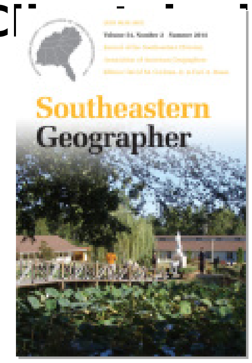
Challenges and Opportunities for Southeast Agriculture in a Changing Climate: Perspectives from State Climatologists



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Challenges and Opportunities for Southeast Agriculture in a Changing Climate

Perspectives from State Climatologists

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Agriculture is one of the most sensitive economic sectors to weather and climate variability. In the Southeastern U.S., agricultural production is widespread and diverse, making it a primary source of commerce. As a result, members of the climate community have garnered extensive experience working with farmers and extension agents to address their sensitivities to climate variability and change. One group of individuals that has established a longstanding relationship with the agricultural community is the state climatologists. In this study, the state climatologists from six southeastern states were interviewed to assess the challenges and opportunities faced by the agricultural sector, particularly in dealing with current climate variability and potential future changes to climate. Based on their experiences, the combination of favorable climatic conditions, ample water resources, and diversity in agricultural production makes the Southeastern U.S. unique in its ability to adapt to current climate variability and potential future changes in climate.

La agricultura es uno de los sectores económicos más susceptibles al clima y la variabilidad climática. En el sureste de los EE. UU. la producción agrícola está muy extendida y diversa, por lo que es una fuente importante de comercio. Como resultado, los miembros de la comunidad del clima han obtenido una amplia experiencia de trabajo con los agricultores y agentes de extensión para hacer frente a su sensibilidad a la variabilidad y el cambio climático. Un grupo de personas que se ha establecido una relación antigua con la comunidad agrícola es los climatólogos estatales. En este estudio, los climatólogos estatales provenientes de seis estados del sureste eran entrevistado para evaluar los desafíos y oportunidades enfrentado por el sector agrícola, particularmente en tratar con la variabilidad climática actual y los potenciales cambios futuros al clima. Sobre la base de sus experiencias, la combinación de condiciones climáticas favorables, amplios recursos hídricos y la diversidad de la producción agrícola se hace que el sudeste de los EE. UU. es único en su capacidad de adaptación a la variabilidad climática actual y los potenciales cambios futuros en el clima.

KEY WORDS: agriculture, climate variability, climate change, El Niño-Southern Oscillation, climate service

PALABRAS CLAVE: agricultura, variabilidad del clima, cambio climático, el Niño-Oscilación del Sur, el servicio climático

INTRODUCTION

As a society, our sensitivity to climate variability and extreme events has increased dramatically in recent years, and this has created a greater need for climate data and information (i.e. climate service) across a diverse user community (Changnon 2007). Such information is particularly important in the context of adaptation strategies to address potential future changes in climate. The provision of climate services in the United States has generally revolved around data stewardship (e.g. collection, quality control, and dissemination) and the interpretation of data to generate useful climate information, such as analysis tools, products, and applied research, based on interactions with users (Changnon 2007; Brooks 2013). These functions are typically facilitated by climate scientists and climate service providers.

One of the most prominent and enduring organizations involved in climate service is the group of state offices, whose core functions are directed by the state climatologists (AASC 2008). As of December 2013, 48 states and one U.S. territory had an official state climatologist. Most state climatologists are located at universities, although a few are housed in state agencies, and serve as resources for climate information in their states. Collectively, they provide a uniquely regional perspective on climate conditions and vulnerabilities, while individually they provide a local perspective on their state's climate sensitivities. This allows them to paint a more detailed and comprehensive picture of regional conditions and their variations. The primary role of the state climatologists is to deliver climate services across a range of different economic sectors and users, including government officials, educators, farmers, water managers, and private citizens (Hecht 1984; Smith et al. 1995; AASC 2008). State climatologists have been recognized as the single most trusted source of information on climate variability and change by broadcast meteorologists, many of whom serve locally diverse audiences (Maibach et al. 2010). In addition, state climatologists are involved in facilitating engagement activities (e.g. workshops and webinars) and have established long-standing relationships with key stakeholders and decision-makers. For example, the South Carolina state climatologist, who is housed in the state's Department of Natural Resources, works closely with several federal and state agencies (e.g. U.S. Department of Agriculture, South Carolina Forestry Commission), as well as with utility companies (Carbone et al. 2008) emergency managers, coastal managers, universities, local governments, extension agents, and individual farmers. The specific responsibilities of each state climate office vary depending on their administrative placement, but all offices provide services (e.g. writing of reports, delivering presentations to commodity groups) across multiple levels of government, stakeholder groups, academia, media outlets, and private citizens.

One of the sectors with which state climatologists have established a particularly strong relationship is agriculture. In fact, when the office of the state climatologist was created under the U.S. Weather Bureau in the early twentieth century (at the time part of the U. S. Department of Agriculture), one of its primary roles was to provide agricultural forecasts. Indeed, agriculture is one of the most sensitive economic sectors to changes in weather and climate conditions. Lazo and others (2011) suggest that year-to-year agricultural production across the United States can vary by over $100 billion due to variability in weather and climate. In the Southeast, agriculture is a primary source of commerce, with over $55 billion in commodity production annually, which accounts for approximately 17 percent of the total United States production (Asseng 2013). There is also great variety in agricultural production across the Southeast, including cropland, pasture, forest, and range. Because of the importance of agriculture as a driver of their states' economies, state climatologists in the region have garnered extensive experience working with extension agents and farmers to address their sensitivities to weather and climate and their needs for climate information. In the process, state climatologists have developed considerable expertise in agricultural science and applications and have participated in many agricultural projects including field trials on drought, diseases and irrigation methods (Brolley et al. 2007; Carbone et al. 2008; McNider et al. 2011; Ingram et al. 2013). State climatologists serve on their states' drought task forces, contribute regularly to agricultural bulletins, and participate in meetings of extension agents and commodity groups in their states (SCDNR 2012; Southeast Climate Extension 2013). Partnerships between service climatologists, particularly state climatologists, and extension are critical in providing farmers with the most reliable and useful information possible. In addition, some state climatologists have been involved in legislative or regulatory actions to protect farmers from financial losses due to weather events and climate variability (Georgia Department of Natural Resources 2006).

While numerous articles and reports have been published on specific engagement activities between climate service providers (including state climatologists) and members of the agricultural community (Bartels et al. 2012), there has been comparatively little effort to synthesize the long-term, collective experiences and perspectives of climate service providers. Much of the applied climate work conducted by state climatologists is published in technical papers, fact sheets, and newsletters within their states rather than in more traditional refereed journals. Therefore, it is difficult to assess the relationships between agriculture and climate in the Southeast using a traditional literature search alone. To help fill this gap in knowledge, state climatologists from six southeastern states (Virginia, North Carolina, South Carolina, Georgia, Alabama, and Florida) were interviewed to assess the challenges faced by the agricultural sector, particularly in dealing with current climate variability and potential future changes in climate. State climatologists were also asked to assess future opportunities for the agricultural sector in the Southeast as climate conditions evolve, particularly as society becomes increasingly sensitive to climate variability and extreme events.

OVERVIEW OF THE CLIMATE OF THE SOUTHEAST

> ". . . the South remains a land apart—a land that still owes much of its distinctiveness to climatic forces"
>
> (Arsenault 1984, p 628).

The climate of the southeastern U.S. (Figure 1) is a powerful driver of the region's economy and culture. Generally mild temperatures combined with a relative abundance of sunshine and water resources compared to other parts of the U.S. support a wide range of activities, including energy production, manufacturing, recreation, and agriculture. There is, however, significant variation in local climates due to factors such as latitude, topography, and proximity to large bodies of water. Mean annual temperatures across the Southeast range from around 21.1°C (70°F) across much of the Florida Peninsula to near 10°C (50°F) across northern Virginia and the higher elevations of the southern Appalachian Mountains (Kunkel et al. 2013). These temperatures generally support long and productive growing seasons, particularly across South Florida where annual minimum temperatures usually exceed 4.5°C (40°F) (Kunkel et al. 2013). However, intrusions of continental polar air during winter and heat waves in the spring and summer can place significant stress on crops, pasture, and livestock. Severe weather, especially during spring and summer, can also cause damage to crops due to hail and strong winds. Most areas across the region receive an average of over 101.6 cm (40 in) of precipitation annually, which is typically sufficient to support a wide variety of crops (Kunkel et al. 2013). The highest annual amounts [over 152.4 cm (60 in)] are generally found across southern Alabama, the western panhandle of Florida, and southeastern parts of the southern Appalachian Mountains, while the lowest amounts are found across central portions of Virginia, the Carolinas, and Georgia (Kunkel et al. 2013).

One of the major influences on climate across much of the Southeast is the El Niño-Southern Oscillation, or ENSO (Ropelewski and Halpert 1986; Harrison and Larkin 1998). ENSO is a coupled ocean-atmosphere phenomenon with two predominant phases: a warm phase known as El Niño and a cool phase known as La Niña. The El Niño (La Niña) phase is characterized by above-normal (below-normal) sea-surface temperatures in the eastern equatorial Pacific Ocean and is typically associated with cooler and wetter (warmer and drier) conditions across Florida and southern parts of Alabama and Georgia during winter (Ropelewski and Halpert 1986). The presence of El Niño or La Niña can, therefore, indicate a decreased or increased potential for drought during the subsequent growing season, respectively, due to changes in the recharge of soil moisture in winter. Each El Niño and La Niña is unique, however, so the exact impacts of a particular event may differ from the most likely deviation based only on statistics. Other teleconnections such as the North Atlantic Oscillation and Arctic Oscillation also have impacts on climate in the Southeast, but are of higher frequency than ENSO, which make them less useful for predictions of seasonal climate (Hurrell 1995).

The influence of ENSO on crop production in the Southeast has been studied extensively and is the basis for several climate forecasts and crop models developed through partnerships between scientists and extension agents across the region (Hansen et al. 1998; AitSahlia et al. 2011; Pathak et al. 2012; Southeast Climate Consortium 2013). These ENSO-based products can provide weather information with useful skill at lead times

Figure 1. Map of the southeastern states included in this study.

of up to several months, allowing farmers to tailor their practices (e.g. planting, fertilizer application) to reduce losses or take advantage of favorable conditions. The extent of impacts from any particular ENSO event depends on the magnitude of the event and the state of other global and hemispheric cycles. According to the Florida state climatologist, about 95 percent of commodities in the state are buffered against the effects of ENSO (including drought) by irrigation, but other parts of the Southeast, such as Alabama, are more susceptible to ENSO variability due to the relative lack of irrigation.

Secular trends in climate across the Southeast do not mirror trends observed in other parts of the U.S. (Misra and Michael 2012). Over the last century, many areas in the region have experienced a net decrease in annual average temperature (Kunkel et al. 2013; Rogers 2013). This negative trend may be due to a variety of factors, including the transition of agricultural land from row crops and bare soils to mostly forested land. The increase in tree cover is likely to have both reduced maximum temperatures near the surface and increased humidity as a result of evapotranspiration (Gu et al. 2007). Since the early 1970s this trend has reversed with forested land being replaced by urban and suburban development and agriculture (Drummond and Loveland 2010). Increasing urbanization and expansion of agricultural land has coincided with a steady increase in temperatures across the region, particularly during the summer, with the most recent decade (2001–2010) being the warmest on record (Kunkel et al. 2013).

Many areas in the Southeast have observed an increase in annual average precipitation over the past century, particularly along the northern Gulf Coast (Kunkel et al. 2013). However, these changes have not occurred equally throughout the year. Summer precipitation has generally decreased across the Southeast (except in Florida), while autumn precipitation has increased, except in the Florida Peninsula. Over the past several decades, there has been an increase in the inter-annual variability of precipitation across the region, with more exceptionally wet and dry years observed compared to the middle part of the twentieth century (Groisman and Knight 2008). At the same time, the frequency of extreme precipitation events has increased (Kunkel et al. 2013). While the causes of these trends are not well understood, they have significant implications for the future of crop production if they continue.

INTERVIEW METHODS

In the summer of 2011, the Southeast Regional Climate Center (SERCC) conducted a series of semi-structured interviews with state climatologists (hereafter referred to as SCs) from Virginia, North Carolina, South Carolina, Georgia, Alabama, and Florida. Collectively, these SCs have over 120 years of experience in the field of climatology, including more than 45 years of service as official SCs. Drawing on these experiences, the goals of these interviews were to: 1) assess the ways in which particular economic sectors in the region are vulnerable to climate variability and extreme events (i.e. challenges); and 2) identify new avenues and opportunities to address these vulnerabilities, particularly within the context of a changing climate.

To help inform the interview process, a preliminary survey was conducted whereby each SC was asked to rank his or her level of expertise in working with a list of sectors, including agriculture, engineering, coastal resources, ecosystems, energy, public health, litigation, tourism, transportation, and water resources. Based on the results of the survey, the sectors chosen for discussion among all six SCs were agriculture, coastal resources, energy, transportation, and water resources. Using a semi-structured approach (Bernard 1995; Crane et al. 2010; Furman et al. 2011), a general list of questions was prepared for each sector to facilitate discussion, but topics were allowed to flow naturally as part of the interview process. This allowed each SC to cover the topics and issues most relevant in their state, while minimizing time spent on topics not germane to the climate-related issues of their citizens and stakeholders. The semi-structured approach was chosen to allow discussion of the wide variety of climate conditions and vulnerabilities across the Southeast, as well as to identify commonalities in each state with regard to current and future impacts of climate variability in different economic sectors. Interviews were conducted either in person or over the telephone, each lasting between one and three hours. In some cases, follow-up interviews were conducted. Each interview was tape-recorded and transcribed, after which the authors reviewed and analyzed the content of the discussions. Interview questions and procedures were approved by the institutional review board (Study #11-0889) at the University of North Carolina at Chapel Hill. In the pre-interview survey, all six SCs ranked agriculture as the sector for which they have the most experience in providing climate service, followed closely by water resources. Therefore, the focus of this paper will be on those discussions centered on agriculture, including the use of water resources in promoting sustainable agricultural practices across the region.

VULNERABILITIES OF AGRICULTURE TO CLIMATE IN THE SOUTHEAST

Agriculture in the Southeast is highly heterogeneous, in response to variations in local topography, soils, land use, and access to transportation, as well as weather patterns. According to the SCs, the wide range of climatic conditions from north to south as well as due to elevation and proximity to coasts has led to much diversity in the number of crops that are cultivated in the region, perhaps more than any other region in the U.S. The North Carolina SC noted that "diversity is one of our strengths—it allows us to adapt more easily" to changes in climate. The Georgia SC also noted that "the greater diversity and year-round production of agriculture across the Southeast make the industry more resilient to climate change compared to other regions of the country." Indeed, many farmers in the Southeast may grow several different crops in a single growing season (for example, wheat followed by soybeans or cotton), taking advantage of different planting and harvesting dates to get the maximum use from their land. In five of the six southeastern states, poultry and egg production are the largest source of agricultural income, followed by livestock production of cattle, swine,

Table 1. Percentage distribution of farm income by different agricultural sectors (excluding forestry) for each of the six southeastern states. Data were obtained from the National Agricultural Statistics Service (United States Department of Agriculture 2014) for the year 2007, the most recent year available online.

	Virginia	North Carolina	South Carolina	Georgia	Alabama	Florida
Poultry & Eggs	33.4	39.6	54.8	59.7	70.5	5.3
Cattle and calves	19.8	2.8	4.5	4.8	9.2	5.6
Milk and dairy	11.4	1.6	2.2	3.7	0.9	5.3
Grains and dry beans	9.3	6.8	9.1	4.2	2.7	0.4
Nursery and sod	8.5	5.6	9.7	4.5	6	27.2
Vegetables	3.2	3.2	5.4	6.5	0.8	18.3
Other and hay	2.7	0.9	2.9	5.2	2.8	6.5
Fruits and nuts	2.3	0.8	1.5	2.8	0.6	27.5
Tobacco	2.3	5.3	3.1	0.8	Not recorded	0.1
Hogs and pigs	2	30.1	3.3	1	1.2	0
Aquaculture	1.8	0.3	0.2	0.2	2.3	0.8
Horses, etc.	1.6	0.2	0.9	0.3	0.3	2.2
Cotton and cottonseed	0.9	2	2	6.1	2.4	0.4
Sheep and goats	0.3	0.1	0.1	0.1	0.1	0
Christmas trees	0.2	0.6	0.3	0	0	0
Other animal products	0.2	0.1	0.1	0.1	0.2	0.5

equines, sheep, and goats (Table 1). Florida is the exception, with the majority of its agricultural income coming from nursery stock, flowers, vegetables, nuts, and fruits, including citrus. Florida's unique mix of products can be tied to a long growing season, accessibility to water, and lack of extreme frosts, particularly across the southern peninsula. While forestry products are not included in Table 1, tree production in the Southeast is considered a form of agriculture, particularly across parts of Georgia and the Carolinas where tree plantations and nurseries are common and provide timber for numerous industries.

Even though the largest share of agricultural income in the Southeast comes from a few large commodities such as poultry, agricultural production covers many different products, including fruits, nuts, and specialty crops like mushrooms, olives, and hops. Southeastern states lead the market in peaches and pecans, even though their overall economic value is small compared to large enterprises like poultry production. Each of these crops is impacted in unique ways by variations in weather and climate. Commodity crops such as corn and soybeans are particularly sensitive to the effects of long-term drought (e.g. months to years in length), and large field sizes make them difficult to effectively irrigate. Long-term droughts also tend to affect broad areas, which can lead to widespread losses across multiple farms. However, most commodity crops are typically covered by crop insurance policies, which protect farmers from some of the financial losses that result from climate-related impacts like water stress. In some cases, insurance incentives may be lucrative enough that farmers will risk planting certain crops even if current and forecasted conditions are unfavorable for production. Agricultural regulations, prices, and field conditions in other parts of the country and around the world also dictate a farmer's decision to plant. As the Georgia SC stated, "markets trump climate," while the Alabama SC noted that "farmers will only grow things on which they can make a profit." On the other hand, most specialty crops are not covered by insurance policies. Since specialty crops comprise a greater proportion of agricultural production in the Southeast compared to other regions such as the Midwest, the resilience of agriculture in the Southeast can be negatively affected. Moreover, even when or if it is available, the cost of crop insurance may be too expensive for some farmers. As a result, much of the economic burden from climatic events is placed directly on individual farmers.

Drought also has significant impacts on both crop and livestock production in the Southeast. Several SCs noted that long-term droughts can decimate the productivity of fruit and nut trees (including peaches, apples, and pecans), which may take years to recover due to the length of time needed for the trees to reach maturity. Drought can also reduce bud production and increase the likelihood of insect and disease outbreaks (Coder 1999; Lopez et al. 2011; Rohla 2012). Pine plantations in drought-stricken areas are also susceptible to insect and disease outbreaks, which can reduce yields and weaken the trees, making them more likely to snap and fall during high wind events (Kloeppel et al. 2003; Klos et al. 2009). Droughts can also negatively affect livestock and poultry by reducing production of pasture and forage and increasing the incidence of diseases through dispersion of dust and bacteria. In addition, the hot and humid conditions that typically prevail across the Southeast during the summer place much stress on water resources due to increases in evapotranspiration and water use through cooling barns used for livestock.

Individual weather events, such as severe thunderstorms and tropical cyclones, can also have a negative impact on agriculture in the Southeast. Several SCs noted that for individual farmers, a single hail storm, flood, or freeze can destroy an entire season's yield. In other cases, these events can significantly reduce the value of certain crops, such as fruits, by damaging their appearance. In fact, the sensitivity of certain crops to individual weather events exceeds their sensitivity to longer-term climate variability and change. Tropical cyclones (i.e. hurricanes and tropical storms) pose a significant threat to agriculture in the Southeast, especially for the many crops in the region that are harvested during the peak of the hurricane season (August–October). The heavy rain from a tropical cyclone can saturate fields, making it difficult for machinery to harvest the crop. Excess rain and moisture can also affect the quality of crops that require ample drying time, such as cotton, hay, and tobacco. As an example, the combination of heavy rain and high winds from Tropical Storm Fay in August 2008 resulted in over $250 million in direct and indirect losses to the agricultural sector across northern Florida and southern Georgia (Flanders et al. 2008). Vegetable crops in the region were particularly affected, with more than 70 percent of the expected production value lost. Even in non-tropical storms, high intensity rainfall can cause erosion of land and movement of fertilizer and agricultural chemicals into streams and coastal estuaries, leading to potential eutrophication and its associated ecological impacts.

Although some of the most visible and costly impacts to agriculture stem from droughts, excess moisture can also lead to agricultural losses from fungal diseases, both in the soil and on the leaves of plants and trees. To combat fungal diseases, as well as insect and pest infestations during dry periods, farmers apply fungicides and pesticides. Both short-term weather and long-term seasonal climate forecasts can be beneficial to farmers in helping to determine when to apply these chemicals so as to minimize their impact on the environment and human health.

In addition to climate, another factor that has increased the variety of agricultural products produced across the Southeast is land ownership patterns. The SCs noted that agricultural land in the region has been decreasing over the past several decades, particularly across parts of Georgia and Florida. Although the average farm size across the Southeast has increased due mainly to the consolidation of row crop operations, it remains considerably smaller than the average farm size in the Midwest and in western regions of the U.S (Moo-Chi 2013). A smaller average farm size allows for greater variety in cropping patterns. The types of crops grown are also dependent on latitude. Since the growing season is shorter at higher latitudes, the variety of cropping patterns is limited. Farmers in these regions will therefore choose crops that are most appropriate for their local climate regime to maximize their economic returns. Other factors that affect agricultural production include soil type and access to water supplies. Since most soil types across the Southeast have relatively low water-holding capacity compared to soils across the northern tier of the U.S., they respond more quickly to changes in precipitation and other hydrologic inputs (Kern 1995). As a result, drought conditions can develop quickly, sometimes in a matter of weeks, particularly if precipitation deficits occur in conjunction with extreme high temperatures. Because of the unique hydrological and geomorphological characteristics of the Southeast, much of the water used for agricultural and commercial purposes is derived from groundwater aquifers. In contrast, northern regions of the U.S. rely mostly on surface water sources (Kenny et al. 2009).

CLIMATE CHANGE AND THE FUTURE OF AGRICULTURE IN THE SOUTHEAST

Recent climate assessments across the Southeast reveal much uncertainty in both short and long-term climate conditions. In the short-term, natural climate variability is expected to exceed climate changes associated with the increase in greenhouse gases (Kunkel et al. 2013). Long-term projections from the middle to the end of the 21st century reveal a general increase in temperatures, with the largest increases observed during the summer. Precipitation projections, on the other hand, are much less certain, as most global and regional climate models fail to agree on the sign and magnitude of precipitation changes through the end of the 21st century (Kunkel et al. 2013). There is also much uncertainty in how changes in precipitation will affect other aspects of the hydrologic cycle, as well as how these changes will interact with changes in land-use patterns and water use. The influence of aerosols and clouds and their feedbacks are also uncertain and could impact future climate in the Southeast. Improvements and advances in technology (e.g. machinery) and land management practices, along with the continued development of new, more productive crop varieties, will have significant effects on the sensitivity of the agricultural sector to climate variability and change and will need to be considered in adaptation strategies and future guidelines for the provision of climate services (Brooks 2013).

Faced with such uncertainty, the SCs stated that the most logical question to ask might be how can farmers in the Southeast *weather* the current trends in climate conditions. Planning timetables for most farmers are only one to two years, except for those who plant tree-based crops (i.e. agroforestry) or have infrastructure needs that require long-term investments (e.g. cooling barns for livestock). As a result, farmers in the Southeast are most interested in how to use short-term seasonal climate outlooks in their planning activities. For example, if the upcoming spring is forecasted to be wetter than normal, farmers may have to delay planting, putting them at increased risk from a fall frost before the crop reaches maturity. Or, if the soils are too dry early in the growing season, germination in the seeds may be reduced or delayed, forcing farmers to plant a secondary crop.

Farmers in the Southeast, particularly across the southern half of the region, are becoming increasingly adept at using ENSO-based forecasts to drive their planning activities and manage their sensitivities to weather and climate. ENSO has been shown to influence crop yields and values. For example, about 25 percent of the value of corn in the Southeast can be explained by ENSO phase (Hansen et al. 1998). Websites such as AgroClimate.org, which was developed by the Southeast Climate Consortium, provide farmers with a suite of decision-support tools, crop models, and agricultural metrics (e.g. chill hours) based on ENSO phase (Breuer et al. 2009). Additionally, other groups, such as pine plantation owners could use ENSO forecasts to help determine which areas of their land to harvest. For instance, if a La Niña is forecasted, bottom lands that are typically too wet may be dry enough to support heavy equipment. Most of the SCs noted that variations in precipitation by ENSO phase are much greater during the cooler months compared to the warmer months of the growing season. As a result, seasonal ENSO forecasts are generally more skillful during the cooler months of the year. However, basic quantitative seasonal forecasts of temperature and precipitation, irrespective of ENSO phase, can still be of great value to farmers across the entire Southeast and during the warmer months of the year (Solis and Letson 2012). Forecasts of the number of tropical storms and hurricanes expected each year, which are provided by the National Oceanic and Atmospheric Administration and research groups at Colorado State University and Florida State University, among others, could also be of benefit to farmers in general planning for harvest conditions. However, the usefulness of those forecasts may be limited due to their lack of information about landfall potential.

Several of the SCs noted that while there is much uncertainty in the expected climate conditions across the region by the end of the 21st century, a continuation of the observed trends and variability in temperature and precipitation will fall within the bounds of extremes that have been observed in the past for at least the next 20–30 years. Therefore, if farmers are able to adjust their existing practices to address current climate variability and extremes, they should be more resilient to the climate trends projected to occur over the next several decades. One trend that is unequivocal is the increase in mean temperatures since the 1970s, which has led to an increase in the length of the growing season. According to the North Carolina SC, many farmers are already taking advantage of longer growing seasons by planting multiple crops and varieties (i.e. dual-cropping). This practice can significantly increase crop yields (Sanford et al. 1973; Wagger and Denton 1988; Hatch et al. 1999). He also noted that this practice may increase in northern parts of the region, similar to the year-round cultivation that is common across Florida. On the other hand, increases in temperature may reduce the number of available chill hours required for certain crops to reach maturity, particularly across parts of southern Alabama, Georgia, and central Florida. In this case, the total yield, quality, and value of the crop may be significantly reduced (Byrne and Bacon 2004).

One adaptive measure that will greatly increase resilience to climate variability and change is irrigation. The use of irrigation in the Southeast has been increasing as farmers recognize its potential for improving yields and sustaining crops during periods of dry weather (Harrison 2001; Goklany 2002; Dukes et al. 2010). This is particularly the case across parts of southern Alabama, Georgia, and northern Florida, where more than 50 percent of crops are currently irrigated. However, unlike other regions, such as the Midwest, widespread use of irrigation across the Southeast has been slow to emerge due to the financial costs, aging infrastructure, inefficient water storage practices, and increasing competition for water resources. This has been costly in some areas. Because of the lack of irrigation in Alabama, the number of acres of row crops has dropped from 12 million in the 1950s to about 2 million today. According to the Alabama SC, "Our rain-fed production simply cannot compete with irrigated crops in surrounding states." Competing interests between agriculture, conservation, recreation, and utilities makes appropriating limited water supplies difficult, especially in vulnerable basins where demand for water is high (e.g. the Apalachicola-Chattahoochee-Flint river basin that stretches across parts of western Georgia, eastern Alabama, and the Florida Panhandle). According to several of the SCs, these limitations have thus far overshadowed the fact that precipitation in the Southeast is much more abundant than other regions that rely heavily on irrigation. In fact, during the driest years of the past century each of the six southeastern states still received over 60 cm (23.6 in) of precipitation, which is similar to the annual *average* precipitation observed across the top six agricultural producing states, all of which rely heavily on irrigation (Figure 2). As a result, much less irrigated water (perhaps as little as a few inches, according to the SCs) is necessary across the Southeast to control moisture levels during critical periods of crop development, such as corn tasseling and fertilization. According to the Virginia SC, "water use in the Southeast is more a management issue than a climate issue." Several of the SCs suggested that a more economically and environmentally sustainable approach to water storage and irrigation may provide farmers in the region with the resources necessary to increase yields. One such approach involves on-farm pond storage of water withdrawn from streams in winter when flows are highest. This water could then be used for irrigation during the summer when precipitation is more variable and dry spells are more likely, thereby minimizing withdrawals from streams when flows are low and demand for water is high.

CONCLUDING REMARKS

Based on their collective experiences working with members of agricultural sector, the six southeastern SCs believe that farmers in the region are well-situated to respond to changes in climate that are likely to occur over the next 20–30 years. While the frequency and intensity of drought conditions may increase in the future, the proximity of the region to moisture from the Atlantic Ocean and Gulf of Mexico will continue to provide adequate precipitation for agriculture and other sectors if it is stored effectively and used efficiently. Recent legislative actions, such as the development of the Agricultural Water Enhancement Program in 2008, have provided greater impetus for farmers to consider more sustainable irrigation and water storage practices. At the state level, tax credit incentives are now available in Alabama for farmers who use off-stream water resources. By sustaining adequate water supplies throughout the year and during periods of droughts, agriculture in the Southeast can become more competitive with other regions in the U.S.

In addition to sustaining adequate water supplies, increases in the length of the growing season combined with ample sunshine and open land will provide farmers in the Southeast with opportunities to maximize agricultural production through dual cropping and the use of new crop varieties. Improvements in land management practices and soil properties and more widespread use of sustainable irrigation can also help in maintaining adequate soil moisture levels, which will increase resiliency to climate variability and change. Increases in temperature may also promote a return of the citrus industry to more northern locations such as Savannah, Georgia and Charleston, South Carolina. Since the mid-1800s, the citrus industry has been confined mostly to south Florida. While this move provided the industry with a buffer from killing frosts, it made the industry more susceptible to the damaging effects of tropical storm winds and citrus diseases that thrive in warm, humid conditions.

The SCs also noted that while changes in climate will provide opportunities for some farmers, they will also create challenges for others. Many farmers will be able to adapt to short-term climate variability

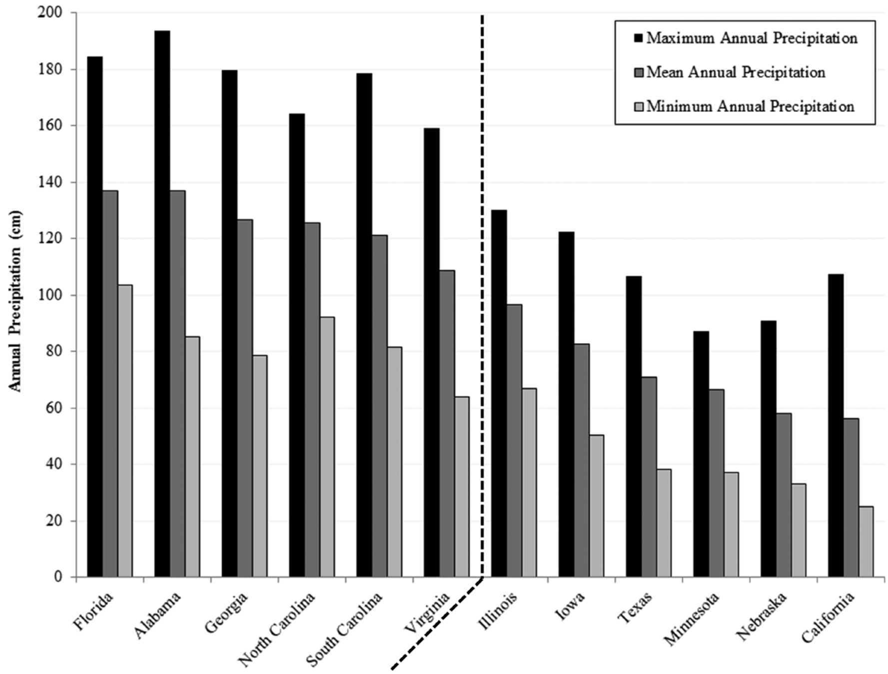

Figure 2. Mean, maximum, and minimum annual precipitation totals from 1895 to 2012 recorded across the six southeastern states compared to statewide average totals recorded across the top six agricultural producing states based on cash receipts from the United States Department of Agriculture (2013). Statewide precipitation data obtained from the National Climatic Data Center.

and change by altering cropping patterns. However, farmers involved in orchard crops and agroforestry will need to consider longer-term changes in climate. For example, peach trees may take up to four years to produce fruit after planting, but once established may continue to provide fruit for many years, even during periods where growing conditions are less favorable (Kamas et al. 2010). Pecan trees may take up to 10 years to become fully productive (Wells 2012), while loblolly pine trees may not be ready for harvest until 35 to 50 years after planting (Rawlings 2009). Another challenge currently faced by farmers that will continue to affect the agricultural sector is building resiliency to extreme heat. Several crops in the Southeast are already grown near their thermal limits. Increases in temperature, including increases in extreme heat events, may negatively affect yields and values due to stunted growth and degraded nutritional quality. One prominent example is corn, which is particularly sensitive to extreme temperatures—generally above 35°C (95°F)—during pollination and silking. However, moisture inputs from irrigation can allow most crops, including corn, to tolerate short periods of extreme heat.

In addition to climate, increases in population will lead to greater competition for water resources across the Southeast, particularly in the Piedmont region and along the coast where population growth is especially high. In contrast, rural areas are experiencing decreases in population, which may reduce water needs in those areas. Changes in farm size may also lead to changes in resilience to climatic effects through the ability to vary crop choices and cropping patterns. It is also important to recognize that changes in climate conditions in other agricultural regions of the U.S. and the world will have effects that will undoubtedly influence both national and international markets. For example, the extensive drought that began in 2011 across much of the central and midwestern U.S. resulted in significant shortages of corn. These shortages caused prices to spike, which resulted in major hardships to producers in the region, but improved the market for producers in other regions such as the Southeast. Indeed, several SCs noted that climate is one of several factors that affect agricultural markets. Other factors include politics, natural disasters, and socioeconomic conditions. However, the combination of favorable climatic conditions and diversity in agricultural production makes the Southeast unique in its ability to adapt to both current climate variability and potential future changes in climate.

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