Evaluating the Ability of Drought Indices as Predictors of North Carolina Agricultural Yields

Kelly Chapman, Seung Joon Lee, Minju Nam

North Carolina State University

Adviser: Dr. Brian Eder   Client: North Carolina State Climate Office

Introduction and Methodology

North Carolina's agricultural industry contributes approximately $70 billion annually to the State's economy, accounting for almost twenty percent of the State's total income[1]. This contribution is highly variable, however, due to the industry's vulnerability to meteorological conditions, especially drought and/or excessive precipitation. This study analyzed the effects of drought and precipitation on average grain corn yields in bushels per acre for each of the eight North Carolina climate divisions. Monthly values for seven separate drought indices are archived by the North Carolina State Climate Office (NCSCO) for each climate division. Each index is uniquely derived and emphasizes different aspects of drought and precipitation. We calculated average values and median values for a seven-month period (March-September), five-month period (March-July), and three-month period (March-May), per index, per climate division. The time periods reflected typical corn growth periods. Linear regression was then used to determine which combination of time period, statistic type (mean or median) and index was the strongest predictor of average corn yields per climate division over a 30-year period (1981-2011) A summary of the defining characteristics and predictive capabilities of each index is described below, along with a map of North Carolina's eight climate divisions.

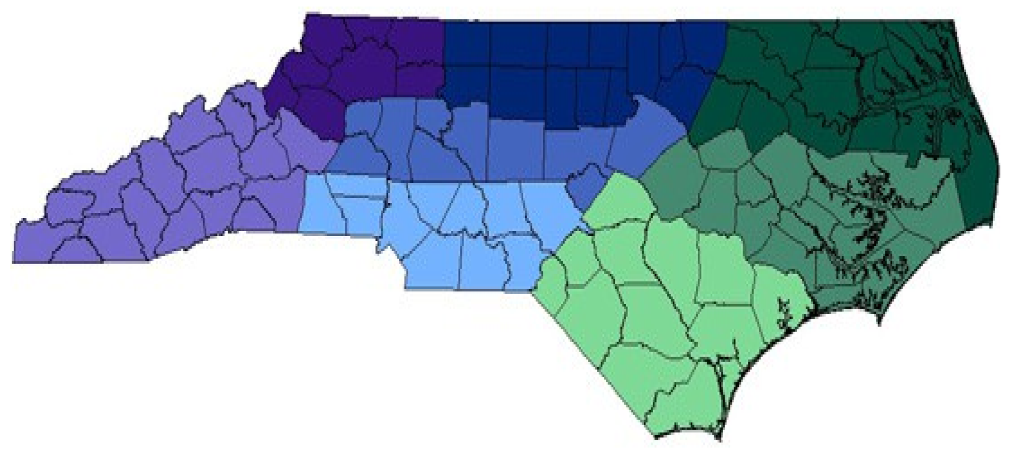
Palmer Drought Severity Index (PDSI) – The Palmer Drought Severity Index is a long term index that measures drought levels based on several factors like transpiration, temperature, precipitation, etc. The range of this index is from -6 to 6, with negative values indicating drier conditions and positive values indicating wetter conditions.

Palmer Hydrological Drought Index (PHDI) – The Palmer Hydrological Drought Index is a long term index that measures drought levels based on ground water condition and reservoir levels. PHDI is less impacted by change in precipitation than PDSI, but has the same range. It is generally a poor predictor of corn yields.

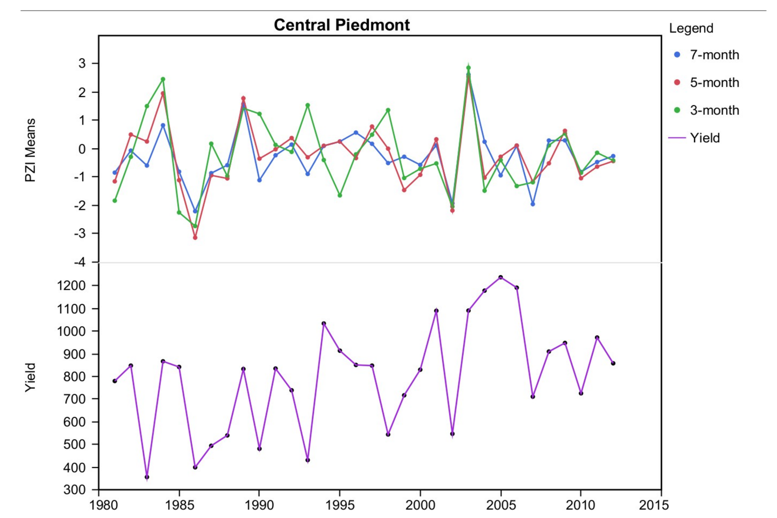
Palmer "Z" Index (PZI) – The Palmer "Z" Index measures short-term drought on a monthly scale. The range of the index is from -2.75 to 3.5, with more positive values indicating wetter conditions. It is one of the best predictors of corn yields.

Modified Palmer Drought Severity Index (MPDSI) – The Modified Palmer Drought Severity Index is an evolved version of PDSI. It is usually quite similar to the PDSI during established periods of drought or high precipitation, but differs during transition periods.

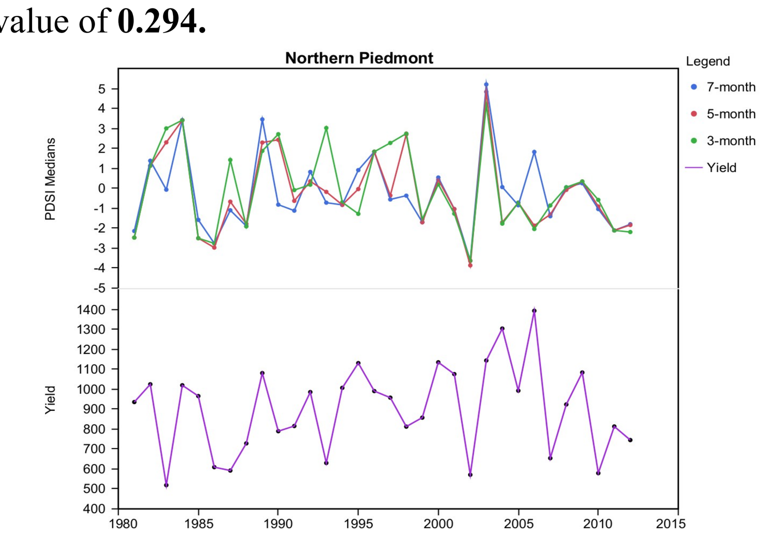
Standardized Precipitation Index (SPI#) – The SPIs allow us to view precipitation in both short and long term periods. The number suffix indicates the number of months measured (1, 2, or 3). This is especially relevant for our purposes, as the various stages of corn development run over a short period of 125 days. The SPIs allow us to pinpoint periods of extreme drought or precipitation during critical points in the corn's development. They are generally strong predictors of corn yields, depending on the severity of precipitation or lack thereof.



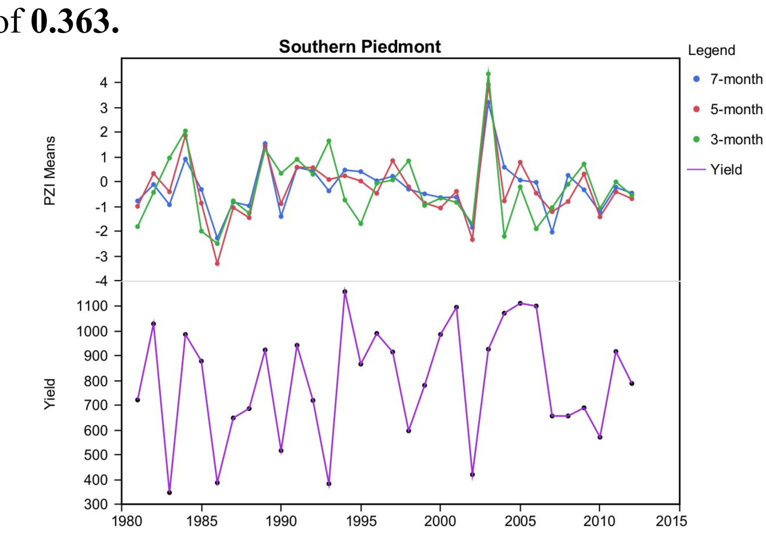
The following plots show each division's best predictor and its time period companions graphed alongside average corn yields in bushels per acre per year for the division in question. The R^2 value for each correlation describes the strength of the predictor's capability. The higher the R^2 value, the stronger the correlation between predictor and average corn yields.



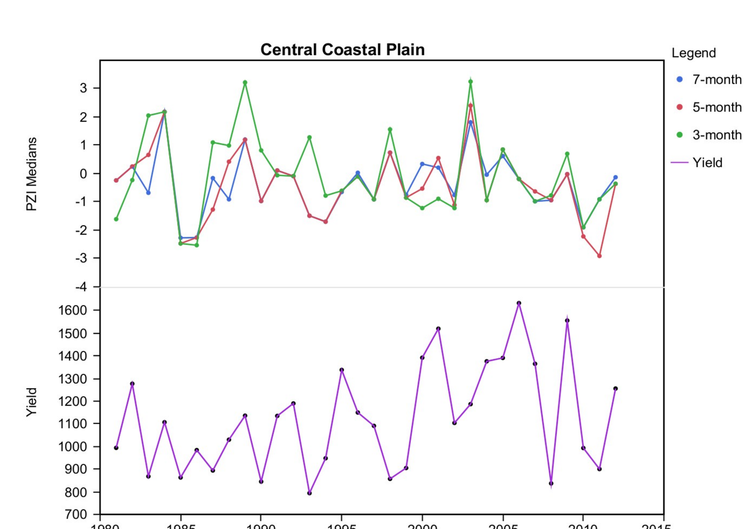
The mean of PZI values for a 7-month period (March-September) is the best predictor of corn yields for the **Central Piedmont** climate division with an R^2 value of **0.294.**



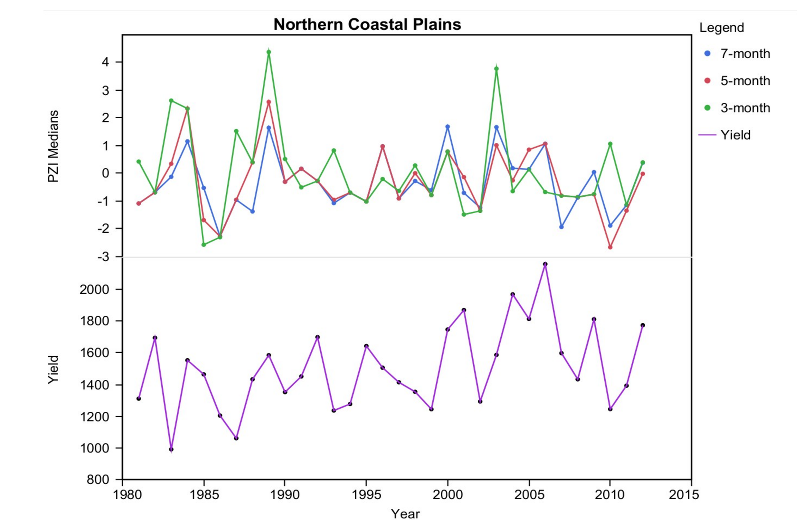
The median of PDSI values for a 7-month period (March-September) is the best predictor of corn yields for the **Northern Piedmont** climate division with an R^2 of **0.363.**



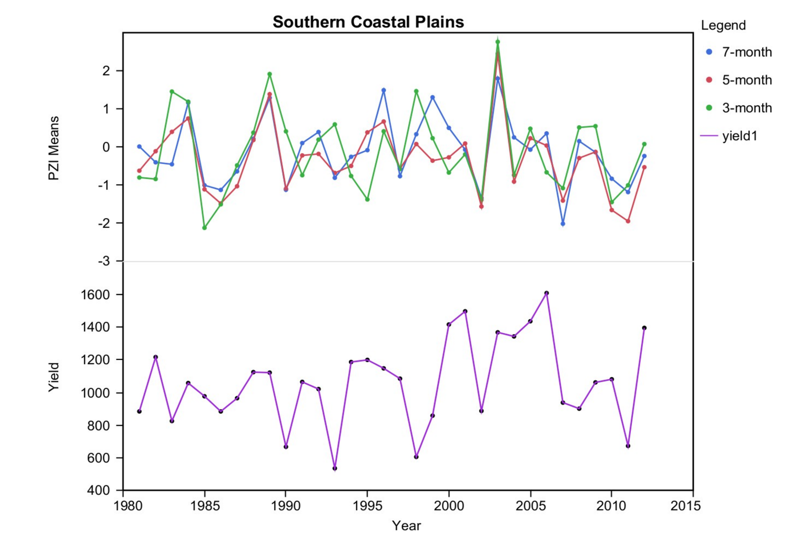
The mean of PZI values for a 7-month period (March-September) Is the best predictor of corn yields for the **Southern Piedmon**t climate division with an R^2 value of **0.329.**



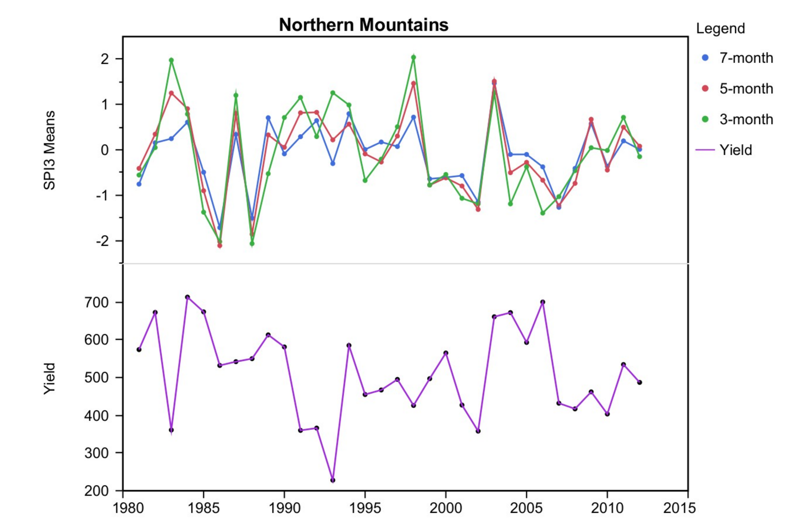
The median of PZI values for a 7-month period (March-September) is the best predictor of corn yields for the **Central Coastal Plain** climate division with an R^2 value of **0.159.**



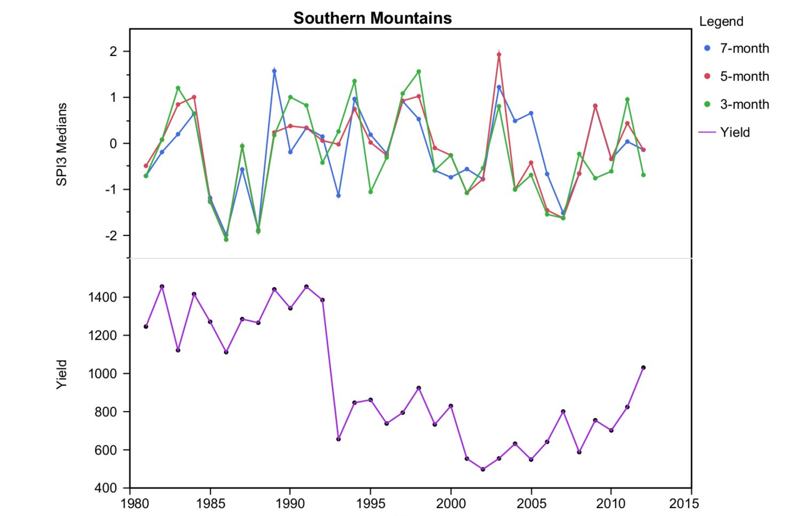
The median of PZI values for a 7-month period (March-September) is the best predictor of yields for the **Northern Coastal Plain** climate division with an R^2 value of **0.231.**



The mean of PZI values for a 5-month period (March-July) is the best predictor of yields for the **Southern Coastal Plain** climate division with an R^2 value of **0.164.**



The mean of SPI3 values for a 3-month period (March-May) is the best predictor of yields for the **Northern Mountain** climate division with an R^2 value of **0.064.**



The median of SPI3 values for a 3-month period (March-May) is the best predictor of yields for the **Southern Mountain** climate division with an R^2 value of **0.021.** This particular plot shows a large drop in corn yields in the early 1990's, which likely accounts for the very low R^2 value and is a subject for future research.

Analysis and Conclusion

An analysis of each predictive factor (time period, index, and statistic type) returned information that could be generalized across all of the corn yield data for every division. The more specified per-division analysis illustrated in the preceding graphs returned strong predictors that differed from the generalized analysis' results. However, an understanding of the generalized best predictors could still prove to be useful as a starting point in understanding the best predictors for other North Carolina crops.

The time-period predictive factor that had the highest mean R^2 value overall was the 7-month index mean over all divisions and indices. It was also a significantly stronger predictor of corn yields than the 5-month and 3-month means according to an analysis of variance performed on all the R^2 values in the statistical software package JMP. This is most likely due to the extra information available in the additional months for the 7-month mean. When the data was split into divisions, differences arose and the subtleties between time periods became more apparent.

There was no statistically significant difference between the R^2 values of the mean index values and the R^2 values of the median index values over all the data. When the data was split into divisions, however, the subtle differences between mean and median index scores proved to be useful on an division-by-division basis.

The index predictor with the highest mean R^2 value over all the data was the PZI, followed by SPI1 and SPI2, respectively. The prevalence of short term indices as strong predictors of corn yields merited a closer look at the growth stages of corn.

Grain corn goes through several stages of development, the most critical of which is its pollination stage. Excessive precipitation or drought is thus especially influential on overall corn yields during that period of the grain corn's development (typically a short time in March-June, depending on when the corn was planted). Even a short four days of extremely high or low moisture during certain critical periods of the corn's development can reduce overall yields by 5 to 10 percent.[2] This is why the combination of short time periods and short-term SPI indices proved to be consistently strong predictors for the climate divisions affected by extremes during the pollination period. Those predictors were more sensitive to subtler – but still critical - changes in precipitation.

This information on the general predictive capability of drought indeces will prove useful in further analysis of the effects of drought and precipitation on other important North Carolina crops like tobacco, sweet potatoes, Christmas trees and cotton.

Acknowledgments and Citations

Special thanks to Adrienne Wooten at the NCSCO for her advice and expertise.

Corn yield data obtained from the USDA's online National Agricultural Statistics Service.

Monthly index data and climate division map obtained from the NCSCO's website. <http://www.nc-climate.ncsu.edu/climate/climdiv.php>

[1]http://www.ncagr.gov/stats/general/overview.htm>

[2]Thomison, Peter. *Corn Pollination Overview*. Crop Observation and Recommendation Network Newsletter. 2011. Web. 14 Nov. 2013. <http://corn.osu.edu/newsletters/2011/2011-23/corn-pollination-overview>