North Carolina Agriculture: Impacts of Climate Change

Abbi McKann GIS II Park University

NC Climate Change

North Carolina's climate is changing, and local economies and farmers are in trouble. Agriculture is both critical to the state economy and vulnerable to extreme weather, making it a critical consideration in climate change adaptation. Short-term planning is insufficient to mitigate the economic damage that projected climate change will bring. 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. The southeast, along with the world, has been warming steadily since the 19th century due to human CO2 emissions. Winter and overnight temperatures have increased more than maximums. At the same time, extreme weather has become more frequent and severe.

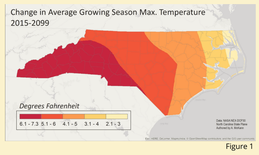


Figure 1

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. The science is clear: these trends will continue and accelerate through the end of this century (Wuebbles et al., 2017).

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. Winter storms, already observed to be increasingly common and severe, will likely be more frequent (Easterling et al., 2017).

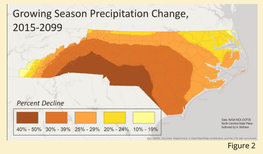
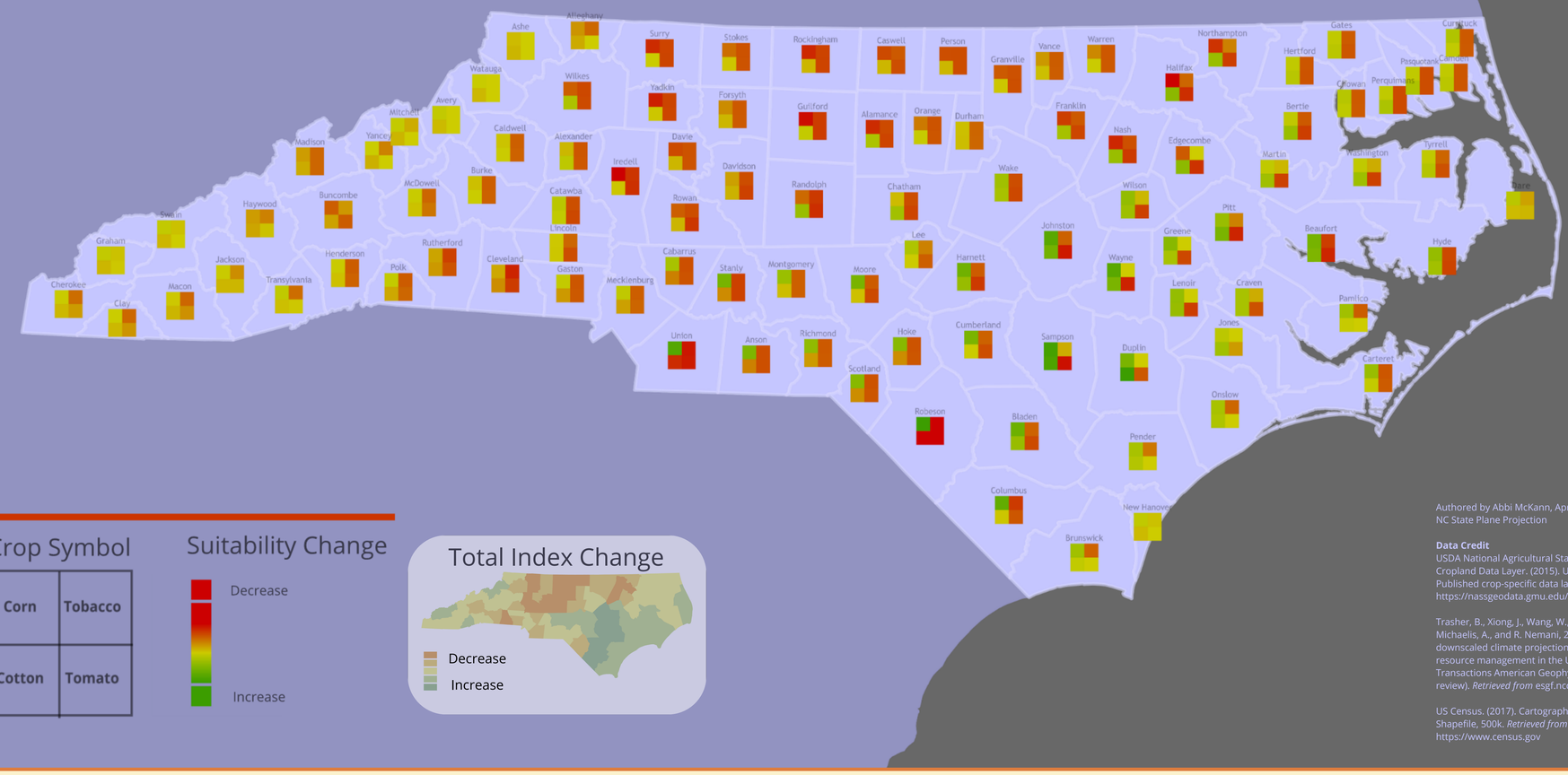


Figure 2

In keeping 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 (Figure 1). Summertime rainfall is expected to decrease about 30% on average, with extremes in the southern Piedmont and the northern coast (Figure 2). The distribution of summertime rainfall will also be more sporadic: extreme rain events will become more common with intervening periods of drought more likely (Easterling et al., 2017).

Change in Climate Suitability, 2015 - 2099

Four Key NC Crops by County



Authored by Abbi McKann, April 2018
NC State Plane Projection

Data Credit
USDA National Agricultural Statistics Service Cropland Data Layer. (2015). USDA/NASS Published crop-specific data layer. Available at https://nassgeodata.gmu.edu/CropScape/

Trasher, B., Xiong, J., Wang, W., Melton, F., Michaelis, A., and R. Nemani, 2013. New downscaled climate projections suitable for resource management in the U.S. Eos, Transactions American Geophysical Union (in review). *Retrieved from* esgf.nccs.nasa.gov

US Census. (2017). Cartographic Boundary Shapefile, 500k. *Retrieved from* https://www.census.gov

PURPOSE

The purpose of this research is to model changes in NC agriculture under projected climate change and represent 1) distributional changes in suitability for key crops and 2) qualitative by-county impact. The conceptual framework employed is simple: Heat and drought tolerance comes at the cost of productivity, quality, or both. Fertilizer and irrigation are expenses that reduce net profit. Though crop failure can be mitigated, there is always a cost, and so 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.

DATA

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 derivative prediction of 33 Global Climate Models (GCMs), downscaled to increase spatial resolution.

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. The four most important NC crops (corn, tobacco, cotton and tomato) were assessed. Several others, not currently grown in the state, where also assessed for potential viability.

USDA/NASS CDL
This dataset uses satellite imagery processed to identify crop types based on their reflectance of certain colors. The most recent publication available (2015) was used.

METHODOLOGY

NEX-DCP30 is published by variable in NetCDF format. Monthly precipitation, minimum temperature and maximum temperature datasets for 2015 and 2059-2099 were preprocessed in R and ArcGIS. Monthly slices of each variable for 2015 and 2099 Dec-Jan-Feb and Jun-Jul-Aug were extracted as individual raster datasets. 2015 was chosen as a baseline because it is representative of current climate normals and to eliminate errors due to change in crop plantings over time when comparing predictions to CDL. Four break-values for suitability, culled from FAO Ecocrop data, were used for each variable. They are the "cardinal numbers": absolute minimum, optimal minimum, optimal maximum, absolute maximum.

Using these values as criteria suitability rasters for each variable were created (using reclassify), then combined (multiplied using raster calculator) for each assessed crop in 2015 and 2099. The 2015 result was then validated against the distribution of crops for that year as estimated by USDA/NASS and was found to be predictive (maximum error was for tobacco at approximately 10% disagreement).

A by-county total suitability change map was then created for each crop. 2015 and 2099 suitability rasters were extracted using CDL cultivated, pasture and fallow land as a mask. Each suitability category was then extracted using reclassify, then summed (with 50% weight applied to optimal category) and the 2015-2099 difference found with raster calculator. The rasters were then summed by county using zonal statistics. The by-county change rasters were then extracted to points (to reduce processing time) to be spatially joined to a Census county feature class. Figure 3 offers a visualization of my methodology.

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.

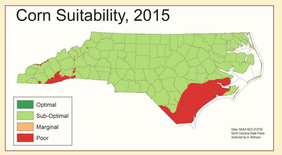
Marginal, where both temperature and precipitation are within extreme ranges.

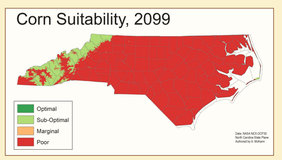
Poor, where either temperature or precipitation is outside of extreme range.

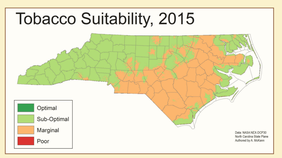
RESULTS & DISCUSSION

This model indicates that suitability for all four key crops assessed will decrease during this century due to climate change. The spatial distribution of the changes is uneven, however, and the preferred growing regions appear to shift within the state. Corn/soybeans are the worst affected—a concerning observation considering that together these crops are the largest contributor to state agriculture income. Tobacco, the single most valuable crop in the state, is modeled as becoming far less profitable in the Coastal Plain where the preponderance is grown. A minority is grown in the Mountain region where suitability will increase, indicating a possible intrastate welfare shift. Similarly, the growing region for cotton shifts north. One limitation of this model is that water resources are not considered. Most of NC faces increasing water scarcity, but the viability of increased irrigation to mitigate heat/water stress certainly varies across the state. The analysis does give credence to the proposition that water resources must be proactively managed to stave off serious consequences in coming decades. In this regard the state is seriously delinquent. Beyond water mining and groundwater pollution, hydrological modeling and water crisis prevention plans mandated by the legislature following the 2002 drought are yet to be completed. Another major limitation of this model is the ordinal nature of the analysis. This could be addressed in further research by incorporating soil-yield, climate-yield, and input-climate relationships. The logical scale would be basin or sub-basin, and Esri offers access to preprocessed, analysis-ready SSURGO datasets at this scale. Fuzzy Set membership and Analytic Hierarchy Process are excellent methods that could be employed to improve predictions. Economic impact at state-and-below levels could be modeled once relationships were quantified. This research primarily points to areas and crops of greatest concern where further research, and proactive adaptation, are most urgent.

Right: 2015 and 2099 suitability maps for corn and tobacco.







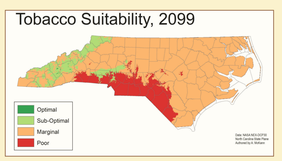
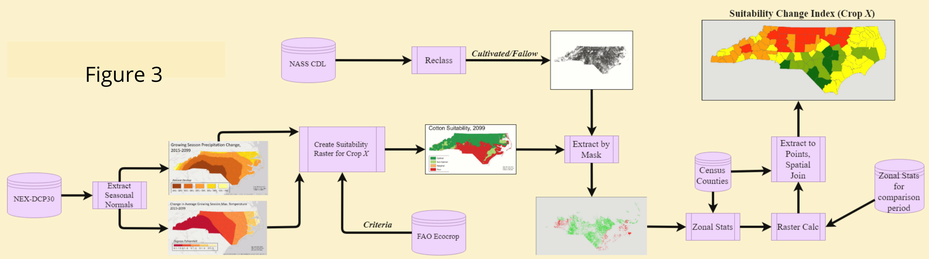


Figure 3



References

Asseng S., Bartels, W., Boote, K., Breur, N., Cammarano, D., Fortuin, C., ... Solis, D. (2013). Agriculture and Climate Change in the Southeast USA. In K.T. Ingram, K. Dow, L. Carter & J. Anderson (Eds.), Climate of the Southeast United States (pp. 128-164). Washington, DC: Island Press. doi: https://doi.org/10.5822/978-1-61091-509-0_7

Carter, L. M., Jones, J. W., Berry, L., Burkett, V., Murley, J.F., Obeysekera, J., ... Wear, D. (2014). Ch. 17: Southeast and the Caribbean. Climate Change Impacts in the United States. In J. M. Melillo, T. Richmond, & G. W. Yohe (Eds.), The Third National Climate Assessment (pp. 396-417). Washington, D.C.: U.S. Global Change Research Program. doi:10.7930/J0NP22CB

Easterling, D.R., Kunkel, K.E., Arnold, J.R., Knutson, T., LeGrande, A.N., Leung, L.R., ... Wehner, M.F. (2017). Precipitation change in the United States. In [Wuebbles, D.J., Fahey, D.W., Hibbard, K.A., Dokken, D.J., Stewart, B.C., & Maycock, T.K. (Eds.) Climate Science Special Report: Fourth National Climate Assessment, Volume I (pp. 207-230). Washington, DC: U.S. Global Change Research Program. doi: 10.7930/J0H993CC

UN Food and Agriculture Organization Ecocrop database. (2018). Ecocrop.fao.org. Retrieved 22 April 2018, from http://ecocrop.fao.org/ecocrop/srv/en/

Roberson, R. (2012). Saltwater intrusion threatens eastern North Carolina crops. Southeast FarmPress. Retrieved 24 April 2018, from http://www.southeastfarmpress.com/management/saltwater-intrusion-threatens-eastern-north-carolina-crops

Semuels, A. (2017). North Carolina: Where the Government Has Already Weakened Environmental Protections. The Atlantic. Retrieved 20 April 2018, from https://www.theatlantic.com/business/archive/2017/04/the-saga-of-north-carolinas-contaminated-water/521211/

Thrasher, B., Xiong, J., Wang, W., Melton, F., Michaelis, A., & Nemani, R. (2013). New downscaled climate projections suitable for resource management in the U.S. Retrieved 3 April 2018, from https://esgf.nccs.nasa.gov/

U.S. Climate Extremes Index (CEI) | National Centers for Environmental Information (NCEI). (2018). Ncdc.noaa.gov. Retrieved 12 April 2018, from https://www.ncdc.noaa.gov/extremes/cei/graph/se/5/04-09

USDA National Agricultural Statistics Service Cropland Data Layer. (2015). USDA/NASS Published crop-specific data layer. Available at https://nassgeodata.gmu.edu/CropScape/

USDA/NASS 2017 State Agriculture Overview for North Carolina. (2018). Nass.usda.gov. Retrieved 10 April 2018, from https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=NORTH%20CAROLINA

Walthall, C.L., Hatfield, J., Backlund, P., Lengnick, L., Marshall, E., Walsh, M., ... Ziska, H. 2012. Climate Change and Agriculture in the United States: Effects and Adaptation. USDA Technical Bulletin 1935. Washington, DC: USDA. Retrieved 24 March 2018, from http://lib.dr.iastate.edu/ge_at_reports/1

Wuebbles, D.J., Fahey, D.W., Hibbard, K.A., DeAngelo, B., Doherty, S., Hayhoe, K., ... Weaver, C.P. (2017). Executive summary. In [Wuebbles, D.J., Fahey, D.W., Hibbard, K.A., Dokken, D.J., Stewart, B.C., & Maycock, T.K. (Eds.) Climate Science Special Report: Fourth National Climate Assessment, Volume I (pp. 12-34). Washington, DC: U.S. Global Change Research Program. doi: 10.7930/J0DJ5CTG