Effects of Drought Conditions on Agricultural Productivity in Central and Western Tennessee

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Abstract

This paper analyzes the relationship between agricultural productivity of farms in drought conditions. The variables used in this research include fertilizer expense, precipitation totals, and average temperature. The model integrates all of the mentioned variables and finds the connection between the land value of farms and the variables. The outcomes show that both fertilizer expense and precipitation have negative relationships to land values for farms, while average temperature has a positive relationship.

JEL Classification: Q15, Q25, Q54

Keywords: Droughts, Agricultural Productivity

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1.0 INTRODUCTION

As of March 2015, almost fifteen percent of the continental US was classified under moderate or extreme drought (NOAA). This percentage has been increasing for over the past years and seems to be prevalent in the southern and western regions and a census of scientists conclude that these effects will only increase with the side effects of global warming. Drought is defined by Palmer 1965 as “an interval of time, generally of the order of months or years in duration, during which the actual moisture supply at a given place rather consistently falls short of the climatically expected or climatically appropriate moisture supply.”

Where these regions are experiencing consistent shortfalls, other issues begin to rise; this could include increased crop failure, lack of water for municipalities and farms, and the increase of natural disaster such as floods and wildfires. A Washington Post piece sheds light on this topic in 2016 It identifies the less national publicized drought in the southeast. This drought effects the states of Alabama, Georgia, Mississippi, South Carolina, and Tennessee. Particularly, in Tennessee, there has been an increase in wildfires and their spread, i.e. Gatlinburg fires in February of 2017 as well as extreme drought throughout the state.

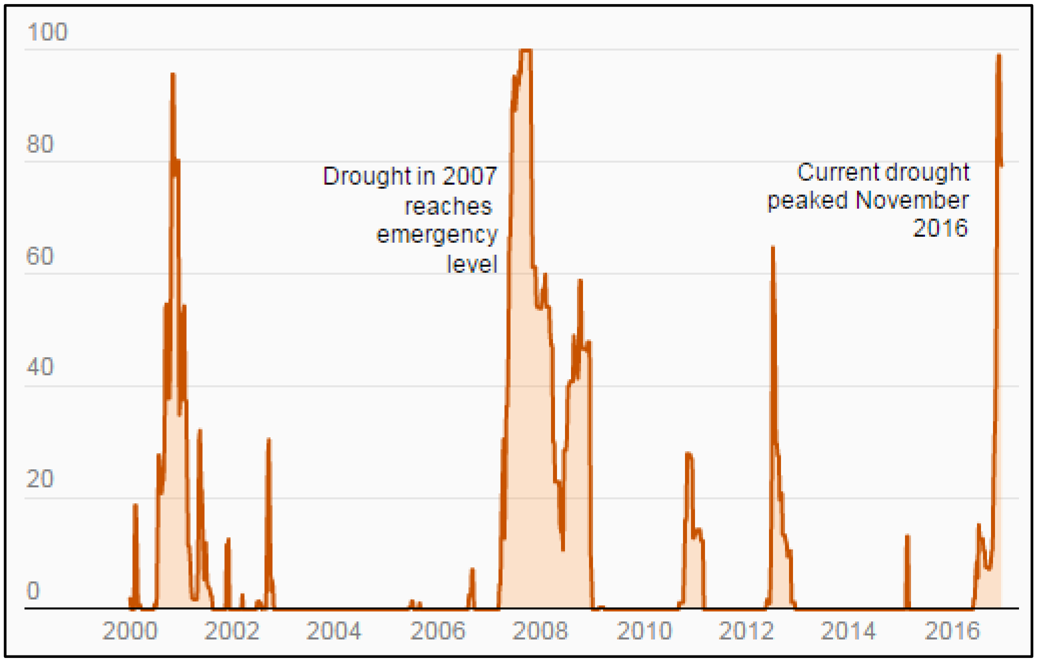
Tennessee’s drought complications are part of the motivation of this paper. The aims of this paper are to evaluate a state crucial to agricultural output on a national level and see how this agriculture is effected by these drought conditions. The objective of this paper to do discover, if any, the relationship concerning environmental factors and the industries, specifically agriculture, that rely on stable conditions, rather than the variable ones that exist currently.

This paper is organized in a way that special attention will be given to the recent trends in the region of droughts and farm yields. Next, the study will look into supplementary material in regards to the relationship between climate effects and agricultural production. Following this, we will analyze and discuss the model and its results.

2.0 TRENDS: DROUGHT AND CROPS IN TENNESSEE

Tennessee is an interesting study because of recent developments in forest fires and drought conditions. As a strong agricultural state, it is important to see how drought impacts around the US are being seen. Drought conditions in Tennessee over the past two years have put between 90-100% of the state in moderate to extreme drought conditions (US Drought Monitor). Tennessee has ranked number ninth in total agricultural acres in the US (Farmer). Figure 1 depicts the trend and frequency of droughts in the state of Tennessee from 2000 to 2016. There have been four significant or drought in that time, lasting for serval month. The largest in this graph is depicted in 2007-2009 when drought ratings were above 40 percent.

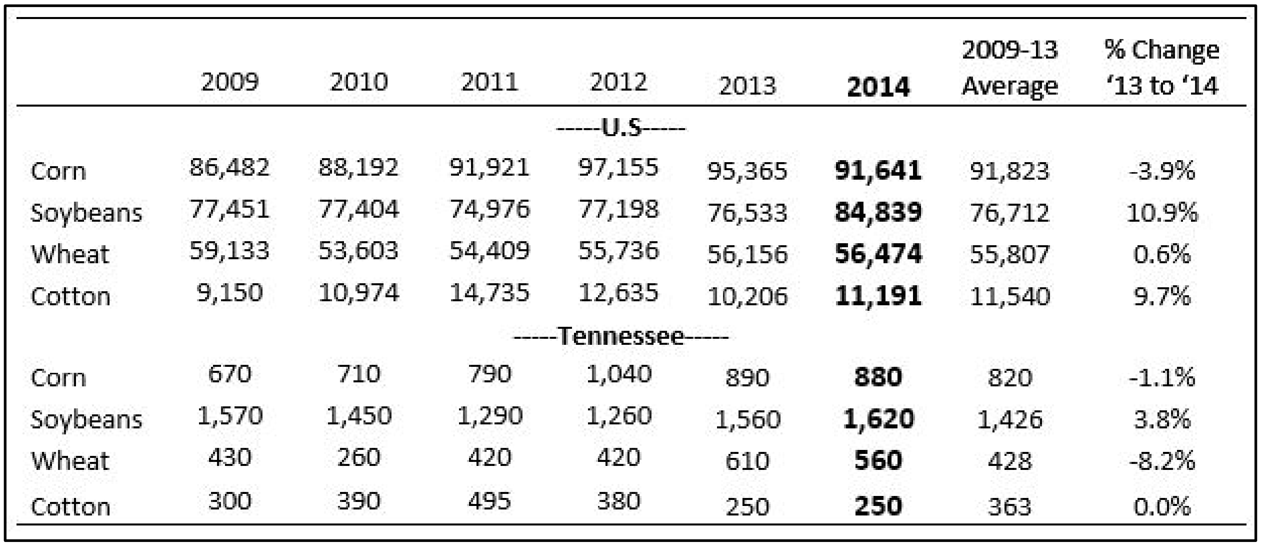
Figure 1: Percent of Tennessee under serve drought



Source: US Drought Monitor

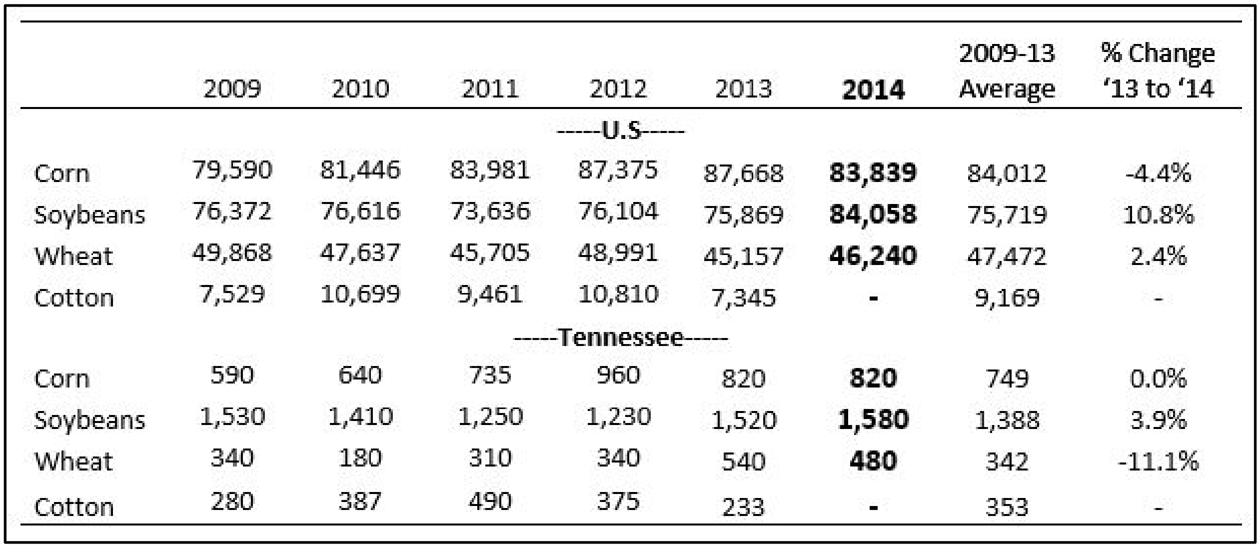
It is also important to evaluate the overall farmland in Tennessee to see how the state could be potentially impacted by these varying droughts. Figure 2 and 3 is showing the breakdown of crop planting and harvesting in Tennessee. This gives an idea to what crops may be effected by the drought in the region and how that may translate to a national level of production. This chart shows an analysis between 2009 and 2014.

Figure 2: Planted acreage for major row crops produced in Tennessee in thousands of acres



	2009	2010	2011	2012	2013	**2014**	2009-13 Average	% Change '13 to '14
				-----U.S-----				
Corn	86,482	88,192	91,921	97,155	95,365	**91,641**	91,823	-3.9%
Soybeans	77,451	77,404	74,976	77,198	76,533	**84,839**	76,712	10.9%
Wheat	59,133	53,603	54,409	55,736	56,156	**56,474**	55,807	0.6%
Cotton	9,150	10,974	14,735	12,635	10,206	**11,191**	11,540	9.7%
				-----Tennessee-----				
Corn	670	710	790	1,040	890	**880**	820	-1.1%
Soybeans	1,570	1,450	1,290	1,260	1,560	**1,620**	1,426	3.8%
Wheat	430	260	420	420	610	**560**	428	-8.2%
Cotton	300	390	495	380	250	**250**	363	0.0%

Source: University of Tennessee Institute of Agriculture



	2009	2010	2011	2012	2013	**2014**	2009-13 Average	% Change '13 to '14
				-----U.S-----				
Corn	79,590	81,446	83,981	87,375	87,668	**83,839**	84,012	-4.4%
Soybeans	76,372	76,616	73,636	76,104	75,869	**84,058**	75,719	10.8%
Wheat	49,868	47,637	45,705	48,991	45,157	**46,240**	47,472	2.4%
Cotton	7,529	10,699	9,461	10,810	7,345	**-**	9,169	-
				-----Tennessee-----				
Corn	590	640	735	960	820	**820**	749	0.0%
Soybeans	1,530	1,410	1,250	1,230	1,520	**1,580**	1,388	3.9%
Wheat	340	180	310	340	540	**480**	342	-11.1%
Cotton	280	387	490	375	233	**-**	353	-

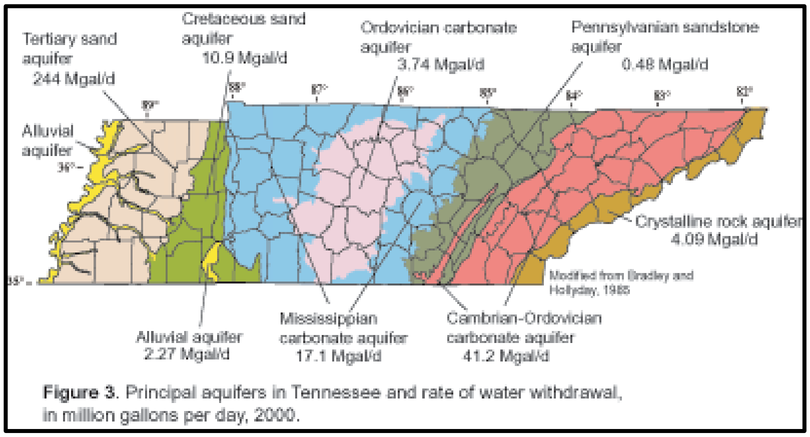
Source: University of Tennessee Institute of Agriculture

The above mentioned definition of drought is crucial to this study because it defines that the drought can vary in severity and length. Palmer's method incorporates historic precipitation and temperature, something that will be added to this study as well. One main confusion is the difference between arid regions and drought regions. There is a tendency to equate a drought to the images of barren, dried up lake beds and cacti, but that is misleading. A drought is indeed a shortage of water in a particular region, but a drought is a temporary effect on a water supply. However, this effect can be re occurring and may have wider scale implications. One industry effected most by water shortages can be agriculture. It is also important to remember the broader impacts of the drought. As Ding et al. 2010 finds "…farmers with crop losses will reduce their supplies to the downstream industries, such as food processors and ethanol plants. These consumers would have to bid a higher price for the inputs or otherwise reduce their production for the lack of inputs."

In the US alone, agriculture uses up to 80 to 90 percent of consumptive water use, or water that is not returned to the resource used (WRI). An example of this is when water is taken directly from a watershed or aquifer and if transported or directed straight to a farm and use exclusively for the watering of crops. So shortages in the amount of water effect farmers often first and the harshest. An interesting part about Tennessee, not only its varied soil compositions across several regions, but is the reliance on ground water in Western countries. Nashville is the largest metropolitan area in the world that relies on ground water (USGA). This is an important factor because in states like California, this can drastically effect farm prices with farm values. The Fresno Assessor's office found that "access to surface water and groundwater go for about $20,000 per acre. The same piece of property in a district with no surface supply or underground wells goes for $750 per acre." Figure 4 shows the aquifers throughout Tennessee which is where we can conclude some of the water used in the agriculture production. The argument is presented by Fereres and Soriano (2006) in which he explains how some find that irrigation is crucial to the production of food in the future. Not only is the irrigation found be crucial in agricultural performance, but overall rainfall is also found to be important. A study done by Frekedulegn et al. (2003) found that tree growth was stunted in rain deprived regions in the US. One on the trees that was found to be affected the most was a tree that was "site specific," meaning the growth of the tree was effect more because of the lack of root dispersal. This could be equated to a smaller crop like corn or cotton where there is little root growth. As mentioned, a drought condition is present when there is a shortfall of moisture supply. This shortfall could come in the form of rainfall, but also could be accelerated by higher temperatures. Saft et al.

(2015) discusses the relationship between a multi-year drought and rainfall. It found that evaporation levels can potentially increase when there is increase surface radiation and warmer temperatures. This could be important in seeing historical trends in droughts and temperature changes.

Figure 4: Aquifer Location throughout Tennessee



Source: USGS

The FOA, Food and Agriculture Organization of the United Nations, states. “When evaluating the performance of a production unit or the agricultural sector, it is common to use production (the level of output), productivity (output per unit of input) or efficiency (actual output relative to the potential output or best practices) as indicators.” We will use this analysis when deciding what variables will be used in the model. In analyzing productivity, we can see the impacts of certain factors on productivity. Battisti & Naylor (2009) have found that higher growing season temperatures can have drastic impacts on agricultural productivity along with farm incomes. The research along highlighted the 2003 European heat wave that not only took lives, but decrease French and Italian corn production by over 30% (Battisti & Naylor 2009). It is important than to see how the above mentioned regions have been coping with these prolonged droughts.

4.0 DATA AND EMPIRICAL METHODOLOGY

For this study, I will focus on the state of Tennessee and see the effects on agricultural productivity in the regions of the state effected most by drought. It is also important to keep in mind the cyclical nature that droughts may have. Over the past several years, Tennessee has seen a drought in its central basin as well as some of its eastern counties. All regions contain some form of agricultural crop production, at varying levels. In order to see the differences in the agricultural productivity in these regions, one must first assess what that can be defined as.

4.2 Empirical Model

This model includes historical precipitation and temperature total in crop production. This paper will include an additional variable for fertilizer expense to assess economic output. This model will be run in an OLS regression and a panel data study. This a modified model from Nicholls (1997)

$$\text{SVaule} = \text{SRain} + \text{STemp} + \text{SFert}$$

Where SValue represents the value of the farmland, SRain, STemp, and SFert represent average rainfall, average temperature, and amount spent on fertilizer per acre, respectively. The value in both the land assessment and the fertilizer is per acre and in USD.

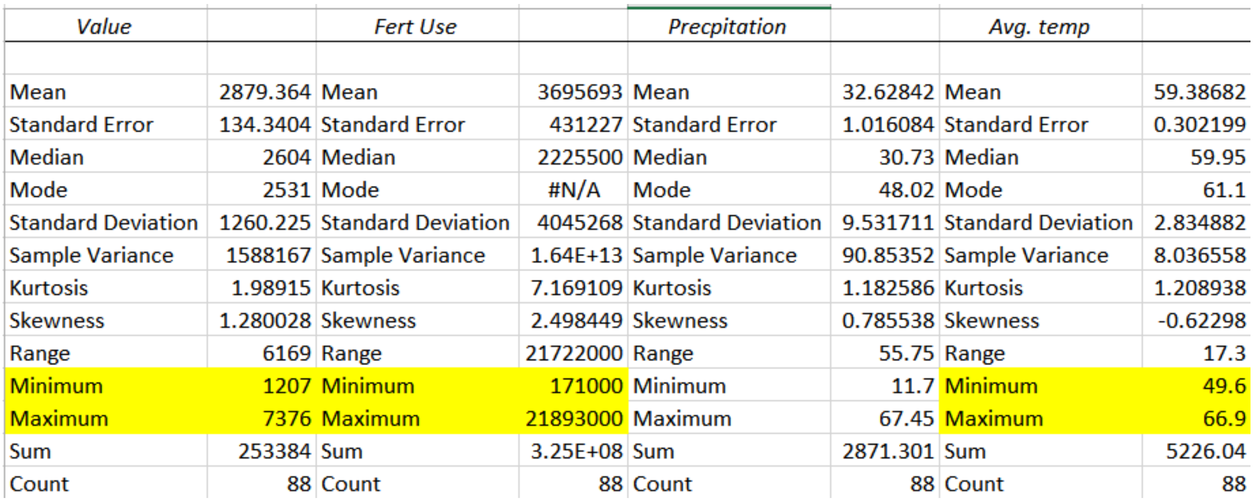
For this study, the productivity will be measured in both total crop production and asset value of the farms by county. The crop production to judge the yield, the dependent variable will be the asset value to see the effects of profits on those yields. When assessing the drought conditions, the independent variables of precipitation averages and temperature will be used. The model will also contain fertilizer purchase per acre. This data will be retrieved from the USDA, NOAA, and Drought ACIS from reporting stations in 14 counties in Tennessee. The model will be replicated from *Effects of precipitation and temperature on crop production variability in northeast Iran* (Bannayan et al).

5.0 EMPIRICAL RESULTS

Figure 6: Correlation Table

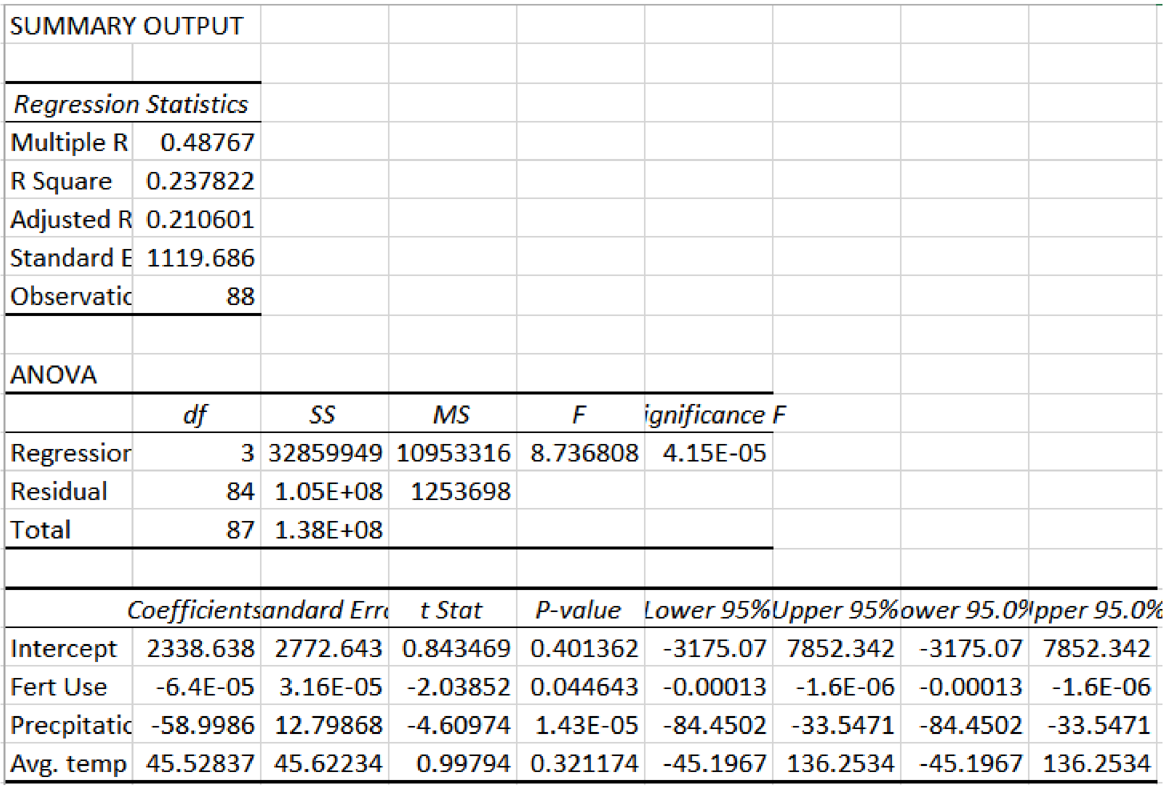
	Value	*Fert Use*	*Precpitation*	*Avg. temp*
Value	1			
Fert Use	-0.13274	1		
Precpitation	-0.44618	-0.08731	1	
Avg. temp	0.110095	0.342163	-0.175732101	1

Figure 7: Descriptive Statisitcs



Value		*Fert Use*		*Precpitation*		*Avg. temp*	
Mean	2879.364	Mean	3695693	Mean	32.62842	Mean	59.38682
Standard Error	134.3404	Standard Error	431227	Standard Error	1.016084	Standard Error	0.302199
Median	2604	Median	2225500	Median	30.73	Median	59.95
Mode	2531	Mode	#N/A	Mode	48.02	Mode	61.1
Standard Deviation	1260.225	Standard Deviation	4045268	Standard Deviation	9.531711	Standard Deviation	2.834882
Sample Variance	1588167	Sample Variance	1.64E+13	Sample Variance	90.85352	Sample Variance	8.036558
Kurtosis	1.98915	Kurtosis	7.169109	Kurtosis	1.182586	Kurtosis	1.208938
Skewness	1.280028	Skewness	2.498449	Skewness	0.785538	Skewness	-0.62298
Range	6169	Range	21722000	Range	55.75	Range	17.3
Minimum	1207	Minimum	171000	Minimum	11.7	Minimum	49.6
Maximum	7376	Maximum	21893000	Maximum	67.45	Maximum	66.9
Sum	253384	Sum	3.25E+08	Sum	2871.301	Sum	5226.04
Count	88	Count	88	Count	88	Count	88

Figure 8: Regression Table



SUMMARY OUTPUT

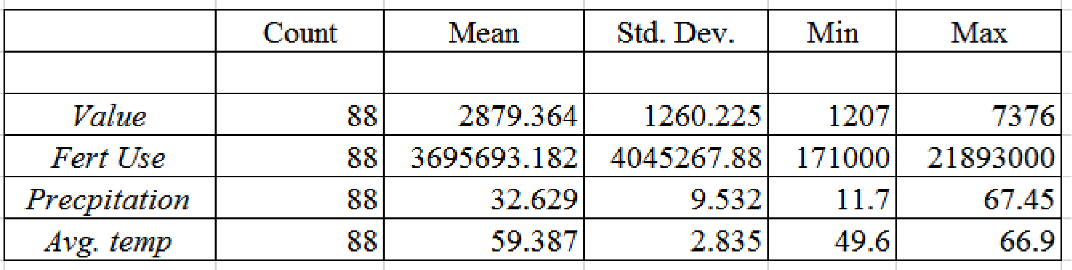
Regression Statistics	
Multiple R	0.48767
R Square	0.237822
Adjusted R	0.210601
Standard E	1119.686
Observatic	88

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regressior	3	32859949	10953316	8.736808	4.15E-05
Residual	84	1.05E+08	1253698		
Total	87	1.38E+08			

	Coefficients	*andard Err*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*ower 95.0%*	*pper 95.0%*
Intercept	2338.638	2772.643	0.843469	0.401362	-3175.07	7852.342	-3175.07	7852.342
Fert Use	-6.4E-05	3.16E-05	-2.03852	0.044643	-0.00013	-1.6E-06	-0.00013	-1.6E-06
Precpitatic	-58.9986	12.79868	-4.60974	1.43E-05	-84.4502	-33.5471	-84.4502	-33.5471
Avg. temp	45.52837	45.62234	0.99794	0.321174	-45.1967	136.2534	-45.1967	136.2534

Figure 9: Summary Statistics



	Count	Mean	Std. Dev.	Min	Max
Value	88	2879.364	1260.225	1207	7376
Fert Use	88	3695693.182	4045267.88	171000	21893000
Precpitation	88	32.629	9.532	11.7	67.45
Avg. temp	88	59.387	2.835	49.6	66.9

5.1 DISCUSSION:

Interpreting these results, over a period of time between 1997 and 2012, and 88 observations, there is a positive relationship between average temperature and land value. Conversely, precipitation and fertilizer use have negative relationships. As rainfall amounts decrease, land value will see a decrease by $58 an acre, while fertilizer use will decrease the value by cents on the dollar. The fertilizer trend could be explained by rising price of fertilizers, demonstrated by a 2013 BLS report. Import prices of fertilizers have remained high due to a large demand. This could indicate that farmer take into careful consideration what crops to grow based on required fertilizers. Another theory could be that prolonged fertilizer use makes land harder to cultivate. A lack of precipitation does seem appropriate to decrease land value because "food grows where water flows." It should also be noted that average temperature does have a positive relationship, but is found to be insignificant in this regression. The overall accuracy of this regression, the r-squared, remains low at .237. It is also worth mentioning the descriptive statistics. The average value of farm land in these counties in $2879, which is about $500 more an acre than the intercept. Also, the spread of the data is quite large. When looking at fertilizer use, the dollars spent on fertilizer is between the minimum, $171,000 and $21 million. That could skew some of the data because not only do different size farms impact the amount of fertilizer used, also the type of crops grown on the land. With reduced evaporation and decreased rainfall, regions effected by drought may remain in those conditions for a prolonged time due to the lack of water to be evaporated to promote rainfall, almost a self-sustaining drought. However, in our connected world, water can be transported to the locations it is in demand, so drought regions may not see as much of a severity; they may be in a drought condition, but not feeling the effects. In Tennessee, this is effected by the closeness to an urban center. Individual farmers would have to spend much more of their own capital drilling for ground water, going to depths of 1,000-2,000 feet. Dyson (1999) talks about wider implications of these two variables and indicates that water must be used more efficiently due to an increase and agriculture around the world. Moreover, Dyson concludes that there will be an even larger reliance on fertilizers, an example he shows in South Asia. In continuing evaluations of the implications of this study, a TIME Magazine article points out an interesting thesis as well, “Farmers in developed countries tend to grow crops uniformly across large areas. Drought affects those crops uniformly. Growing a wide variety of crops in a given region in the developing world mitigates the risk that all crops will be wiped out thanks to a given weather event.” All of the above mentioned should be considered for additional research as well as bettering this study itself.

5.2 LIMITATIONS:

This study, as most do, does have some limitations. To begin, this study only uses three distinct variables. There are definitely deeper research that can be done into the Palmer Index on moisture and evaporation rates of soil in the region. Another limitation can be seen in the transportation of water. In this study, some of the counties measured share a border or are close enough that there is some connection to an outside water source. This could allow for farmers in what is a drought ridden can still grow crops and the effects may not be as strongly felt. On the precipitation front where the type of precipitation is of interest as well. If there is severe rain, such as thunderstorms or hail, crops may be damaged, which outweighs the benefit of the rainfall. Floods could also be accounted in the same way as a decrease in soil moisture and heavy rains may produce flash floods or runoff, both potentially dangerous to crop and the farms themselves. When looking at the minimum and maximum value for all the variables, there is some discrepancies. An example would be fertilizer use. The minimum value is \$171,000 and the maximum is \$21,893,000. These numbers represent a large spread in the amount of fertilizer these use, which could be because of some crops requiring a large amount of fertilizer, but also could be because of the size of the farms in the county. The data was also taken from census data, which is every years which could have some issues with current data taken. An additional study could be done that only assess similar sized farms and/or one crop regressions.

6.0 CONCLUSION:

The results of the study aimed to find a causal relationship between agricultural production and drought indicators. In Tennessee, impact on agricultural production is a very important area of research, seeing as there has been prolonged and frequent droughts. In 2008, coupled with economic hardships and drought, drought mitigation measured could have softened the impact. With anticipation rain averages, there could be an increase in the equal distribution of water and also equitably use fertilizer to increase yields and prevent economic hardships. Increase spending on fertilizers to help prevent drought effects may protect the crops, but has should to lower the value of the land. However, responsible water measures must be taken to ensure droughts are not prolonged and effect of agricultural productivity is not as effected, as the cyclical effect cannot be prevented.

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