



Keeping North Carolina's Farms and Forests Vibrant and Resilient



An Adaptive Management
Planning Strategy

June 2015



**North Carolina Agriculture
and Forestry Adaptation
Work Group**



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FOREWORD

Over the past year, we have had the privilege of Co-Chairing the North Carolina Agriculture and Forestry Adaptation Work Group (NC-ADAPT), a collaboration involving leaders from the agriculture and forestry sectors, along with our business, academic, research and government partners.

Our mission was to explore the impacts of increasingly extreme weather events and changing climatic conditions on the agricultural and forestry sectors of North Carolina and determine whether we as producers were adequately prepared for what is coming. Our conclusion: Preparation is needed and the state as a whole would benefit from the development of a comprehensive adaptive management strategy for the state’s two biggest industries - agriculture and forestry.

The evolution of modern day agriculture and forestry in North Carolina is truly a remarkable success story characterized by adaptation, hard work and innovation. Since 1950, producers have more than doubled their productivity, benefiting from breakthroughs in technology, genetics, mechanization and automation, conservation systems and alternative production practices.

Looking ahead, our sectors will be called upon to do even more by providing food, feed, fiber, forest products, energy and ecosystem services to sustain a world population that is expected to grow from 7.2 billion today to 9.6 billion by 2050. This epic challenge will be further complicated by increasingly erratic weather and climatic variability that scientists predict will occur with greater frequency as we move towards mid-century.

This report outlines NC-ADAPT’s findings and recommendations and offers a roadmap for constructing an adaptive management plan to improve agriculture and forestry resiliency and further enhance the economic viability of these sectors for decades to come.

Please join us in improving the resilience of North Carolina’s two most defining and important industries - agriculture and forestry.

Sincerely,

RC Hunt and Chip Miller

Co-Chairs
North Carolina Agriculture and Forestry Adaptation Work Group

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INTRODUCTION

As farmers, foresters, conservationists, researchers, program administrators and value chain business partners, we have dedicated our lives to the production of food and fiber.

We have benefited greatly and learned much from the decades of expertise we have had managing land sustainably and believe strongly that the future of agriculture and forestry in North Carolina is worth protecting. Through our work together, we have come to understand that while agriculture and forestry will continue to be the economic backbone of the state's economy for decades to come, changing climatic conditions represent a risk management threat multiplier that will challenge and compromise the future economic viability of our state's agricultural and forestry industries.

We are not alarmists. We are pragmatists who appreciate the multiple arenas in which adaptive management must be applied in order to maintain vibrant farming and forestry operations - changing climatic conditions being one of many. Other challenges exacerbated by extreme weather and changing climatic conditions include regulatory uncertainty, changing market structures, plant and animal diseases, invasive species, transportation infrastructure stability, land fragmentation/ownership profiles, land use change, water quality/quantity, energy security/costs and others.¹

While the cropping and harvest cycles of farmers and foresters are quite different, we are dependent upon

natural systems that are in fact changing. Our focus is not on what is causing climate change to occur. We acknowledge that the climate is changing and recognize the need to be proactive in preparing for what science is telling us to expect in the coming decades. While there are many reasons for elevating the priority of adaptive management planning in North Carolina, perhaps the most important is that it is a cost effective way to maintain and enhance the economic viability of our industries.

As leaders representing diverse, independent yet interdependent industries, we believe that the risks associated with changing climatic conditions warrant expanded and accelerated adaptive management planning. More specifically we urge agriculture and forestry leaders to join us and our academic, industry and government partners in identifying risk management tools, production and conservation practices, and research and extension priorities that can be used to ensure that our production platforms remain resilient and economically viable. The time has come to make adaptive management planning in North Carolina a priority so the full range of goods and services delivered by our state's farms and forests can be maintained for generations to come.

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AGRICULTURE AND FORESTRY: ECONOMIC ENGINES IN NORTH CAROLINA

North Carolina produces more sweet potatoes and tobacco than any other state and ranks second in Christmas tree cash receipts, combined poultry (broilers, turkeys and eggs) cash receipts and the production of swine and farm-raised trout.

The state is also fifth in the nation in greenhouse/nursery cash receipts. Our state also ranks in the top ten nationally in the production of fresh market cucumbers, strawberries, tomatoes, cabbage, snap beans, watermelons and sweet corn, upland cotton, bell peppers, catfish, peanuts, squash, blueberries and grapes.² The total value of agricultural products sold in 2012 was \$12.58 billion.³ In short, agriculture is a major industry in North Carolina.

As for forestry, in 2013 the sector contributed more than \$4.5 billion to the state's gross production and provided more than \$23 billion in economic benefit. Today the wood products industry is the largest sector in the state's manufacturing economy. The value of all shipments totaled \$15.3 billion in 2011.⁵ However, emerging bioenergy markets such as wood pellet production for renewable energy generation are creating new opportunities for woody biomass. Demand for bioenergy resources is expected to increase over the next few years and could develop into a multibillion dollar industry for the state.⁶



Figure 1 - North Carolina is one of the most diversified agricultural states in the nation. The state's 50,000 farmers grow over 80 different commodities, utilizing 8.5 million of the state's 31 million acres to furnish consumers with dependable and affordable supplies of food, feed and fiber.⁴

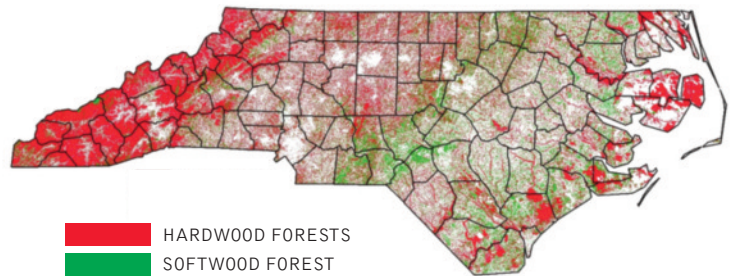


Figure 2 - North Carolina's timberland is diverse and includes more than 60 commercially-important tree species. Hardwoods are the dominant forest type, occurring on 68 percent of the state's timberland acres, compared with 32 percent in softwood forest types.⁷

We believe that proactive planning and prudent investments in adaptive management can help ensure the financial contributions that these major industries provide to the state economy are not disrupted by changing climatic conditions.

The agriculture and forestry sectors in North Carolina together contributed \$78 billion to the state's economy in 2013 accounting for more than 17 percent of the gross state product, and employing 16 percent of the work force.⁸





CLIMATE VARIABILITY: A THREAT TO AGRICULTURE AND FORESTRY IN NORTH CAROLINA

Media reports, public discourse and political biases often portray climate change as something that will happen well into the future or not at all. In fact it is happening today.

As farmers, ranchers and foresters who make their living off the land we are already witnessing the effects of changing climatic conditions and recognize that more attention to adaptive management planning is required.

will likely be the same but precipitation events will be harder to predict. Most likely, precipitation events will be more intense, and will include more frequent flash storms that will cause and accelerate soil erosion, exacerbate nutrient leaching and degrade soil health.

SEASON OF CHANGE IN NORTH CAROLINA

			
FUTURE SPRINGS	FUTURE SUMMERS	FUTURE AUTUMNS	FUTURE WINTERS
<ul style="list-style-type: none"> ■ More warm days ■ Possibly more intense thunderstorms (not likely to get weaker) ■ Perhaps more tornadoes, hail (much less certain) 	<ul style="list-style-type: none"> ■ Likely more hot days, warm nights ■ Perhaps fewer days with rain but more days with intense rain ■ Perhaps more drought 	<ul style="list-style-type: none"> ■ More intense hurricanes (but perhaps a decrease in frequency) 	<ul style="list-style-type: none"> ■ Probably more warm days in winter ■ Probably fewer very cold days ■ Probably fewer days with snow in lower elevations
— Ryan Boyles, state climatologist			

As documented in the *Third National Climate Assessment*, climate will continue to change over this century and beyond and is projected to have more pronounced impacts on crops and livestock across the country – a trend that could diminish the security of our food and fiber supplies.⁹

Here in North Carolina, state climatologists are projecting that changing climatic conditions will result in longer, warmer and wetter growing seasons. Cool weather events

As for seasonal variations that we should anticipate, future winters in the state will likely be defined by more warm days, fewer very cold days and fewer days with snow at lower elevations. Impacts to agriculture could include less pest die off and slower chill accumulation. However, more warm days could mean better pasture performance and increased soil microbe activity.¹⁰

Future spring seasons will likely include more warm days in February and March, possibly more intense thunderstorms and perhaps more tornadoes and hail. Of particular concern to us is that fruit and vegetable producers could be impacted by an earlier emergence of pests and earlier plant and tree flowering. Warmer days does not necessarily mean an earlier last freeze, thus increased risk of freeze damage to budding plants is expected. More severe weather could increase the need for crop insurance.¹¹

INFORMATION FOR FOREST LAND MANAGERS

According to United States Forest Service data, forests occupy approximately 751 million acres, about one third of the country's total land area. Forests provide many benefits and services to society, including clean water, recreation, wildlife habitat, carbon storage, and income and jobs derived from a variety of forest products. Climate influences the structure and function of forest ecosystems and plays an essential role in forest health. A changing climate may amplify many of the threats to forests, such as pest outbreaks, fires, human development, and drought.

Agencies and organizations around the nation have developed tools and other sources of information for land managers to utilize in order to help them make forest management decisions that decrease the risks associated with disturbances on your forestland. Examples of these resources include *Healthy Forests: Managing for Resilience*, published by the North Carolina Cooperative Extension. This document offers examples of good management practices for increasing forest resilience.

Another good resource is *Protecting Your Forest Asset: Managing Risks in Changing Times*. This pamphlet published by Southern Regional Extension Forestry will help forest landowners understand the current and potential risks to forestlands and outlines forest management strategies that minimize threats to forest productivity.

Summers in North Carolina will likely bring more hot days and warmer nights potentially disrupting pollination. Increased instances of drought could be possible and increase fire hazards. Fewer days with rain, but more instances of intense rain when it does rain, could become more common. More intense rains could impact field preparation and result in erosion and nutrient loss. The increased heat and moisture could cause plant and animal stress and increase the need for irrigation at critical times in a crop's growing period. But drier periods could reduce fungal risks in crops.¹²

Upcoming autumns could bring more intense hurricanes and later first frosts. North Carolinians are already very much aware of the catastrophic impacts that a hurricane making landfall could deliver. But longer growing seasons could possibly allow for double cropping.¹³

Crop production is influenced by complex relationships with temperature, moisture, nutrient concentrations, weeds, pests, and disease. As temperatures increase, crop production areas may shift to regions where the temperature range for optimal growth and yield have moved,

though production in any given location will be more influenced by available soil moisture during the growing season.¹⁴ Input costs are expected to rise with increasing temperatures and carbon dioxide concentrations.

A changing climate can also influence and degrade livestock performance, production and fertility, limiting the production of meat, milk, or eggs. Changes in core body temperatures, feed and forage types and nutrient content will likely influence management needs.¹⁵ Livestock manure management systems can be compromised if weather events exceed design specifications and best management practices cannot be implemented.

The changing climate can also alter tree species ranges and has the potential to alter forest ecosystems structure as evidenced by the mountain pine beetle epidemic in the West. When combined with sustained drought conditions, these impacts pose challenges to maintaining healthy forests and the supply of goods and services upon which society depends, such as clean drinking water, forest products, outdoor recreation opportunities, and wildlife habitat.

ADAPTIVE MANAGEMENT PLANNING IN NORTH CAROLINA: A NEW WAY FORWARD

While there remains some uncertainty as to the extent to which changing climatic conditions will impact agriculture and forestry in North Carolina, what is clear to us is that our sectors will be affected, creating economic challenges for producers, their value chain partners and the local economies and communities that depend on their operations.

Given the magnitude of the risks and potential financial losses that climate change will cause, we believe and recommend that a comprehensive Adaptive Management Strategy be developed for the state's agricultural and forest sectors. The strategy should be the product of a collaborative planning effort led and managed by a team of agriculture and forestry producers and supported by academia and government partners, value chain industries and other stakeholders.

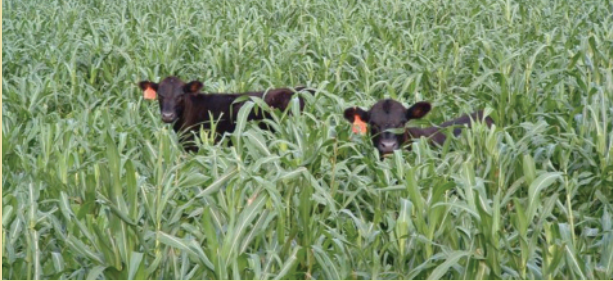
The target audiences for the Adaptive Management Strategy should include first and foremost producers, but also policy makers, academia and researchers, business leaders, soil and water conservationists, extension agents, crop consultants, non-governmental

organizations, land trusts, insurance companies and lenders.

As farmers and foresters also face the challenge of deciphering large amounts of technical information, climate adaptation research and best practice recommendations, special efforts should be directed at developing tools and information that summarize and communicate climate knowledge and response strategies in a more accessible and understandable format.

We will use the following steps to develop a North Carolina Agriculture and Forestry Adaptive Management Strategy: a strategy designed to empower producers to reduce the risks that climate variability is causing and build greater resilience to climate-related hazards.

INTEGRATED CROP LIVESTOCK SYSTEMS A WIN-WIN: AN EXAMPLE OF ADAPTIVE MANAGEMENT



A cow and calf grazing on a summer cover crop of pearl millet. ARS scientists conducted studies on cover crops and cattle grazing and found that moderate grazing does not significantly affect the amount of organic matter in the soil. USDA-ARS

Dr. Alan Franzluebbers, a scientist for the USDA-Agricultural Research Service (ARS) conducted a 7-year study in the Piedmont region of North Carolina to see if grazing cattle on cover crops affects the health of soils typical in the region. The research showed that cover crops provide high quality forage for cattle without significantly reducing nutrient levels or compacting the soil. Additionally, much of what is consumed by the cattle is returned to the soil by manure. Farmers increase their resilience to adverse weather and climate effects by protecting their soil and diversifying their production.

Planting and grazing cover crops in the off-season via an integrated crop-livestock system provides a win-win solution for farmers.

PROCESS FOR ADAPTATION PLANNING IN NORTH CAROLINA

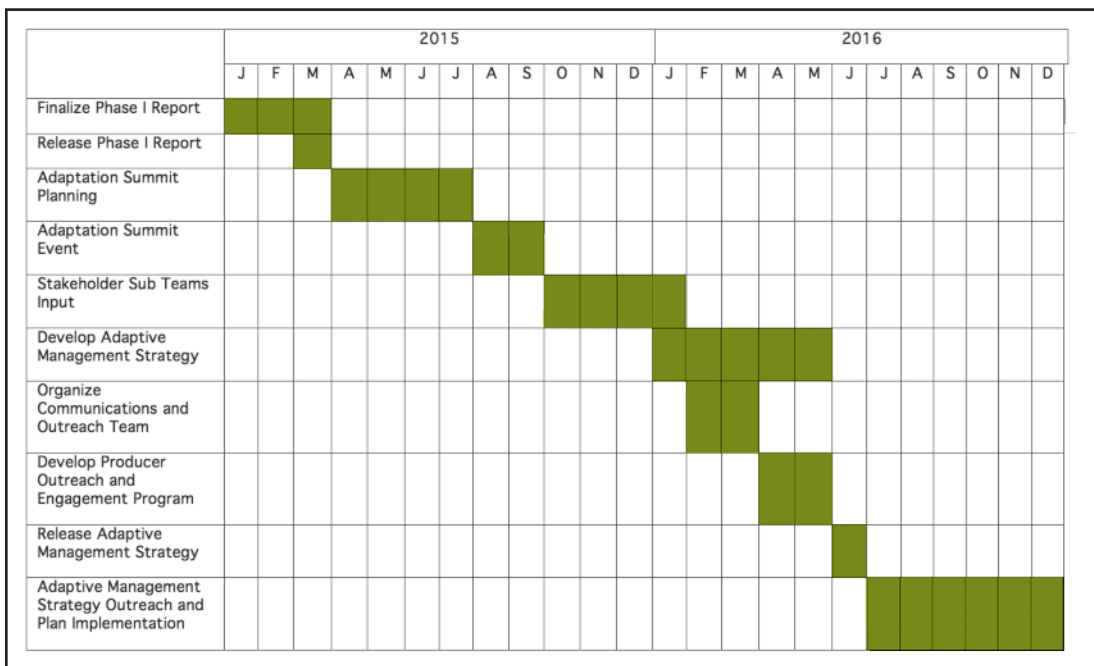
1. An Adaptation Planning Team will be formed to guide and support the development of a North Carolina Agriculture and Forestry Adaptive Management Strategy (NC-STRAT). As leaders committed to this work, we volunteer to form the nucleus of a larger planning team that will undertake this assignment. Individuals with expertise not currently represented on the Work Group, such as risk management and infrastructure experts and poultry producers, will be recruited to join the planning team.
2. The Planning Team will organize and host an information and needs assessment summit where top agricultural, forestry, conservation and supporting academic, government and business leaders will convene to identify issues, concerns and priorities around adaptive management work in North Carolina. The results of the summit will inform and shape the content of the NC-STRAT.
3. Following the summit, agricultural and forestry stakeholder sub teams will be formed to develop material and recommendations for inclusion in the NC-STRAT.
4. The Planning team will then integrate the sub teams work into a draft report which will be widely circulated to farm, forest, conservation, finance, risk management, financial, higher education leaders and organizations; policy makers and government agencies; and other interests for discussion and comment.
5. On a parallel track, a special Communications and Outreach Team will be organized to develop a Producer Outreach and Engagement Program that will support and facilitate peer-to-peer grower leader dialogues and information networks and nodes around adaptive management implementation strategies.

6. A final NC-STRAT report citing priority actions and initiatives that are needed to help producers adapt and improve resiliency, including short synopses for policy makers and other target audiences, will be developed and released, marking the beginning of the Outreach and Engagement Phase of Work. In support of this next phase of work, the Planning Team will recruit a cadre of agricultural and forestry thought leaders

who will serve as discussion facilitators and adaptation mentors. Farm and forestry organizations will be recruited to integrate climate-smart agriculture programming into their work plans.

See Figure 3 for anticipated time line to accomplish these tasks.

Figure 3 - North Carolina Adaptive Management Strategy Timeline



THE ROAD AHEAD

Despite the complexities surrounding conversations about climate change, the agricultural and forestry leaders we know understand the magnitude of the challenges which these conditions are creating and we are confident that they will rise to the occasion to meet these challenges with sound scientific approaches.

Going forward we will measure our progress by the quality and diversity of leaders who commit to participate in the project; the success that we achieved in developing an agriculture/forest sector adaptation engagement plan for the state; the willingness of the

project team members to provide leadership in engaging their peers in conversations about the risks that changing climatic conditions pose for their operations; and the commitments that farm and forestry organizations make to undertake actions to help their members enhance sustainability and improve resiliency in production systems and reduce greenhouse gas emissions.

Please join us in our effort to develop and implement systems and practices to improve the resilience of our production systems, adapt and mitigate present and future risks from changing climatic conditions.

Report References: Maps and Diagrams

Figure 1 – NC Agriculture Overview,
<http://www.ncagr.gov/stats/general/overview.htm>

Figure 2 – Derived from the 2011 National Land Cover Database
 (<http://www.mrlc.gov/>), NC State University Extension Forestry by J.A. Jeuck.

Figure 3 - North Carolina Adaptive Management Strategy Timeline

Report References: End Notes

- ¹ Climate Change Adaptation Sensing Meetings with Leaders of North Carolina's Agriculture and Forestry Sectors, December 2013.
- ² North Carolina Agricultural Statistics, "2013 Annual Statistics Book," <http://www.ncagr.gov/stats/2013AgStat/index.htm>.
- ³ USDA-NASS 2013 State Agriculture Overview – North Carolina, http://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NORTH%20CAROLINA.
- ⁴ North Carolina Agriculture Overview, <http://www.ncagr.gov/stats/general/overview.htm>.
- ^{5,6} North Carolina Forest Service, "2013 Biennial Report," http://www.ncforestservice.gov/NCFS_statusreport.pdf.
- ⁷ North Carolina Cooperative Extension Service, "Forests and the North Carolina Economy"
- ⁸ Dr. Michael L. Walden, William Neal Reynolds Distinguished Professor of Agricultural and Resource Economics, N.C. State University College of Agriculture and Life Sciences, (<http://ag-econ.ncsu.edu/sites/ag-econ.ncsu.edu/files/faculty/walden/agribusiness-2014.pdf>).
- ⁹ *Third National Climate Assessment - Agriculture*, page 152.
- ^{10, 11, 12, 13} Ryan Boyles, "Climate and Agriculture in the Carolinas", 25x25 NC Ag and Forest Adaptation Workgroup, December 2, 2014.
- ^{14, 15} *Third National Climate Assessment - Agriculture*.

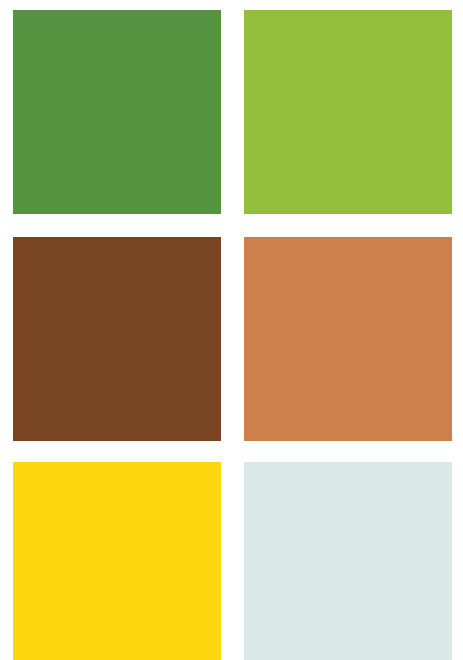
Side Bar Report Links

Healthy Forests: Managing for Resilience:
<http://content.ces.ncsu.edu/managing-for-resilience.pdf>.

Protecting Your Forest Asset: Managing Risks in Changing Times:
http://www.pinemap.org/publications/fact-sheets/Protecting_Your_Forest_Asset.pdf



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Addendum I

NORTH CAROLINA AGRICULTURE AND FORESTRY
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Dr. Deanna Osmond - NCSU Dept. of Soil Science

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Ernie Shea – Project Coordinator
Brent Bailey – State Activities Coordinator



Addendum II

PREPAREDNESS PLANNING IN NORTH CAROLINA

Efforts have been underway for a number of years to consider the potential impacts of climate change on North Carolina. These reports summarize the research and provide recommendations to address this threat. A list of the reports developed to date can be found at http://climateadaptationnc.nemac.org/NC_Climate_Reports.html.

The North Carolina Climate Action Plan Advisory Group *Recommended Mitigation Options for Controlling Greenhouse Gas Emissions* report (2008) contained both mitigation and adaptation measures. Chapter 6 of the report details the challenges and opportunities of the agriculture and forestry sectors to reduce and mitigate GHG emissions.

The Legislative Commission on Global Climate Change (Commission) was established in Session Law 2005-442 to conduct an in-depth study of issues related to global climate change. In its *Final Report to the General Assembly and the Environmental Review Commission* (2010), the Commission concludes that the actions taken by states can have a significant effect on global greenhouse gas levels and that the General Assembly should not wait for national or international action before responding to these threats. The Commission recommended that North Carolina develop a comprehensive Climate Change Adaptation Plan that includes numerous elements,

including a focus on “adaptation needs resulting from sea-level rise, as well as changes in rainfall and temperature that could alter traditional industries such as agricultural, forestry, and fishing.”

Session Law 2010-180 required state agencies to determine whether the impacts of global climate change are being considered in state regulatory and planning programs. Each agency considered the projected impacts of global climate variability and change, as well as recent extreme events, in this evaluation. This report, *Agency Planning and Regulatory Program Information Related to Climate Change* (2011), includes responses for 77 planning and regulatory programs within the eight specified departments, including the Department of Agriculture and Consumer Services.

The *Climate-Ready North Carolina: Building a Resilient Future* strategy (2012) developed by the North Carolina Interagency Leadership Team discusses how North Carolina can proactively prepare for projected impacts of climate variability and weather extremes on its economy, infrastructure and natural resources. The report includes a section on the impacts, risks, and vulnerabilities to agriculture and forestry and includes numerous actions that could be implemented in response to potential changes in climate (see Appendix C of report).

Addendum III

NORTH CAROLINA'S CLIMATE, TRENDS AND FORECASTS

PHYSICAL FEATURES¹

With its nearly 7,000-foot range in elevation and 300-mile range from the ocean, North Carolina has one of the most varied and diverse climates of any eastern state. Latitude accounts for some climatic variations, as do soils, plant cover, and inland bodies of water. The Gulf Stream has some direct effect on North Carolina temperatures, especially on the immediate coast.

North Carolina has three primary climate drivers: latitude; topography; and, proximity to oceans. The state is centrally located along the eastern seaboard of the

U.S. The extreme length from east to west is 503 miles: greater than any other state east of the Mississippi, and its widest width from north to south is 187 miles. The total area of the state is 52,712 square miles, of which 49,142 square miles are land and 3,570 square miles are water.

The range of altitude is also the greatest of any state east of the Mississippi River, ranging from sea level along the Atlantic coast to 6,684 feet at the summit of Mount Mitchell, the highest peak in the eastern United States, in the heart of the Blue Ridge in western North Carolina.

In winter, the greater part of North Carolina is partially protected by the mountain ranges from the frequent outbreaks of cold air which move southeastward across the central states.

The Gulf Stream lies some 50 miles offshore and warm water eddies spin off from it and moderate the winter air temperatures along the Outer Banks. However, the southern reaches of the cold Labrador Current pass between the Gulf Stream and the North Carolina coast, offsetting most of the general warming effect the Gulf Stream might otherwise have on coastal temperatures.

The three principal physiographic divisions of the eastern United States are particularly well developed in North Carolina. From east to west, they are the Coastal Plain, the Piedmont, and the Mountains.

NATURALLY OCCURRING PHENOMENON

Winter climate is often influenced by El Nino and La Nina ocean temperature anomalies along the equator in the Pacific Ocean. The El Nino winter jet stream drives weather conditions that move atmospheric moisture up the Gulf of Mexico coastline and up the eastern side of the Appalachian Mountains stimulating the development of storms. This condition increases precipitation in the Southeast U.S.

The La Nina winter jet stream causes moisture and storms to track along the Ohio River Valley and west of the Appalachian Mountains. The Southeast U.S. experiences a decrease in precipitation events during this weather phenomenon.²

Summertime climate and precipitation is greatly influenced by the strength and location of the Bermuda High Pressure. When high pressure is centered over the east-central Atlantic Ocean, moisture is pumped up from the Gulf of Mexico and the Atlantic Ocean bringing increased precipitation. When the high pressure is centered over the mainland in the Southeast U.S., drier air is pulled from the central plains triggering drought conditions in North Carolina.³

TEMPERATURE⁴

In all seasons of the year, the average temperature varies more than 20° Fahrenheit from the coastline to the highest elevations in the west. Winter temperatures in

the eastern sections are modified by the Atlantic Ocean which raises the average winter temperature and decreases the average day-to-night range. The rise in average temperatures is greater in May than in any other month. The average daily maximum reading in midsummer is below 90° F for most localities. The warmest days are found in the interior rather than near the coast in summer. Autumn is the season of most rapidly changing temperature, the daily downward trend being greater than the corresponding rise in spring. The drop-off is greatest during October, and continues at a rapid pace in November.

PRECIPITATION⁵

While there are no distinct wet and dry seasons in North Carolina, average rainfall does vary around the year. Summer precipitation is normally the greatest, and July is the wettest month. Summer rainfall is also the most variable, occurring mostly in connection with showers and thunderstorms. Daily showers are not uncommon, nor are periods of one to two weeks without rain. Autumn is the driest season, and November the driest month.

In southwestern North Carolina, where moist southerly winds are forced upward in passing over the mountain barrier, the annual average is more than 90 inches. This region is the rainiest in the eastern United States. Less than 50 miles to the north, the valley of the French Broad River, sheltered by mountain ranges on all sides, is the driest point south of Virginia and east of the Mississippi River. Here the average annual precipitation is only 37 inches. East of the Mountains, average annual rainfall ranges mostly between 40 and 55 inches.

Average winter snowfall over the State ranges from about inch per year on the outer banks and along the lower coast to about 10 inches in the northern Piedmont and 16 inches in the southern Mountains. Some of the higher mountain peaks and upper slopes receive an average of nearly 50 inches a year.

SEVERE STORMS⁶

In most years, the greatest economic loss entailed in North Carolina from severe weather is probably due to summer thunderstorms. These storms usually affect only limited areas, but hail and wind occurring with some of

them account for an average yearly loss of over \$5 million. In any given locality, 40 or 50 thunderstorms may be expected in a year.

North Carolina is outside the principal tornado area of the United States, but still averages two to three per year. They occur mostly east of the Mountains during early spring.

Tropical hurricanes come close enough to influence North Carolina weather about twice in an average year. Much less frequently, perhaps averaging once in 10 years, these storms strike a part of the State with sufficient force from wind and rain to do inland property damage. In many cases, existing drainage systems were not designed to accommodate the runoff from more intense precipitation events.

CLIMATE TRENDS⁷

North Carolina already experiences almost every kind of severe weather and climate event and the best science suggests these events will not become less severe (and may become worse). There is much that is understood about current climate patterns and the state's vulnerabilities. North Carolina's known vulnerabilities to storms, hurricanes, flooding, and drought serve as strong motivations for action even in the absence of global climate change.

While observations show increases in globally averaged air and ocean temperatures, the Southeast region has not exhibited an overall warming trend in surface temperature during the 20th century. Factors such as reforestation could have helped to moderate temperatures in the region.

When North Carolina average temperatures are separated into daily maximum and minimums (highs and lows), some meaningful trends are observed. While maximum temperatures show no trend, a significant trend of increasing minimum temperature (morning lows) in urban areas has been recorded. These minimum temperature trends are significant, but similar trends are not observed at rural locations, suggesting that the observed changes in minimum temperatures are influenced and associated with urbanization of our cities and surrounding areas.

No long-term annual trend in precipitation has been seen across North Carolina since 1895, though there has

been a slight upward trend in fall season precipitation and a slight downward trend in summer season precipitation. Year-to-year variability in precipitation is expected to continue.

CLIMATE FORECASTS

Climate Change Impacts in the United States, the Third National Climate Assessment assesses the science of climate change and its impacts across the United States, now and throughout this century. It documents climate change related impacts for various sectors and regions, with the goal of better informing public and private decision-making. The *Assessment* draws from a large body of scientific peer-reviewed research, technical input reports, and other publicly available sources. The report was extensively reviewed by the public and experts, including a panel of the National Academy of Sciences, the 13 Federal agencies of the U.S. Global Change Research Program, and the Federal Committee on Environment, Natural Resources, and Sustainability.

The Third National Climate Assessment projects that the climate will continue to change over this century and beyond. The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, and how sensitive the Earth's climate is to those emissions. Report findings⁸ include:

- Temperatures in the United States are expected to continue to rise. However, temperature rise has not been, and will not be, uniform or smooth across the country or over time.
- More winter and spring precipitation is projected for the northern United States, and less for the Southwest, over this century.
- Increases in the frequency and intensity of extreme precipitation events are projected for all U.S. regions.
- Droughts in the Southwest and heat waves everywhere are projected to become more intense, and cold waves less intense everywhere.
- Hurricane-associated storm intensity and rainfall rates are projected to increase as the climate continues to warm.

KEEPING NORTH CAROLINA'S FARMS AND FORESTS VIBRANT AND RESILIENT

- Winter storms have increased in frequency and intensity since the 1950s, and their tracks have shifted northward over the United States. Trends in severe storms, including the intensity and frequency of tornadoes, hail, and damaging thunderstorm winds, are uncertain.
- Across the United States, the growing season is projected to continue to lengthen.
- Sea level is projected to rise 1 to 4 feet by 2100.

Confidence in projections of future climate change has increased. However, the best global climate models do not do a good job of simulating the temperature and precipitation patterns over the southeastern US, and North Carolina in particular. It doesn't necessarily mean the model predictions for the future are wrong, but it does mean that some climate scientists have low confidence in models' future predictions.⁹ Climate prediction models show different levels of trends, but all show a general warming over time. While regional and localized climate prediction information is not yet fully trusted for individual states, historical extreme events in the Southeast give a good indication of what we may expect in North Carolina's future climate.

Climate Ready North Carolina: Building a Resilient Future, developed by the North Carolina Interagency Leadership Team in 2012, revealed five climate conditions that are most likely to impact North Carolina in the coming decades: drought, sea-level rise, tropical cyclones, heavy precipitation, and increased heat. All these climatic conditions impact agriculture and forestry in different ways.

ADDENDUM III REFERENCES

¹ State Climate Office of North Carolina, Aspects of NC Climate, Overview, Topographic Features, <http://www.nc-climate.ncsu.edu/climate/ncclimate.html#topo>.

² State Climate Office of North Carolina, Aspects of NC Climate, Global Patterns - El Niño-Southern Oscillation (ENSO), <http://www.nc-climate.ncsu.edu/climate/patterns/ENSO.html>.

³ Ryan Boyles, "Climate and Agriculture in the Carolinas", 25x25 NC Ag and Forest Adaptation Workgroup, December 2, 2014.

⁴ State Climate Office of North Carolina, Aspects of NC Climate, Overview, Temperature, <http://www.nc-climate.ncsu.edu/climate/ncclimate.html#temp>.

⁵ State Climate Office of North Carolina, Aspects of NC Climate, Overview, Precipitation, <http://www.nc-climate.ncsu.edu/climate/ncclimate.html#precip>.

⁶ State Climate Office of North Carolina, Aspects of NC Climate, Overview, Severe Storms, <http://www.nc-climate.ncsu.edu/climate/ncclimate.html#severe>.

⁷ North Carolina Interagency Leadership Team, *Climate Ready North Carolina: Building a Resilient Future*, 2012.

⁸ *Climate Change Impacts in the United States – Highlights*, Climate Trends, page 16-17.

⁹ State Climate Office of North Carolina, *Climate Change in North Carolina, Climate Model. Evaluation and Implications for the Future*.



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