

Using SAS In Analyzing Trends in Corn Yields, Surface Temperature, and Precipitation in U.S. South Atlantic Census Division States

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Abstract

Utilizing SAS ODA web application, this paper analyzes a panel dataset regarding corn yields, surface temperatures, and precipitation in the South Atlantic Census Region. The contiguous eight states that belong to the U.S. South Atlantic census region include Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia. Corn (Maize) is a versatile crop utilized both as a grain and vegetable. However, according to a few recent agro-climatic simulation studies, corn and other agricultural products' yields may be adversely impacted due to climate change. Most of these studies rely on data representing larger spatial units. Recognizing the imperative of microclimate studies, this paper analyzes county-level data, state-level data, and census division-level data to examine trends of corn yields, surface temperature, and precipitation and explore direction, magnitude and statistical significance of correlation coefficients and regression coefficients of variables of interest. At the individual state-level, most of the states within the South Atlantic division displayed positive correlations between corn yields and temperatures and corn yields and precipitation with an exception for two states. West Virginia data showed a statistically significant negative correlation between temperature and corn yield. Florida showed a negative correlation between temperature and corn yield, but this result is not statistically significant. According to the regression results, for the South Atlantic division the estimated coefficients of temperature variable are negative and statistically significant across the baseline model, and the variant models with log-transformed variables and annual growth rate variables.

Key words: *SAS, corn yields, surface temperature, precipitation, U.S. South Atlantic Census region, Data Visualization, Correlation, Trends, Regression*

I. Introduction

Global warming driven by the greenhouse effect is accelerating climate change at an alarming rate. According to a recent report by the World Meteorological Organization (WMO, 2023), the past decade (2011-2020) was the warmest on record. Both climate change and global warming pose significant threats to global food security. A NASA study indicates that climate change could adversely impact maize (corn), and wheat yields and can pose challenges to overall agricultural

production which may be apparent as early as 2030¹. During this period, maize yields are predicted to decline by 24%. Achieving food security by 2030 is a key sustainable development goal embraced by the USA and all United Nations member countries. At the World Food Summit in 1996, the USA and other nations jointly adopted a resolution identifying four critical dimensions of food security (FAO, 2006). The USA produces 361 million tons of corn (Maize) per year which is about one 32% of the global corn production (Erenstein et al., 2022). While the ‘corn belt’ states in the Midwest region have been historically the main suppliers of U.S.-grown corn, the southern states located in the South Atlantic census division also have incentive to step up their corn production efforts to take advantage of the extended growing season. Such efforts would also entail concerted efforts by relevant stakeholders to examine how the heat stress and other climate change related adversities can be mitigated as it can not only boost yield, but also can help diversify the geographic distribution of corn production and can reduce risk associated with regional weather events or natural disasters.

Maize (*Zea mays*), or corn, is one of the most vital crops globally. According to the Encyclopedia Britannica, corn is a highly productive and widely cultivated crop for human and livestock consumption, as well as for biofuel and industrial use. It is a versatile agricultural product classified as a vegetable, fruit, and grain. It originated in Mexico, with archaeological evidence suggesting that it was domesticated from a wild grass variant between 10,000 and 6,000 years ago. Corn has been cultivated for millennia. In 2023, the USA exported corn worth \$13.11 billion.²

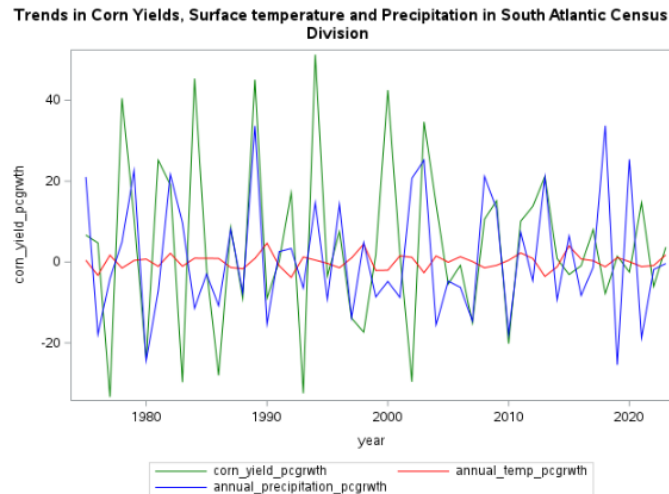
Table 1 presents mean values of annual surface temperature in Fahrenheit, mean annual precipitation in inches, and corn yield per acre in bushel for the period 1974 through 2023 for the South Atlantic Census division. During this period mean temperature increased by 3.29 percent, precipitation decreased by 1.21 percent and corn yield increased by 137.55 percent.

Table 2 shows corn yield (bushel per acre) data between 1974 and 2023. During this period, the percentile growth rate of corn yield was highest for Florida (yield grew by over 229.17 percent), followed by Georgia (216.86 percent), South Carolina (151.83 percent), Delaware (138.13 percent), North Carolina (102.62 percent), Virginia (101.19 percent), Maryland (94.03 percent), West Virginia (90.79 percent). The corn yield growth in the South Atlantic census division was 137.38 percent which trails below the U.S. national average yield growth of 146.59 percent during this five-decade-long period (1974-2023). As seen in Figure 1 and Figure 2 below, in terms of year-to-year growth rates of these variables, corn yields growth rate fluctuated the most followed by that of precipitation and then by surface temperature for the South Atlantic region as a whole, as well as, for individual states with the South Atlantic census division.

Figure 1 Year-to-Year growth trend in Corn Yield, Temperature, and Precipitation in the South Atlantic Census Division

¹ NASA. <https://climate.nasa.gov/news/3124/global-climate-change-impact-on-crops-expected-within-10-years-nasa-study-finds/>

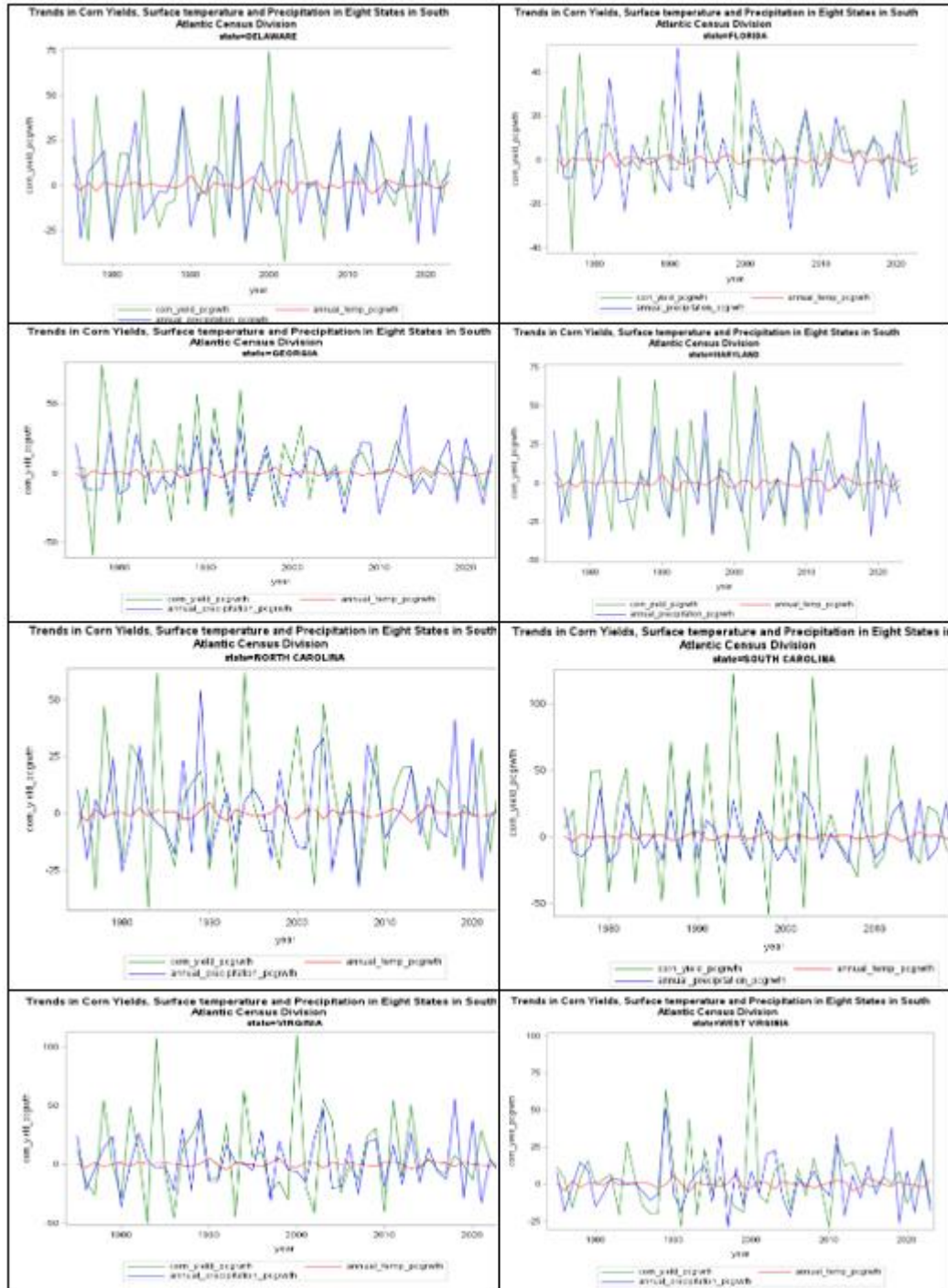
² USDA. Foreign Agricultural Service (<https://fas.usda.gov/data/commodities/corn>)



[source: Chart created by author using data from USDA and NOAA databases]

Since the corn yield growth rate in the South Atlantic region trailed the yield growth rate for the U.S., there remains an opportunity to bolster the South Atlantic region’s competitiveness in corn production so that this region can fare better and come up to the national corn yield growth.

Figure 2 Year-to-Year growth trend in Corn Yield, Temperature, and Precipitation in Eight States located in the South Atlantic Census Division



[source: Chart created by author using data from USDA and NOAA databases]

rate in the coming years. Figure 3 depicts that all states in the South Atlantic division are ‘hotter’ than the U.S. national average surface temperature. West Virginia is the only state from the region that displays some aberration in that for some years its average temperature is above the national average temperature and for some other years it is at par or slightly below the national average. Figure 3 presents graphical trends in annual precipitation across eight states in the South Atlantic region over the past five decades. Here also we see that the South Atlantic census division states

have annual precipitation above national average consistently throughout the period. Thus, the historical temperature and precipitation data reveal that the South Atlantic region is not only ‘hotter’ but also ‘wetter’ in comparison with the national average data.

This paper found statistical evidence of statistically significant negative correlations between corn yields and surface temperature in some correlation studies and in regression models. These empirical findings resonate with some previously published research articles that report the adverse impact of climate change on agriculture. Therefore, concerted efforts from all relevant stakeholders are necessary to tackle the challenges of climate change and global warming. The remainder of the paper contains sections delving into the review of some recent literature, a discussion of trends in corn yield, surface temperatures, and precipitation in the states in the South Atlantic census division, and a summary of correlation results and regression results.

II. Literature Review

A growing strand of empirical studies report the adverse impact of climate change on crop yields. Minoli et al. (2021) simulate crop growing periods and corresponding yields from 1986 to 2099, predicting that timely adaptation to climate change-induced modifications in growing periods can mitigate the negative effects of climate change and potentially boost overall crop yields by approximately 12%. Jagermeyr et al., (2021) predict the adverse impact on crop yield may be noticeable by as early as 2030. The study predicts that if the current climate change trend is left unabated, then the Maize(corn) crop yields can decrease by 24% by the end of this century. Lee and Durmaz (2016) utilize a U.S. panel data regression model, incorporating corn yield and climate change data (temperature, precipitation, and drought indices) across 10 states (IL, IN, IA, KS, MN, MO, NA, OH, SD, WI) for the years 2002 to 2007. Their findings reveal that the elasticity of corn yield relative to temperature is -8.6, while it is 15.3 concerning precipitation. The study also predicts that a one-unit increase in drought conditions could reduce corn production by between 15 and 90 bushels per acre by the end of the century. Welikhe et al. (2016) employed a calibrated Crop Environment Resource Synthesis (CERS) model for maize (corn) to simulate corn growth and yields under projected climate change scenarios for 2045 and 2075 in six counties of Alabama. They forecast a decrease in average yield of 19.55% and 37.5% for these respective scenarios.

In addition to examining the impact of temperature and precipitation on corn yields, an emerging strand of research papers is focusing on the compounding effects of multiple variables such as temperature, soil moisture, drainage conditions across seasons, etc. on crop yields in the context of climate change. For example, Lesk et al. (2022) examined Since around 2000, compound extremes—particularly hot droughts—have been associated with severe harvest losses, sometimes up to 30%, in regions including India, Ethiopia, the USA, Europe, and Russia. Stephens (2024) found that the frequency of prevented maize planting is significantly affected by soil moisture and drainage conditions during winter and spring, and it is expected to decrease in frequency but increase in severity on average due to climate change. Despite the increase in surface temperature of 3.29 percent and the decline in precipitation by 1.21 percent, corn yield per acre grew by 137.55% over the past five decades. This growth in corn yield is due to several factors including improvements and innovations in agricultural technology, scale economy, and management efficiency, suitable soil, and favorable weather conditions, etc. However, there is a concern that climate change can have a visible adverse impact on corn yields in the coming years if adequate adaptive measures are not taken. There is a growing concern among researchers about

whether technological progress and innovation be able to continue raising corn yields defying climate change posed adversities.

Table 1 Mean Corn Yields Per Bushel, Mean Surface Temperatures, And Mean Precipitation in The South Atlantic Census Division

year	corn_bushel_peracre	annual_temp_fahrenheit	annual_precip
1974	66.806994	58.706322	46.019551
1975	71.084044	58.944926	56.39513
1976	74.591952	56.995244	46.133244
1977	49.913584	58.018069	43.845535
1978	70.463826	57.084662	46.254581
1979	77.809721	57.300561	56.76688
1980	59.567637	57.759962	43.131194
1981	73.890202	57.16329	39.705466
1982	87.262551	58.363813	47.965288
1983	62.886202	57.751786	52.964626
1984	89.245967	58.338066	47.049503
1985	88.756427	58.862191	45.846214
1986	64.222106	59.36623	40.430457
1987	69.682736	58.553197	43.996834
1988	62.891799	57.520142	40.778291
1989	91.155829	58.033566	54.445087
1990	82.800436	60.746889	45.87891
1991	83.814048	60.216939	47.313634
1992	96.550404	57.89703	48.829862
1993	66.37245	58.585374	45.503635
1994	99.133482	58.861721	52.187048
1995	95.925378	58.679486	47.269869
1996	102.49481	57.849196	54.659427
1997	89.822548	58.476734	46.649255
1998	73.152068	61.215109	49.11495
1999	70.684458	58.788827	44.336162
2000	106.29784	58.57196	42.66403
2001	109.2948	59.504921	38.157235
2002	75.247079	60.212427	46.969032
2003	102.87063	58.619733	59.199561
2004	116.25414	58.576704	49.880436
2005	110.73789	59.535263	47.594044
2006	110.65793	60.3509	44.505281
2007	94.5764	60.310805	37.817362
2008	104.38044	59.46128	46.283244
2009	120.14031	58.813634	53.735647
2010	95.812343	58.275049	41.853994
2011	107.2837	59.464394	45.716039
2012	121.67254	60.043615	42.034103
2013	147.53237	57.586001	52.344292
2014	148.55454	58.917254	46.17693
2015	142.27386	59.17548	50.586972
2016	140.41178	59.812175	45.618011
2017	152.13461	61.127074	44.326891
2018	136.87518	60.397467	61.68335
2019	136.7426	61.012683	45.188097
2020	139.34853	61.094674	59.099552
2021	160.39664	60.407705	46.42673
2022	145.47543	59.884196	44.554893
2023	157.68221	60.923312	45.931066

[Source: Tabel created by the author using data obtained from NOAA and USDA databases.]

Table 2 Average Corn Yields Per Acre (in Bushels) in USA and South Atlantic Census

year	eld_US _averag e	eld_So uth_Atl antic_D	eld_Flo rida	eld_Del aware	eld_Ge orgia	eld_Ma ryland	eld_Nor thCaroli na	eld_So uthCar olina	eld_Virg inia	eld_We stVirgini a
1974	71.9	63.4	48	80	52.8	82.1	68.8	54.6	75.5	76
1975	86.4	66	45	93.3	55	88.4	64.1	57.9	85.1	85
1976	88	68.1	60	93.7	57.1	89.6	71.2	69.5	72.1	88
1977	90.8	42.4	35	64.9	23	70.4	47.5	32.5	53.3	74
1978	101	62.1	52	97.4	41	94.7	69.9	48.4	82.4	77
1979	109.5	70.2	53	103.2	54.6	96.5	71.9	72.6	83.6	89
1980	91	52.7	49	73.7	34.5	69.2	57.1	42.1	60.4	89
1981	108.9	67.2	57	86.7	44.2	97.8	74.5	52.7	89.6	92
1982	113.2	85.1	66	102.3	74.6	96.9	92.2	79.9	98.3	98
1983	81.1	58.5	67	74.5	57.5	66.8	53.9	51.6	48.8	78
1984	106.7	83.4	65	114	71.3	113.1	87.2	72	101.6	100
1985	118	83.2	65	110	75.9	102.7	79.4	78.8	95.1	105
1986	119.4	56.5	62	84.3	49.8	72	61.1	40.3	52.7	90
1987	119.8	66.6	69	75.9	67.5	78	64.8	69.4	59.7	72
1988	84.6	62.8	58	69.6	52.4	64.1	73.6	56.4	74.4	58
1989	116.3	89.4	74	99.6	82.2	106.9	87.3	84.8	105	95
1990	118.5	71.7	71	115	59.4	114.8	65.7	46.1	92.1	105
1991	108.6	83.3	68	105.7	87.6	89.9	83.9	78.7	81.4	75
1992	131.5	92.9	75	118.2	89.4	122.1	87.2	76	109.1	108
1993	100.7	60.7	65	83.7	61.8	79.4	58.3	37.1	59.9	85
1994	138.6	96.1	85	125.6	99.2	112.4	94.6	82.7	97.5	105
1995	113.5	93.8	90	105.4	83.4	105.9	98.9	87.4	103.4	100
1996	127.1	94.6	88	142.3	83.1	135.4	91.2	72.9	114.7	105
1997	126.7	88.9	80	97.8	94.6	90.8	84.5	86.2	88.3	95
1998	134.4	68.3	62	97.9	72.5	104.7	64.4	36.1	75.3	80
1999	133.8	70.1	93	83.5	87.6	87	70.1	64.5	52.7	65
2000	136.9	98.3	75	146	92.6	150.5	96.8	58.1	111.2	130
2001	138.2	103.7	87	136.8	124.1	129.7	98.2	93.7	90.2	120
2002	129.3	72.4	96	79	101.6	73.5	67.6	43.8	52.8	105
2003	142.2	100.1	82	119.9	118.5	120	100.2	96.5	82	115
2004	160.3	112.2	90	149.1	115.5	147.8	115	91.5	112.5	131
2005	147.9	106.3	94	146.6	122.5	127.1	108.7	107	86.1	109
2006	149.1	104.2	82	148.7	101.6	131.1	124.2	100.9	85.1	120
2007	150.7	90.6	90	104.5	112.3	95.2	86.2	85.9	74.1	111
2008	153.3	98.1	110	116.3	129.4	118.6	83.3	60	91.8	130
2009	164.4	116.3	97	145	131.2	141.9	108.7	96.9	120	126
2010	152.6	91.8	109	114.5	131.5	99	81.8	74.2	71.6	90
2011	146.8	103.2	104	127.4	132.3	107.6	90.1	63.9	110.4	114
2012	123.1	122.5	115	129.6	162.5	117	108.3	107.4	99	128
2013	158.1	146.1	133	164.8	168.4	155.6	130.6	123.2	148.3	147
2014	171	140.2	135	197.5	153.1	162.8	129.3	112.5	141.9	149
2015	168.4	132.9	141	191.2	156.5	159.9	108.8	90.1	149.3	148
2016	174.6	135.8	145	169.6	151.5	144.9	125.5	110.7	142.3	145
2017	176.6	144.3	161	184.6	163.7	165	137.7	131.1	130.6	152
2018	176.4	135.4	157	146.9	166	136.4	111.7	119.7	140.5	152
2019	167.5	130.7	161	160.7	145.9	157.9	116.1	100.2	139.8	165
2020	171.4	133	138	160.6	163.4	151.8	115	123.7	121.5	144
2021	176.7	155.8	176	183.4	174.3	170.5	147.5	130.8	155.9	144
2022	173.4	139.7	164	167.1	152.9	160.7	123.1	106.4	162.6	168
2023	177.3	150.5	158	190.5	167.3	159.3	139.4	137.5	151.9	145
Growth	146.59%	137.38%	229.17%	138.13%	216.86%	94.03%	102.62%	151.83%	101.19%	90.79%

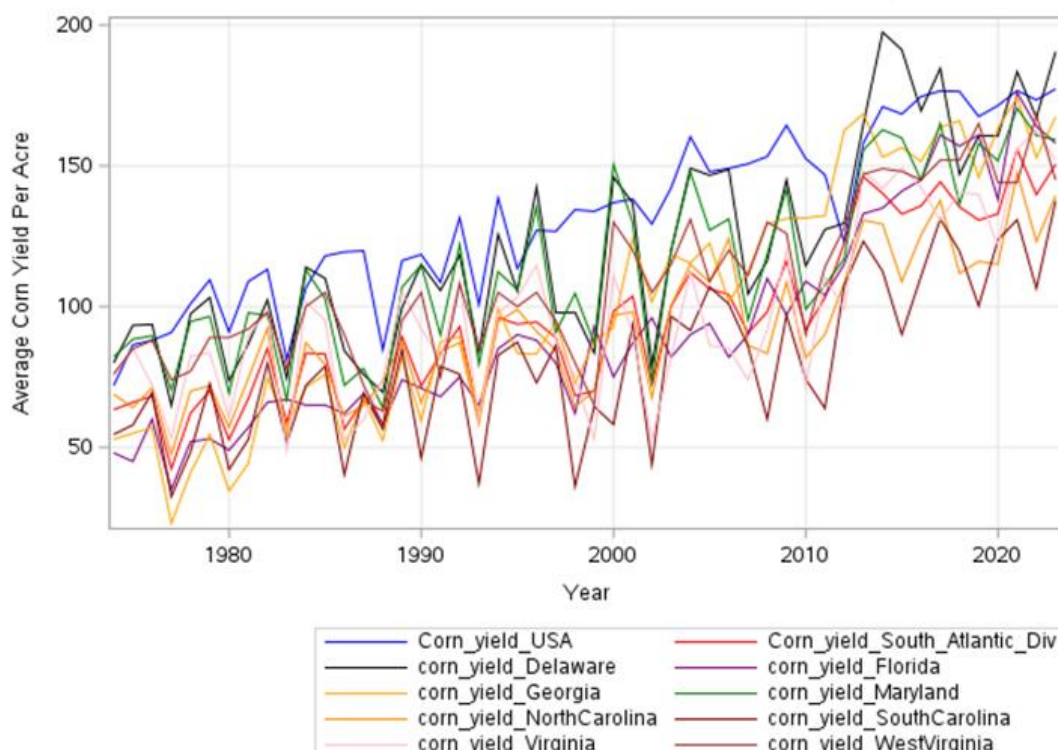
[Source: table created by author using data from USDA Agricultural Statistics Database.]

III. Trends in Corn Yields in South Atlantic Division States

Figure 2 presents the year-to-year growth rates of corn yields in eight states that are in the South Atlantic census division. Here we see that the South Atlantic census division states trail the national average in terms of corn yields. In the USA, corn yield is highest in the “corn belt” states

some of which is overlapped with the ‘West North Central’ census division states. Heat stress and poorer soil quality Over the past five decades, the most growth in corn production within the South Atlantic census division was seen in Florida, followed by Georgia, South Carolina, Delaware, North Carolina, Virginia, Maryland and then West Virginia. When we rank the growth in corn production for first 25 years between 1974 and 1998, we see that Georgia experienced the most growth in corn yields in the region, followed by Florida, Maryland, Delaware, West Virginia, Virginia, North Carolina, and South Carolina.

Figure 2 Annual Average Corn Yields Per (Acre in Bushels) in the U.S., In South Atlantic Census Division and States Therein



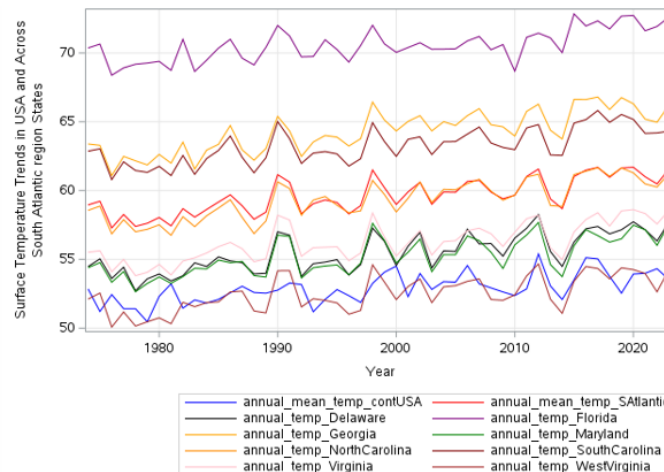
[Source: Chart created by author using data from USDA database]

IV. Trends in Surface Temperature in South Atlantic Census Division States

Figure 3 presents the average annual surface temperature over the past half century (1974-2023) for eight states located in the South Atlantic census division. For comparison we also examine the temperature trends for the South Atlantic division as a whole and the average temperature recorded for the contiguous USA. Here we see that all but one state in the division has surface temperature higher than that for the nation. Over the five decades, most percentile growth in surface temperature was experienced by Delaware (5.89%) followed by Maryland (5.83%), Virginia (5.48%), North Carolina (4.59%), Georgia (4.45%), West Virginia (4.11%), Florida (3.17%), and South Carolina (2.31%). During this period, the overall south Atlantic census division’s growth in surface temperature was 2.31% and the national growth in temperature was

1.27%. When we rank the growth in temperature for the 25 years period between 1974 and 1999 we see that Maryland's surface temperature grew the most (3.64%), followed by Delaware's (3.38%), Georgia's (2.75%), West Virginia's (2.38%), Virginia's (2%), North Carolina's (1.98%), South Carolina's (1.11%) and Florida's (0.43%).

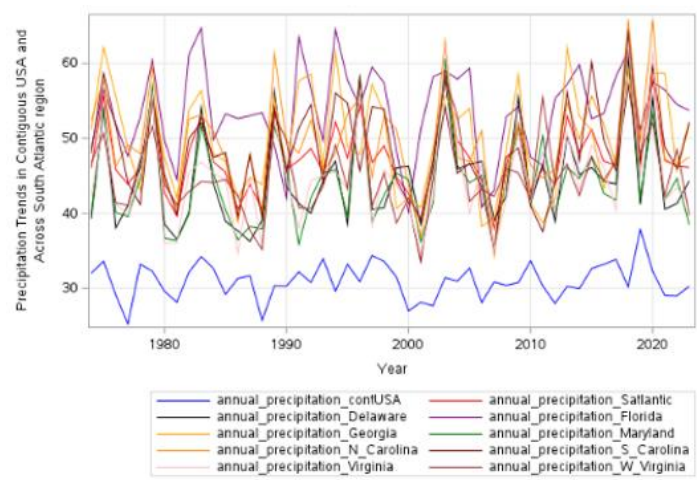
Figure 3 Trends in surface temperature in contiguous USA and across South Atlantic Census Division States



[Source: Chart created by the author using data from NOAA database]

V. Trends in Precipitation in South Atlantic Census Division States

Figure 4 Trends in Annual Precipitation (In Inches) In Contiguous USA And Across South Atlantic Census Division States



[Source: Chart created by the author using data from NOAA database]

Figure 4 displays the average annual precipitation over the past half-century (1974-2023) for eight states in the South Atlantic Census Division. For context, we also compare these temperatures with trends for the South Atlantic Division as a whole and the contiguous USA. The data reveals that all the states in the division have received more precipitation than the national average precipitation. Over the five decades, Delaware experienced the highest percentile increase in precipitation (12.77%), followed by Florida (10.34%), South Carolina (8.56%), Georgia (1.15%). Among the states that experienced negative growth in precipitation, the most reduction in precipitation in terms of percent was experienced by West Virginia (-15.04 %), followed by North Carolina (-9.24%), Maryland (-3.94), and Virginia (-1.94%). During this time, the overall growth in precipitation in the South Atlantic division was 0.13% while nationally precipitation declined 5.4%. When examining the 25-year period from 1974 to 1999, we see that Delaware experienced the most percentile growth in precipitation (17.22%) followed by Maryland (13.18%), and Virginia (3.67%). Following states in the division experienced a percentile decline in precipitation during this 25 years period (1974-1999): Florida (-0.64%), North Carolina (-2.25%), South Carolina (-7.6%), West Virginia (-17.2%), and Georgia (-20.62%). During this period precipitation decreased for the South Atlantic division (-2.74%) and the USA (-1.56%).

VI. Correlations of Variables of Interest Across South Atlantic Division States

Table 3A Correlation Matrix for South Atlantic Census Division States

Simple Statistics							
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum	Label
corn_bushl_peracre	400	100.95113	34.87917	40380	23.01923	197.46667	corn_bushl_peracre
annual_temp_fahrenheit	400	59.61730	5.78804	23847	50.07455	72.83756	annual_temp_fahrenheit
avg_annual_precipitation	400	47.59267	7.04107	19037	33.60286	65.85540	avg_annual_precipitation

Pearson Correlation Coefficients, N = 400 Prob > r under H0: Rho=0			
	corn_bushl_peracre	annual_temp_fahrenheit	avg_annual_precipitation
corn_bushl_peracre	1.00000	-0.11217	0.08965
corn_bushl_peracre		0.0249	0.0733
annual_temp_fahrenheit	-0.11217	1.00000	0.39016
annual_temp_fahrenheit		0.0249	<.0001
avg_annual_precipitation	0.08965	0.39016	1.00000
avg_annual_precipitation		<.0001	

Table 3A presents the correlation between corn and temperature is weakly negative (-0.11), indicating a slight tendency for corn yields to decline with rising temperature, but the association is weak. The correlation is statistically significant with a p-value of 0.03. The correlation between corn yield and precipitation is weak (0.09), indicating a minimal positive linear relationship. Also, the correlation is not statistically significant at the 0.05 level (p-value = 0.07). This suggests that we do not have sufficient evidence to claim that there is a significant linear relationship between corn yield and precipitation. There is a statistically significant positive correlation between precipitation and temperature in the South Atlantic census division.

Table 3B Correlation Coefficients for Variables of Interest for Florida

Pearson Correlation Coefficients Prob > r under H0: Rho=0 Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000 830	-0.25805 <.0001 830	-0.03529 0.3099 830
annual_precip_allcnty	-0.25805 <.0001 830	1.00000 926	0.12921 <.0001 926
corn_bushl_peracre	-0.03529 0.3099 830	0.12921 <.0001 926	1.00000 926

Table 3B presents correlation coefficients for Florida for the variables of interest. The correlations between temperature and corn yields for this state for the period is negative but not statistically significant.

The estimated correlation coefficient between corn yield and precipitation is positive and statistically significant (0.13, p-value <0.0001).

The estimated correlation coefficient between precipitation and temperature is negative (-0.26) and this relationship is statistically significant (P value <0.001).

Table 3C Correlation Coefficients for Variables of Interest for Delaware

Pearson Correlation Coefficients, N = 150 Prob > r under H0: Rho=0			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000	-0.01671 0.8392	0.44308 <.0001
annual_precip_allcnty	-0.01671 0.8392	1.00000	0.22619 0.0054
corn_bushl_peracre	0.44308 <.0001	0.22619 0.0054	1.00000

Table 3C presents correlation coefficients for Delaware for the variables of interest. The correlations between temperature and corn yields for this state for the period is positive and statistically significant (0.44, p-value <0.0001).

The estimated correlation coefficient between corn yield and precipitation is positive and this relationship is not statistically significant (0.23, p-value 0.005).

The estimated correlation coefficient between precipitation and temperature is negative but this relationship is not statistically significant (-0.02, p-value 0.84).

Table 3D Correlation Coefficients for Variables of Interest for Georgia

Pearson Correlation Coefficients Prob > r under H0: Rho=0 Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000 4877	-0.30754 <.0001 4877	0.34571 <.0001 4877
annual_precip_allcnty	-0.30754 <.0001 4877	1.00000 5179	0.10960 <.0001 5179
corn_bushl_peracre	0.34571 <.0001 4877	0.10960 <.0001 5179	1.00000 5179

Table 3D presents correlation coefficients for Georgia for the variables of interest. The correlations between temperature and corn yields for this state for the period is positive and this relationship is found to be statistically significant (0.35, p-value <0.0001).

The estimated correlation coefficient between corn yield and precipitation is positive and statistically significant (0.11, p-value <0.0001).

The estimated correlation coefficient between precipitation and temperature is negative and this relationship is statistically significant (-0.31, p-value <0.0001).

Table 3E Correlation Coefficients for Variables of Interest for Maryland

Pearson Correlation Coefficients Prob > r under H0: Rho=0 Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000 1084	-0.04467 0.1416 1084	0.17295 <.0001 1084
annual_precip_allcnty	-0.04467 0.1416 1084	1.00000 1084	0.26218 <.0001 1084
corn_bushl_peracre	0.17295 <.0001 1084	0.26218 <.0001 1084	1.00000 1110

Table 3E presents correlation coefficients for Maryland for the variables of interest. The correlations between temperature and corn yields for this state for the period is 0.17 and this relationship is statistically significant (p-value <0.0001).

The estimated correlation coefficient between corn yield and precipitation is positive and statistically significant (0.26, p-value <0.0001).

The estimated correlation coefficient between precipitation and temperature is small and negative, although this relationship is not statistically significant (-0.05, p-value 0.14).

Table 3F Correlation Coefficients for Variables of Interest for North Carolina

Pearson Correlation Coefficients Prob > r under H0: Rho=0 Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000 4218	-0.12430 <.0001 4218	0.24362 <.0001 4218
annual_precip_allcnty	-0.12430 <.0001 4218	1.00000 4218	0.16770 <.0001 4218
corn_bushl_peracre	0.24362 <.0001 4218	0.16770 <.0001 4218	1.00000 4369

Table 3F presents correlation coefficients for North Carolina for the variables of interest. The correlations between temperature and corn yields for this state for the period are positive and this relationship is statistically significant.

The estimated correlation coefficient between corn yield and precipitation is positive and statistically significant (0.17, p-value <0.0001).

The estimated correlation coefficient between precipitation and temperature is negative and this relationship is statistically significant (-0.12, p-value <0.0001).

Table 3G Correlation Coefficients for Variables of Interest for South Carolina

Pearson Correlation Coefficients Prob > r under H0: Rho=0 Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000 1802	-0.08233 0.0005 1802	0.28225 <.0001 1802
annual_precip_allcnty	-0.08233 0.0005 1802	1.00000 1802	0.20801 <.0001 1802
corn_bushl_peracre	0.28225 <.0001 1802	0.20801 <.0001 1802	1.00000 1925

Table 3G presents correlation coefficients for South Carolina for the variables of interest. The correlations between temperature and corn yields for this state for the period is positive and statistically significant (0.28, p-value <0.0001).

The estimated correlation coefficient between corn yield and precipitation is positive (0.21) and statistically significant (<0.0001).

The estimated correlation coefficient between precipitation and temperature is negative (-0.08) and this relationship is statistically significant (p-value <0.0005).

Table 3H Correlation Coefficients for Variables of Interest for Virginia

Pearson Correlation Coefficients Prob > r under H0: Rho=0 Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000 3630	0.13867 <.0001 3630	0.20373 <.0001 3630
annual_precip_allcnty	0.13867 <.0001 3630	1.00000 3630	0.22491 <.0001 3630
corn_bushl_peracre	0.20373 <.0001 3630	0.22491 <.0001 3630	1.00000 3843

Table 3H presents correlation coefficients for Virginia for the variables of interest. The correlations between temperature and corn yields for this state for the period is 0.2 and this relationship is statistically significant (p-value <0.0001).

The estimated correlation coefficient between corn yield and precipitation is positive (0.22) and this relationship is statistically significant (p-value <0.0001).

The estimated correlation coefficient between precipitation and temperature is positive and this relationship is statistically significant (0.14, p-value <0.0001).

Table 3I Correlation Coefficients for Variables of Interest for West Virginia

Pearson Correlation Coefficients Prob > r under H0: Rho=0 Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000 978	-0.27232 <.0001 978	-0.06172 0.0537 978
annual_precip_allcnty	-0.27232 <.0001 978	1.00000 1080	0.11703 0.0001 1080
corn_bushl_peracre	-0.06172 0.0537 978	0.11703 0.0001 1080	1.00000 1080

Table 3I presents correlation coefficients for West Virginia for the variables of interest. The correlations between temperature and corn yields for this state for the period are negative and this relationship is statistically significant (p-value 0.05).

The estimated correlation coefficient between corn yield and precipitation is positive and statistically significant (0.12, p-value <0.0001).

The estimated correlation coefficient between precipitation and temperature is negative and this relationship is statistically significant (-0.27, p-value <0.0001).

VII. Regression Models and results

We recognize that in addition to temperature and precipitation, there are various other factors such as state of technology and scale economy, soil quality, management efficiency etc. that impacts corn yields. However, in this study we use the regression analysis as a robustness check of the relationship between the variables of interest that was explored in the correlation analyses reported in the earlier section. Besides, we attempt to explore some of quantifiable marginal relationship between the dependent variable (corn yield per acre) and temperature and precipitation using level data at county level and state level for the states located in the South Atlantic division. Besides, we use the natural log values of these variables and annual growth rates of these variable as robustness checks.

The baseline model is as follows:

$$\text{Corn yield per acre} = B_0 + B_1 * \text{Annual surface temperature} + B_2 * \text{Annual precipitation} + \varepsilon$$

The state-level variant models using natural log and annual growth rates of the dependent and independent variables thus are as follows:

$$\text{Ln_Corn yield per acre} = B_0 + B_1 * \text{Ln (Annual surface temperature)} + B_2 * \text{Ln (annual precipitation)} + \varepsilon$$

$$\text{grwth_Corn yield per acre} = B_0 + B_1 * \text{grwth_Annual surface temperature} + B_2 * \text{grwth_annual precipitation} + \varepsilon$$

Prefix ‘Ln’ denotes natural log and ‘grwth’ denotes annual growth rate, and the ‘ ε ’ denotes stochastic error term.

Table 4 , Table 5A through Table 5C contain regression result highlights.

Table 4, and Tables 5A through 5C contains results highlights from three regression models listed above. As shown in the Table 4 and Table 5A the baseline model’s estimated coefficient for the temperature variable is negative and statistically significant (-1.05, p-value 0.001) implying a negative correlation between surface temperature and corn yields in the South Atlantic division states. It denotes that a 1-unit increase in temperature a decrease in corn yield by 1.05 unit, holding other factors constant. The estimated coefficient for the precipitation variable is positive and statistically significant (0.78, p-value 0.004). This result implies that each one-inch increase in annual precipitation may result in an increase in corn yield by 0.78 unit holding other factors

constant. The low r-squared value (0.03) of the model that several other factors currently not included in the model might be more important in explaining variations in corn yield.

Table 4 and Table 5B present highlights of the results of the regression of natural log of corn yields. The estimated coefficient for log of temperature is negative (-0.85) and statistically significant (p-value <0.0001) implying that a 1 percent increase in precipitation will decrease corn yields by 0.85 percent. Per the estimated coefficient of log of precipitation, this variable has statistically significant positive correlations with corn yield and a 1 percent increase in precipitation may increase yield by 0.43% holding other factors constant.

Table 4 Summary of the regression results from the Baseline model and variant models

Baseline model: Regression of Corn Yields		
annual_temp_fahrenheit	Annual surface temperature in Fahrenheit	-1.05*** (0.001)
avg_annual_precipitation	Annual precipitation in inches	0.78*** (0.003)
No. of observations 400		
Adj. R-squared 0.03		
Variant model -Regression of Natural Log of Corn Yield		
ln_annual_temp_fahrenheit	Natural log of annual surface temperature	-0.85*** (<0.001)
ln_avg_annual_precipitation	Natural log of annual precipitation in inches	0.43*** (0.001)
No. of observations 400		
Adj. R-squared 0.044		
Variant model: Regression of annual growth rate of Corn Yield		
annual_temp_pcgrwth	Annual growth rate in temperature	-3.78*** (<0.0001)
Annual_precipitation_pcgrwth	Annual growth rate in precipitation	0.36*** (<0.001)
No. of observations 382		
Adj. R-squared 0.141		

*[Note: **** denotes statistical significance of the estimated coefficient at 1% and ** denotes statistical significance at 5%.]*

Table 4 and Table 5C present the results highlight of the regression of annual growth rate of corn yields. The estimated coefficient of annual growth rate of temperature is negative (-3.78) and statistically significant (p < 0.0001), indicating a significant negative relationship with corn yields in the South Atlantic division states. The coefficient of annual growth rate of precipitation is positive (0.36) and statistically significant (p < 0.0001), indicating a significant positive relationship with the corn yields in this region. The low r-squared value is a reminder that

there are several other factors that are associated with corn yields that are not included in the current model.

Table 6 presents a comparison of estimated correlation coefficients and estimated regression coefficients for the South Atlantic division and for eight individual states therein. The correlation coefficients for individual states vary widely, ranging from -0.06 to 0.44. Most states show a positive correlation with corn yield and temperature, though the significance levels vary. Out of the correlation results, the South Atlantic region and the State of West Virginia showed a statistically significant negative correlation between surface temperature and corn yields. The state of Florida showed a negative correlation between temperature and corn yields; however, this relationship was not statistically significant.

Regression coefficients for temperature are highly variable among states. Delaware, Georgia, and South Carolina show large positive coefficients, suggesting a significant impact of temperature on corn yield in these states. The South Atlantic Census Division shows a highly negative coefficient, indicating a general trend across the division where higher temperatures are associated with reduced corn yields. Precipitation's Impact on Corn Yield: Precipitation coefficients are positive for all states, suggesting that higher precipitation correlates with higher corn yields. The coefficients are consistent across states with Virginia and North Carolina showing notable positive effects, though the adjusted R-squared values indicate limited explanatory power for precipitation in most cases. The adjusted R-squared values are low across the board, indicating that the models explain only a small proportion of the variance in corn yields. Delaware, Georgia, and South Carolina have slightly higher R-squared values, suggesting better model fits for these states. In summary, while temperature has a notably negative impact on corn yields in the South Atlantic Census Division as a whole, its effect varies significantly by state. Precipitation has a positive effect, but again, the explanatory power of these models is limited, as indicated by the low adjusted R-squared values.

Table 5A Regression of Corn Yields on Annual Temperature and Annual Precipitation Across Eight States in the South Atlantic Division

The REG Procedure

Model: MODEL1

Dependent Variable: corn_bushl_peracre corn_bushl_peracre

Number of Observations Read	400
Number of Observations Used	400

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	16298	8149.15571	6.90	0.0011
Error	397	469108	1181.63123		
Corrected Total	399	485406			

Root MSE	34.37486	R-Square	0.0336
Dependent Mean	100.95113	Adj R-Sq	0.0287
Coeff Var	34.05100		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	Intercept	1	126.20666	18.53052	6.81	<.0001
annual_temp_fahrenheit	annual_temp_fahrenheit	1	-1.04594	0.32291	-3.24	0.0013
avg_annual_precipitation	avg_annual_precipitation	1	0.77954	0.26545	2.94	0.0035

Table 4B Regression of Natural Log of Corn Yields on Natural Logs of Annual Temperature and Annual Precipitation Across Eight States in the South Atlantic Division

The REG Procedure
Model: MODEL1
Dependent Variable: ln_corn_bushl_peracre

Number of Observations Read	400
Number of Observations Used	400

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	2.61626	1.30813	10.23	<.0001
Error	397	50.78094	0.12791		
Corrected Total	399	53.39720			

Root MSE	0.35765	R-Square	0.0490
Dependent Mean	4.55141	Adj R-Sq	0.0442
Coeff Var	7.85794		

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	6.37609	0.79172	8.05	<.0001
ln_annual_temp_fahrenheit	1	-0.85105	0.20418	-4.17	<.0001
ln_avg_annual_precipitation	1	0.42848	0.13262	3.23	0.0013

Table 4C Regression of Annual Growth Rate of Corn Yields on Annual Growth Rates of Temperature and Precipitation Across Eight States in the South Atlantic Division (State-level Data)

The REG Procedure
Model: MODEL1
Dependent Variable: corn_yield_pcgrwth corn_yield_pcgrwth

Number of Observations Read	400
Number of Observations Used	392
Number of Observations with Missing Values	8

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	48089	24044	33.03	<.0001
Error	389	283154	727.90241		
Corrected Total	391	331243			

Root MSE	26.97967	R-Square	0.1452
Dependent Mean	5.59363	Adj R-Sq	0.1408
Coeff Var	482.32846		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	Intercept	1	5.36574	1.37172	3.91	0.0001
annual_temp_pcgrwth	annual_temp_pcgrwth	1	-3.77727	0.68024	-5.55	<.0001
annual_precipitation_pcgrwth	annual_precipitation_pcgrwth	1	0.35890	0.07126	5.04	<.0001

Table 5 Regression results for Eight States Located in South Atlantic Division

State=DELAWARE

Number of Observations Read 150

Number of Observations Used 150

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	51715	25858	24.52	<.0001
Error	147	154404	1050.36618		
Corrected Total	149	206120			

Root MSE	32.40935	R-Square	0.2509
Dependent Mean	121.57333	Adj R-Sq	0.2407
Coeff Var	26.55827		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-537.69655	97.99034	-5.49	<.0001
annual_temp_fahrenheit	1	10.83801	1.73080	6.26	<.0001
annual_precip_12mo	1	1.29319	0.39514	3.27	0.0013

The REG Procedure

Model: MODEL1

Dependent Variable: corn_bushl_peracre

State=GEORGIA	5179
Number of Observations Read	4877
Number of Observations Used	302

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	1525193	912596	511.23	<.0001
Error	4674	8700660	1785.11659		
Corrected Total	4676	10525853			

Root MSE	42.25064	R-Square	0.1734
Dependent Mean	54.91993	Adj R-Sq	0.1731
Coeff Var	49.75544		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-381.25233	14.50552	-26.10	<.0001
annual_temp_fahrenheit	1	6.32129	0.20582	30.74	<.0001
annual_precip_12mo	1	1.25891	0.07063	17.82	<.0001

The REG Procedure

Model: MODEL1

Dependent Variable: corn_bushl_peracre

State=NORTH CAROLINA

Number of Observations Read	4369
Number of Observations Used	4218
Number of Observations with Missing Values	151

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	435511	217756	231.99	<.0001
Error	4215	3959386	938.84439		
Corrected Total	4217	4391897			

Root MSE	30.63730	R-Square	0.0992
Dependent Mean	88.55697	Adj R-Sq	0.0987
Coeff Var	34.59224		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-112.03975	9.75887	-11.48	<.0001
annual_temp_fahrenheit	1	2.80353	0.15377	18.23	<.0001
annual_precip_12mo	1	0.70221	0.05145	13.65	<.0001

State=VIRGINIA

Number of Observations Read	3843
Number of Observations Used	3630
Number of Observations with Missing Values	213

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	442098	221049	159.70	<.0001
Error	3627	5020159	1384.10788		
Corrected Total	3629	5462255			

Root MSE	37.20380	R-Square	0.0809
Dependent Mean	92.04953	Adj R-Sq	0.0804
Coeff Var	40.41694		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-95.87930	13.05951	-7.33	<.0001
annual_temp_fahrenheit	1	2.54841	0.23284	10.94	<.0001
annual_precip_12mo	1	1.00830	0.08083	12.47	<.0001

The REG Procedure

Model: MODEL1

Dependent Variable: corn_bushl_peracre

State=FLORIDA

Number of Observations Read	926
Number of Observations Used	830
Number of Observations with Missing Values	96

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	7430.78022	3715.39311	7.82	0.0004
Error	827	393124	475.38140		
Corrected Total	829	400555			

Root MSE	21.80278	R-Square	0.0188
Dependent Mean	65.33759	Adj R-Sq	0.0182
Coeff Var	33.39643		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	46.15340	37.87384	1.27	0.2039
annual_temp_fahrenheit	1	-0.00235	0.53617	-0.00	0.9985
annual_precip_12mo	1	0.31080	0.08135	3.82	0.0001

The REG Procedure

Model: MODEL1

Dependent Variable: corn_bushl_peracre

State=MARYLAND

Number of Observations Read	1110
Number of Observations Used	1084
Number of Observations with Missing Values	26

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	131654	65827	62.00	<.0001
Error	1081	1150509	1064.35294		
Corrected Total	1083	1282549			

Root MSE	32.82442	R-Square	0.1029
Dependent Mean	112.50549	Adj R-Sq	0.1012
Coeff Var	28.99752		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-84.89254	23.17132	-3.66	0.0003
annual_temp_fahrenheit	1	2.87358	0.40089	6.42	<.0001
annual_precip_12mo	1	1.25197	0.13349	9.38	<.0001

State=SOUTH CAROLINA

Number of Observations Read	1925
Number of Observations Used	1802
Number of Observations with Missing Values	123

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	238852	119326	138.59	<.0001
Error	1799	1548955	851.00870		
Corrected Total	1801	1787807			

Root MSE	29.34295	R-Square	0.1335
Dependent Mean	76.40017	Adj R-Sq	0.1325
Coeff Var	38.40892		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	-273.11858	22.68827	-11.88	<.0001
annual_temp_fahrenheit	1	4.82505	0.35251	13.69	<.0001
annual_precip_12mo	1	0.64851	0.08953	10.57	<.0001

State=WEST VIRGINIA

Number of Observations Read	1080
Number of Observations Used	978
Number of Observations with Missing Values	102

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	6493.23030	3246.61515	5.50	0.0042
Error	975	575815	590.57928		
Corrected Total	977	582308			

Root MSE	24.30184	R-Square	0.0112
Dependent Mean	91.13384	Adj R-Sq	0.0091
Coeff Var	26.68809		

Parameter Estimates

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	98.98244	20.94091	4.73	<.0001
annual_temp_fahrenheit	1	-0.41731	0.36886	-1.13	0.2579
annual_precip_12mo	1	0.31202	0.11597	2.69	0.0073

Table 6 Comparison of Correlation Coefficients and Regression Coefficients

	Correlation coefficient	Regression coefficient	Adj.
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States in the South Atlantic Census Division	Corn yield and Temperature	Corn yield and precipitation	Dep. Var: Corn yields. Estimated coefficient of Temperature	Dep. Var: Corn yields. Estimated coefficient of Precipitation	r-squared
South Atlantic census division	-0.11*** (0.02)	0.09 (0.07)	-1.05*** (0.001)	0.78*** (0.003)	0.03
Delaware:	0.44*** (<0.0001)	0.23*** (0.005)	10.83*** (1.73)	1.29*** (0.40)	0.24
Florida	-0.04 (0.31)	0.13*** (<0.0001)	-0.002 (0.54)	0.31*** (0.08)	0.02
Georgia	0.35*** (<0.0001)	0.11*** (<0.0001)	6.32*** (0.21)	1.26*** (0.07)	0.17
Maryland	0.17*** (<0.0001)	0.26*** (<0.0001)	2.57*** (0.40)	1.25*** (0.133)	0.10
North Carolina	0.24*** (<0.0001)	0.17*** (<0.0001)	2.80*** (0.15)	0.70*** (0.05)	0.10
South Carolina	0.28*** (<0.0001)	0.21*** (<0.0001)	4.83*** (0.35)	0.95*** (0.09)	0.13
Virginia	0.20*** (<0.0001)	0.22*** (<0.0001)	2.55*** (9.23)	1.00*** (0.08)	0.08
West Virginia	-0.06* (0.05)	0.12*** (0.0001)	-0.42 (0.36)	0.31*** (0.12)	0.01

[Note: For correlation coefficients, associated p-values are given in parentheses. For regression results, the standard errors are given in parentheses. asterisks denote conventional statistical significance as follows: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$]

VIII. Concluding remarks

In this study, we found a statistically significant negative correlation between corn yields and temperature for the South Atlantic division and for West Virginia. For Florida, the correlation is negative but not statistically significant. The estimated correlation coefficients for temperature for the South Atlantic division is negative and statistically significant. For West Virginia and Florida, the correlation coefficient for temperature is negative but it is statistically significant only for West Virginia. Correlation coefficients between corn yields and precipitation were positive and, in most instances, statistically significant across jurisdictions. Although at the state-level regression results suggest that for some states the

marginal effect of rising temperature causes a drag on corn yields and for some other states it is a boosting factor for corn yield. The regional level regression suggests that the marginal impact of temperature on corn yield is negative in the South Atlantic division. This negative impact of temperature on corn yield is robust (as shown by the sign and statistical significance) across the baseline model and variant models with log-transformed data and growth rate data. There are some missing values for county-level corn yield data for two states in the region in the recent years. Inclusion of these missing data will enrich total number of observations under analyses and thereby it will further enrich the correlation studies and regression estimations. More research is needed to explore the impact of interactions between changes in surface temperature, soil moisture, and other relevant environmental factors to influence the yield of corn and other agricultural produce. As more real-time, and granulated data and novel estimation techniques become available, future research studies may explore novel techniques to decompose marginal effects of environmental factors, and technology factors including scale economy and managerial efficiency with respect to corn yields. Climate change-related research focuses on a longer time horizon. Thus, a natural extension of this paper would be to examine future trends of corn yields under various forecasted scenarios about surface temperature, precipitation, and other variables of interest.

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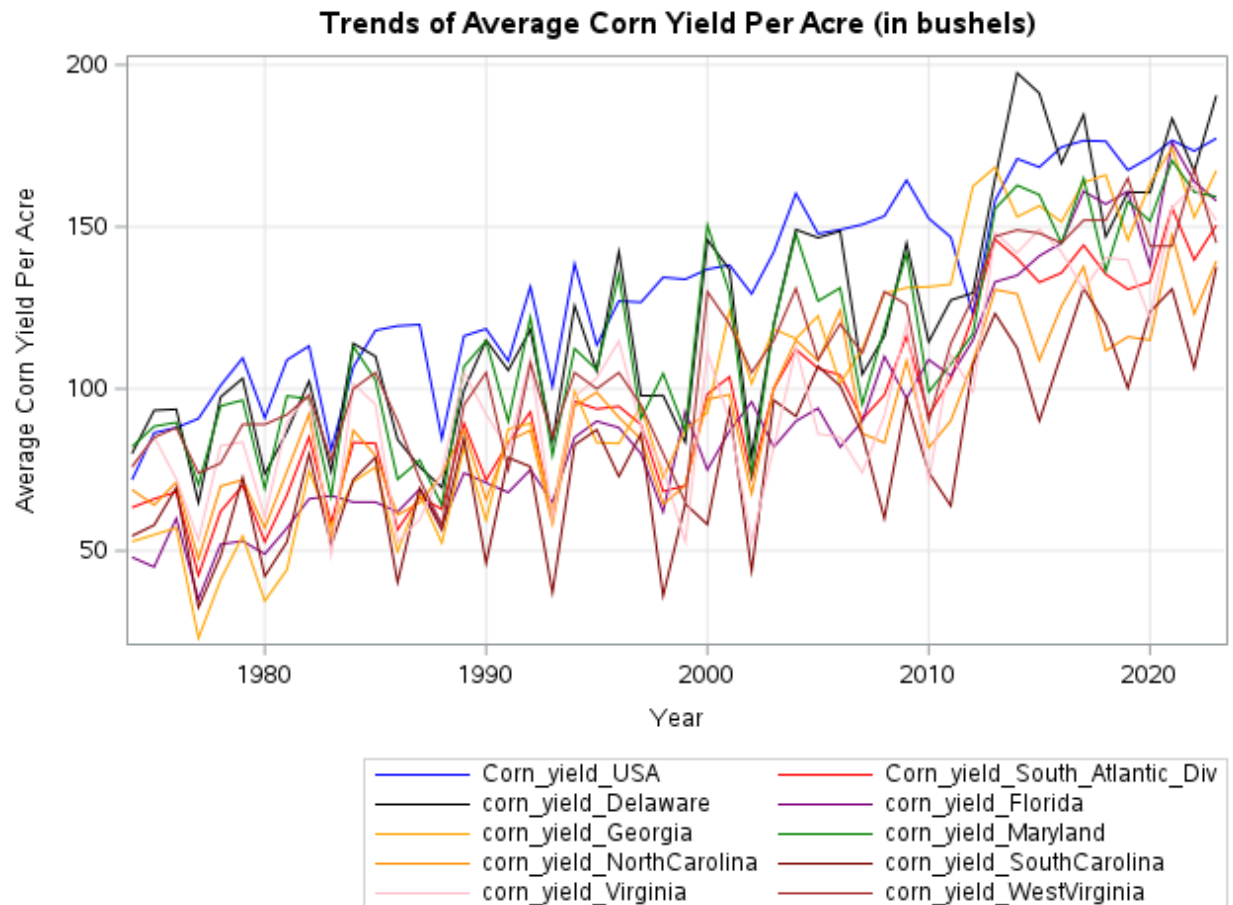
Appendices (excerpts from selected SAS codes and highlights of associated SAS output used in this paper):

SAS Codes and relevant output examples:

To generate a spaghetti plot of annual corn yields in the U.S. in the South Atlantic census division and in the individual states therein I used the following SAS commands:

```
1082 PRCL SPLUT DATA=sasug24.corn_yields_usnstates;
1083 /* Overlay line plots for each variable */
1084 series x= year y= corn_yield_US / lineattrs=(color=blue pattern=solid) name="corn_yield_US" legendlabel="Corn_yield_USA";
1085 series x= year y= corn_yield_SouthAtlantic_Div / lineattrs=(color=red pattern=solid) name="Average_corn_yield_SouthAtlantic_Div" legendlabel="Corn_yield_SouthAtlantic_Div";
1086 series x= year y= corn_yield_Delaware / lineattrs=(color=black pattern=solid) name="corn_yield_Delaware" legendlabel="corn_yield_Delaware";
1087 series x= year y= corn_yield_Florida / lineattrs=(color=purple pattern=solid) name="corn_yield_Florida" legendlabel="corn_yield_Florida";
1088 series x= year y= corn_yield_Georgia / lineattrs=(color=orange pattern=solid) name="corn_yield_Georgia" legendlabel="corn_yield_Georgia";
1089 series x= year y= corn_yield_Maryland / lineattrs=(color=green pattern=solid) name="corn_yield_Maryland" legendlabel="corn_yield_Maryland";
1090 series x= year y= corn_yield_NorthCarolina / lineattrs=(color=darkorange pattern=solid) name="corn_yield_NorthCarolina" legendlabel="corn_yield_NorthCarolina";
1091 series x= year y= corn_yield_SouthCarolina / lineattrs=(color=maroon pattern=solid) name="corn_yield_SouthCarolina" legendlabel="corn_yield_SouthCarolina";
1092 series x= year y= corn_yield_Virginia / lineattrs=(color=pink pattern=solid) name="corn_yield_Virginia" legendlabel="corn_yield_Virginia";
1093 series x= year y= corn_yield_WestVirginia / lineattrs=(color=brown pattern=solid) name="corn_yield_WestVirginia" legendlabel="corn_yield_WestVirginia";
1094
1095 /* Customize axes */
1096 xaxis label="Year" grid;
1097 yaxis label="Average Corn Yield Per Acre" grid;
1098
1099 /* Add a title */
1100 title "Trends of Average Corn Yield Per Acre (in bushels)";
1101 /*add a legend*/
1102 keylegend / position=bottomright;
1103 run;
```

The resulting spaghetti plot graph is as follows:



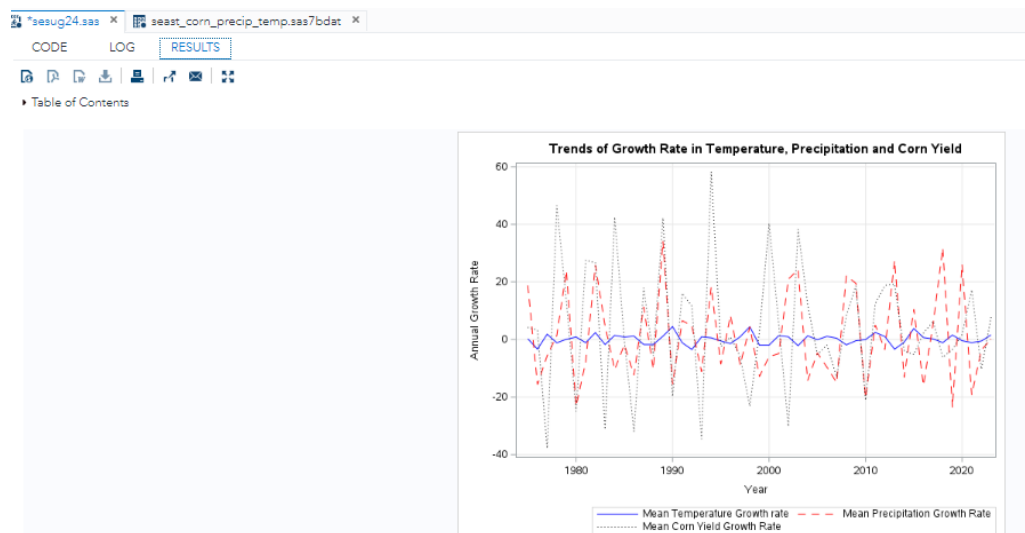
To generate a spaghetti plot of annual growth rates in mean temperature, mean precipitation, and mean corn yields in the South Atlantic census division I used the following SAS commands:

```

33 *now graph these three annual growth rates (temp, precip, corn yield) for SE region in total;
34
35 proc sgplot data=SESUG24.mean_corn_precip_temp_southeastx;
36     /* Overlay line plots for each variable */
37     series x= year y=TEMPGRTHRATE / lineattrs=(color=blue pattern=solid) name="Temperature growth rate" legendlabel="Mean Temperature Growth rate";
38     series x= year y= PRECIPGRTHRATE / lineattrs=(color=red pattern=dash) name="Precipitation growth rate" legendlabel="Mean Precipitation Growth Rate";
39     series x= year y= CORNGRTHRATE / lineattrs=(color=black pattern=dot) name="Corn yield growth rate" legendlabel="Mean Corn Yield Growth Rate";
40     /* Customize axes */
41     xaxis label="Year" grid;
42     yaxis label="Annual Growth Rate" grid;
43
44     /* Add a title */
45     title "Trends of Growth Rate in Temperature, Precipitation and Corn Yield";
46
47     /* Add a legend */
48     keylegend / position=bottomright;
49 run;

```

The resulting graph is as follows:



To generate report of mean corn yields, mean precipitation, and mean temperature I used the following SAS commands:

```
32 PROC REPORT DATA= SESUG24.SEAST_CORN_PRECIP_TEMP OUT=SESUG24.mean_corn_precip_temp_8states NOWD;
33 COLS YEAR State annual_temp_fahrenheit annual_precip_allcnty corn_bushl_peracre;
34 DEFINE YEAR / ANALYSIS GROUP;
35 DEFINE State / ANALYSIS GROUP;
36 DEFINE annual_temp_fahrenheit / ANALYSIS MEAN;
37 DEFINE annual_precip_allcnty / ANALYSIS MEAN;
38 DEFINE corn_bushl_peracre / ANALYSIS MEAN;
39 RUN;
```

The resulting output excerpts are given below:

CODE

LOG

RESULTS

OUTPUT DATA

Table of Contents

year	State	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
1974	DELAWARE	54.469444	3.2761111	80
	FLORIDA	68.530855	4.0726607	47.18
	GEORGIA	63.382644	4.2630182	52.831646
	MARYLAND	54.389493	3.3381522	82.130435
	NORTH CAROLINA	58.55475	4.363175	68.84
	SOUTH CAROLINA	62.856703	4.0026993	54.593478
	VIRGINIA	55.510051	3.5151117	75.546392
	WEST VIRGINIA	51.956633	3.8487722	73.334
1975	DELAWARE	55.033334	4.4933333	93.333333
	FLORIDA	68.571847	5.1688088	44.235
	GEORGIA	63.2819	5.1765128	54.959873
	MARYLAND	54.764855	4.481087	88.391304
	NORTH CAROLINA	58.865083	4.8167	64.12
	SOUTH CAROLINA	63.031884	4.8883696	57.93913
	VIRGINIA	55.620876	4.3817698	85.123711
	WEST VIRGINIA	52.389626	4.1901722	80.41

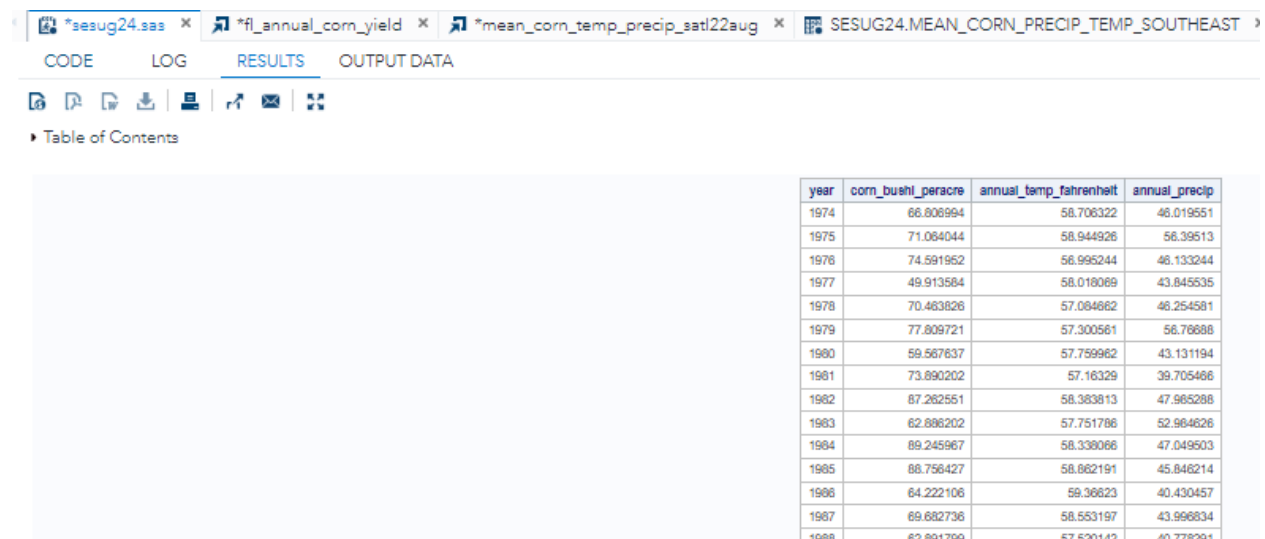
To generate report of mean corn yields, mean surface temperature and mean precipitation, the relevant SAS codes are as follows:

```

1625
1626 PROC REPORT DATA= SESUG24.MEAN_CORN_PRECIP_TEMP_8STATESX OUT=SESUG24.MEAN_CORN_PRECIP_TEMP_8STATESY NOWD;
1627 COLS YEAR corn_bushl_peracre annual_temp_fahrenheit annual_precip;
1628 DEFINE YEAR / ANALYSIS GROUP;
1629 DEFINE corn_bushl_peracre / ANALYSIS MEAN;
1630 DEFINE annual_temp_fahrenheit / ANALYSIS MEAN;
1631 DEFINE annual_precip / ANALYSIS MEAN;
1632 RUN;
1633

```

The resulting output excerpts are as follows:



year	corn_bushl_peracre	annual_temp_fahrenheit	annual_precip
1974	66.806994	58.708322	46.019551
1975	71.064044	58.944926	56.39513
1976	74.591952	56.995244	46.133244
1977	49.913584	58.018069	43.845535
1978	70.463826	57.064662	46.254581
1979	77.809721	57.300561	56.76688
1980	59.567637	57.759962	43.131194
1981	73.890202	57.16329	39.705486
1982	87.262551	58.383813	47.965288
1983	62.886202	57.751786	52.964626
1984	89.245967	58.338066	47.049503
1985	88.756427	58.862191	45.846214
1986	64.222106	59.36623	40.430457
1987	69.682736	58.553197	43.996834
1988	65.801706	57.520145	40.778204

To generate line graph on mean surface temperature I used the following commands:

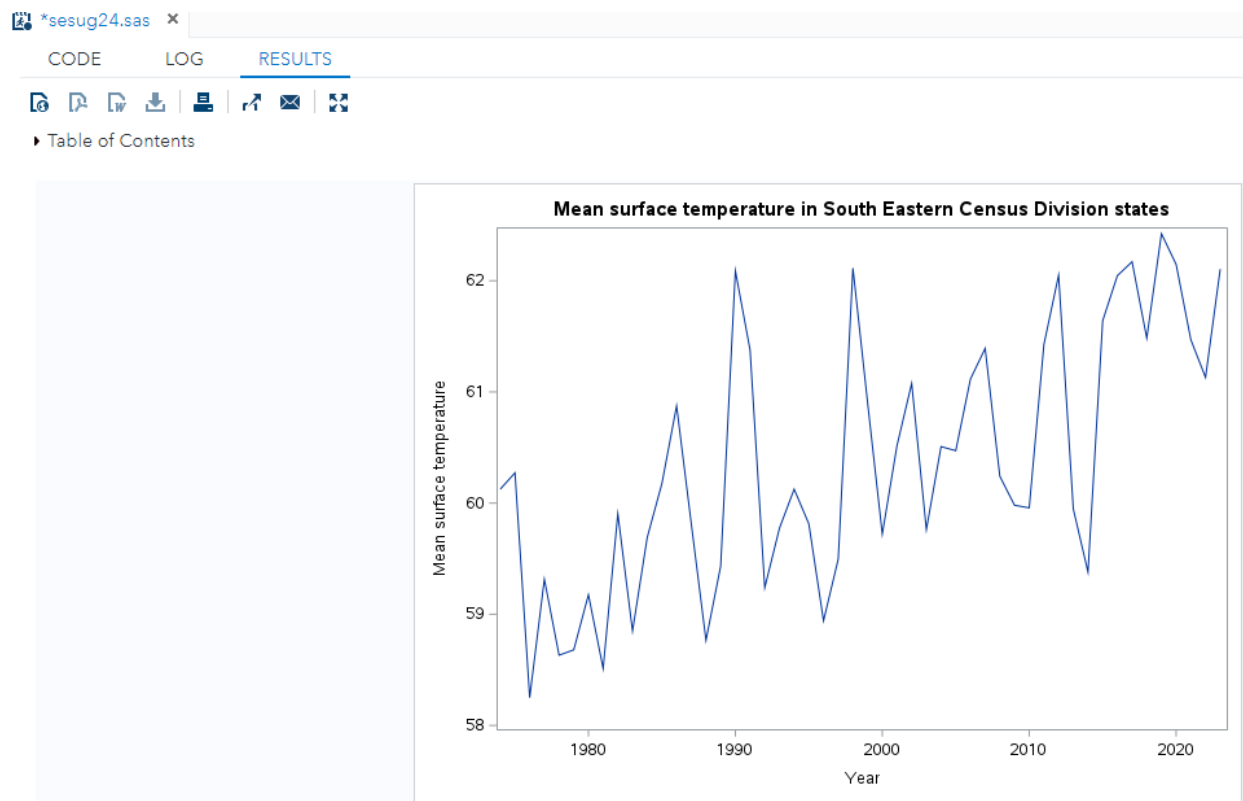
SAS coding examples:

```

63 *Proc SGPlot southeast temperature over time;
64
65 PROC SGPlot DATA=SESUG24.mean_corn_precip_temp_southeastx;
66 SERIES X= YEAR Y= annual_temp_fahrenheit;
67 title "Mean surface temperature in South Eastern Census Division states";
68 xaxis label= 'Year';
69 yaxis label='Mean surface temperature';
70 run;

```

The resulting graph excerpt is given below.



To generate line graph to compare mean surface temperature in eight states located in the South Atlantic Census Division, we use the following SAS command:

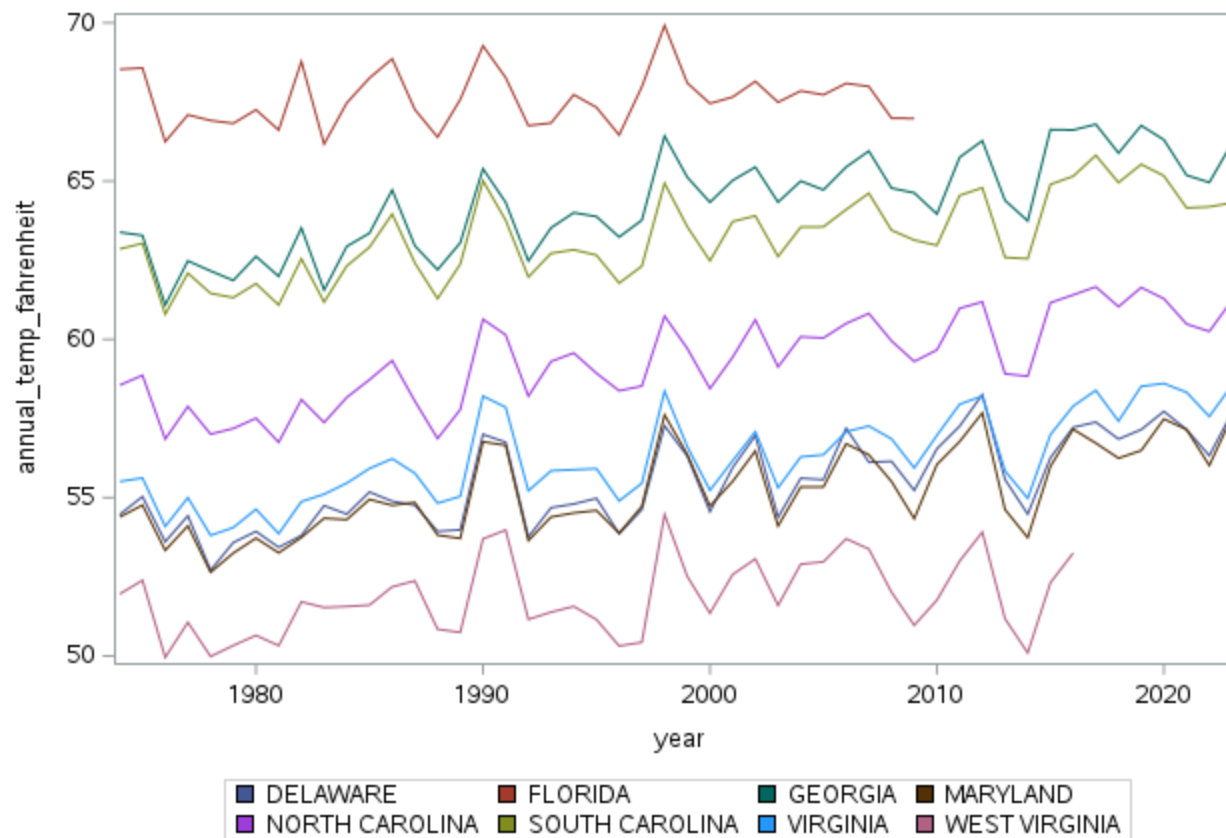
```

72 *now create SG PLOT for mean surface temperatures for 8 SE states;
73
74 proc sgplot data=SESUG24.mean_corn_precip_temp_8statesx;
75     title 'Mean Surface Temperature Trends in Individual States in the South Atlantic Census Division';
76     series x= year y= annual_temp_fahrenheit / group= State groupplc= State name='State';
77     keylegend 'State' / type=linecolor;
78 run;

```

The resulting graph is copied below.

Mean Surface Temperature Trends in Individual States in the South Atlantic Census Division



To generate correlation matrix in eight states located in the South Atlantic Census Division, we use the following SAS command:

```
PROC CORR DATA=SESUG24.SEAST_CORN_PRECIP_TEMP;
Title 'Correlations Matrix for South Atlantic Division States';
VAR annual_temp_fahrenheit annual_precip_allcnty corn_bushl_peracre;
RUN;
```

```
254 PROC CORR DATA=SESUG24.SEAST_CORN_PRECIP_TEMP_SC;;
255 VAR annual_temp_fahrenheit annual_precip_allcnty corn_bushl_peracre;
256 RUN;
```

The resulting correlation matrix is as follows:

*sesug24.sas

*sc_mean_temp_precipt_corn

SESUG24.MEAN_CORN_PRECIP_TEMP_8STATES

CODE

LOG

RESULTS

Table of Contents

Correlations Matrix for South Atlantic Division States

The CORR Procedure

3 Variables: annual_temp_fahrenheit annual_precip_allcnty corn_bushl_peracre

Simple Statistics						
Variable	N	Mean	Std Dev	Sum	Minimum	Maximum
annual_temp_fahrenheit	29937	58.22045	16.29435	1742946	-53.60833	78.56667
annual_precip_allcnty	30437	3.86552	1.49086	117655	-6.10000	8.79083
corn_bushl_peracre	18582	88.10483	38.47396	1637164	0	240.00000

Pearson Correlation Coefficients			
Prob > r under H0: Rho=0			
Number of Observations			
	annual_temp_fahrenheit	annual_precip_allcnty	corn_bushl_peracre
annual_temp_fahrenheit	1.00000	0.83352	-0.00958
		<.0001	0.2042
	29937	29937	17569
annual_precip_allcnty	0.83352	1.00000	0.08823
	<.0001		<.0001
	29937	30437	18069
corn_bushl_peracre	-0.00958	0.08823	1.00000
	0.2042	<.0001	
	17569	18069	18582

The following codes were used for conducting regression of corn yield on temperature and precipitation using county level data and state level data for the eight states located in the South Atlantic Census Division.

County level regression:

```

L401 *simple linear regression;
L402 PROC REG DATA=SESUG24.SEAST_CORN_PRECIP_TEMPX;
L403 MODEL corn_bushl_peracre = annual_temp_fahrenheit annual_precip_allcnty;
L404 run;
L405

```

Regression results:

Number of Observations with Missing Values	13381
--	-------

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	227908	113954	76.94	<.0001
Error	17568	28016416	1481.06660		
Corrected Total	17568	28244323			

Root MSE	38.48463	R-Square	0.0087
Dependent Mean	87.82964	Adj R-Sq	0.0086
Coeff Var	43.81736		

Parameter Estimates					
Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	1	80.55201	3.66915	21.95	<.0001
annual_temp_fahrenheit	1	-0.20225	0.05986	-3.38	0.0007
annual_precip_allcnty	1	4.83687	0.39199	12.34	<.0001

State level regression:

```

1413 *simple linear regression;
1414 PROC REG DATA=SESUG24.updated_temp_corn_precip_8states;
1415 MODEL corn_bush1_peracre = annual_temp_fahrenheit avg_annual_precipitation;
1416 run;

```

Regression results:

The REG Procedure
 Model: MODEL1
 Dependent Variable: corn_bushl_peracre corn_bushl_peracre

Number of Observations Read	400
Number of Observations Used	400

Analysis of Variance					
Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	16298	8149.15571	6.90	0.0011
Error	397	469108	1181.63123		
Corrected Total	399	485406			

Root MSE	34.37486	R-Square	0.0336
Dependent Mean	100.95113	Adj R-Sq	0.0287
Coeff Var	34.05100		

Parameter Estimates						
Variable	Label	DF	Parameter Estimate	Standard Error	t Value	Pr > t
Intercept	Intercept	1	126.20666	18.53052	6.81	<.0001
annual_temp_fahrenheit	annual_temp_fahrenheit	1	-1.04594	0.32291	-3.24	0.0013
avg_annual_precipitation	avg_annual_precipitation	1	0.77954	0.26545	2.94	0.0035