Keeping North Carolina’s Farms and Forests Vibrant and Resilient through Adaptive Management:

Priorities and Recommendations for Advancing Adaptive Management in Specialty Crop Agriculture

January 2017
North Carolina Agriculture and Forestry Adaptation Work Group

About North Carolina Agriculture and Forestry Adaptation Work Group

First convened in December 2014, the North Carolina Agriculture and Forestry Adaptation (NC ADAPT) Work Group is a coalition of leaders from the agriculture and forestry sectors, along with partners from the business, academic, research and government communities. The NC ADAPT Work Group’s initial mission was to explore the threats and impacts of increasingly extreme and erratic weather events and changing climatic conditions on North Carolina’s agriculture and forestry sectors to determine if these sectors are adequately prepared for what scientists are projecting through mid-century. The NC ADAPT Work Group concluded that climate variability is a threat to agriculture and forestry in North Carolina, preparation is needed, and the state would benefit from the development of a comprehensive adaptive management strategy. The NC ADAPT Work Group’s findings and roadmap for constructing an adaptive management plan are outlined in the report, *Keeping North Carolina’s Farms and Forests Vibrant and Resilient: An Adaptive Management Planning Strategy*.

In August 2015, the NC ADAPT Work Group hosted an Adaptation Summit that brought together a diverse set of stakeholders to begin the process of identifying and forging consensus on the unique adaptation challenges that North Carolina’s agriculture and forestry sectors will face going forward. Summit attendees also established a pathway 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. The NC-ADAPT Agriculture and Forestry Adaptation Summit Synopsis reflects the spirit that North Carolina stakeholders are ready to engage in the vital discussion of adaptation and preparation for an uncertain future and would be utilizing sound science in the adaptive management planning process.

After examining the challenges and opportunities associated with variable, extreme weather events, the NC ADAPT Work Group turned to developing a North Carolina Agriculture and Forestry Adaptive Management Strategy (NC-STRAT). Four Teams were created to collect feedback from stakeholder meetings, as well as surveys of producers and sector experts to help develop key actions, initiatives and recommendations to address the anticipated impacts of climate change on agriculture and forestry in North Carolina. This document outlines recommendations and actions that producers, researchers, policy makers, and supporting groups can take to build resiliency and reduce risks to not only meet future challenges, but thrive in the midst of them.
PROJECT LEADERS, TECHNICAL PROFESSIONALS AND SUPPORT STAFF

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Solutions from the Land is a not-for-profit entity focused on land based solutions to global challenges. Funds to support the work carried out under this project were provided through a grant from the Z. Smith Reynolds Foundation. The North Carolina Agriculture and Forestry Adaptation Work Group acknowledges and appreciates their contributions that made this work possible.
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EXECUTIVE SUMMARY

From the very first seeds that were planted in the ground to the first meat and dairy animals that were domesticated, producers have historically been making adjustments to meet the many challenges of variable and extreme weather events. The history of the United States agriculture is a tale of adaptation and remarkable progress in the face of these challenges.

Recent years have demonstrated just how vulnerable production systems are to changing weather and extreme weather events. An extended dry period from 1998-2000 was followed by a historic drought in 2007 when all of North Carolina’s 100 counties experienced moderate to exceptional drought conditions that cost hundreds of millions of dollars. Tropical systems have now adversely impacted North Carolina in back to back years just as the row crop harvest was hitting its stride. The historic floods have also dealt blows to the livestock and forestry sectors and everyone is impacted when key components of the state transportation network are disabled. Estimated total agricultural losses resulting from Hurricane Matthew could total in the hundreds of millions of dollars, but the damage is still being assessed in the east side of the state. Wildfires in western North Carolina driven by late summer drought conditions have burned over 100,000 acres of public and private forest lands and caused thousands to be evacuated. The costs incurred to control these fires increase each day.

The adaptation conversation is nothing new in North Carolina. The Climate-Ready North Carolina: Building a Resilient Future strategy 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 presents numerous actions that could be implemented in response to predicted changes in climate. The recommendations from the report provided helpful background information for this project.

The NC ADAPT Work Group created four (4) stakeholder Teams – Commodity Crops; Livestock; Forestry; and Specialty Crops. Each Team established their own process to identify adaptation needs, priorities and strategies. However, several themes and cross-cutting recommendations were observed and are captured below:

- All production sectors indicate that research on water management, in particular irrigation methods, technology and/or feasibility is important going forward.
- Drought resistant cultivars and adaptive cover cropping systems for improved soil and nutrient management are needed for production and practice systems across all production platforms (i.e. specialty crops, commodity crops, etc.).
- Agriculture and forestry each identify a desire for a “Risk Management Collaborative” to collect and share information on policies and programs, and that will help to steer adjustments in programs that reflect changing conditions.
- Each sector also identify access to new markets as a risk management option for creating product demand and increasing revenues.

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It is important that localized decision-making tools and technical assistance be tailored to each of North Carolina’s recognized geographical regions: Coastal, Piedmont, and Mountain.

Information is key in managing farms and forests, and producers wish to have continuing faith in Cooperative Extension Service personnel to provide timely and accurate precision agriculture information, utilization support and technical knowledge.

The best technologies, research findings, programs and planning tools to implement adaptation strategies must find its way to producers. If producers are not involved in the development and delivery of adaptation strategies, the success rate of the adaptation strategies will drop.

Agriculture and forestry stakeholders recommended that outreach be expanded, knowledge sharing networks created, adaption education enhanced and increased promotion of programs.

The history of agriculture and forestry is one of constant change and continuous improvement. No one can precisely state what climate and weather patterns will be for North Carolina in the future. Scientific research and producer experience does point to growing challenges – some say unprecedented challenges – for our agriculture and forestry sectors, as shifts in weather patterns continue and weather events intensify. For this reason, adaptation has increasingly become a focus of interest. A focus on adaptation measures opens the door to the collection of solutions for addressing production challenges. For instance, solutions which increase an operation’s resilience to climate changes can also create economic and ecological added-value for landowners and society. Practices such as terrestrial carbon sequestration, methane capture and conversion, waste-to-energy, etc. can improve soil health, water quality, wildlife habitat and other natural, societal, financial and operational benefits.

Changes ahead are expected to be unprecedented, but with good planning and through proactive management North Carolina’s agriculture and forestry producers can remain productive and provide many benefits beyond food and fiber. North Carolina’s farmers, foresters and livestock producers will have to adjust to more variable weather and extremes by merging new knowledge, experience, planning and practices with new technologies and decision-making tools. However, they also will need focused support to innovate and adapt to the changes ahead in a way that strengthens production systems, improves profits and reduces environmental impacts. The state’s leadership should support North Carolina’s producers by making investments in public research, and expanding the state’s economic development focus on agriculture and forestry.

The recommendations included in this document mark the beginning of new conversations around resilience and adaptive management.

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INTRODUCTION

Throughout the United States, farmers, foresters, and ranchers are adjusting their operations to reduce the risks associated with increasingly variable and unpredictable weather. In Western states, farmers and ranchers are coping with drought by employing new weather tracking technology, building new water storage and conveyance systems, enhancing conservation to support fragile ecosystems, and creating resilient farm systems through soil health improvement initiatives. In the Northeast states, an observed increase in extreme precipitation events poses greater risk to farms and forests from flooding, erosion and other effects. Producers in this region are reexamining infrastructure needs, land management and operational location. Throughout the Midwest states, average temperatures have risen steadily over the last several decades. A potential effect from higher temperatures is an increase in insect and disease populations that will impact crop and livestock productivity. Producers and scientists are working now to develop measures to respond to these risks.

In addition to weather challenges and climate shifts, producers are facing economic, social and environmental pressures. These challenges include feeding, clothing, housing, and fueling a rapidly growing world, making decisions in increasingly volatile local and global markets, and managing soil, water, and air resources. These pressures are accompanied by high levels of uncertainty, which compel land managers to reevaluate past decisions, seek new information and strategies, and take adaptive actions.

The U.S. Global Change Research Program issued a report that found “changes in climate factors, such as temperature, precipitation, and extreme weather, are key drivers of pathogen introduction, food contamination and foodborne disease, as well as changes in the level of exposure to specific contaminants and chemical residues for crops and livestock.” Furthermore, the expansion of various

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pests spurred by warmer weather and longer growing seasons could impact the effectiveness of pesticides and/or lead to increased pesticide use.⁶

North Carolina farmers, foresters and livestock producers are also subject to these same challenges and pressures. Previous investigations have found that North Carolina producers are also concerned with 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.⁷ Like their counterparts across the country and around the world, North Carolina farmers, foresters and livestock producers recognize the need to be proactive in preparing for what science is telling them to expect in the coming decades – and with good reason.

Climate and extreme weather related hazards and vulnerabilities are a growing threat to North Carolina’s agriculture, livestock and forestry sectors. Signals of change in important climate drivers include: 1) Days with daytime temperatures above 95°F are expected to increase by up to 50 days annually, 2) nights below freezing are expected to decrease by up to 20 days annually, and 3) coastal working lands are vulnerable to sea level rise and saltwater intrusion. Reduced farm and forest productivity may result from altered rainfall patterns, increased frequency/severity of extreme events, and heat stress.⁸ Appendix I of this report provides a more detailed description of the threats posed to agriculture and forestry by changing climatic conditions as outlined by North Carolina-based scientists.

The precise future effects of climate and extreme weather events on agriculture and forestry are very difficult to predict, and will depend on many parameters. Producers in different regions of the state are expected to cope with climate variability in ways that are economically, agronomically and ecologically compatible with their production system.

Agriculture and forestry are the two leading mainstays of the North Carolina economy, and adaptation options are needed to eliminate or reduce adverse impacts that could result from increasing climate variability. The recommendations in this report are designed to reflect the critical adaptation options that many producers can begin – and in some cases have already begun – to implement on their farms, forests and ranches.

Despite advances in plant and animal genetics, automation and robotics, natural resource conservation, alternative production systems, and many other technologies and tools that have helped to increase

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⁷ Climate Change Adaptation Sensing Meetings with Leaders of North Carolina’s Agriculture and Forestry Sectors, December 2013

food and fiber production, recent weather events have demonstrated just how vulnerable our production system remains to changing weather conditions.

North Carolina began 2015 with above average temperatures and drier than normal conditions until a tropical storm dumped rain across the state. At the end of summer 2015, North Carolina was experiencing significant above-average temperature conditions and below-average precipitation. However, a dramatic shift to historic rainfall amounts and flooding events occurred across the Carolinas when Hurricane Joaquin interacted with an upper level low in October. As 2015 concluded, December recorded record high temperatures for the month. Despite the warmer temperatures, a historically strong El Nino pattern extended the wetness throughout the winter and well into the first months of 2016. Then in October 2016, almost one year to the day of Hurricane Joaquin, Hurricane Matthew brought widespread flash flooding and record river flooding to eastern North Carolina where hourly rainfall estimates from radar were as high as 7 inches per hour. Buildings and homes were flooded, roads washed out, and sections of Interstates 95 and 40 closed due to flooding. In addition, harvests were disrupted, crops lost, livestock mortality was recorded and some manure lagoons flooded. The effects of these severe, unpredictable weather events have real economic impacts.

Before these devastating hurricanes even hit, agriculture and forestry producers came together as the NC ADAPT Work Group recognizing the need to proactively address these challenges and the need to identify priority actions and initiatives to help producers adapt and improve resilience in the face of present and future climate change risks. North Carolina agriculture and forestry is worth protecting and through pragmatic actions, the two sectors will remain the economic backbone of the state’s economy.

**NORTH CAROLINA’S SPECIALTY CROP INDUSTRY**

North Carolina specialty crops are the mortar and accent stones between the larger agricultural building blocks of livestock and row crops that comprise the state’s agriculture sector. Specialty crops add tremendous diversity to North Carolina agriculture, provide relatively high value returns to growers, and contribute ecosystem services that enhance the well-being of our state. Specialty crop growers produce nutritious fruits and vegetables, Christmas trees, flowers, and many other ornamental plants that bring beauty to our landscapes and our lives. Along with these products, specialty crops produce jobs and economic diversity along the food value chain, from production to consumption.

Nursery, greenhouse, floriculture and sod production is the largest single specialty crops category in North Carolina, valued at about $580 million.10

| Nursery, greenhouse, floriculture and sod value of sales and farm numbers |
|---------------------------------|------------------|-----------------|
| Crop type         | Value of sales   | Number of farms |
| Floriculture      | $286.8 million   | 980             |
| Ornamental        | $234.7 million   | 1,194           |
| Sod              | $35 million      | 98              |

North Carolina’s nursery and ornamental industry is renowned across the country as a center point for new crops development. Plant selections made by the state’s nurserymen on their own farms are bolstered by creative and innovative ornamental horticultural breeding at NC State University and at 18 research stations with different growing environments across the state.

North Carolina’s horticultural food crops producers grow about $520 million in fruit and vegetables annually\(^\text{11}\) on 143,842 acres, representing about 1.7% of all agricultural acres in the state.\(^\text{12}\) With a geography, geology and climate that facilitates a broad range of horticultural food crops, North Carolina is an important supplier in the national food chain. The most economically important crops include apples, green beans, blueberries, cabbage, cucumbers, bell peppers, Irish potatoes, sweet potatoes, squash, strawberries, tomatoes, and watermelons.

<table>
<thead>
<tr>
<th>Top fruit and vegetable crops</th>
<th>Value of production</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweet potatoes</td>
<td>$331.7 million</td>
</tr>
<tr>
<td>Melons</td>
<td>$32.3 million</td>
</tr>
<tr>
<td>Strawberries</td>
<td>$23.4 million</td>
</tr>
<tr>
<td>Peppers</td>
<td>$21.7 million</td>
</tr>
<tr>
<td>Apples</td>
<td>$19 million</td>
</tr>
<tr>
<td>Cucumbers</td>
<td>$12.5 million</td>
</tr>
<tr>
<td>Sweet corn</td>
<td>$12.1 million</td>
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<tr>
<td>Greenhouse vegetables</td>
<td>$8.4 million</td>
</tr>
<tr>
<td>Cabbage</td>
<td>$6.8 million</td>
</tr>
<tr>
<td>Squash</td>
<td>$6.6 million</td>
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<tr>
<td>Peaches</td>
<td>$6.2 million</td>
</tr>
<tr>
<td>Grapes</td>
<td>$5.5 million</td>
</tr>
<tr>
<td>Snap beans</td>
<td>$3.5 million</td>
</tr>
</tbody>
</table>

In-state consumers of North Carolina’s horticultural food crop bounty find a rich assortment that includes these mainstays as well as remnants from our state’s agricultural heritage when most farmers produced food for their own families and sold only locally. North Carolinians frequenting one of the four state-run Farmer’s Markets or any of the several hundred tailgate markets will also find newer, trendy crops reflecting current consumer trends, as well as a changing in-state population base that includes more individuals of Latino and Asian descent.

Vegetable crops may also be grown for their ornamental value, for instance pumpkins and gourds, production of which now exceeds an estimated 4,000 acres. Herbs such as lavender, grown for its medicinal value or clary sage, grown on nearly 25,000 acres in Northeastern North Carolina for its sclareolide that’s sold to the fragrance industry,\(^\text{13}\) are also part of the specialty crops sector.

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\(^\text{11}\) [Id.](#)

\(^\text{12}\) 2015 State Agriculture Overview (USDA NASS).
[https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NORTH%20CAROLINA](https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NORTH%20CAROLINA)

\(^\text{13}\) [North Carolina Field and family, The Age of Sage; February 15, 2016,](http://www.ncfieldfamily.org/farm/the-age-of-sage/)
A growing network of plant propagators specializing in seed production, seedling/transplant/plug production, rooted liner production and grafted plant production supplies North Carolina’s specialty crops sector as well as shipping plants to customers out-of-state. This emerging group of producers is growing crops currently valued at $13.5 million.

North Carolina ranks second in the country in Christmas tree production. While dominated by fresh cut Fraser fir grown in the High Country of the state’s Appalachia Mountains, a small contingent of producers in the Piedmont and Coastal Plain also produce a range of other evergreen species sold for use as Christmas trees. North Carolina’s Christmas tree industry cuts 4.2 million Christmas trees on 1,370 farms spanning 40,000 acres and generating over $90 million annually.14

Most North Carolina-grown Christmas trees are sold on farmer-owned and independent tree lots primarily in the Eastern US, but the industry has also diversified. Some farms are marketing trees throughout the US, Mexico, Canada, the Caribbean and other international points. In addition to trees, farmers grow species such as white pine, boxwood, cedar and varieties that are clipped for greenery and sold to national and international wholesale florist markets. Some farms set up temporary manufacturing warehouses to craft North Carolina grown greenery into wreaths, garland and other holiday decorations. Agritourism ‘cut-your-own’ operations are more and more popular among tree farmers.

SPECIALTY CROP PRODUCERS FACE CHALLENGES

North Carolina’s specialty crops farmers regularly experience variable and extreme weather. The same geographic and geologic features that create microclimates to accommodate a wide range of crops, also give North Carolina a complex climate. Mountains to the West and the Atlantic Ocean to the East produce variable weather and climate.15

Summer rainfall can be spotty, producing large differences in quantity across short distances. Hurricanes can unleash a deluge of water combined with wind. Specialty crops producers are all too familiar with hurricane damage. Pecan and muscadine grape crops in the Coastal Plain ripen in the fall and are regularly under threat of hurricane damage. Wind damage and flooding are both routine when a specialty crops farm finds itself in the path of a hurricane, as often occurs in eastern North Carolina. However, even farmers in the mountains can be hard hit by hurricanes as was the case in the fall of 2004 when rains from hurricanes Frances and Ivan hit Gulf Coast states and moved inland causing devastating flooding in western North Carolina. Dozens of specialty crops producers were hard hit including a number of nurseries and vegetable/tomato farmers. USGS recorded period-of-record peak river stages at more than 20 sites in western North Carolina.16

**North Carolina’s Fraser Fir Industry Faces Complex Weather Problems**

Due to its long production cycle, the Fraser fir Christmas trees are subject to the full range of weather-related problems including winter injury, spring freezes, drought, flooding and heat stress.

Trees lose some of their dormancy during mild winter days and nights and are no longer acclimated to the same level of freezing conditions. When severe cold follows a warm spell, foliage can become desiccated and burnt by freezing wind. When this occurs in late winter or early spring, damage can include bud abortion and damage to new growth. With the symmetrical nature of a Christmas tree, the loss of a “crown” bud or other key buds can set a tree back in its production cycle two or more years.

No grower installs field irrigation across mountain terrain. In severe droughts, some growers employ nurse tanks of water on trucks as mobile irrigation to hand water and keep young trees alive. Tree establishment can be efficient under gentle weather conditions or be an overwhelming cost when droughts occur. If droughts were to increase in frequency, profitability could tip from profit to loss. Despite these difficulties in establishing young trees, many growers fear wet periods even more because of the risk of Phytophthora root rot. When a grower loses a tree to this water-borne disease, the soil is forever contaminated with the fungus. There is little chance that a Fraser will ever grow there again. Further, the disease spreads downhill with water runoff. Growers have lost whole fields of trees to this disease. The hurricane floods of 2004 created a disease problem that growers still talk about.

Hotter than usual summer temperatures are believed to stimulate trees to set cone buds that emerge as cones the following spring. In the 1980’s, NC growers seldom had to pick cones out of Christmas tree-sized Fraser fir. In recent years, young Fraser firs have frequently produced stress-related cones. Growers are forced to hand-pull cones off of trees in the spring before they mature. For some growers, this is their most expensive annual practice.

Warm autumn temperatures delay dormancy and may cause trees to retain internal needles. In 2015, many Frasers were still holding internal needles when harvest began in late October. The needles that are naturally destined to drop are trapped inside trees baled during harvest, carried to retail lots, and possibly to consumers’ living room floors. Currently NC growers do not mechanically shake their trees prior to baling them, but this added practice could be necessary if delayed needle drop becomes a regular occurrence. Furthermore, growers must go to greater lengths (more labor and equipment) to insure their trees stay fresh when it is hot during harvest. Like all farmers, Christmas tree growers are able to innovate and adapt their way around minor changes, but temperature and water have widespread influences to farming.

Greenhouse floriculture producers marketing annual crops such as bedding plants and vegetable starts have seen sales surge in springs with early warm weather, only to be abruptly halted when late spring frosts strike. The widespread freeze that occurred in the Eastern U.S. over Easter weekend 2007 was a
devastating blow to North Carolina’s specialty crops, especially the state’s apple, peach, blueberry, grape and nursery crops.17

This was not a typical spring freeze event. Nights dipped into teens and remained there for four nights back-to-back. Daytime temperatures remained low as well. The cold temperatures occurred on the heels of a blast of 80°F temperatures that encouraged perennial crops to break winter dormancy. Sap was freely flowing as plants were actively growing and many crops were fully leafed out. Crops broke dormancy more rapidly than normal due to high temperatures. Most fruit trees and bushes were in full flower when the freeze hit. All fruit growers were affected, some worse than others. Many blueberry producers without overhead sprinklers lost 80-90% of their crop.

In addition to extreme weather such as the examples cited above, the State Climate Office of North Carolina projects the state will face additional weather threats. For instance, a larger number of hotter days (and nights) in summer, likely combined with periods of drought that last several weeks will increase crop stress during the growing season. The State Climate Office projects farmers will see an increased need for irrigation, especially in the summer.

North Carolina’s winters are likely to have fewer very cold days. Ornamental horticultural and Christmas tree producers are noting changing phenology in regards to bud break on tree and shrub species, and needle shedding. Likewise, these same patterns are noticed on perennial horticultural food crops such as tree fruit, tree nuts and berries. The lack of consistent cold periods during winter can impact product yield and quality in the following year.

SPECIALTY CROP PRODUCER SURVEY

In order to better understand the adaptation needs of specialty crop producers in North Carolina, the Specialty Crops Team conducted an informal statewide survey with the help of specialty crop producer organizations, state extension specialists, and the NC Farm Bureau. The survey asked growers to describe any major changes in weather variability or extremes that they have observed over the time that they have been farming, how they have adapted to those changes, and what kinds of new knowledge and tools would best support their adaptation efforts. Two hundred twenty-nine completed surveys were returned to the Specialty Crops Team. The full Specialty Crop Producer Survey and responses can be found in Appendix III.

Survey respondents were skewed towards less experienced diversified vegetable growers who manage medium and small scale operations and sell into direct markets. About 50% of respondents reported managing specialty crops for 10 years or less, with about 30% reporting 20 years or more management experience at or nearby their current location. Almost 70% of respondents reported growing vegetables or vegetables and fruits as principle crops. Over 50% of respondents direct marketed their products (most common markets were farm stands, farmers markets, and restaurants), and less than 15% of respondents marketed their products to distributors, processors and packing houses. More than 70% of

respondents reported managing 10 acres or less and large scale growers managing 200 acres or more of specialty crops accounted for about 8% of respondents.

Nearly half of the respondents reported experiencing changing weather patterns. More than 40% reported that the variability of temperature and precipitation have increased over the time they have been growing, along with warmer temperatures and heatwaves (30%) as well as patterns of excess moisture (25%). About 15% of respondents reported observing no changes in weather patterns.

Survey respondents have adapted to these changing weather patterns in a number of ways. More than 30% of respondents report that they have changed the timing of field operations and water management practices. About 25% of respondents reported changes to pest management practices (weeds, diseases and insects). When asked about how they would alter production if these weather conditions continue to change, they responded:

- Irrigation is one way farmers can help to ensure yield in periods of low or no rainfall.
- Greenhouses and hoop houses can protect crops and modify temperatures to bring crops on earlier than those grown outdoors.
- Automatic harvesting equipment is being developed and employed primarily for specialty crops producers to rely less on hand harvesting due to limited availability of cost-effective field labor. However, it also allows the farmer to rapidly harvest a crop in the shadow of impending weather events such as a severe thunderstorm, hail or hurricane.
- Grafted vegetable plants are one way produce farmers can deal with soil-borne pathogens. Desired scion material of market varieties can be grafted onto resistant rootstock.
- North Carolina’s erratic spring weather has spurred a number of farmers to invest in frost protection systems, such as row covers, overhead irrigation, and wind machines to mix warmer air above the crop with cooler air at the ground. Farmers also employ passive freeze protection methods like orchard/field site selection, variety selection and cultural practices.
- Farmers employ programs and GPS apps tied to National Weather Service radar sweeps that provide them with up-to-the-minute information on the location of rain bands, high temperature waves and low temperature troughs to enable them to make decisions.
- Advanced plant breeding allows specialty crops farmers to cope with weather challenges. Contender, for instance, is an NC State University spring frost tolerant peach cultivar that’s revolutionizing production in North Carolina and other states as well.
- Entrepreneurs have a good opportunity to leverage state resources and add innovation by creating new markets for existing crops, whether those markets are developing incremental business, or making use of excess or low-quality production.

Should climate variability and weather extremes become more pronounced as predicted by state and federal climate scientists, North Carolina farmers, ranchers and foresters will need new tools, technologies and programs to help them better manage potential future risks.
changes continued or grew more intense in the future, nearly 40% of respondents reported they would make improvements to farm infrastructure, and about 30% reported they would diversify crops.

Survey respondents reported using a mix of on- and off-farm tools to manage weather-related production risks. More than 50% reported management experience was an important asset for managing more variable weather and extremes. About 40% recognized the risk management value of general crop production knowledge, farm infrastructure, weather-based decision tools, and weather forecasts. Just over 30% reported that crop diversity was helpful to their management of weather-related production risks. Between 20 and 30% recognized the potential for high soil quality, abundant, high-quality water, and landscape variability to reduce weather-related production risks.

When asked what kinds of improvements in risk management practices would be most beneficial to their efforts to manage more variable weather and extremes, about 40% of respondents said improvements in weather forecasting. About 30% suggested that improved production and conservation practices and further development of existing information networks would also help them better manage risks related to weather. About 25% suggested that their risk management would be improved with access to more information about species/cultivars and the development of new cultivars that are better adapted to increased weather variability, particularly heat and drought, as well as improved decision support tools. About 20% indicated that access to crop insurance for weather hazards would be most beneficial to their operations.

Because diversified vegetable growers represented almost 70% of the sample, survey results were also analyzed according to principle crop grown: vegetables (202), fruits (135), nursery/greenhouse (69), and nuts (31). In general, the results reported above were not affected by principle crop, except in a few instances. Nearly 20% of nursery/greenhouse growers reported that, along with diversifying crops, improving infrastructure and switching to better adapted cultivars, they would also seek out higher value markets if the changes in weather that they have experienced continue or grow more extreme. Nut producers reported a number of additional adaptations that were not mentioned above. Almost 30% of nut growers reported changing harvest and post-harvest handling practices in response to more variable weather and extremes. Nearly 50% reported changing disease management and about 35% reported changing insect pest management as a result of changing weather conditions.

These survey results resonate with other surveys and case study research conducted in the southeast and other parts of the country to document the adaptations of American farmers, growers and ranchers to more variable weather and extremes, but many questions remain. This survey was just a small first step in bringing the knowledge, experience, and perspectives of North Carolina’s specialty crops growers into adaptation planning.

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Not surprisingly the survey raises more questions than answers and points to an urgent need for further research to understand the complexity of the climate change adaptation needs of the specialty crop industry in North Carolina. For instance, understanding the differences between producers of perennial crops such as Christmas trees, grapes, fruit/nut orchards and nursery crops vs. those farmers producing an annual crop such as tomatoes, watermelon or bedding plants.

However, North Carolina’s Specialty Crops sector enjoys a number of competitive advantages:

- Proximity to expanding in-state and regional markets;
- Diversity of geographic climates and microclimates; and
- State-funded infrastructure like NC State University; NC Agricultural and Technical State University; NC Cooperative Extension; NC Department of Agriculture and Consumer Services (NCDA&CS); and Research Stations.

For the state’s specialty crops farmers to continue to leverage North Carolina’s current competitive advantages, expanded research and innovative tools to improve the resilience of production systems and adapt to and mitigate present and future risks of changing climatic conditions is needed.

**DEVELOPMENT OF ADAPTATION RECOMMENDATIONS**

Adaptation represents a powerful tool in addressing many of the uncertainties facing producers, value chain partners and supporting entities. Adaptation strategies come in many different forms ranging from minor adjustments designed to protect the existing production system to major changes in production and marketing practices. These strategies tend to fall into one of three different groups: 1) actions that protect the existing production system from a specific risk, such as drought, through minor
adjustments such as the purchase of insurance or the addition of irrigation; 2) actions that protect the existing production system from a broad range of risks, such as drought, increased pest pressures and nutrient losses, through major adjustments such as crop diversification; and, 3) actions that protect the farm or forestry business as a whole from a broad range of risks through major changes to the existing system such as the a shift from annual to perennial crops or the integration of livestock into annual cropping systems.\textsuperscript{19} Resilient systems typically exhibit some characteristics of all three kinds of adaptation strategies.\textsuperscript{20}

Effective adaptation strategies will also support four integrated objectives over the long term:

- **Profitability** – Adaptation measures must maintain or improve the producer’s bottom line.
- **Productivity** – Adaptations measures must improve production efficiency and enhance a producer’s ability to meet changing demands for food, feed, fiber and fuel.
- **Stewardship** – Adaptation measures must restore and maintain the natural resources upon which the resilience of agriculture depends, particularly soil, water, and air quality, and biodiversity.
- **Self-determination** – The power to take adaptive action must be in the hands of the land owner and land manager, because they are in the best position to select locally-appropriate adaptation options.

The NC ADAPT Work Group created four (4) stakeholder Teams – Commodity Crops; Livestock; Forestry; and Specialty Crops. Each Team established their own process to identify adaptation needs, priorities and strategies. To help build a record of recommendations, the Specialty Crop Team utilized information and feedback collected from the August 2015 Adaptation Summit Specialty Crop Team Breakout Session, the Specialty Crop Producer Survey, and the March 2016 Specialty Crop Team stakeholders meeting and employed other appropriate outreach measures.

Each team explored how research, best management practices, risk management and insurance, decision-making tools, and communications, outreach and education programs could support the long-term viability of the specialty crop industry in North Carolina, as well as address any short-term immediate issues or needs. **The Specialty Crop Team identified the following areas for key action items:**

**Research and Development**

- Research and development of new crop varieties with characteristics of: drought resistance; disease or insect resistance; earlier or later yielding; day-length neutrality; night temperature tolerance; chilling requirements; etc. **These are all features of varieties that empower the farmer to meet yield and income requirements in light of weather obstacles.** Horticultural crop breeding at NCSU has been vitally important to the growth and vitality of the state’s specialty crops producers. For example, Covington sweet potatoes and other NCSU varieties are planted on 90% of the sweet potato acres in the state. Blueberry varieties bred at NCSU are planted on 68% of the blueberry acres. About 60% of the state’s tomato crop is planted in NCSU developed varieties. Fruit crop varieties bred for Southeastern conditions for our state’s peach and raspberry farmers have also been released. **Continuing financial and institutional support of**

\textsuperscript{19} Walthall et. al. Adapting Agriculture to Climate Change, Ch. 7 in, *Climate Change and Agriculture in the United States: Effects and Adaptation.* USDA Bulletin 2935.

the development of robust cultivars tolerant of multiple stresses and are suited to local conditions is vitally important to a thriving specialty crops sector.

- Along with breeding new varieties, life science research centers should also screen existing commercial varieties to understand their performance under North Carolina’s climatic conditions. In many cases, this is a more cost-effective measure.
- Researchers should investigate new crop systems that previously could not be grown in North Carolina.
- Research ways to artificially induce crop dormancy or to extend shelf life will give specialty crops growers tools to hedge the market. Further work into post-harvest treatments allow farmers to better control their sales. NCSU developed MCP (SmartFresh), an anti-ethylene agent that has revolutionized the apple industry worldwide. It is considered the most significant development in postharvest research for all crops and for basic science in the last 30 years.

Production Systems and Practices

- Specialty crops farmers need adaptive cropping systems that provide more farmer control; moving away from horticultural crop models that optimize growing conditions and moving to systems that allow for robust solutions such as multiple approaches to production outcomes.
- Develop improved specialty crops mechanization to increase flexibility of management, reduce the burden of hand harvesting and reduce exposure of labor to weather extremes. About 20 to 25% of the U.S. vegetable acreage and 40% to 45% of the U.S. fruit acreage is totally dependent on hand harvesting. Nationally, it’s estimated that hand harvesting 11.2 million acres annually requires at least 780 million labor hours/year (0.98 million workers for 20 weeks/year), and would easily exceed the labor force of workers willing to do seasonal crop harvesting. North Carolina is the leading H2A labor contracting state, bringing in an estimated 15,000 workers annually to work and harvest crops. Reducing the need for manual harvest through mechanization will allow farmers to harvest when the crop is ready, or to accommodate a pending weather event such as a hurricane, when hand labor is not available.
- Better understanding of effective weed management systems under more variable weather conditions and their subsequent effects on crop performance and yield is needed to inform specialty crops farmers how to achieve acceptable weed management under potential future climatic conditions.
- Develop production practices that give farmers new cultural tools for managing weather-related risks such as diversified cropping systems, soil quality management to improve soil characteristics (like infiltration rate and water holding capacity) that buffer more variable precipitation, promote crop health and reduce pest pressures.

Decision-Making Tools

- Develop decision support tools that provide farmers with reliable predictive weather forecasts that are readily accessible and that include additional data such as soil moisture, solar radiation, wind, etc., and can be overlain to specific fields. Repackage existing programs into a farmer accessible platform so that farmers can see how weather is changing and then have

21 Center for Immigration Studies, Alternatives to Immigrant Labor?, http://cis.org/FarmMechanization-ImmigrationAlternative.
specific crop/management information on actions that need to be taken to protect the crop based on proven models.

- **Develop smart phone apps based on weather forecasts and analysis as well as validated crop and pest models.** For example, specialized smart phone apps that help blueberry growers decide the optimal time to use pesticides to prevent damage from pests such as Spotted Wing Drosophila.

**Risk Management**

- As the percentage of the state’s total farm income from specialty crops increases, the need for expanded risk management policies for specialty crop producers also expands. Without cost-effective risk management programs, specialty crops producers face increased difficulty in accessing operational credit, and greater vulnerability in the event of a natural disaster. North Carolina has had 19 weather disaster declarations in the past 15 years. In 2011, crop insurance covered just 13.7% of NC specialty crops income, leaving more than $1.4 billion in specialty crops income uninsured. For many producers, the transition from tobacco income to specialty crops income is a transition from extensive risk management programs, to little or no risk management program availability. This transition and uninsured specialty crops income represents significant vulnerability for NC farmers and the NC agricultural economy, and limits specialty crops-based entrepreneurship and economic development. **A statewide Risk Management Collaborative needs to be created to inform specialty crops stakeholders of new whole-farm revenue crop insurance policies and other risk management options being made available from the public and private sectors.**

- **Continue support at the state level for programs such as AgWRAP (Agriculture Water Resources Assistance Program) to help farmers with cost share for on-farm water resources and water use efficiency.**

- **Specialty crops stakeholders need assistance identifying win-win solutions that address regulatory and marketing challenges while enhancing the adaptive capacity of specialty crops agriculture.** Emerging regulatory issues and other changing conditions (new markets, new competition) add to the complexity of adaptation.

- North Carolina’s fruit and vegetable producers will be mandated to meet new U.S. Food & Drug Administration (FDA) Produce Safety Standards for the crops they produce. The new standards will require growers to reexamine their production, harvest and packing practices. For many it will be necessary to invest in new or retrofit equipment that will enable them to meet the new standards. **North Carolina should invest in the state’s core capacity to meet in-state and national demand for fruit and vegetables by developing a cost share program for specialty crop producers.** The NC Fresh Produce Safety Task Force, an interagency working group that reports to the Governor’s Food Safety and Defense Task Force can be instrumental in developing such a program.

**New Markets**

- Specialty crops create a direct beneficial tie from rural agriculture to urban populations in the areas of human health and manmade environments. **North Carolina has unique resources to leverage the specialty crops sector as a key player in the arena of human health from foods**
and nutraceuticals-botanical assets through the North Carolina Research Campus at Kannapolis and the Bent Creek Institute at the North Carolina Arboretum in Asheville.

- North Carolina can position its ornamental and environmental horticulture industry as a national leader in the emerging areas of human well-being and ecosystem services through interdisciplinary partnerships across agencies and institutions. **North Carolina’s specialty crops sector can have a direct positive influence on the urban environment through ecosystem services that reduce governmental storm water expense, improve air quality, and provide aesthetics and positive health outcomes through green spaces and higher property tax values.** New food system planning termed “city region food system,” can help integrate food and nutrition security with climate action planning, disaster risk reduction, economic and community development, water, biodiversity and other aspects of natural resource management.

- **Continue support at the state level to implement recommendations from the Governor’s Food Manufacturing Task Force.** Entrepreneurs within the state’s specialty crops sector have a good opportunity to leverage state resources and add innovation and entrepreneurship. The result could be increased profitability and new market opportunities while adapting to more variable weather.

- **Continuing support of the existing legal and regulatory framework that facilitates small-scale agriculture, even in cities, is an important way to add resilience to the food supply through diversified sourcing.** The specialty crops value can approach $40,000 or more per acre, depending on the crop. High value crop production is one reason specialty crops are grown all over the state. While achieving economies of scale to market fruits or vegetables into mainstream consumption channels, such as supermarkets or large-scale institutional buyers, requires larger plots of land. Just a few acres near a city can produce enough income for a small producer selling direct to the public. This ability of specialty crops to work in the interstices, allows for open space in our increasingly urbanized state to recharge aquifers, provide wildlife habitat and provide agritourism destinations for city dwellers to connect to the land. North Carolina is seeing growth in urban agriculture and community gardening, which are frontline connections between agriculture and the consumer.

**Communications and Outreach**

**Going forward, it will be important to create knowledge sharing networks promoting adaptive management tools.** The best technologies, tools and programs will matter little if we cannot effectively engage producers in the development of effective adaptation options and to share information with technical experts and producers.

- **Provide additional farmer outreach by state support agencies to keep the agricultural community apprised of available resources for disaster planning and recovery; cost share for equipment; and, infrastructure purchases and programs.**

- **Develop and deliver new interdisciplinary training modules for Cooperative Extension agents that emphasize collaboration with farmers. The models should inform robust, flexible, on-the-ground solutions to evolving production problems.**

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- Hire a statewide Extension Specialist with knowledge of evolving weather patterns and their effects on specialty crops and agriculture production. Help cultivate climate literacy among state specialists and county agents.

**PATH FORWARD**

Though the recommendations included in this document are the result of a year of work with stakeholders from the specialty crops sector, they mark the beginning of new conversations. Changing weather patterns affect North Carolina’s specialty crop sector in complex ways. Geography, specific crops produced, farmer expertise, farm resources and markets are just a few of the variables that frame opportunities and threats to our state’s specialty crops farms.

North Carolina’s specialty crop growers are learning to deal with more variable weather and extremes through traditional and non-traditional means. Thoughtful planning, food and fiber production experience, and comprehensive knowledge of working lands are merged with new technology in the form of GPS, Lidar and information-based decision tools to maximize results under certain circumstances.

North Carolina’s producers need new and continuing support to ensure that all sectors of agriculture and forestry remains a vibrant, growing sector of the North Carolina economy. The state’s leadership can improve the competitiveness of North Carolina’s producers by making investments in research and continuing to support the state’s existing economic development, as well as review its regulatory framework for agriculture and forestry. New programs to help farmers deal with changing markets, stressed infrastructure, lack of labor, food safety regulations and extreme weather will yield solid returns from a diverse, dynamic group of agricultural entrepreneurs.

Changes ahead are unprecedented and North Carolina’s agriculture and forestry producers can remain productive and provide many community benefits besides food – energy, wildlife habitat, water filtration, carbon sequestration, recreation, etc. – but they can’t do it alone. They need focused support from public and private partners to innovate and adapt to the changes ahead in a way that strengthens productions systems, improves profits, and reduces environmental impacts.

A communications and outreach program that includes a peer-to-peer information network should be formed to support grower leader dialogues around strategies to advance adaptive management. It is important that specialty crop thought leaders be committed to serve as discussion facilitators and adaptation mentors and integrate climate-smart agriculture concepts that improve resilience and mitigate future risks from changing climatic conditions.
APPENDIX I

Extreme and Variable Weather:
A Threat to North Carolina Agriculture and Forestry

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

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 threatens farm family well-being nationwide and could diminish the security of our food and fiber supplies.¹

Here in North Carolina, state climatologists are projecting that changing climatic conditions will result in longer and warmer growing seasons, with more periods of drought punctuated with fewer, more intense rainfalls. Precipitation events will be harder to predict, but most likely will include more frequent flash storms that will cause and accelerate soil erosion, exacerbate nutrient leaching and degrade soil health.

SEASONS OF CHANGE IN NORTH CAROLINA

FUTURE SPRINGS
- More warm days
- Possibly more intense thunderstorms (not likely to get weaker)
- Perhaps more tornadoes, hail (much less certain)

FUTURE SUMMERS
- Likely more hot days, warm nights
- Perhaps fewer days with rain but more days with intense rain
- Perhaps more drought

FUTURE AUTUMNS
- More intense hurricanes (but perhaps a decrease in frequency)

FUTURE WINTERS
- Probably more warm days in winter
- Probably fewer very cold days
- Probably fewer days with snow in lower elevations

--- Ryan Boyles, state climatologist

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.²

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.  

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 drought 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.

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 can deliver. But longer growing seasons could possibly allow for double cropping, longer pasture grazing and more successions for a vegetable producer.

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 follow optimal growth conditions, though production in any given location will be more influenced by water availability during the growing season. These weather-related impacts on crop growth are likely to increase production costs.

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. 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.

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1 Third National Climate Assessment - Agriculture, page 152.
2,3,4 Ryan Boyles, "Climate and Agriculture in the Carolinas", 25x25 NC Ag and Forest Adaptation Workgroup Presentation, December 2, 2014.
6,7 Third National Climate Assessment - Agriculture.
APPENDIX 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 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 (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.

“Agriculture has had and will continue to have the ability to adapt to new conditions. The ability to change with a changing climate will depend on a strong research base that can supply required information.” (Reilly et al., 2001).

From the report:
Because of its dependence on the natural environment, agriculture and agribusiness must be capable of adapting to a variety of broadly changing conditions, including potential changes in climate. Responding to climate variability “is manifest in nearly every dimension of farm management. Included are technologies such as crop drying, irrigation, drainage and tiling, and storage; shading and cooling for livestock; selection and breeding of livestock and crops that are hardy or hardier under a wider range of climatic conditions.” (Reilly et al., 2001).

Even in the absence of global warming, there is strong reason for proactive planning given North Carolina’s known vulnerabilities to hurricanes, winter storms, flooding, and drought. Maintaining and enhancing the ability of farmers and private landowners to provide an adequate, wholesome supply of food, natural fiber and wood products given potential changes in climate, technology and market conditions must be a continuing priority. Private firms, as well as numerous federal, state, and local agencies, provide assistance to producers in response to the variety of risks faced by the agricultural sector.

### Adaptive Response Options

“Agriculture is considered one of the sectors most adaptable to changes in climate. However, increased heat, pests, water stress, diseases, and weather extremes will pose adaptation challenges for crop and livestock production.” (Legislative Commission on Global Climate Change 2010). In order to remain in business, farmers must make production decisions in response to market incentives, available technology and the capacity of the natural resource to sustain production.

There are numerous actions that could be implemented in response to potential changes in climate:

- Promote research and technological innovation for new crop types/varieties and improved pesticides/herbicides to adapt to changing growing conditions.
- Provide education/outreach to the farming community regarding Climate Ready North Carolina: Building a Resilient Future recommendations for adaptation of new crops, varieties, or technologies.
- Conduct research regarding breeds of livestock most suitable for current climatic conditions, as well as educate/advise the livestock sector of adaptive strategies for dealing with variation in climate.
- Encourage livestock producers to select breeds that are genetically adapted to prevalent climatic conditions.
- Provide adequate disaster response resources in response to natural disasters.
- Minimize risk of disaster through adequate education, planning, emergency response capacity and appropriate disaster insurance.
- Ensure availability of flood/crop insurance in order to maintain land in agricultural production instead of a more intensive land use that has the potential to be more susceptible to flooding events and will have higher damages when flooding events occur.
- Provide for maintenance of drainage infrastructure to minimize flood severity and duration.
- Encourage adoption of agricultural best management practices to conserve water, reduce erosion, and increase soil productivity.
- Provide technical and financial assistance to producers to encourage adoption of water storage/water use efficiency technologies.
- Increase available on-farm water storage capacity to minimize drought impacts.
- Improve the availability of irrigation infrastructure in order to relieve drought/heat stress.
- Adopt more efficient irrigation technology to minimize drought stress and maximize the benefits of available water.
APPENDIX III

Specialty Crop Producer Survey and Survey Results

1. About how many years of experience do you have as a specialty crops grower?

![Pie Chart showing the distribution of years of experience.]

- Less than 5: 28, 9%
- 5-10: 98, 31%
- 10-15: 71, 23%
- 15-20: 30, 9%
- More than 20: 79, 25%

2. About how many years have you been growing at, or near, your current location?

![Pie Chart showing the distribution of years at current location.]

- Less than 5: 109, 35%
- 5-10: 214, 68%
- 10-15: 25, 8%
- 15-20: 5, 2%
- More than 20: 30, 9%

3. How many acres of specialty crops do you typically manage each year?

![Pie Chart showing the distribution of acres managed.]

- Less than 10: 63, 20%
- 10-50: 214, 68%
- 51-100: 18, 6%
- 101-150: 4, 1%
- 151-200: 5, 2%
- More than 200: 10, 3%
4. What are the principle specialty crops that you produce? Select all that apply. If you select other please detail in the space provided.

- Vegetables: 33, 7%
- Fruits: 57, 11%
- Nuts: 61, 12%
- Nursery, Greenhouse, Ornamental Horticulture: 194, 38%
- Plant Starts: 30, 6%
- Other: 134, 26%

5. Where do you market your products? Select all that apply.

- NC State Operated farmers markets: 28
- Packing Houses: 20
- Processors: 21
- Distributors: 45
- Supermarkets: 44
- Restaurants: 89
- Local farmers markets: 166
- Farm Stand/other farm direct sales: 141
- CSA/Subscription sales: 57
- Garden centers/Home improvement/Hardware stores: 23
- Other growers: 37
- Other: 55
6. Think now about your experience growing over the years. What are some of the most difficult crop production challenges that you've experienced? Select up to 5 items representing the most difficult crop production challenges at your current location.

7. Think again about your experience growing over the years. What are some of the most difficult weather-related production challenges that you have experienced during that time? Select up to 5 items from the list below.
8. Think again about your experience growing over the years. Have you noticed any changes in weather-related production challenges? Select any items that apply from the list below.

- No changes in weather-related production challenges
- Variability in precipitation
- Variability in temperatures
- Length of growing season
- Flowering/Pollination/Fruit set
- Excess moisture
- Flooding
- Dry periods/Drought
- Warmer temperatures/Heatwave
- Cooler temperatures/Coldwave
- Frost/Freeze
- Excess moisture
- Flooding
- Dry periods/Drought
- Warmer temperatures/Heatwave
- Cooler temperatures/Coldwave
- Frost/Freeze
- Other

9. Have these changes in weather-related production challenges caused you to make any major changes in growing practices? Select any items that apply from the list below.

- Crop mix
- Crop cultivar
- Timing of field operations
- Crop succession planning
- Cover crops
- Soil management
- Weed management
- Insect management
- Disease management
- Water management
- Fertility management
- Field equipment
- Harvest
- Post-harvest handling
- Other
10. Have these changes in weather-related conditions or challenges created any new production opportunities for you? Select any items that apply from the list below.

- Adopted: New crops
- Adopted: New cultivars
- Adopted: New markets
- Adopted: New nutrient management
- Adopted: New pest management
- Adopted: New soil and/or water conservation practices
- Increased: Crop quality
- Increased: Crop yields
- Reduced: Fertilizer costs
- Reduced: Pesticide costs
- Reduced: Irrigation costs
- Reduced: Equipment costs
- Reduced: Fuel costs
- Reduced: Insurance costs
- Reduced: Field operations
- Reduced: Pests
- Other

11. If the changes you have noticed in weather variability or extremes continue or grow more intense how will you most likely respond? Select any items that apply from the list below.

- Spend more for production inputs
- Invest in infrastructure improvements like controlled drainage, efficient irrigation, physical protection
- Switch to drought resistant cultivars
- Switch to heat resistant cultivars
- Modify timing, placement, form, or application method of nutrients
- Switch to commodity crops
- Accept lower crop quality
- Accept lower crop yields
- Modify timing, placement, form, or application method of nutrients
- Switch to commodity crops
- Accept lower crop quality
- Accept lower crop yields
- Invest in preventing soil erosion
- Purchase more insurance
- Diversify crops
- Diversify markets
- Seek out higher value markets
- Quit growing
- Lease out farmland
- Other
12. What sources of weather information do you use in planning and management decisions?

- NOAA: 31%
- TV News: 35%
- Purchased from private company: 8%
- Cooperative Extension: 13%
- USDA Drought Monitor: 4%
- Other: 9%

13. Of all the resources available to you as a grower, which ones among those listed below do you use most often to reduce weather-related production risks? Select any items that apply from the list below.
14. Think again about all of the resources available to you to manage current weather-related risks. What improvements in information, management practices or technologies would be most likely to improve your success in managing weather-related risks? Select all that apply.

- Federally-subsidized specialty crop insurance for weather-related hazards
- Improved natural disaster relief programs
- More accurate short-term and seasonal weather forecasts
- More information about better adapted crop species and cultivars
- Development of better adapted crop cultivars
- Improved planning and decision support tools for soil, nutrient, water, and pest management
- Better adapted production equipment and facilities
- Better adapted post-harvest practices and facilities
- Production and conservation practices that maintain or increase the productive capacity of land in more variable weather and extremes
- Development of new networks for producer-to-producer information exchange about weather-related risks and effective practices and tools for managing those risks
- Development of existing information networks (i.e., extension/university/agency/trade association/policy makers) about weather-related risks and effective practices and tools for managing those risks

Other

15. Are you confident that you have access to the resources you need to successfully manage current weather variability and extremes?

- Yes: 41%
- No: 26%
- I don't know: 33%