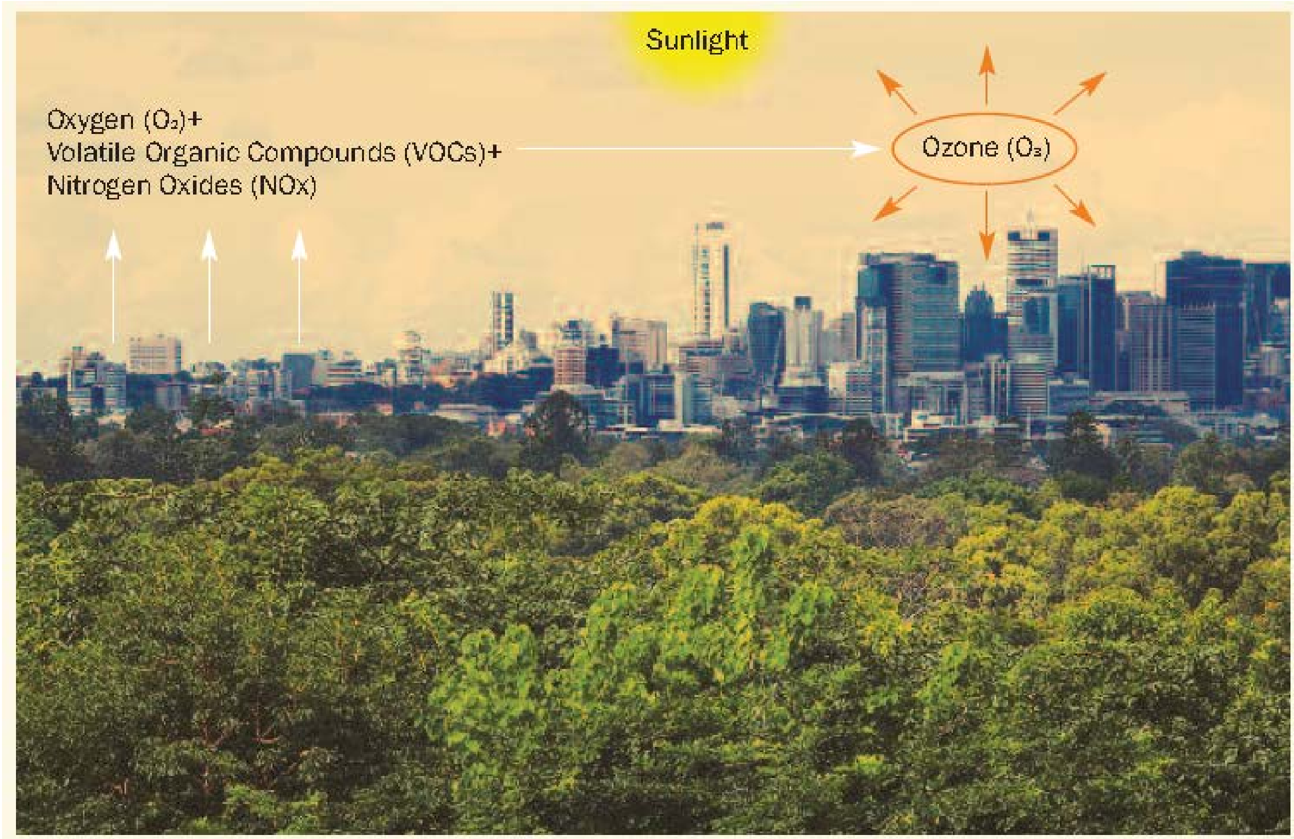


FIGURE 22: RELATIONSHIP BETWEEN THE URBAN HEAT ISLAND EFFECT AND AIR POLLUTANT DISPERSAL, APHA 2011

The Piedmont Triad has the state's largest and fastest-growing older adult population. Older adults are the most vulnerable group to the increased heat and higher air pollution levels predicted by climate change models.

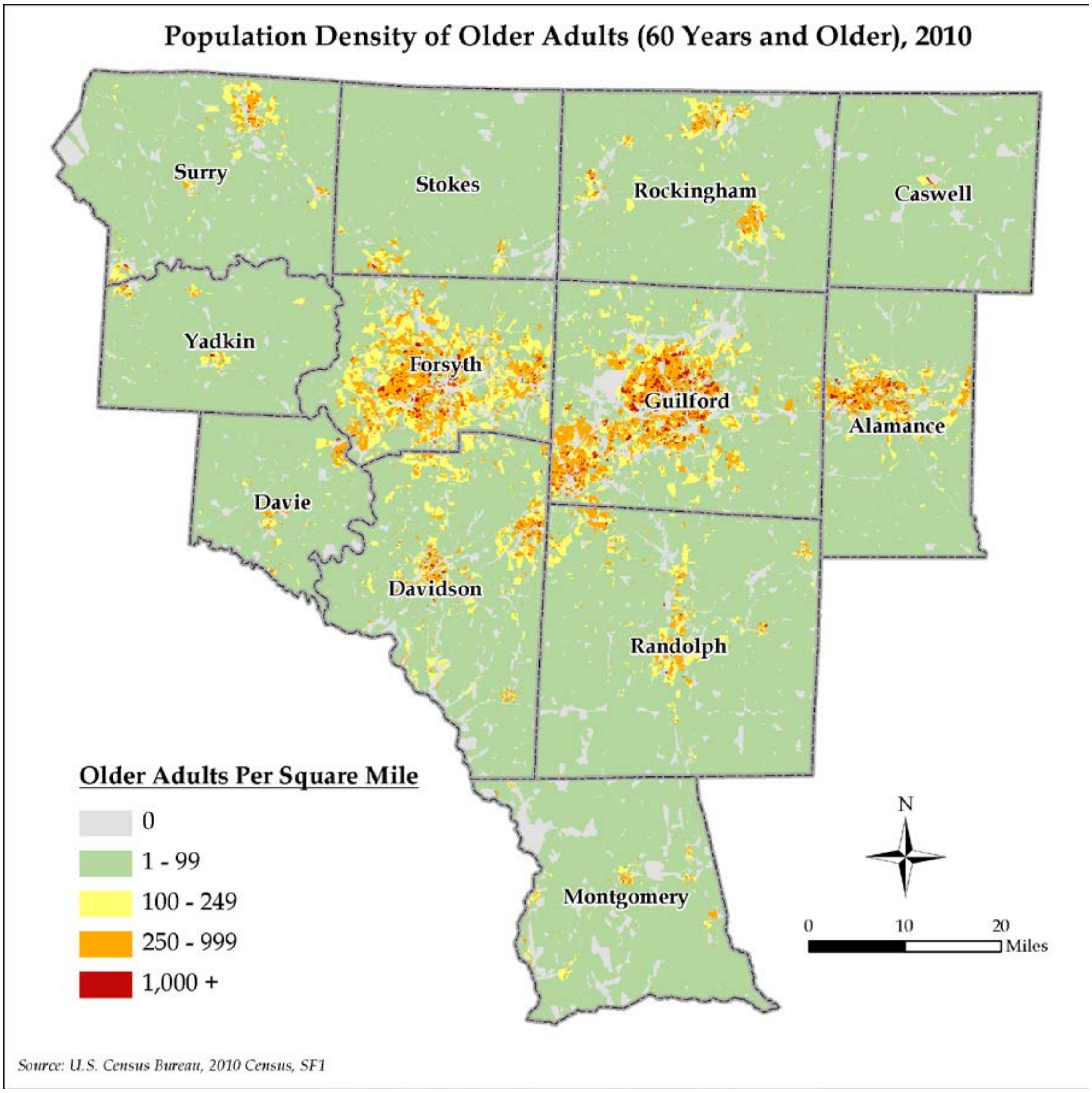


FIGURE 23: POPULATION DENSITY OF OLDER ADULTS

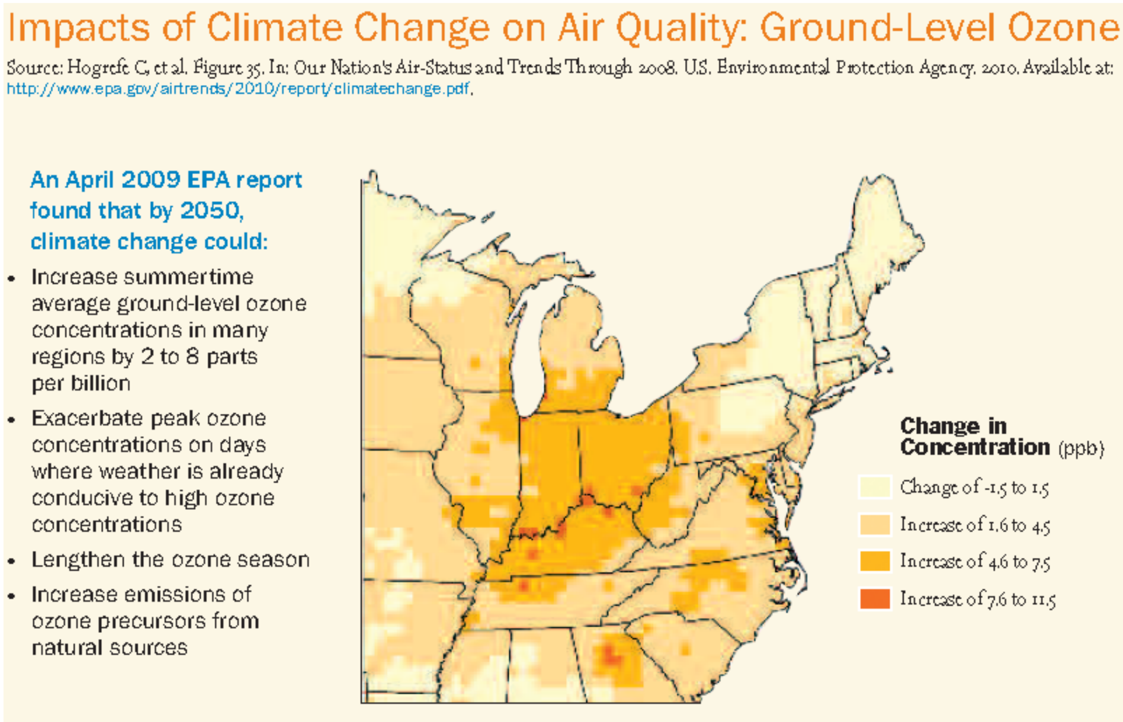


FIGURE 24: ***APHA 2011***

As with all anticipated climate change impacts to regional weather, the past ten years show how much work needs to be done to prepare for these hotter and drier summers. In the 2007-2008 drought, North Carolina recorded heat stress levels of almost 16 hospitalizations per 100,000 people and almost 13 deaths per 100,000, with 84% of these hospitalizations occurring between June and August. Of these cases, 25% occurred during the two weeks where there were intense heat waves (UNC-CH, 2011). While this was a year of unprecedented drought of record, it has been noted by the NC State Climate Office that such temperatures and droughts are commonly found in the state's long-term historic records.

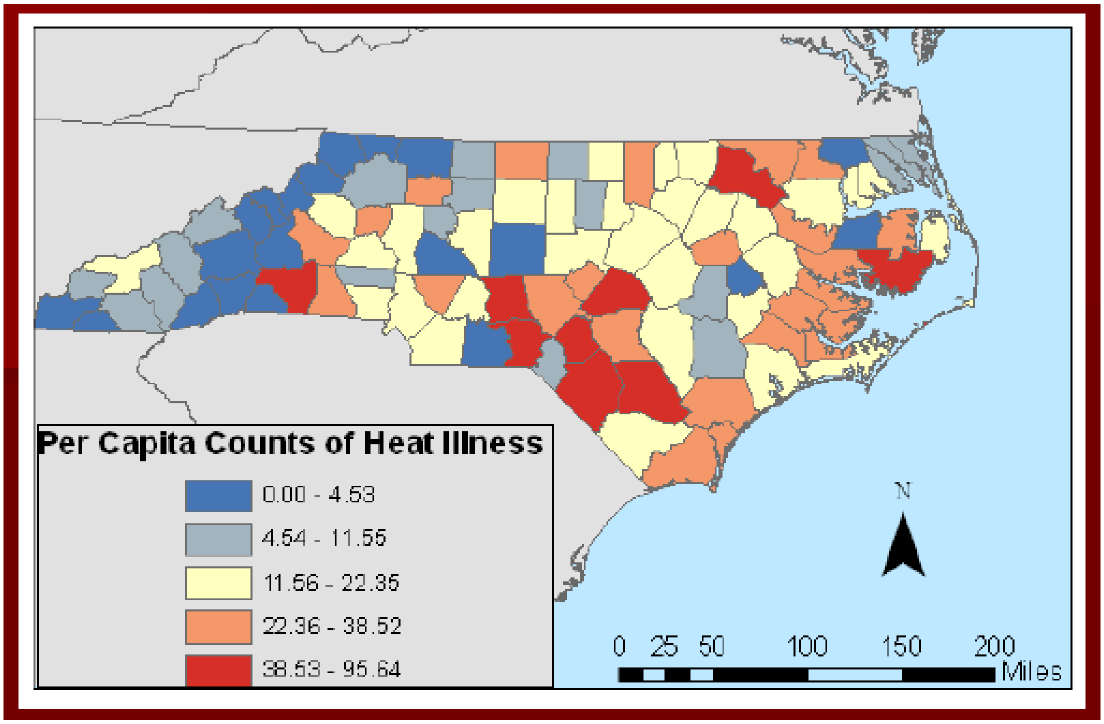


FIGURE 25: HEAT-RELATED HOSPITALIZATIONS DURING THE TWO HEAT WAVES OF THE 2007 – 2008 NORTH CAROLINA DROUGHT, *UNC-CH 2011*

The hospitalizations were focused in the Piedmont Triad's rural counties of Montgomery, Rockingham, and Yadkin, indicating a need for more robust emergency management services for these highly rural counties (Figure 25). In urban areas, the 18 & under age group experiences higher rates of hospitalization due to heat related illnesses than their rural counterparts, largely due to organized athletics. The greater impact to rural communities is likely due to the lack of access to healthcare facilities and the reliance on manual labor in the agricultural sector (UNC-CH 2011). Given the region's reliance upon the agricultural sector, heat stress has significant economic ramifications that should further prioritize preparedness and resiliency investments to address these impacts (NC ILT 2012). The hospitalization rates support this, showing higher rates of admission during the work week than on weekends (Figure 26) (UNC-CH 2011).

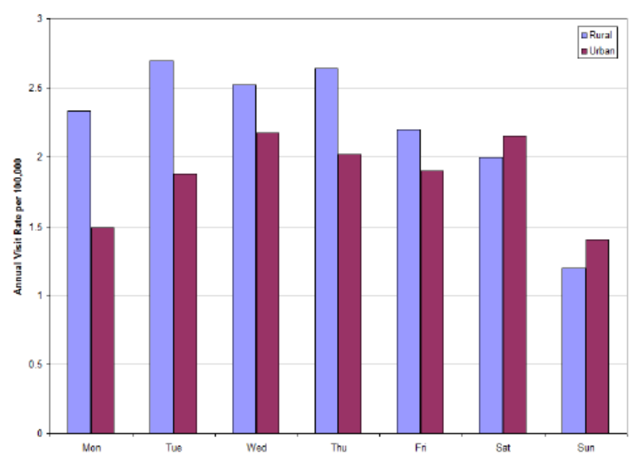


FIGURE 26: HEAT-RELATED HOSPITALIZATIONS BY DAY OF THE WEEK DURING THE 2007-2008 NORTH CAROLINA DROUGHT, *UNC-CH 2011*

Climate Adaptation Strategies

One of the more expedient strategies to manage the urban heat island effect is green infrastructure, which cools local areas through evapotranspiration and, in the case of large trees, shading. With green infrastructure, declines in energy use, air pollutant levels, temperatures, and human health care costs (including deaths) are all seen. Urban greening initiatives reduce the urban heat island effect, and cool urban centers at night, relieving a significant source of heat stress. The best ways to do this are to enhance park land within a city or town, plant and care for more urban trees (including street trees), and install green roofs where possible and reflective coverings/coatings on all other roofs. With increased parks and recreation areas, the regional population may be fitter and more resilient to heat stress, which can be measured in health care savings.

Indirect benefits of such green infrastructure features include greater shade, more recreational resources, and higher property values. Residential neighborhoods with tree cover are, on average, 4-6°F cooler than neighborhoods without trees, which is often seen in higher property values. A 20% increase in residential tree cover can lower household cooling costs by 8-18%. In parking lots, tree cover can keep cars' internal temperatures 45°F cooler than those in uncovered lots (Ingram, *et al.,* 2013; US EPA 2012a). Trees provide shade cover that reduces structure temperatures by 20-45°F. See the *Piedmont Together Green Infrastructure Report* for more details.

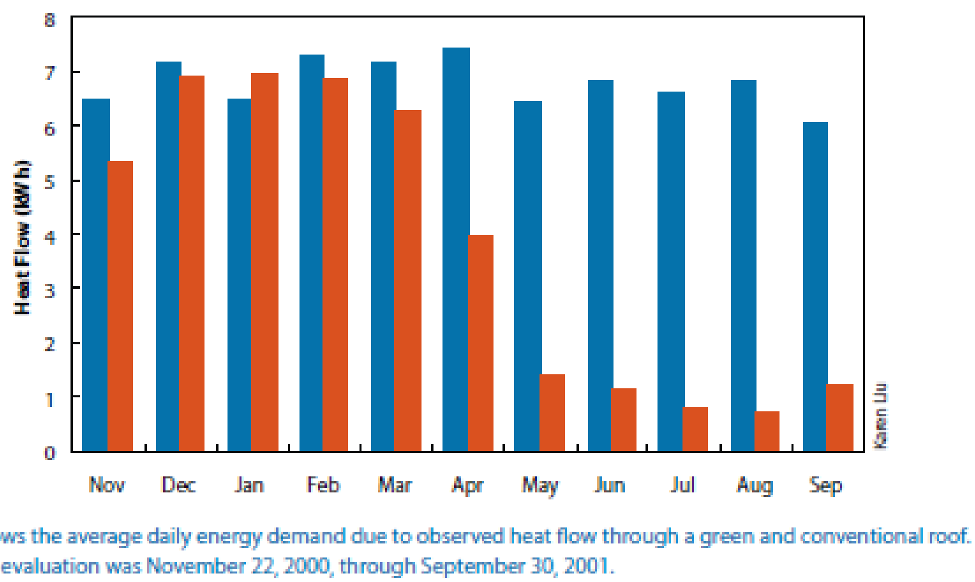


FIGURE 27: COMPARISON STUDY OF GREEN VS. CONVENTIONAL ROOFS IN OTTAWA, ON, CANADA, *US EPA 2012A*

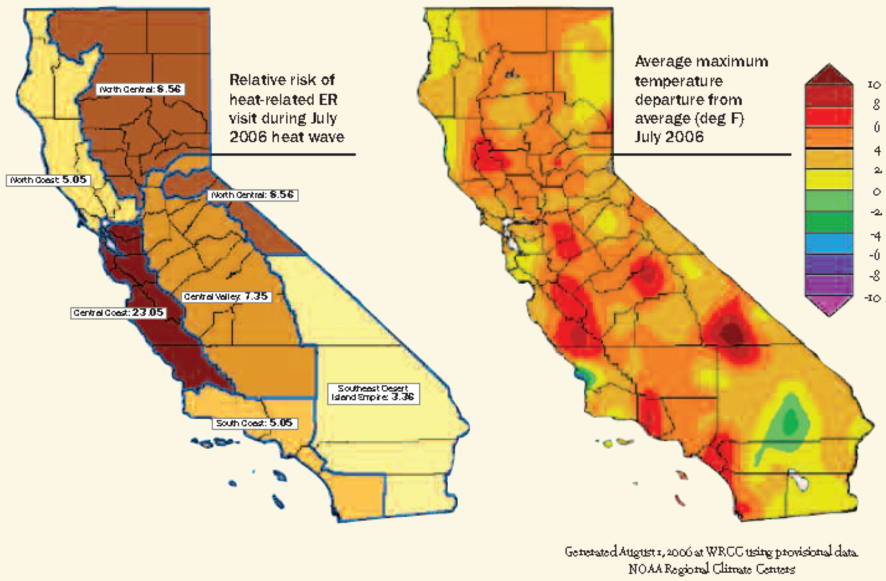
Green roofs are vegetated surfaces that are installed on building roofs. They can absorb solar heat, stormwater, and air pollution, improving a structure's environmental footprint, partly through on-site cooling. Green roofs in Florida have been found to cool buildings by 50°F. These natural heat relief measures translate to a 7-10% reduction in energy expenses and directly prevent heat stresses from occurring. In temperate climates, the impacts of green roofs can be more pronounced (Figure 27). Used at a larger extent, green roofs can directly combat the urban heat island effect, cooling entire urban centers by up to 4°F.

CASE STUDY: California Heat Disaster Response Strategy

Relative risk of heat-related emergency room visits in California during July 2006 heat wave

Source: Knowlton K, Rotkin Ellman M, King G, et al. The 2006 California heat wave-impacts on hospitalizations and emergency department visits. Environ Health Perspct. 2009;117(1):61-67.

Edwards L. Monthly weather summary. California Climate Watch. 2006;3(7):1-2. Available at: http://www.calclim.dri.edu/climatewatch/CalClim200607 2.pdf.



Similar to North Carolina's 2007 drought, California experienced deadly dry and hot weather conditions in 2006, which killed 140 people. The state responded by attempting to determine where and who were most vulnerable to heat stress. Using publicly-available data, they concluded that 80% of the deaths occurred in seven counties; 73% people had histories of chronic illnesses; 66% of all deaths were male; 64% of all deaths occurred in impoverished communities; and 46% of all deaths were people who lived alone. Such programs would provide more accessible cooling centers throughout the region, as well as services to ensure that those most at risk are aware of the heat emergency and have transportation to the cooling centers. Programs specializing in emergency prevention would also be valuable, weatherizing homes to reduce their energy consumption and ensure that cool homes are not leaking air. These approaches can save lives and money in a very short amount of time if multiple partners can collaborate to adapt to such impacts from climate change (CA DPH, 2007; APHA 2011).

AGRICULTURAL IMPACTS

Agriculture is the keystone of the Piedmont Triad's heritage and economy. In 2011, the region generated $768,857,512 in gross revenues and $75,962,859 in net revenues in agricultural products (NCDACS 2011). Timber operations, promise to be a considerable factor for the regional economy as well due to growing biofuels and construction markets. The Piedmont Triad grosses over $900,000,000 total from all of these agricultural practices, which does not include indirect beneficiaries of the economy such as farmers markets or sawmills (NCSU 2011). The exact impacts of the changing climate upon agriculture are unknown, but within the last ten years, the region has been reclassified in the USDA hardiness zone maps from "7" to "8" due to a longer growing season and higher annual average temperature (Figure 28).

In recent years, the eastern U.S. has increased its growing season, especially relative to the western U.S. (Figure 29). This trend indicates that the historic strength of the Piedmont as an agricultural producer will likely persist and grow, though the increasing seasonality of precipitation and heat waves will require adjustments from current norms. Investments in conservation measures to use available water supplies prudently and a shift to different crops such as those grown in northern Georgia and South Carolina will be required. Indeed, if the South becomes a major agricultural producer in the United States, it will likely utilize monocultures, which demand more water and intensive land uses. They are also not supportive of local food economies or producing edible crops, so those interests may need to be accounted for separately from the mainstream agricultural sector. With increasing demands from the agricultural, energy, and residential sectors, the use of these water resources will need to be carefully considered and distributed wisely and equitably.

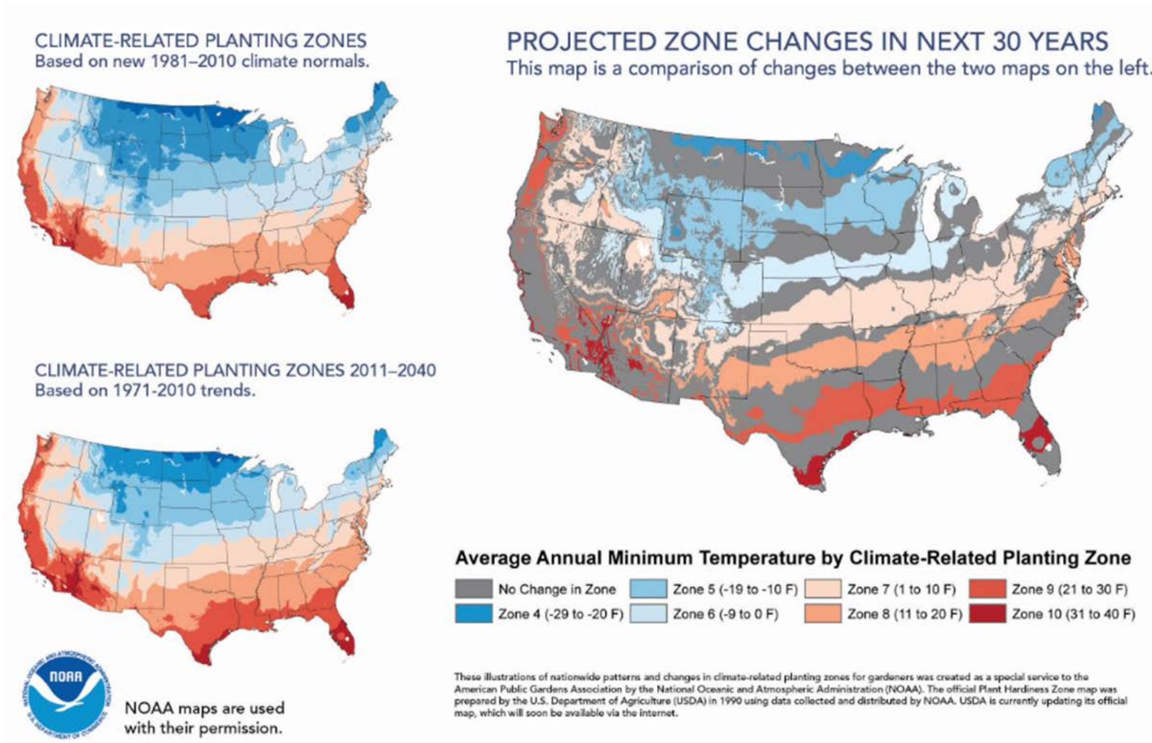


FIGURE 28: PAST, PRESENT, AND PROJECTED FUTURE FEDERALLY-DESIGNATED PLANTING ZONES, INGRAM, *ET AL.*, 2013

Higher annual average temperatures will likely create a longer growing season that may be supportive of agriculture. However, these hot, dry summers and wetter winter conditions could stress farms. Looking to the crops that have historically thrived in the USDA's Hardiness Zone 8 (South Carolina, Georgia, and much of the Deep South) will be helpful in adapting to these conditions. Lessons may also be taken from drier areas to better use water efficiently and better prepare for more regular drought.

Farms are also the workplace of one of the more vulnerable populations to heat stress in the region. Farmworkers typically work long hours exposed to the sun and heat throughout the summer and fall. Those are the two seasons that are anticipated to see the greatest increases in temperature (Figure 14). In order to maximize workplace safety and health issues, the more stressful conditions of hotter and drier growing seasons should be mitigated through appropriate measures. Lessons could be taken from southwestern states that have dealt with these conditions as their baseline for a longer time.

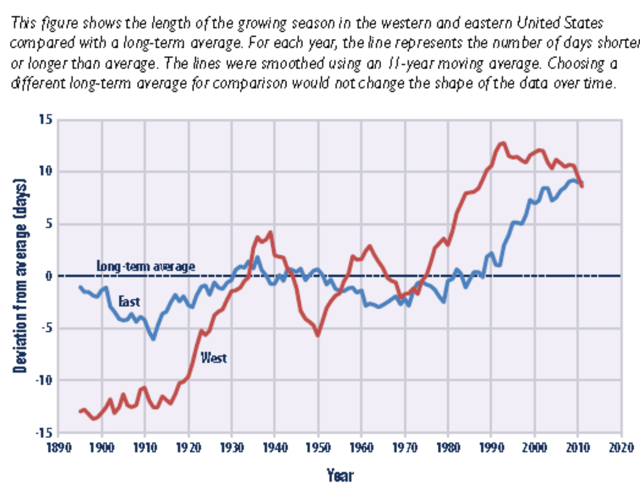


FIGURE 29: LENGTH OF GROWING SEASON IN CONTIGUOUS 48 STATES, 1895-2011, WEST VS. EAST, *US EPA 2012A*

ECOLOGICAL IMPACTS

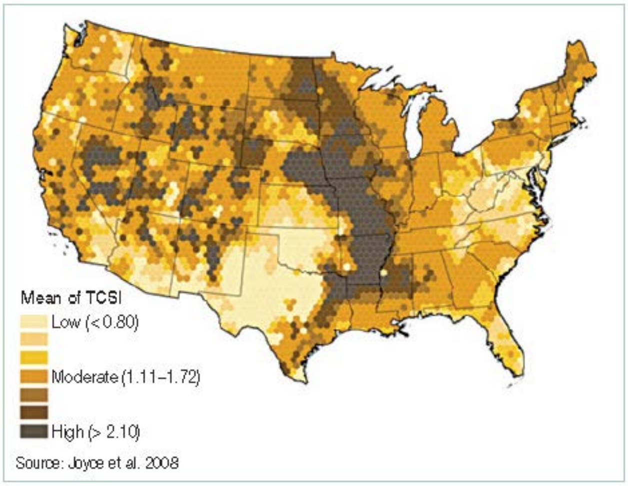


FIGURE 31: FORECASTED STRESS TO LAND ECOSYSTEMS, USDA 2012

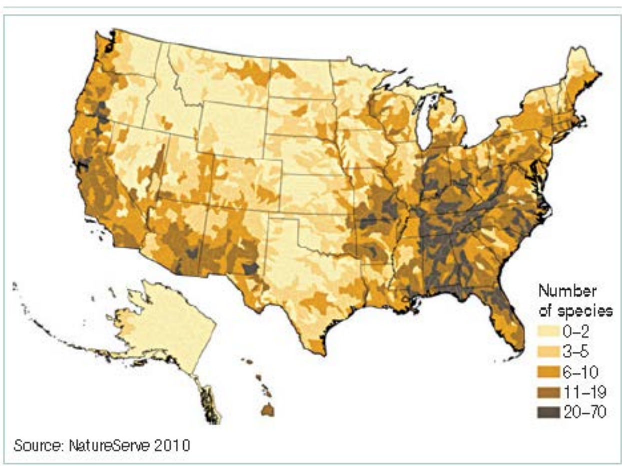


FIGURE 30: RISK OF AQUATIC SPECIES TO EXTINCTION BY WATERSHEDS, *USDA 2012*

The impacts of climate change on natural systems in the Southeast are anticipated to be lower than that experienced by most of North America. However, part of this is due to a history in which the environment has been damaged to a greater extent than most of the nation. North Carolina was tied for sixth in the nation for the loss of species in the twentieth century, most of which were plants. Habitat fragmentation from urban sprawl has been the leading stressor to ecological conditions (as well as agriculture) in the US Southeast (ENC 2007; USDA 2012). The greater seasonality in precipitation patterns, higher temperatures, in combination with the loss of tree cover due to increased urbanization is anticipated to stress the overall quality of life in the region – affecting the agricultural, commercial, residential, and environmental sectors (Figures 18, 30 & 31) (NFWPCAP, 2012).

The threats from climate change and urbanization to regional aquatic ecosystems are high, with 12% of all waters in the US Southeast deemed to be at "high-risk" by the US Department of Agriculture (Figures 15, 16 & 30). Indeed, the majority of the 278 threatened or endangered species listed under the authority of the Endangered Species Act since 2000 are aquatic species (USDA 2012). Smaller streams may completely dry out in the summers, especially without stormwater management, effectively destroying aquatic habitats on headwater tributaries in the region (Figure 30; American Rivers, 2009). Terrestrial species can migrate northward out of North Carolina or up mountainsides as an effort to find better growing conditions; most aquatic species do not have these options (Figures 30 & 32).

Greater urbanization will create more stormwater runoff from impervious surfaces, further stressing Piedmont waters. Stormwater is the runoff that occurs because of rain or snow that flows to nearby streams, rivers, and lakes. Normally, this precipitation soaks into the ground and is used by plants, filtering out many pollutants. During heavy rain events, runoff flows directly to urban and suburban streams and rivers, rendering them inhospitable for native ecology due to erosion, heat, and water pollutants (NC ILT 2012). With more intense storms and hotter urban temperatures, the impacts of stormwater to the local environment and the risks of flash flooding are expected to rise.

Untreated stormwater can be 20 - 30°F hotter than atmospheric temperatures and loaded with urban pollutants. Trout die of heat shock when their waters rise by 2-4°F, which could impact northwestern Triad communities, where fly fishing is a significant part of the local economies (American Rivers, 2009; US EPA 2012b). If measures are not taken to curb urban sprawl and adapt to climate change impacts with resiliency, this leadership of ecological degradation will continue, possibly with ramifications to the related parks and recreation economies that fuel North Carolina's robust toruism economy (NC ILT, 2012).

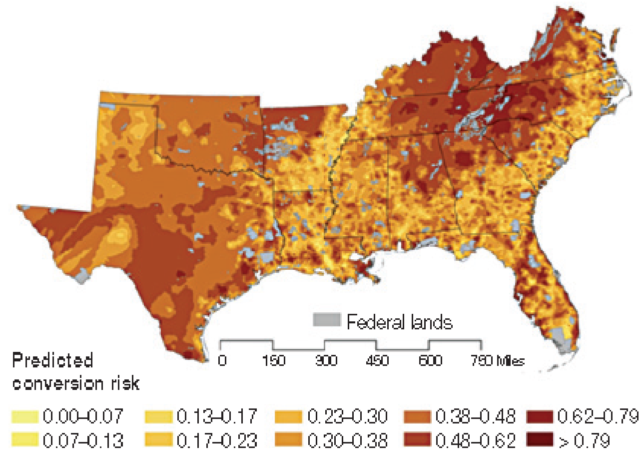


FIGURE 32: PREDICTED RISK FOR WETLANDS LOSS IN THE SOUTHEASTERN US, *USDA 2012*

These impacts may be reduced but there are few regulations to require such measures in the US Southeast. Wetlands would be a highly effective way to not only filter pollutants and slow stormwater runoff, but store large volumes of water (1 million gallons in 1 acre) (American Rivers, 2009). Unfortunately, current rates of land consumption and wetland loss are anticipated to be very high across the US Southeast (Figure 32).

Green roofs and urban trees can mitigate or at least reduce the intensity of these impacts, especially if implemented at a large scale. A 5% increase in urban tree cover can reduce stormwater volumes by 2% (SWF 2005). Green roofs can be even more valuable in reducing or managing stormwater runoff,

CASE STUDY: Clayton, GA, Wastewater Wetland

Through the use of a wetland system to treat its wastewater and Clayton County, GA, was able filter and rely upon a 230-day supply through the 2007 drought while nearby Atlanta had less than a 90-day supply left, and engaged in an interstate battle over water rights. These wetlands filter 20% of the pollutants in the wastewater. A grey infrastructure solution to achieve similar goals would cost twice as much as this green infrastructure approach. Furthermore, the wetland solution returns greater value to Clayton County, attracting over 20,000 visitors over a year to view the 130 species of bird that use the wetland as a permanent home or migratory stop (American Rivers 2012).

intercepting at least 75% of rainfall and removing 95% of most pollutants in the runoff (US EPA 2012a). This is a value not only for the physical stresses stormwater volumes cause to streams, but in mitigating the heat that urban runoff delivers to aquatic ecosystems.

DISCUSSION

Throughout the United States, communities are facing unprecedented challenges from climate change. However, a 2011 survey of local governments found that only 59% are planning for climate adaptation (Bierbaum et al., 2007). Only 13% of the local governments surveyed were developing risk assessments, leaving the other 87% vulnerable to the impacts of climate change (Bierbaum, et al., 2007). The preparedness of Piedmont Triad counties and municipalities appears to be lower than these national figures. Failing to preapre for anticipated extreme weather events places communities and the entire region in a situation which can leave them structurally and financially devastated, and reliant upon federal assistance for full recovery. This is not a prediction of a future scenario – it is a reflection of the past ten years of weather preparedness in Piedmont Triad communities, as seen in the enormous amount of federal aid North Carolina receives for disaster relief and recovery. This history shows a lack of adequate preparation to address weather and, ultimately, an unsustainable financial and administrative strategy to address this persistent problem. However, only small changes to confront these challenges have been seen in the region.

There are examples to follow in addressing these forecasted climate change impacts to the Piedmont Triad, and many resources to mitigate these impacts. Many other communities and organizations are working on climate change mitigation and resiliency simultaneously with the Piedmont Together effort. Most obviously are the other US Department of Housing and Urban Development Sustainable Communities grant recipients, who are all tackling shared concerns in different ways and from different perspectives.

The National Association of County and City Health Officials (NACCHO) and the ICLEI Local Governments for Sustainability program offers many models for how local governments are responding to the effects of climate change to protect their residents. Thus far, the City of Winston-Salem is the only Triad government participating in either of these programs and actively tapping into these resources. Only five Triad cities (Burlington, Greensboro, Lewisville, Pleasant Garden, and Winston-Salem) have signed the U.S. Conference of Mayors Climate Protection Agreement, which requires them to strive toward the goals of the 2005 Kyoto Protocol to address "climate disruption" (US Mayors, 2013). Involvement with such groups and having access to these networks has been shown to be a significant factor in taking steps towards mitigating climate change impacts at the local level (Krause, 2011).

There are also a number of vested stakeholders in climate change impact mitigation, including several non-profits such as American Rivers, which has published many resources for local governments to consult on improving their environmental footprint and preparing climate change impacts, perhaps most notably *The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits* (Figure 33). In addressing the effects of heat waves upon the populace, California's statewide assessment of vulnerable populations and Philadelphia's municipal warning system and relief network have proven effective in identifying immediate gaps in infrastructure that can warn their residents of heat waves, inform them of what measures they can take to avoid heat stress, and provide emergency services. In promoting urban greening efforts, several cities have used rebate coupons and partnerships with the private sector to promote street tress, and others have offered grants to promote green roofs (See Appendix B) (Ingram, *et al.,* 2013; US EPA 2012c).

Benefit	Reduces Stormwater Runoff											Improves Community Livability						
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

Yes Maybe No

FIGURE 33: THE VALUE OF GREEN INFRASTRUCTURE: A GUIDE TO RECOGNIZING ITS ECONOMIC, ENVIRONMENTAL AND SOCIAL BENEFITS, AMERICAN RIVERS, 2013

There are still opportunities to prevent the more dire climate change impacts from occurring. This approach would require immediate steps to reduce the emissions of carbon dioxide, methane, and other greenhouse gasses from the region's automobiles, power plants, homes, and businesses. This can be done directly (i.e. reduction of tailpipe emissions) and indirectly (greening urban centers to reduce the urban heat island effect).

The region can mitigate these impacts, which does not require prevention of global climate change, but will minimize the effect of these impacts upon the region. This will be a challenging strategy for some forecasted impacts, such as more intense summer thunderstorms and hurricanes, but perhaps feasible for impacts such as heat waves, in which the institution of more stringent water conservation measures and then further emergency drought measures may be effective.

Lastly, the region can attempt to be resilient to the effects of climate change. Resiliency strategies, however, may require the region to take greater steps to protect human lives, communities, and the regional culture than the other two approaches. It is one thing to acknlowedge that more frequent droughts and more violent hurricanes are going to be a part of life in the Piedmont Triad. It is another thing to attempt to take steps to ensure that these changes do not have a degradative effect upon the regional economy, community, or environment. In the case of the environment, it is likely impossible.

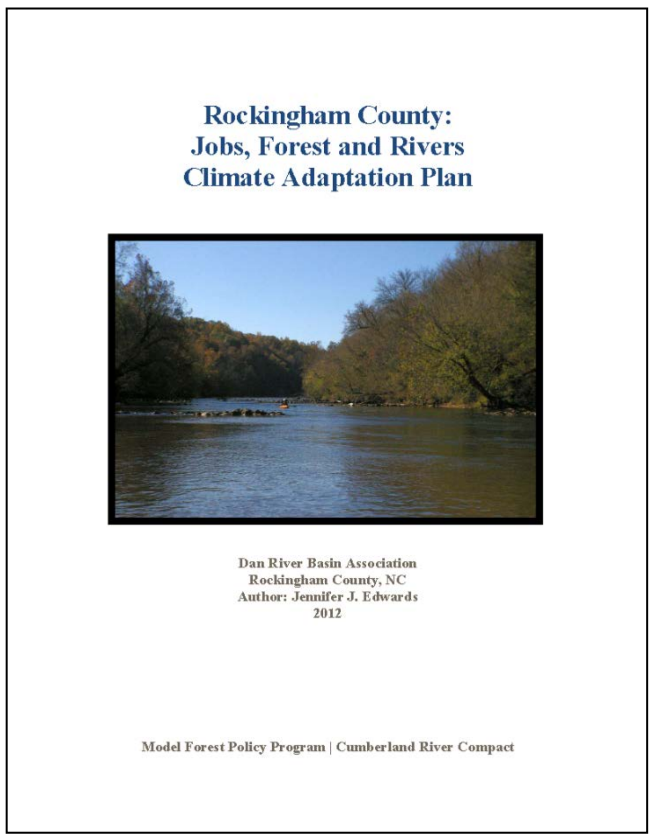
The Piedmont Triad has three options to address the local impacts of global climate change: prevention, mitigation, or adaptation.

The Piedmont Together Project Integration Team (PIT) has proposed a number of measures to address the region's economic, societal, and environmental vulnerabilities, risks, and needs as they relate to green infrastructure. These goals and objectives are founded in the efforts and conversations of the Green Infrastructure and Climate Adaptability & Energy work groups, and have been refined through public feedback at joint work group sessions and more public livability summits. They represent strategies that will be necessary to ensure the health of the Triad's people, economy, and ecosystems as the region grows to 2 million people and North Carolina ascends to a greater role nationally with its greater constituency. Implementation and adapative management of a climate adaptation strategy that serves all sectors and communitues of the Piedmont Triad will require the participation of those parties that will have to respond to the impacts of climate change most immediately: emergency management services, farmers, transportation authorities, power utilities, local elected officials, etc. The goals and objectives include:

Piedmont Together Resilient Climate Adaptation Strategy		
Goal	**Objective**	**Example Strategy**
Decrease the Piedmont Triad's Vulnerability to Climate Change	Decrease the Piedmont Triad's Vulnerability to Extreme Heat	Update county hazard mitigation plans to include extreme heat response strategies
	Decrease the Piedmont Triad's Vulnerability to Frozen Precipitation and Extreme Low Temperatures	Focus household weatherization programs on vulnerable populations
	Protect the Piedmont Triad's Water Supply and Quality	Develop source water protection plans for all drinking water sources
	Protect the Piedmont Triad's Air Quality	Promote and support the enhancement of the available alternative transportation infrastructure to reduce vehicle miles traveled
	Preserve Piedmont Triad Plants, Trees and Natural Landscapes	Enhance urban forest canopies so that all Triad municipalities have a 40% canopy cover
	Decrease the Piedmont Triad's Vulnerability to Wildfires	Partner with the county EMS and the NC Division of Parks and Recreation staffs to improve public awareness of wildfire risks
	Reduce the Vulnerability of Piedmont Triad Residents to Health Risks	Work with hospitals to monitor and respond to extreme heat conditions
	A Climate-Educated Piedmont Triad Public	Share Piedmont Together work with vested parties and develop a public engagement campaign
	Plan for Future Challenges	Adopt a regional green infrastructure plan to anticipate needs an mitigate their impacts to the public and ecology

Reduce Energy Consumption	Retrofit Commercial and Industrial Buildings	Develop weatherization program that targets those most vulnerable to extreme weather events
	Increase the Use of Energy-Efficient Appliances	Collaborate with retail partners to build upon existing appliance buy-back programs
	Promote Energy Reduction Through Water Conservation	Develop leak detection programs for water utility in the region
	Streamline Resources	Work with public and private sector partners to make structural and programmatic retrofits simpler and easier to implement
	Promote Clean and Renewable Energy Sources	Diversify the sources of energy generation used by power plants
	Improve Transportation Options	Promote transit-oriented development patterns
	Reduce Waste and Industrial Pollution	Switch to newer, less-toxic refrigerants

The Dan River Basin Association (DRBA) has stepped up to address these concerns in the absence of government leadership. A non-profit dedicated to the health of the Dan River and its tributaries for both ecological and human needs, the DRBA authored *Rockingham County: Jobs, Forests and Rivers Climate Adaptation Plan*, which assess the impacts of climate change upon Rockingham County's lands, waters, and natural resources. It assesses risks and vulnerabilities within the county and its municipalities to address forecasted impacts, and has developed some programmatic strategies to address many of them in cooperation with the government bodies as well as the public-at-large of the municipalities. This report was suppprted by the Model Forestry Planning Program, which is supporing similar studies and reports for rural countiies throughout the United States in an effort to protect and ensure the resiliency of the nation's forests (DRBA 2013).


Rockingham County:
Jobs, Forest and Rivers
Climate Adaptation Plan

Dan River Basin Association
Rockingham County, NC
Author: Jennifer J. Edwards
2012

Model Forest Policy Program | Cumberland River Compact

Table 1*

NORTH CAROLINA INTERAGENCY LEADERSHIP TEAM		OTHER PARTNERS
State Agencies	**Federal Agencies**	**Non-ILT State Agencies**
Agriculture and Consumer Services	Environmental Protection Agency	DHHS-Public Health
Commerce	Federal Highway Administration	Emergency Management
Cultural Resources	National Oceanic and Atmospheric Administration	Insurance
Environment and Natural Resources	U.S. Army Corps of Engineers**	
Transportation	U.S. Fish and Wildlife Service	
Wildlife Resources Commission		

Key Advisors and Stakeholders also provided input.

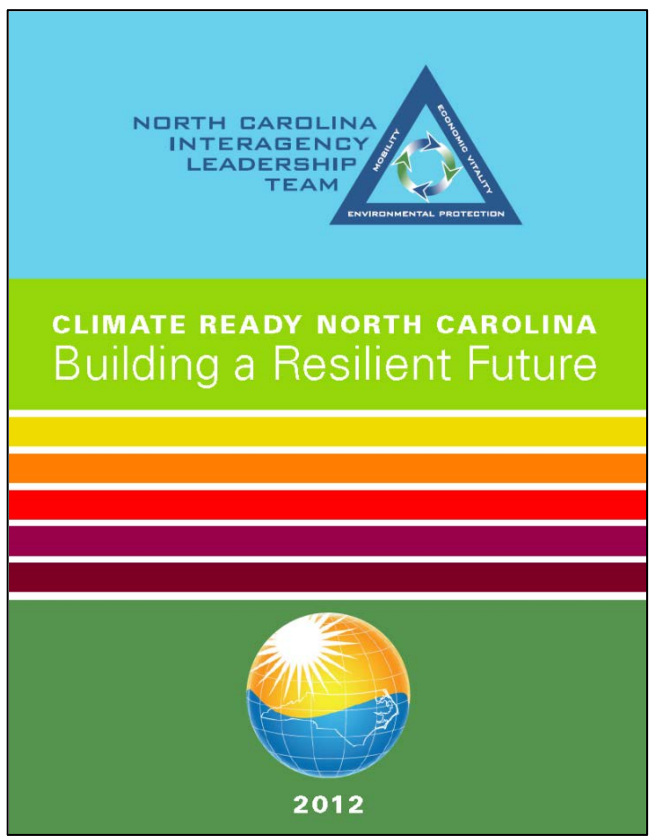
North Carolina State Climate Office	Duke University-Nicholas Institute
University of North Carolina-Chapel Hill	University of North Carolina-Asheville
East Carolina University	North Carolina State University
Local and county governments	Regional Councils of Government

**The Climate-Ready North Carolina Strategy was collaboratively developed by a working group with representatives from these entities.*

***Participates in an advisory capacity.*

FIGURE 34: NC ILT, 2012

The North Carolina Interagency Leadership Team that is engaging in cross-sector strategies and adaptive responses to mitigate the impacts of climate change to North Carolina (Figure 34). Through this partnership, the state received input from the insurance industry, energy organizations, trade representatives, and professional organizations on their concerns regarding climate change and its potential impacts. Members of the partnership have also participated in the Governors' South Atlantic Alliance and the Southeast Regional Partnership for Planning and Sustainability. One result from this collaboration has been the development of a resource handbook by the NC Division of Emergency Management and the UNC-Chapel Hill School of Planning on how to incorporate climate change into resiliency planning. They have many implementation strategies that are sector-specific and should be useful for mitigation and resiliency planning purposes statewide, and serve as the basis for recommendations made by the Piedmont Together project.



There are undoubtedly aspects of climate change and its impacts to the region that have been missed by this assessment and must be contributed by other stakeholders, citizens, and organizations. Much of this input needs to come from local parties, but there are also national agencies assessing these concerns and their potential impacts nationally and regionally. These include:

- the US Department of Interior, which are conducting a water census to evaluate water quality and quantity trends;
- the US Centers for Disease Control, which is tracking waterborne diseases;
- the National Oceanic and Atmospheric Admisnistration, which is attempting to downscale global climate models to the local watershed scale for use by decisionmakers;
- the US Department of Agriculture, which has developed a Climate Change Adaptation Plan (see Appendix C for details);
- the US EPA, which has a Climate Ready Utilities program that is a resource for water and wastewater utilities attempting to mitigate the stresses of higher temperatures, limited water supplies, and higher pollutant loads;
- a collaboration between the US EPA and FEMA that encourgaes resiliency planning and the use of sustainable recenstruction of infrastructure and bolstering of emergency management services following disasters; and
- a collaboration between NOAA and the DOI to develop a vulnerability index for water resources and utilities.

There are many water use efficiency programs available to conserve and use limited water supplies effectively, include:

- the US DOI's WaterSMART;
- the USGS's Water Census;
- the US EPA's WaterSense; and
- the NRCS's Agriculture Water Enhancement Program (US DOC 2011; USDA 2012).

This Climate Adaptabaility Report is just one part of the much larger Piedmont Together project aimed at serving the economic, social, and environmental needs of the region and all of its local communities. It details the most immediate effects of a hotter, drier summers; wetter, warmer winters; and more intense hurricanes and thunderstorms. The project team and the Piedmont Triad as a whole community needs to determine how it will address these potential impacts – with strategies to mitigate their occurrence, adapt to these impacts, and/or ensure resiliency to the impacts of these changes.

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APPENDIX A

From National Fish, Wildlife & Plants Climate Adaptation Strategy, *USFWS, NOAA, AFWA, 2012*

temperature increases

INCREASING LEVELS OF GREENHOUSE GASES ON U.S. ECOSYSTEMS & SPECIES: OBSERVED & PROJECTED ECOLOGICAL CHANGES

Major Changes	Forests	Shrublands	Grasslands	Deserts	Tundra	Inland Waters	Coastal	Marine
Increased temperatures U.S. average temperatures have increased more than 2 °F in the last 50 years, and are projected to increase further. Global ocean temperatures rose 0.4 °F between 1955 and 2008.	» Increase in forest pest damage » Changing fire patterns » Longer growing season » Higher evapo-transpiration/ drought stress	» Increased fire frequency may favor grasses over shrubs » Increased evapo-transpiration/ intensified water stress » Spread of non-native species	» Spread of non-native plants and pests » Changing fire patterns	» Elevated water stress » Mortality in heat-sensitive species » Possible desert expansion » Spread of non-native species	» Higher water stress » Changing plant communities » Longer growing season » Invasion by new species » Increased fire » More freeze-thaw-freeze events » Changes in sub-nivean temp. (underneath the snow pack)	» Expansion of warm-water species » Depleted O_2 levels » Stress on coldwater species » Increased disease/ parasite susceptibility » More algal blooms	» Increase of salt marsh/ forested wetland vegetation » Distribution shifts » Phenology changes (e.g., phytoplankton blooms) » Altered ocean currents and larval transport into/out of estuaries	» Coral mortality » Distribution shifts » Spread of disease and invasives » Altered ocean currents and larval dispersal patterns » New productivity patterns » Increased stratification » Lower dissolved O_2
Melting sea ice/ snowpack/ snow melt: Arctic sea ice extent has fallen 3–4% per decade over the last 30 years, and further loss is predicted. In terrestrial habitats, reduced snowpack, earlier snow melt, and widespread glacier melt and permafrost thawing are predicted.	» Longer frost-free periods » Increase in freeze/thaw events can lead to icing/ covering of winter forage » Decreased survival of some insulation-dependent pests	» Reduced snowpack leads to hydrological changes (timing and quantity)	» Reduced snowpack leads to hydrological changes (timing and quantity)	» Reduced snowpack leads to hydrological changes (timing and quantity)	» Thawing permafrost/ soil » Hydrological changes » Terrain instability » Vegetation shifts » Longer snow-free season » Contaminant releases	» Snowpack loss changes the temperature, amount, duration, distribution and timing of runoff » Effects on coldwater and other species » Loss of lake ice cover	» Loss of anchor ice and shoreline protection from storms/ waves » Loss of ice habitat » Salinity shifts	» Loss of sea ice habitats and dependent species » Changes in distribution and level of ocean » Changes in ocean carbon cycle » Salinity shifts
Rising sea levels: Sea level rose by roughly 8´ over the past century, and in the last 15 years has risen twice as fast as the rate observed over the past 100 years. Sea level will continue to rise more in the future.	 USFWS/STEVE HILLEBRAND				» Salt water intrusion » Loss of coastal habitat to erosion	» Inundation of freshwater areas » Groundwater contamination » Higher tidal/ storm surges	» Inundation of coastal marshes/low islands » Higher tidal/ storm surges » Geomorphology changes » Loss of nesting habitat » Beach erosion	» Loss of coral habitats » Negative impacts on many early life stages
Changes in circulation patterns: Warming of the atmosphere and ocean can change spatial and temporal patterns of water movement and stratification at a variety of scales.	 UNITED NATIONS FOOD AND AGRICULTURE ORGANIZATION/DANILO CEDRONE					Altered productivity and distribution of fish and other species with changes in lake circulation patterns	Altered productivity, survival, and/or distribution of fish and other estuarine dependent species	Altered productivity, survival, and/or distribution of fish and other species (particularly early life history stages)

precipitation increases

INCREASING LEVELS OF GREENHOUSE GASES ON U.S. ECOSYSTEMS & SPECIES: OBSERVED & PROJECTED ECOLOGICAL CHANGES								
Major Changes	Forests	Shrublands	Grasslands	Deserts	Tundra	Inland Waters	Coastal	Marine
Changing precipitation patterns Precipitation has increased approximately 5% in the last 50 years. Predictions suggest historically wet areas will become wetter, and dry, drier.	» Longer fire season » Changes in fire regime » Both wetter and drier conditions projected	» Dry areas getting drier » Changing fire regimes	» Invasion of non-native grasses and pests » Species range shifting » Changes in fire regime	Loss of riparian habitat and movement corridors	» More icing/ rain-on-snow events affect animal movements and access to forage » Increased fire	» Changing lake levels » Changes in salinity, flow	» Changes in salinity, nutrient, and sediment flows » Changing estuarine conditions may lead to hypoxia/anoxia » New productivity patterns	» Changes in salinity, nutrient and sediment flows » New productivity patterns
Drying conditions/drought Extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years.	» Decreased forest productivity and increased tree mortality » Increased fire	» Loss of prairie pothole wetlands » Loss of nesting habitat » Increased fire	» Loss of prairie pothole wetlands » Loss of nesting habitat » Invasion of non-native grasses » Increased fire	» Increased water stress » Increased susceptibility to plant diseases	» Moisture stressed vegetation » Loss of wetlands » Fish passage issues	» Loss of wetlands and intermittent streams » Lower summer base flows » Decreased lake levels	» Changes in salinity, nutrient and sediment flows » Shifting freshwater input to estuaries	» Changes in salinity, nutrient and sediment flow » New productivity patterns
More extreme rain/weather events Rain falling in the heaviest downpours has increased approximately 20% in the past century. Hurricanes have increased in strength. These trends are predicted to continue.	» Increased forest disturbance » More young forest stands	More variable soil water content	Changing pest and disease epidemiology	Higher losses of water through run-off	More landslides/ slumps	» Increased flooding » Widening floodplains » Altered habitat » Spread of invasive species/ contaminants	» Higher waves and storm surges » Loss of barrier islands » Beach erosion » New nutrient and sediment flows » Salinity shifts; » Increased physical disturbance	» Higher waves and storm surges » Changes in nutrient and sediment flows » Impacts to early life stages » Increased physical disturbance

carbon dioxide increases

INCREASING LEVELS OF GREENHOUSE GASES ON U.S. ECOSYSTEMS & SPECIES: OBSERVED & PROJECTED ECOLOGICAL CHANGES

Major Changes	Forests	Shrublands	Grasslands	Deserts	Tundra	Inland Waters	Coastal	Marine
Increase in atmospheric CO_2 The concentration of CO_2 in the atmosphere has increased by roughly 35% since the start of the industrial revolution.	» Increase forest productivity/ growth in some areas » Insect pests may be affected » Changes in species composition	» Spread of exotic species such as cheatgrass » Impacts on insect pests » Changes in species composition	» Declines in forage quality from increased C:N ratios » Insect pests may be affected » Changes in species composition	» Increased productivity of some plants » Changes in communities » Increased fire risk	» Increased productivity of some plant species » Changes in plant community composition	» Increased growth of algae and other plants » Changes in species composition and dominance	» Increased terrestrial, emergent, and submerged plant productivity	» Increased plant productivity
Ocean acidification The pH of seawater has decreased significantly since 1750, and is projected to drop much more by the end of the century as CO_2 concentrations continue to increase.	 [illegible]						» Declines in shellfish and other species » Impacts on early life stages	» Harm to species (e.g., corals, shellfish) » Impacts on early life stages » Phenology changes » Loss of the planktonic food base for critical life stages of commercial fishes

*This table is intended to provide examples of how climate change is currently affecting or is projected to affect U.S. ecosystems and the species they support, including documented impacts, modeled projections, and the best professional judgment of future impacts from Strategy contributors. It is not intended to be comprehensive, or to provide any ranking or prioritization. Climate change impacts to ecosystems are discussed in more detail in sections 2.3.1-2.3.8, and in online ecosystem specific background papers (see Appendix A).
**References: See IPCC AR4 2007, USGCRP 2009.
See IPCC AR4 2007, USGCRP 2009,
others in Chapter 2.

APPENDIX B

US EPA 2012c

Table 3: Green Roof Resources

Name	Description	Web Link
Guidance Documents		
U.S. Department of Energy Federal Technology Alert: Green Roofs	DOE's Energy Efficiency and Renewable Energy program publishes technology alerts and developed this primer on green roof technology.	<www.nrel.gov/docs/fy04osti/36060.pdf>
Green Roofs as Urban Ecosystems: Ecological Structures, Functions, and Services	The journal *Bioscience* November 2007 issue contains this comprehensive article summarizing the research on green roofs and their costs and benefits.	<www.aibs.org/bioscience-press-releases/resources/11-07.pdf>
National Roofing Contractors Association Green Roof Systems Manual	The NRCA has recently released a guidebook for sale that focuses on the waterproofing needs of green roofs.	<www.nrca.net/rp/pubstore/details.aspx?id=450>
Los Angeles Green Roof Resources Guide	The City of Los Angeles developed this guide as a resource for individuals and groups interested in developing green roofs in Los Angeles. This guide includes information on how to plan, design, and maintain a green roof.	<www.fypower.org/pdf/LA_GreenRoofsResourceGuide.pdf>
Other Resources		
Green Roofs for Healthy Cities	Green Roofs for Healthy Cities offers resources on green roof installation, benefits, projects, and training. This group also publishes the *Green Roof Infrastructure Monitor*.	<www.greenroofs.org>
Greenroofs.com	Greenroofs.com provides green roof industry resources, including how-tos, plant lists, references, and an international database of green roof projects.	<www.greenroofs.com>
Chicago Green Roof Program	Chicago's Green Roof Program has online information on building green roofs in Chicago, including an aerial map of completed and planned projects, frequently asked questions, featured projects, and links to other resources.	<www.chicagogreenroofs.org>

APPENDIX C

Bierbaum R., et al., **Mitigation and Adaptability Strategies for Global Climate Change**

A Comprehensive Review of Climate Adaptation in the United States: More than before, but less than needed

Table 1 Examples of U.S. federal interagency actions to promote, implement, and support adaptation at all scales

Entity	Action	Description
White House and Interagency	Established Interagency Climate Change Adaptation Task Force (ICCATF) and issued E.O. 13514, *federal Leadership in Environmental, Energy, and Economic Performance.*	ICCATF is co-chaired by the White House Council on Environmental Quality (CEQ) and Office of Science and Technology Policy (OSTP), along with the National Oceanic and Atmospheric Administration (NOAA), with senior participation from 20+ agencies. E.O. 13514 charged ICCATF with developing recommendations to help prepare for the impacts of climate change, and required federal agencies to "evaluate agency climate-change risks and vulnerabilities to manage the effects of climate change on the agency's operations and mission in both the short and long term."
Interagency Climate Change Adaptation Task Force (ICCATF)	Developed Guiding Principles for federal adaptation efforts and policy goals and recommended actions for the federal government. Guides interagency adaptation planning efforts.	The October 2010 Progress Report of the ICCATF laid out eight principles for federal adaptation efforts and made five key recommendations, including the development of agency adaptation plans and strategies to address key cross-cutting issues such as water management, natural resource management, and the integrating of adaptation actions into existing planning processes.
ICCATF Water Resources Adaptation workgroup	Developed and is leading implementation of the *National Action Plan: Priorities for Managing Freshwater Resources in a Changing Climate.*	The National Action Plan was released in October 2011, and is designed to ensure adequate water supplies and protect water quality, human health, property, and aquatic ecosystems. The workgroup is chaired by the Department of the Interior's (DOI's) U.S. Geological Survey (USGS) and the Environmental Protection Agency (EPA) and coordinated by CEQ.
ICCATF Agency Adaptation Planning Workgroup	Established and coordinates the federal agency adaptation community of practice.	The community of practice provides information and support to federal agencies working to reduce their climate change-related risks and a forum for collaboration and coordination across agencies. Coordinated by EPA.
Steering Committee of the *National Fish, Wildlife, and Plants Climate Adaptation Strategy*	Developed the *National Fish, Wildlife, and Plants Climate Adaptation Strategy.*	Requested by Congress and the ICCATF, this strategy is a collaborative effort of federal, state, and tribal partners to provide a unified approach for reducing the negative impacts of climate change on these resources. The steering committee is chaired by DOI's Fish and Wildlife Service (FWS), NOAA, and the New York Division of Fish, Wildlife, and

Table 1 (continued)

Entity	Action	Description
		Marine Resources (representing State agencies).
National Ocean Council (NOC)	Developed a chapter on adaptation and ocean acidification for the *National Ocean Policy Implementation Plan.*	This was developed in response to the NOC's call to strengthen resiliency of coastal communities and marine and Great Lakes environments and their ability to adapt to climate change impacts and ocean acidification, and the ICCATF's recommendation for a cross-cutting look at ocean and coastal adaptation issues.
U.S. Global Change Research Program (USGCRP)	National Climate Assessment, decadal National Global Change Research Plan (2012–2021), and annual report to Congress	Responsible for the development of the National Climate Assessment (NCA) every 4 years, as mandated by the Global Change Research Act of 1990 (GCRA, P.L. 101–606). Additionally, submits an annual report to Congress called "Our Changing Planet." In April 2012, the USGCRP released a new decadal National Global Change Research Plan with four new strategic goals, including: advance science, inform decisions, conduct sustained assessments, and communicate and educate.
USGCRP's Adaptation Science Workgroup	Identifying critical science information and decision support needs and capabilities in support of adaptation.	Formerly an ICCATF Adaptation Science Workgroup, the Adaptation Science Workgroup was transferred to USGCRP in 2010 as a new program element to improve the federal government's capacity to provide science in support of adaptation decisions at all scales for a diversity of users.

Material provided in Table is derived from Agency websites

Table 2 Examples of individual U.S. federal agency actions to promote, implement, and support adaptation at multiple scales

Agency	Component	Action	Description
All federal agencies		Developing Adaptation Plans as part of their annual Strategic Sustainability Performance Plans	The 2012 Strategic Sustainability Performance Plans for 50+ federal agencies will contain a specific section on adaptation. Agencies are required to evaluate climate risks and vulnerabilities to manage both short- and long-term effects on missions and operations.
Department of Health and Human Services (HHS)	Centers for Disease Control and Prevention (CDC)	Climate-Ready States and Cities Initiative	Through their first climate change cooperative agreements in 2010, CDC awarded $5.25 million to ten state and local health departments to

Table 2 (continued)

Agency	Component	Action	Description
			assess risks and develop programs to address climate change-related challenges.
Department of Agriculture (USDA)		Integrating climate change objectives into plans and networks.	USDA is using existing networks such as the Cooperative Extension Service, the Natural Resource Conservation Districts, and the Forest Service's Climate Change Resource Center to provide climate services to rural and agricultural stakeholders.
USDA	Forest Service	Developed a *National Roadmap for Responding to Climate Change* and a *Guidebook for Developing Adaptation Options*, among many resources.	The *National Roadmap* was developed in 2010 to identify and long-term actions to reduce climate change risks to the nation's forests and grasslands. The *Guidebook* (developed in 2011) builds on this previous work and provides science-based strategic and tactical approaches to adaptation. Other resources are available on the Forest Service website.
Department of Commerce (DOC)	NOAA	Supports research teams and local communities on adaptation-related issues and develops tools and resources.	Supports research teams such as Regional Integrated Sciences and Assessments (RISAs) to inform resource management, planning, and policy. Established six regional climate centers (RCCs) to better assess and deliver regionally focused climate science and services. Developed the Digital Coast partnership.
Department of Defense (DOD)	U.S. Army Corps of Engineers (USACE)	Developed a USACE climate change adaptation plan, and continues to update guidance for incorporating sea level rise into projects.	The Corps released its climate change adaptation plan in September 2011. The goal of the plan is to reduce vulnerabilities and improve resilience of water resources infrastructure impacted by climate change. The latest update of the guidance on "Incorporating Sea-Level Change Considerations in Civil Works Programs" was released in November 2011.
DOD	Department of the Navy	Developed road maps for adaptation in the Arctic and across the globe.	The Navy Arctic Roadmap (November 2009) promotes maritime security and naval readiness in a changing Arctic. The Climate Change Roadmap (May 2010) examines broader issues of climate change impacts on Navy missions and capabilities globally.
Department of Energy (DOE)		Develops higher spatial and temporal scales of climate projections, and is working to integrate adaptation and climate	Develops community-based, high-resolution (temporal and spatial) models for climate projections and integrated assessment models that increasingly reflect multi-sectoral

Table 2 (continued)

Agency	Component	Action	Description
		considerations into integrated assessments.	processes and interactions, multiple stressors, coupled impacts, and adaptation potential.
DOI	FWS	Developed an FWS climate change strategic plan. Established a network of Landscape Conservation Cooperatives.	The FWS climate change strategy plan (September 2010) establishes a basic framework to help ensure the sustainability of fish, wildlife, plants, and habitats in the face of climate change. In 2009, through Secretarial Order 3289, DOI established a network of 22 Landscape Conservation Cooperatives (LCCs) designed to promote shared conservation goals, approaches, and resource management planning and implementation across the United States, including Alaska, Hawaii, and the Caribbean.
DOI	USGS	Established a network of Climate Science Centers (CSCs).	Operates a National Climate Change and Wildlife Center and eight regional CSCs, which provide scientific information and tools that land, water, wildlife, and cultural resource managers and other stakeholders can apply to anticipate, monitor, and adapt to climate change.
Department of Transportation (DOT)	Federal Highway Administration (FHWA)	Developed Risk Assessment Model for transportation decisions.	DOT worked with five local and state-level transportation authorities to develop a conceptual Risk Assessment Model to help transportation decision-makers identify which assets are: (a) most exposed to the threats from climate change and/or (b) associated with the most serious potential consequences of climate change threats. Completed in November 2011.
DOT		Comprehensive study of climate risks to transportation infrastructure in the Gulf Coast Region, followed by an in-depth study for Mobile, Alabama.	Phase 1 of the study (completed in 2008) assessed the vulnerability of transportation infrastructure to climate change impacts across the Gulf region. Phase 2, expected to be completed in 2013, is focused on Mobile, Alabama. The effort is designed to develop transferable tools that will help transportation planners across the country.
EPA		Developed Climate Ready Estuaries and Climate Ready Water Utilities Working Group. Developed a draft agency water program adaptation strategy.	The Climate Ready Estuaries program works with coastal managers to: (1) assess vulnerabilities; (2) develop and implement adaptation strategies; (3) engage stakeholders; and (4) share lessons learned. The Climate Ready Water Utilities initiative provides

Table 2 (continued)

Agency	Component	Action	Description
			resources and tools to assist the water sector in adapting to climate change. The Draft *National Water Program Strategy: Response to Climate Change* addresses climate change impacts on water resources and EPA's water programs.
NASA		NASA's Climate Adaptation Science Investigator (CASI) Workgroup engages NASA climate models, missions, scientists, and NASA institutional stewards to explore NASA center-specific climate impacts and adaptation strategies.	The team has engaged in a range of activities since CASI's launch in the summer of 2010, including: (1) downscaling center-specific climate hazard information and projections; (2) conducting climate research customized to each Center's needs; (3) building inventories of each Center's existing climate and impact data and research activities; and (4) co-leading adaptation workshops.

Material provided in table is derived from Agency websites

This list contains selected examples of agency work on adaptation and should not be considered all-inclusive

Table 4 Examples of U.S. local/regional and tribal-level adaptation activities

Local/regional government	Adaptation action
Satellite Beach, FL	Collaboration with the Indian River Lagoon National Estuary Program led to the incorporation of sea level rise projections and policies into the city's comprehensive growth management plan (Gregg et al. 2011).
Portland, OR	Updated the city code to require on-site stormwater management for new development and re-development, and provides a downspout disconnection program to help promote on-site stormwater management (EPA 2010b).
Lewes, DE	In partnership with Delaware Sea Grant, ICLEI-Local Governments for Sustainability, the University of Delaware, and state and regional partners, the City of Lewes undertook a stakeholder-driven process to understand how climate adaptation could be integrated into the hazard mitigation planning process. Recommendations for integration and operational changes were adopted by the City Council and are currently being implemented (City of Lewes 2011).
Point Hope, AK	The village of Point Hope, AK created a plan that summarized the effect of climate change on several issues and identified observed changes, health concerns, projected changes, and potential adaptation actions to address each issue (Brubaker et al. 2010).
Groton, CT	Partnered with Federal, state, regional, local, nongovernmental, and academic partners through the EPA's Climate Ready Estuaries program to assess vulnerability to, and devise solutions for, sea level rise (Stults and Pagach 2011).
San Diego Bay, CA	Five municipalities partnered with the port, the airport, and more than 30 organizations with direct interests in the future of the Bay to develop the San Diego Bay Sea Level Rise Adaptation Strategy. The strategy identified key vulnerabilities for the Bay and adaptation actions that can be taken by individual agencies, as well as through regional collaboration (Solecki and Rosenzweig 2012).
Chicago, IL	Through a number of development projects, the city has added 55 acres of permeable surfaces since 2008 and has more than four million square feet of green roofs planned or completed (City of Chicago 2010).
Tulalip Tribes	The Tulalip Tribes in Washington State are using traditional knowledge gleaned from elders, stories, and songs and combining this knowledge with downscaled climate data to inform decision-making (Simmonds 2011).
King County, WA	Created King County Flood Control District in 2007 to address increased impacts from flooding through activities such as maintaining and repairing levees and revetments, acquiring repetitive loss properties, and improving countywide flood warnings (Wolf 2009).
New York City, NY	Through a partnership with the Federal Emergency Management Agency (FEMA), the city is updating FEMA Flood Insurance Rate Maps based on more precise elevation data. The new maps will help stakeholders better understand their current and future flood risks, and allow the city to more effectively plan for climate change (City of New York 2012).
Southeast Florida Climate Compact	Joint commitment among Broward, Miami-Dade, Palm Beach, and Monroe Counties to partner in reducing greenhouse gas emissions and adapting to climate impacts (Southeast Florida Compact 2011).
Haudenosaunee Confederacy	The Haudenosaunee Confederacy is addressing climate impacts by preserving a native food base through seed-banking (Simmonds 2011).
Phoenix, AZ; Boston, MA; Philadelphia, PA; and New York, NY	Climate change impacts are being integrated into public health planning and implementation activities that include creating more community cooling centers and neighborhood watch programs, and reducing the urban heat island effect (EPA 2011; Horton et al. 2012; White-Newsome et al. 2011).
Boulder, CO; New York, NY; and Seattle, WA	Water utilities in these communities are using climate information to assess vulnerability and inform decision-making (EPA 2010b).

Table 4 (continued)

Local/regional government	Adaptation action
Philadelphia, PA	In 2006, the Philadelphia Water Department began a program to develop a green stormwater infrastructure intended to convert more than one-third of the city's impervious land cover to "Greened Acres": green facilities, green streets, green open spaces, green homes, etc., along with stream corridor restoration and preservation (ORNL 2012b).

Table 6 Examples of U.S. private sector actions to adapt to climate risks based on responses to carbon disclosure project

Company	Sector	Climate risk	Examples of actions undertaken
Coca-Cola Company	Consumer Staples	Changes in physical climate parameters; changes in other climate-related developments.	Coca-Cola is working around the world to replenish the water used in finished beverages by participating in locally relevant water projects that support communities and nature. Since 2005, the Coca-Cola system has engaged in more than 320 projects in 86 countries. The range of community projects includes watershed protection; expanding community drinking water and sanitation access; water for productive use, such as agricultural water efficiency; and education and awareness programs. (http://www.thecoca-colacompany.com/citizenship/conservation_partnership.html)
ConAgra Foods, Inc.	Consumer Staples	Company experienced weather-related sourcing challenges, such as delayed tomato harvesting due to unseasonably cool weather and difficulty sourcing other vegetables due to above-normal precipitation.	As part of its business continuity planning, ConAgra Foods has analyzed its supply risk to develop strategic partnerships with suppliers, minimize sole-sourced ingredients, and identify alternate suppliers and contract manufacturers to minimize production disruptions in case of an unexpected disruption in supply. (http://company.conagrafoods.com/phoenix.zhtml?c=202310&p=Policies_Environment)
Constellation Brands	Consumer Staples	Changes in physical climate parameters; changes in other climate-related developments.	Constellation has already taken adaptation actions, particularly in California, where water availability is an issue, to manage or adapt to these risks. Constellation is working with numerous organizations to help fund industry-based research to determine potential climate change impacts on vineyard production.
Munich Re	Reinsurance	Changes in regulation; changes in physical climate parameters; changes in other climate-related developments.	Since 2007, a group-wide climate change strategy covering all aspects of climate change—e.g., weather-related impacts, regulatory impacts, litigation and health risks, etc.—has supported their core corporate strategy. The strategy is based on five pillars: mitigation, adaptation, research, in-house carbon dioxide (CO_2) reduction, and advocacy. (http://www.munichre.com/en/group/focus/climate_change/default.aspx)
Pacific Gas and Electric Company (PG&E)	Utilities	Changes in regulation; changes in physical climate parameters; changes in other climate-related developments.	PG&E's adaptation strategies for potential increased electricity demand include expanded customer energy efficiency and demand response programs and improvements to its electric grid. PG&E is proactively tracking and evaluating the potential impacts of reductions to Sierra Nevada snowpack on its hydroelectric system, and has developed adaptation

Table 6 (continued)

Company	Sector	Climate risk	Examples of actions undertaken
			strategies to minimize them. Strategies include maintaining higher winter carryover reservoir storage levels, reducing conveyance flows in canals and flumes in response to an increased portion of precipitation falling as rain, and reducing discretionary reservoir water releases during the late spring and summer. PG&E is also working with both the U.S. Geological Survey (USGS) and the California Department of Water Resources to begin using the USGS Precipitation-Runoff Modeling System (PRMS) watershed model to help manage reservoirs on watersheds experiencing mountain snowpack loss. (http://www.pge.com/about/environment/commitment/)
SC Johnson & Son, Inc.	Household Products	Changes in physical climate parameters.	SC Johnson is adjusting, through a diversified supplier and global manufacturing base, to the various physical risks imposed by climate change. In March 2009, SC Johnson announced a broad ingredient communication program. The company assesses risks along each ingredient's supply chain to ensure that the company is sourcing from a geographically diverse supplier base. In addition to evaluating product ingredients, SC Johnson has also diversified its operations around the world, allowing it to maintain business continuity in the face of a regional climate-related disruption. (http://www.scjohnson.com/en/commitment/overview.aspx)
Spectra Energy, Inc.	Energy	Changes in regulation; changes in physical climate parameters; changes in other climate-related developments.	Spectra Energy uses a corporate-wide risk analysis framework to ensure the oversight and management of its four major risk categories: financial, strategic, operational, and legal. Physical risks posed by climate change fall within these categories, and the company uses risk management committees to ensure that all material risks are identified, evaluated, and managed prior to financial approvals of major projects. (http://www.spectraenergy.com/Sustainability/)

APPENDIX D

American Rivers, Center for Neighborhood Technology, 2010

The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental and Social Benefits

Benefit	Reduces Stormwater Runoff											Improves Community Livability					
	Reduces Water Treatment Needs	Improves Water Quality	Reduces Grey Infrastructure Needs	Reduces Flooding	Increases Available Water Supply	Increases Groundwater Recharge	Reduces Salt Use	Reduces Energy Use	Improves Air Quality	Reduces Atmospheric CO_2	Reduces Urban Heat Island	Improves Aesthetics	Increases Recreational Opportunity	Reduces Noise Pollution	Improves Community Cohesion	Urban Agriculture	Improves Habitat	Cultivates Public Education Opportunities
Practice										CO_2								
Green Roofs	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Maybe	Maybe	Yes	Yes
Tree Planting	Yes	Yes	Yes	Yes	No	Maybe	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Maybe	Yes	Yes
Bioretention & Infiltration	Yes	Yes	Yes	Yes	Maybe	Maybe	No	No	Yes	Yes	Yes	Yes	Yes	Maybe	Maybe	No	Yes	Yes
Permeable Pavement	Yes	Yes	Yes	Yes	No	Maybe	Yes	Maybe	Yes	Yes	Yes	No	No	Yes	No	No	No	Yes
Water Harvesting	Yes	Yes	Yes	Yes	Yes	Maybe	No	Maybe	Maybe	Maybe	No	No	No	No	No	No	No	Yes

● Yes ◒ Maybe ○ No

APPENDIX E

USDA, 2012

USDA Climate Change Adaptation Plan

Strategic Goal	Objective/ Pillar	Risks and vulnerabilities	Agencies Involved[2]	Possible response strategies
1. Assist Rural Communities to Create Prosperity to be Self-Sustaining, repopulating and Economically Thriving	**1.1 Enhance rural prosperity** • Facilitate sustainable renewable energy development	Energy crops subject to new and challenging growing conditions.	RD, ARS, NIFA, FS, FSA, NRCS, ERS	Renewable energy can offset GHG emissions. Develop new energy crop varieties that can withstand changing climate conditions Promote resource-efficient cropping
	• Develop and support regional food systems	Climate change effects across regions will vary. Some regions will face greater challenges in adapting to changes in extreme events such as droughts and storms.	RD, FSA, AMS, RMA, ARS, NIFA	Better prepare farmers with adaptive responses to climate, encourage regional networks. Develop new crop varieties to withstand changing climate conditions.
	• Capitalize on	Ecosystem services	AMS, FAS, FSA,	Work with

[2] Agency Abbreviations: AMS: Agricultural Marketing Service, ARS: Agricultural Research Service, APHIS: Animal, Plant Health Inspection Service, ERS: Economic Research Service, FS: Forest Service, FAS: Foreign Agriculture Service, FSA: Farm Service Agency, NASS: National Agricultural Statistics Service, NIFA: National Institute of Food and Agriculture, NRCS: Natural Resource Conservation Service, RD: Rural Development, RMA: Risk Management Agency

	opportunities presented by the nation's efforts to develop markets for ecosystem services and mitigate climate change	may be stressed by climate changes and natural disasters.	FS, NRCS, RD, ERS	producers to diversify agricultural practices and protect ecosystem services, promote crops with the mitigation potential and most adaptable to environmental changes
	• Generate and retain green jobs and economic benefits through natural resource and recreation programs	Tourism activities and green jobs will be positively (warm-weather activities) and negatively (snow-related activities) affected by climate change. Coastal tourism could be affected by sea-level rise.	FS, RD	Work with rural communities to manage lands for tourism and outdoor recreation and find ways to use lands to enhance green employment opportunities.
	1.2 Create thriving communities	Clean air, clean water, and access to outdoor recreation will be threatened as climate changes.	RD, FS	Establish community forestry programs and develop 'green' and resilient infrastructure.
	1.3 Support a sustainable and competitive agricultural system	Climatic changes will stress some crops and potentially affect sustainability and competiveness of farming and ranching.	ARS, FAS, FS, FSA, NIFA, NRCS, RMA, ERS	Conduct research to improve seed and feed, improve agricultural practices, and develop ecosystem markets. Provide outreach and education to ensure all producers have necessary risk management tools and knowledge.
2. Ensure Our National Forests and Private Working Lands are Conserved, Restored and	**2.1 Restore and conserve the nation's forests farms, ranches, and grasslands**	Degradation of resources may lead to increased GHG emissions, and threaten wildlife, fish, plants, lands, water, recreation,	FS, NRCS, FSA	Work with private landowners and public managers to restore and protect forests, crop, and grazing lands, provide incentives

Made Resilient to Climate Change		community, and prosperity.		to maintain working lands, preserve open space, and restore public forests.
	2.2 Lead efforts to mitigate and adapt to climate change	Healthy soils and plants are challenged by a changing climate.	FS, NRCS, ARS, ERS, NIFA, FSA, RMA	Integrate research results into policies and conservation practices, disseminate information, and support land managers who use these practices
	2.3 Protect and enhance America's water resources	Drought, infiltration limitations and runoff pose problems for increasingly limited quantities and quality of water resources.	FS, NRCS, RMA	Encourage producers and forest managers to preserve wetlands, use sustainable practices that put minimal stress on water resources
	2.4 Reduce risk from catastrophic wildfire and restore fire to its appropriate place on the landscape	Parts of the country, especially in the west, are increasingly threatened by drought and longer fire seasons.	FS, NRCS	Work with communities to ensure they are fire-adapted, return prescribed fires to ecosystems where needed
3. Help America Promote Agricultural Production and Biotech to Increase Food Security	**3.1 Ensure US agricultural resources contribute to enhanced global food security**	Ensuring global food security will become more challenging as countries address a growing global population, land degradation, scarce water supplies, and climate change.	NIFA, ARS, FAS, FSA, NASS, ERS, APHIS	Research should continue to improve and protect US staple crops to adapt to changing climate conditions, markets can be opened to spread these resources abroad

	3.2 Enhance America's ability to develop and trade agricultural products	Risks to food security and human health increase as shifts in distribution and nature of diseases, invasive species and agricultural pests increase.	FAS, APHIS	Enhance protection of agriculture, natural resources through adaptive risk analysis models, engaging larger number of stakeholders
	3.3 Support sustainable agriculture production in food-insecure nations	Many nations may experience failing crops and food insecurity due to droughts and natural disasters.	NIFA, ARS, FAS	Research into climate-resilient crops and farming practices can be disseminated to world farmers to help them become self-sufficient
4. Ensure All America's Children have access to Safe, Nutritious and Balanced Meals	**4.3 Protect public health by ensuring food is safe**	Flooding effects on ready to eat crops, and increases in temperature potential effects food storage.	APHIS, AMS	Ensure and certify foods are safe to purchase and eat
	4.4 Protect agricultural health by minimizing major disease and pests to ensure access to safe, plentiful, and nutritious food	Diseases, including plant and animal pests and pathogens, are expected to change in distribution as the climate warms and precipitation increases.	APHIS, ARS, FAS, NIFA, ERS	Identify pests and diseases before they enter the US, and continue research into prevention and suppression of disease
Priority Strategic Goal 2: Accelerate Protection of Clean, Abundant Water Resources		Ecosystem services will be stressed by changes in climate variability and extremes, making long-term application of targeted practices more critical.	FSA, FS, NRCS, ERS	Implement high-impact targeted practices in critical and/or impaired watershed and quantify improvements in water quality
Priority Strategic Goal 3: Assist Rural Communities to Build and Maintain Prosperity		Agricultural production is affected by increasing temperatures, changing extremes and precipitation changes.	FAS with cooperator groups from a cross-section of US food and agricultural industries	Increase agricultural exports through key indicators and a baseline of growth over the last 5 years