North Carolina Agriculture

FUTURE CHALLENGES & ADAPTING TO A CHANGING CLIMATE

Abbi McKann
Park University

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Introduction

North Carolina's climate is changing, and local communities and farmers face an extremely difficult adaptation process. Without meaningful long-term planning—and action—agriculture-based economies in the state may collapse. Agriculture is both critical to many county economies and vulnerable to extreme weather, making it an important consideration in climate change adaptation. Reactive adaptation, such as increasing water or fertilizer application, is insufficient to mitigate the economic damage that projected climate change will bring—in fact, these actions chronically increase water scarcity. Resources that are taken for granted today will be gone tomorrow, and investments that are put off for future generations will be out of reach for agriculture-dependent economies within decades. Climate change is a future, historical and ongoing reality—not a far-distant possibility. The southeast, along with the world, has been warming steadily since the 19th century due to human CO2 emissions. In the middle of the 20th century, the region went through a natural cooling period which offset human-caused warming, but as the period ended in the 1990s, average temperatures have steadily increased. Winter and overnight temperatures have increased more than maximums. At the same time, extreme weather has become more frequent and severe (Figure 1).

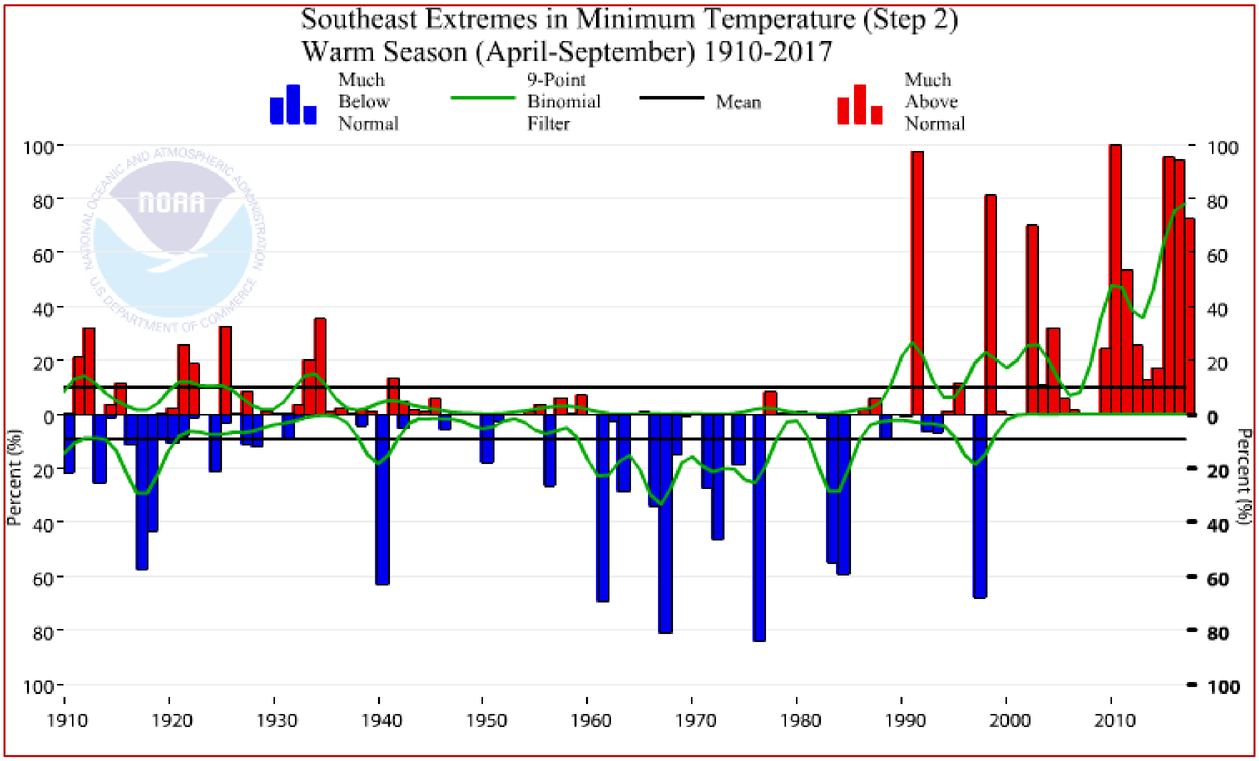


Figure 1

Summary

The purpose of this report is to provide local governments and farmers a starting point for county- and farm-level plans for mitigating harmful effects of climate change on agriculture. Economically-important crops in North Carolina will become increasingly risky and expensive to grow as climate continues to change (Asseng, p.140, 2013). Corn and soybeans—the second and third most valuable crops in the state—are today grown in areas where maximum average temperature is projected to exceed their failure threshold by the end of the century. Higher temperatures and lower rainfall in the growing season can be partially compensated for with fertilization and irrigation, but generous fertilization threatens, and irrigation depletes, water resources. Competition for water is already a major concern as population grows, groundwater and reservoirs are polluted, and aquifers drained.

Solutions exist. Citrus will become more profitable as average minimum winter temperatures rise. Drip irrigation, if installed soon and on a large scale, could help preserve finite water resources while protecting crops from heat and water stress. Communities and growers with subprime soil are finding a way out through North Carolina's fast-growing solar energy industry, which provides better returns to acreage than corn, and with less risk.

Methods

Information in this report comes either directly from US government agencies or is based on analysis of data published and quality-controlled by the same agencies.

Data Sources

Information on climate projections and consequences at a regional scale comes primarily from the United States Department of Agriculture (USDA) and the 13-agency Fourth National Climate Assessment (NCA4) Climate Science Special Report (CSSR). CSSR is the most recent report published as part of the US Global Change Research Program (USGCRP) and is an authoritative, up-to-date, and comprehensive account of historical and projected climate change.

Another key part of this report is primary research conducted through a Geographic Information System (GIS). GIS is a computer platform for the processing and analysis of *spatial data*, or facts pertaining to a place.

Three datasets were used to estimate the impact of future climate change on the long-term productivity of economically-important North Carolina crops:

NASA NEX-DCP30. Climate scenarios used were from the NEX-DCP30 dataset, prepared by the Climate Analytics Group and NASA Ames Research Center using the NASA Earth Exchange, and distributed by the NASA Center for Climate Simulation (NCCS). This dataset is the average prediction of 33 Global Climate Models (GCMs), statistically processed to increase spatial resolution. This dataset reliably reproduces past climate at 900-meter^2 and 1-month resolution. NASA has very high (95%) confidence in the model's temperature predictions. In the Southeast, changes in how air from the north and south circulate could affect predictions of precipitation. Thus, the Southeast may be wetter or drier annually than predictions show, though increasing dryness during the growing season is very likely. This model also assumes that greenhouse gas emissions will go unchecked and continue to increase, though at a slower rate, through the 21st century. A final caveat: recent research indicates that ice shelfs are melting more rapidly than expected. A rapid collapse in Antarctica may be imminent. Such a collapse would greatly accelerate global warming by increasing the amount of solar energy the earth absorbs.

UN FAO Ecocrop database. The United Nations Food and Agriculture Organization crop database contains 2300 plant species grown worldwide. Ecocrop entries include soil, water, and temperature requirements. Of the crops currently cultivated in North Carolina corn/soybeans, tobacco, cotton, and tomato were assessed relative to current and projected climate for the state. 20 other crops, each of local significance to climates similar to North Carolina's projected future, were also assessed for future viability.

USDA National Agricultural Statistics Service (NASS) cropland data. This 900-meter^2 resolution dataset uses satellite imagery processed to identify crop types based on their reflectance of certain colors. The most recent publication (2015) was used to validate crop suitability predictions.

Suitability Analysis

The purpose of this research is to indicate where changes in returns to key crops will occur under projected climate change. Heat and drought tolerance comes at the cost of productivity, quality, or both. Fertilizer and irrigation are expenses that reduce net profit. Crop failure can be mitigated, but there is always a cost. Therefore, when suitability for a crop changes in an area, so will its profitability. (Assuming nothing else changes). A reduction in suitability also indicates increased stress on water resources as growers seek to mitigate losses.

The analysis was performed using 2015 and 2099 NEX-DCP30 data. 2015 was chosen for recency and representativeness: monthly temperature and precipitation were similar in this year to the most recent 30-year average (1987-2017.) Another reason for using 2015 as a baseline is that the most recent cropland data is from the same year, so errors resulting from changing crop planting are avoided.

Site Criteria

Criteria for crop performance was developed based on Ecocrop *cardinal numbers,* which indicate a crop's optimal and extreme ranges for temperature and precipitation. NEX-DCP30 data was then analyzed to determine, at 900-meter^2 resolution, how well a given crop would grow and produce. To estimate conditions likely to stress crops, precipitation and maximum average daily temperature were averaged for June-July-August. Areas were then ranked by suitability.

Site Suitability Categories

Optimal, where both temperature and precipitation are within optimal range during the growing season.

Sub-Optimal, where either temperature or precipitation is outside of optimal range but within extreme range.

Marginal, where both temperature and precipitation are within extreme ranges.

Poor, where both temperature and precipitation are in the crop-failure range.

Scope and Limitations

Model outputs for crop suitability in 2015 were compared to the distribution of cropland in that same year and the model was found to be highly predictive. Differences are noted in the crop analysis and are usually a function of soil type. Determining crop suitability requires data on a scale unsuitable for analysis or presentation at a statewide level. This model is intended as a starting point for local communities and farmers planning for climate change. Because soil will not change over the next century, and because growers know their soil very well, this report is limited to detailing the effects of climate alone. The timing of seasons, frosts, and temperature thresholds, which are extremely important to growers, are also not treated in this report, because spatial variation is too great to examine seasonal timing at this scale.

There are assumptions which, if altered, would affect some of the conclusions of this report. NEX-DCP30 may over- or underestimate precipitation changes. There are also unknowns concerning national and global climate policies and the potential for very rapid climate change pulses driven by feedback from warming poles. For this report, these factors are ignored, as are questions about changing demand and prices for crops. Because net profit is defined as revenue less expenses, future price trends have the potential to either increase or decrease the viability of the assessed crops. Though these effects are beyond the scope of this report, it is worth noting that prices for crops sold locally are expected to fall, while staples sold globally may increase in value (Asseng, p. 139, 2013).

Climate Trends & Projections

The climate of North Carolina is becoming warmer overall, but also more extreme (*US Climate Extremes Index,* 2018). Droughts, floods, and storms are more frequent and severe than they were a century ago (Carter et al., p. 404, 2014; Walthall et al., p. 63, 2013). Winters and summer nights have warmed more than summer days—enough to prompt the USDA in 2012 to update Hardiness Zones drawn in 1990 (figure 2). The science is clear: these trends will continue and accelerate through the end of this century (Wuebbles et al., 2017).

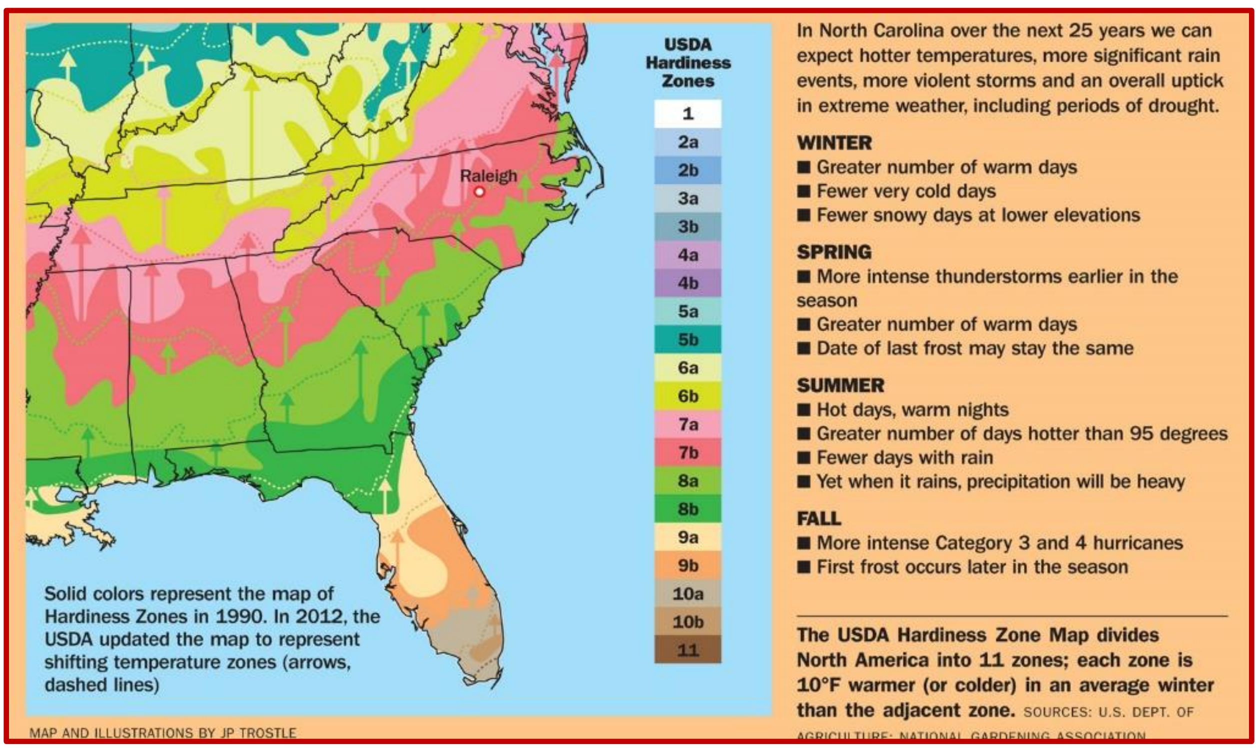


Figure 2 *The migration of USDA hardiness zones. Credit: JP Trostle https://www.indyweek.com*

Projections & Implications for Agriculture

Excluding parts of Appalachia, average low temperatures in the winter will be above freezing by the end of the century—an increase of nearly 6 degrees Fahrenheit (F) on average. Local variation is significant, and some areas will increase over 8F. Precipitation in the fall, winter, and spring is expected to continue to increase significantly. Storms, already observed to be increasingly common and severe, will likely be more frequent (Easterling et al., 2017).

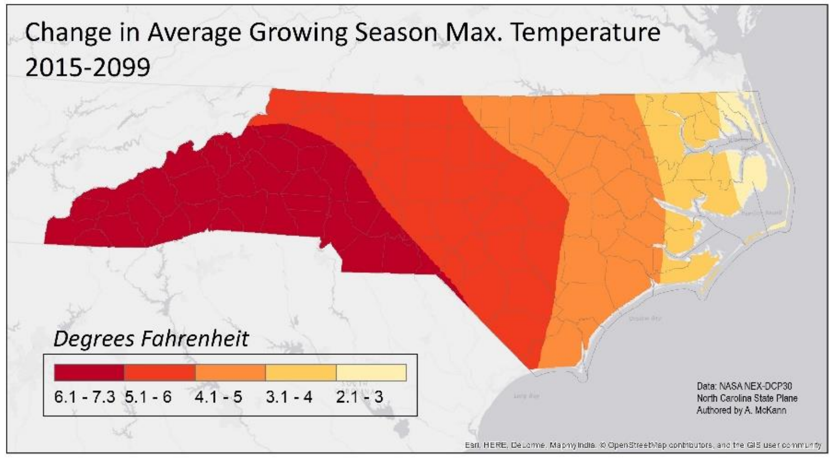


Figure 3

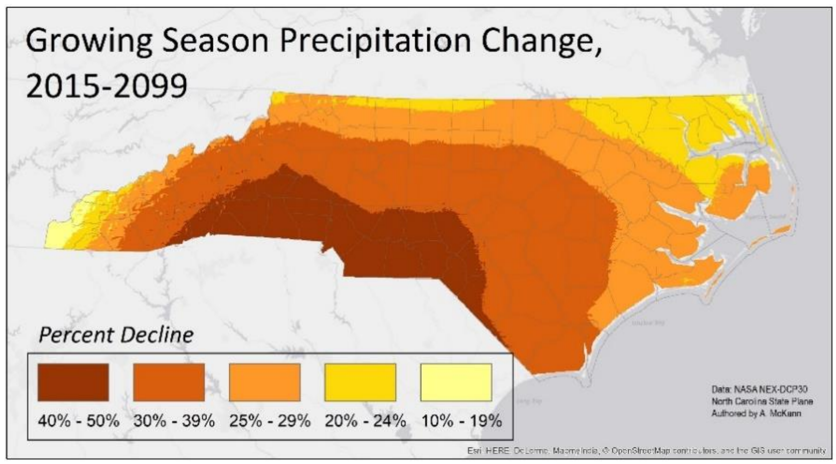


Figure 4

Consistent with recent trends, summer nighttime lows will warm more than daytime highs. Statewide, summer lows will be 7.1F warmer while highs will increase 5.4F. Local variation in these new normals will be significant. The greatest increase will be in the southern piedmont and mountain regions, where average summer highs will be as much as 7.2F warmer than at present (see figure 3). Summertime rainfall is expected to decrease about 30% on average, with extremes in the southwestern Piedmont and the northern coast (figure 4). The distribution of summertime rainfall will also be more sporadic: extreme rain events and will become more common with intervening periods of drought more likely (Easterling et al., 2017).

CO2 and Ozone

CO_2 levels will continue to rise through the 21st century, even if all emissions by humans cease, largely because decay is more rapid under higher temperatures. In the far north, permanently frozen ground is already thawing, allowing the organic matter it contains to decompose. Plants, which use CO_2 to store energy from the sun, benefit from higher levels of the gas through more efficient energy storage (which translates to more vigorous growth) and increased resistance to heat and water stress. Not all plants benefit equally, however. Crops originating in warmer climates—which includes most crops grown in the state, with the notable exception of soy—respond little, or not at all, to increased CO_2 levels. Ground-level ozone damages crops and reduces yields. Ozone levels are projected to increase throughout the piedmont and coastal regions as temperatures rise (Walthall et al., pp. 49-52, 2012).

Weeds, Pests, and Disease

Weeds, already more vigorous than cultivated crops, are substantially more prolific under higher CO_2 concentrations (Asseng, p. 136-137, 2013). Warmer minimum temperature in the winter and during summer nights benefit insect pest by reducing dormancy and die-off. Wet, warm winters are ideal for diseases already prevalent in the state and may open the door for new ones (Walthall et al., pp. 46-51, 2012).

Drought and Water Scarcity

Drought is already a serious concern in North Carolina (Asseng, p.129, 2013). Dryland crops are already cultivated under water-stress conditions in much of the piedmont, and increasing temperature maximums during the growing season, along with erratic and overall lower rainfall, will make irrigation a necessity. At the current trajectory, however, much of North Carolina will be without water by the end of the century (Henderson, 2015).

Water resources in North Carolina are under strain (Semuels, 2017). In the mountains, decreasing rainfall reduces the rate at which aquifers, reservoirs and groundwater are replenished. In the piedmont, aquifers are being drained by demand from industry, agriculture, and fast-growing cities. Piedmont groundwater is also increasingly contaminated from poorly controlled industrial and agricultural run-off waste (Semuels, 2017). On the Coastal Plain, over-drawn wells are subject to saltwater intrusion, a process whereby brackish water replaces fresh as wells near the sea are depleted. Sea level rise, projected at 2-8 feet by end-of-century, is already hastening the decline of Coastal Plain water availability. The quality of groundwater in this region is even poorer than that of the Piedmont (Parker, 2016; Roberson, 2012).

Aside: Solar Farms in NC

North Carolina is poised to become the second-largest generator of solar energy in the country. Climate is one reason. Also influencing the trend is the waning viability of coal, and government incentives. On top of the federal government's 30 percent tax credit for investment in renewable energy, North Carolina offers a 35 percent state tax credit. Landowners typically earn $500-1000 per acre per year (*Cypress Creek*, 2016). For comparison, average 2017 net profit for corn grain production in the state was $83.73 per acre (USDA/NASS, 2018).

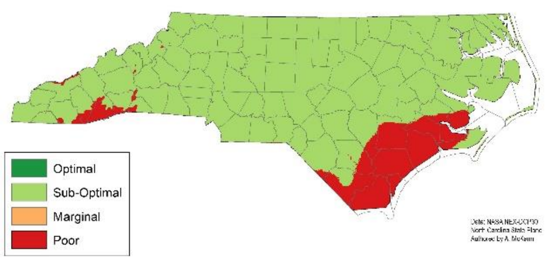
Key Crops: An Assessment

The following conclusions and observations are the result of a GIS-based analysis of climate change in North Carolina and its effects on the distribution of suitable sites for corn and soybeans, tobacco, cotton, tomatoes, and oranges. The climate model used is NASA NEX-DCP30 for RCP8.5 (higher emissions) scenario.

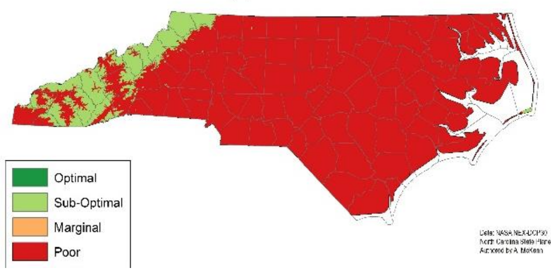
Corn and Soybeans

North Carolina produces over $1.1 billion worth of corn and soybeans annually (USDA/NASS, 2018). Because the crops are grown in rotation and have near-identical climate requirements, they are analyzed together in this report. Based on this analysis, most of North Carolina is sub-optimal for corn and soybean cultivation. The southern Coastal Plain is ranked as poor due to excessive rainfall during the growing season, the timing of which is usually unproblematic. In 2099, the model predicts the entire state, excepting the mountains, will become poor for corn and soybean cultivation. Mountain soils and slopes are not suitable for crops in general, but these factors are beyond the scope of this assessment. The shift from sub-optimal to poor ranking across the state is attributed to average maximum temperatures above crop-failure thresholds during the growing season. It will conceivably be possible to grow heat-tolerant (and thus less productive) varieties in 2099, though predicted sub-optimal rainfall will necessitate irrigation.

Corn Suitability, 2015



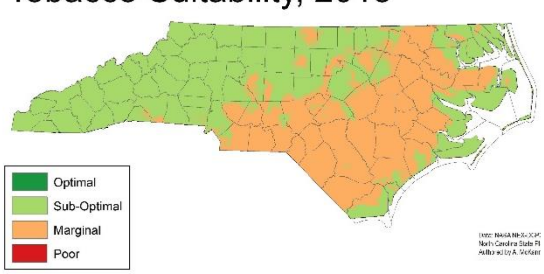
Corn Suitability, 2099



Tobacco

Tobacco is the single most valuable crop in the state, generating $700-900 million a year (USDA/NASS, 2018). In 2015, the western Piedmont is assessed as sub-optimal; from the sandhills

Tobacco Suitability, 2015



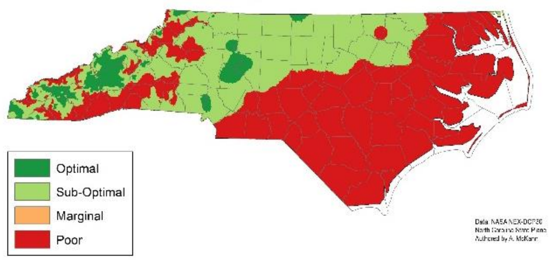
Tobacco Suitability, 2099

east, marginal (due to insufficient rainfall); and along the coast and in the mountains, sub-optimal. Extreme weather and saline soils make the coast poor for tobacco. In the Mountain region, burley tobacco—a variety needing cooler temperatures—is grown. Note that tobacco production is concentrated in the eastern Piedmont region, where precipitation is marginal. Soil explains this distribution; irrigation compensates for low average rainfall. In 2099, the model suggests the southern Piedmont will become poor for tobacco cultivation due to excessive growing-season heat. Nearly the entire Piedmont region is projected to become marginal, with the southern third of the region becoming poor for tobacco cultivation. Mountain region tobacco farms may be able to shift production to varieties currently grown in the Piedmont and Coastal Plain, though irrigation will likely be needed.

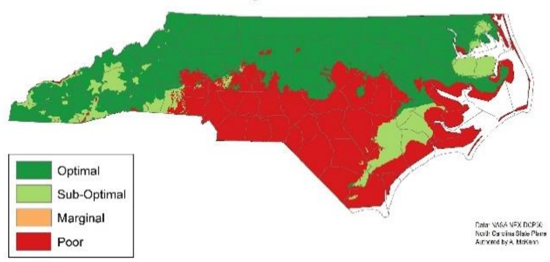
Cotton

Cotton yields over $200 million a year in revenue for the state (USDA/NASS, 2018). Originating in hot, arid climates far from the ocean, cotton is tolerant of heat and drought but requires overnight chilling to produce. For this reason, suitability for cotton was assessed with the added input of average minimum growing-season temperature. In 2015, excessive rainfall makes the coast and southern Piedmont poor for cotton production. The western and northern Piedmont appear most suitable, generally classified as sub-optimal with four optimal zones identified (most notably in the central-west Piedmont.) This pattern is consistent with the distribution of cotton cropland in the state, though more is grown near the coast than expected due to excessively-drained soil which compensates for excess rainfall. In 2099, the model indicates condition become optimal in the north and west Piedmont, northern Coastal Plain, and sub-optimal in the southern Coastal Plain about 10 miles from the shoreline. The improvement in conditions in these areas is attributed to decreased rainfall and increased maximum temperatures.

Cotton Suitability, 2015



Cotton Suitability, 2099

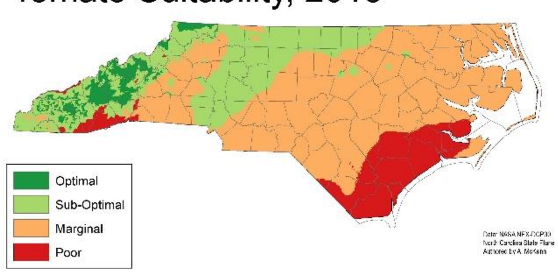


Much of the Piedmont remains poorly suited for cotton because of high overnight temperatures. This analysis suggests that the profitable growing region for cotton may expand inland as growing-season temperatures rise, but only where nights remain sufficiently cool.

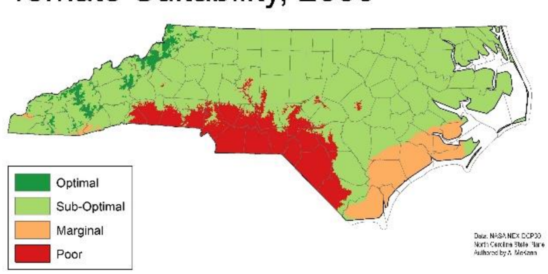
Tomato

Tomatoes grown in the open earn about $40 million a year and are profitably grown throughout the state (USDA/NASS, 2018). The model indicates that

Tomato Suitability, 2015



Tomato Suitability, 2099

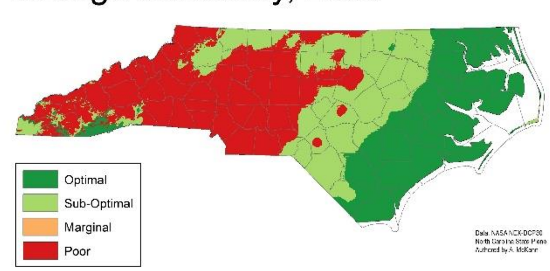


at present the Coastal Plain is poor to marginally suited, the Piedmont is sub-optimal or marginal, and the Mountain region ranges from optimal to sub-optimal. Cloud cover, which is not accounted for in this analysis, limits actual productivity in the mountains. In 2099, the model projects the southern Coastal Plain to become marginal while the northern coast will be sub-optimal; the southern Piedmont to become poorly suited; and the mountains to be predominantly sub-optimal. These changes are attributed to excessive heat, which points to a likely need for compensatory application of water. Unfortunately, tomato quality is highly sensitive to moisture levels, so although irrigation may preserve the quantity produced it will be at the expense of quality and value. Heat-tolerant varieties exist and may be a more sustainable compromise.

Oranges

Due to cold intolerance, oranges are not commercially produced in North Carolina, though varieties hardy to USDA zone 7 (5F) exist. The model indicates the entire state to be poorly suited in 2015 (map omitted). Oranges are examined with the added criteria of average minimum winter temperature above freezing. In 2099, the analysis indicates the Coastal Plain will become optimal, while most of the northern and eastern Piedmont will be sub-optimal. Cold-hardy varieties would also be viable throughout the Piedmont, where average minimum temperatures are projected at approximately 30F. Oranges are under serious threat from climate change in Florida and other tropical/subtropical regions where they are commercially produced.

Orange Suitability, 2099



Conclusions & Recommendations

Important steps can be taken immediately to adapt the state's agricultural practices to climate change. These steps are also sensible in a climate-constant scenario. Broadly, local communities will benefit from incentivizing growers to:

- *Demonstrate better stewardship of soil and water resources.*
- *Diversify crop types to build adaptive capacity in crops and distribution networks.*
- *Transition subprime agricultural land to other uses.*

Preserving Water Resources

Managing agricultural runoff is important to preserving North Carolina's continued access to drinkable water. Planting buffers consisting of trees, shrubs and grass at the margins of fields helps to filter runoff. Applying the correct amount of fertilizer at the right time reduces potential runoff and lowers production cost. Local governments can augment USDA education programs with enforced ordinances aimed at protecting water resources (EPA, 2013).

Corn

It is time to consider intentionally reducing the importance of corn in the state. North Carolina is particularly vulnerable to erosion and increasing intensity and frequency of extreme rainfall events will accelerate soil loss. Crops that leave soil exposed, such as corn, accelerate soil loss. Corn also requires intensive fertilization which may contaminate runoff and threaten groundwater resources. As the state's climate becomes warmer and drier, growers will increasingly turn to irrigation and fertilization to reduce losses, putting further stress on water resources at exactly the time when consumption must be curtailed. Though it is not the place of local governments to dictate what crops are to be grown, incentives to alter cropping strategies are powerful tools. Increasing water prices is within the purview of local government and may be particularly effective in combination with modest subsidization of specialty crops such as okra, asparagus or citrus. Subprime land should be considered for conversion to solar energy production. Local governments can help educate and make it easier to gain permitting; communities may also be able to bargain collectively for better rates on long-term land leases.

Tobacco

Tobacco is a valuable crop and though conditions will remain suitable—or even improve in the mountains—water requirements will increase. At a minimum, drip irrigation should be used to reduce water waste and counties can encourage investment in modern irrigation systems by issuing vouchers. Near the coast, crops currently planted in tobacco could conceivably begin to be transitioned to citrus within a few decades. Land considered subprime for agriculture will be most affected by climate change. County-level vulnerability assessments are needed to determine priorities for altering land-use types. A particularly attractive option for farmers seeing declining yields is leasing land for solar energy generation.

Cotton

Cotton may become less viable in the Coastal Plain, where water resources are increasingly limited. However, the model suggest that the northern Piedmont region will become better suited to cotton cultivation. Precision irrigation and safeguarding of water supplies are requisite to this possibility.

Oranges

A transition to orange production may be an attractive option for several reasons. First, as minimum temperatures rise, higher-yield (less cold-hardy) varieties may be planted. Second, oranges are more drought-tolerant than the crops they would replace, and ground cover may be grown (or allowed to grow) to reduce runoff, erosion, and evaporative moisture loss. Third, global orange production is predicted to come under serious pressure due to climate change. If demand falls less than supply, prices will rise, and even cold-hardy varieties may earn worthwhile profits.

Closing

Climate change will disrupt North Carolina agriculture and test the state's resilience. Counties, communities, and farmers who are already struggling will be affected most, because their resources are already strained. But with change comes opportunity. Predicted supply shortages for citrus, for instance, may be a blessing for North Carolina growers needing to shift production away from intensive annual crops. Solar energy, supported by state and national policy action and increasingly in demand as coal becomes more unprofitable, is a boon for growers whose crop returns no longer pay the bills. The changing climate is going to cost our communities, and we have a choice: pay less now, or pay more later.

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