SOIL MOISTURE AND PEANUT CROP YIELD CORRELATION STUDY IN GEORGIA WITH TWO CONTRASTING PRECIPITATION YEARS

C. W. Strother and S.S. Panda

AUTHORS: Institute of Environmental Spatial Analysis, Gainesville State College, 3820 Mundy Mill Rd, Oakwood, Georgia 30566.
REFERENCE: *Proceedings of the 2011 Georgia Water Resources Conference*, held April 11–13, 2011, at the University of Georgia.

Abstract. According to the Georgia Peanut Commission, the state produces 45% of the peanuts in the U.S. The peanut industry contributes 50,000 jobs to Georgia and is a $2 billion industry (Georgia Peanut Commission, 2010). Therefore, it is a vital crop to the state's economy. Soil moisture in the areas where peanuts are grown is a crucial parameter determining crop yield. This study examines the soil moisture in proximity (0.5 mi) to major peanut producing farms in South Georgia based on data obtained from the Georgia Automated Environmental Monitoring Network (http://www.georgiaweather.net/). In this decade, we had two contrasting precipitation years in Georgia. Due to the La Niña pattern, which is associated with dry, warm winters across much of the Southeast, Year 2007 was a severe drought year with 50-70% of normal precipitation in South Georgia. In contrast, Year 2009 was an extreme precipitation year with severe flooding in several parts of Georgia. The annual precipitations were 37.06 and 53.54 inches for years 2007 and 2009, respectively with an annual average precipitation of 46.94 inch (http://www.georgiaweather.net/). Geospatial models were built for both years to compare the rainfed peanut crop yield and soil moisture content in the study area. By examining the soil moisture versus peanut crop yields through linear regression analysis for 2007 and 2009, coefficient of determination (R^2) values of 0.21 and 0.37, respectively, were obtained. With outlier deletion, coefficient of determination (R^2) values increased to 0.69 and 0.63 for the year 2007 and 2009, respectively. We did not consider other factors, such as soil type and irrigation amount (if any) for peanut crop yield in the analysis. We expect the correlation will be stronger if these factors are included in the analysis.

INTRODUCTION

Agriculture is the major source of livelihood in Southern Georgia counties. Cotton, peanuts, wheat, soybeans, and vegetables are major cash crops that are grown in those counties. According to a study by Nesbitt and Panda (2011), peanuts and wheat are the two most profitable crops in South Georgia. Studies and analysis have been made regarding the crop yield in bushels per acre, pounds per acre, price received per bushel, and price received per acre for several cash crops such as cotton, wheat, peanuts, rye, soybeans, etc., by downloading 27 years (1982 – 2009) of data from the National Agriculture Statistics Service (NASS) website. Their results indicated that in categories of yield and price received, peanuts and wheat were the best crops to plant based on the potential for higher economic gain. According to the Georgia Peanut Commission, the state produces 45% of the peanuts in the U.S. The peanut industry contributes 50,000 jobs to Georgia and is a $2 billion industry (Georgia Peanut Commission, 2010). Georgia has 14,160 peanut farms out of which around 4,800 are active. Approximately 250 peanut related industries are located in Georgia. Therefore, it is a vital crop to the state's economy.

Soil moisture along with soil characteristics in the areas where peanuts are grown are crucial parameters determining its yield. According to Wright and Rao (1994), more than 80% of world's peanut production is due to rainfed agriculture and the rest uses irrigation as the water source. Due to global warming and climate change and change in thermohaline circulation, the Northern Hemisphere's tropics and subtropics (a region between equator and 30^0 N) including Georgia become drier while Southern Hemisphere's similar region becomes wetter (Panda, 2008). Because of these phenomena, erratic and insufficient rainfall is becoming a major constraint in rainfed peanut crop production areas including Georgia (Songri et al., 2009). Water is getting scarcer due to an increase in demand of human and industrial consumption. This problem is exacerbated due to the depletion of the ground water table in feet in South Georgia. According to United States Geological Survey (USGS)'s ground water well study, Cook County, southwest Georgia encountered a 13 feet depletion in ground water during 1967 to 2002 (Perlman, 2011). Drought conditions diminish the peanut yield if the stress continues during the stages of pod and seed formation (Vorasoot et al., 2003).

Therefore, the objective of this study was to examine the relationship of soil moisture in proximity (0.5 mi) to major peanut producing farms in South Georgia to the peanut yield in two contrasting rainfall years of 2007 and 2009. This study intends to facilitate this analysis with the use of geospatial technology, which is rarely used in such studies. In this decade, we had two contrasting precipitation years in Georgia. Due to the La Niña pattern, which is associated with dry, warm winters across much of the Southeast, Year 2007 was a severe drought year with 50-70% of normal precipitation in South Georgia. In contrast, Year 2009 was an extreme precipitation year with severe flooding in several parts of Georgia. The annual precipitations were 37.06 and 53.54 inches for years 2007 and 2009, respectively with an annual average precipitation of 46.94 inch (http://www.georgiaweather.net/). This study did not consider longer duration (more years) for analysis as it is only intended to observe any changes in peanut yield in two contrasting rainfall years. Most of the peanut production areas considered in the study was rainfed. Therefore, irrigation data was unavailable the locations and was not considered as a parameter in the analysis.

MATERIALS AND METHODS

Study Area. At the outset, the spatial distribution data of peanut production in Georgia was downloaded from the United States Department of Agriculture (USDA) National Agriculture Statistics Services (NASS) [http://www.nass.usda.gov/]. The crop production spatial data was obtained as a NASS image of classified crops (Figure 1). From analysis of the NASS image with respect to the Georgia county feature file, all the counties with peanut production were first selected.

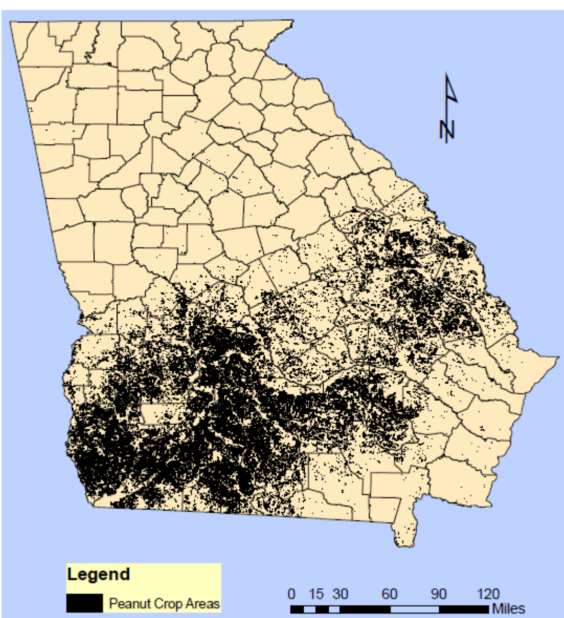

Figure 1. Peanut production area in Georgia.

Next, the study area was selected in compliance with the Georgia Automated Environmental Monitoring Network (GA AEMN; http://www.georgiaweather.net/). The GA AEMN weather stations are set up closer to agricultural farms and records weather data related to crop production every 15 minutes in an automated fashion. To determine which stations were within a 0.5 mile radius of peanut crops in 2007 and 2009, a spatial analysis operation was performed in ArcMap (ESRI, Oakland, CA). This analysis indicated 29 of the 79 total stations are within a 0.5 mile radius of peanut crops. From these 29 stations, 10 lacked the appropriate information from the USDA regarding 2009 crop yield for peanuts, so they were eliminated from the study. Thus, there were a total of 19 stations remained suitable for analysis in 12 different counties in southern Georgia (Figure 2). The counties are: Baker, Brooks, Bulloch, Burke, Coffee, Colquitt, Crisp, Decatur, Dooly, Sumter, Terrell, and Tift. As mentioned earlier, the peanut produced in the area within a 0.5 mile radius of the weather stations were mostly rainfed.

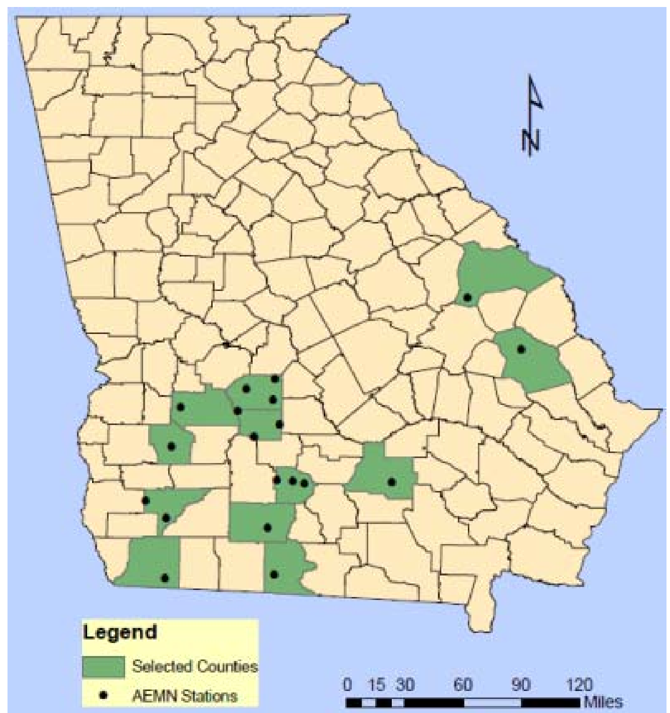

Figure 2. Map showing the locations of GA AEMN weather stations in the study area in selected 12 counties of South Georgia.

Peanut Crop Yield and Soil Moisture Data. Weather data, especially soil moisture data and the peanut crop yield data for this study was obtained in GIS spatial layer format as well as tabular format from the GA AEMN and the downloaded from the USDA NASS web sites. Table 1 has the list of spatial data downloaded for this study. The source of the data, layer name, description of the data, geographic reference system, spatial resolution, and data production date information are provided in detail in Table 1.

Table 1: GIS raw data layers

Layer Name	Description	Source	Coordinate System	Spatial Resolution	Date Produced
StateBoundary.shp	Political boundary map of Georgia with counties	GA Dept. of Community Affairs	GCS North American 1983	N/A	August 2002
cdl_awifs_r_ga_2009_utm17.tif	Raster classified for crops and Land use/cover	National Agricultural Statistics Service (NASS)	WGS 1984 UTM zone 17N	15m	2009
Soil maps	Vector file with all soil attribute information	USDA NRCS Geospatial Data gateway [http://datagateway.nrcs.usda.gov/]	WGS 1984 UTM zone 17N	N/A	Latest (SSURGO)

Table 2 contains the list of AEMN weather stations in the 12 counties of the study area along with their coordinates. From these stations, peanut crop season soil moisture data was downloaded

.

Table 2: Other data from AEMN and USDA

City	County	Zip	Name	Lat	Long
Arabi	Crisp	31712	Hardin Farm	31.8278	-83.8164
Arlington	Baker	31713	Tony Smith Farms	31.3532	-84.6308
Attapulgus	Decatur	31715	Attapulgus Research and Education Center	30.7616	-84.4853
Byromville	Dooly	31007	Murphy Farm	32.1896	-83.8767
Cordele	Crisp	31015	Catahoula Farms	32.0234	-83.9408
Dawson	Terrell	31742	USDA-ARS. National Peanut Research Lab	31.7582	-84.4358
Dixie	Brooks	31629	Boston Tractor Co., Inc.	30.7945	-83.6675
Douglas	Coffee	31533	Clyde Kirkland Farm	31.4886	-82.785
Hatley	Crisp	31015	Coffee Farms	31.9216	-83.6257
Midville	Burke	30441	Southeast Georgia Research and Education Center	32.8756	-82.2161
Moultrie	Colquitt	31788	Sunbelt Agricultural Exposition	31.1459	-83.7164
Newton	Baker	31770	Joseph W. Jones Ecological Research Center	31.2239	-84.4779
Plains	Sumter	31780	Southwest Georgia Research and Education Center	32.0468	-84.371
Statesboro	Bulloch	30458	Bulloch County Board of Education Maintenance & Transportation Annex	32.4852	-81.8139
Tifton	Tift	31793	Coastal Plain Experiment Station	31.4942	-83.5263
Tifton-Bowen	Tift	31749	Bowen Research Farm at the Coastal Plain Experiment Station	31.4808	-83.4391
TyTy	Tift	31795	Ponder Farm	31.5091	-83.6481
Unadilla	Dooly	31091	Griggs Farm	32.2589	-83.6615
Vienna	Dooly	31092	Peavy Farm	32.1112	-83.6754

It was decided to examine the soil moisture for a six month period of time that closely approximates the growing season in Georgia. The data pertaining to soil moisture for the Julian calendar days of May 1-Oct 31 (121-304) was extracted from historical data provided by the GA AEMN for each station in the study. For counties with more than one station, the mean soil moisture for all stations in the county was used in order to compare with the yield per acre for that county.

Geospatial Analysis Procedure for Yield v/s Soil Moisture Relationship Determination. The soil map layers corresponding to each county were added to the analysis to determine any soil type patterns for the 19 stations in the study. Finally, the Inverse Distance Weighting (IDW) interpolation method was used to map the soil moisture for each of the 12 counties in 2007 and 2009. Zonal statistics tools were used to compare the mean soil moisture determined by the interpolation to the data obtained *in situ*. Finally, the difference in soil moisture was determined for each county from 2007 and 2009 and the statistical analysis was performed to quantify correlation between soil moisture and peanut crop yield for the drought year of 2007 and the wet year of 2009.

Geospatial models were built for both years to compare the peanut crop yield and soil moisture content in the study area. By examining the crop yields for 2007 and 2009, a correlation value was determined for soil moisture content and peanut yield.

RESULTS AND DISCUSSION

The soil moisture data collected from GA AEMN weather stations were added to the weather station attribute table and IDW interpolation was conducted to find the distribution of soil moisture in the entire county as described in the previous section. More weather stations were considered in this analysis to get the interpolation results better even if they were not part of the analysis. Figure 3 shows the soil moisture spatial distribution map for 2007. The similar procedure was conducted on 2009 soil moisture data. The average soil moisture for each county was obtained by the zonal statistics procedure as described in the Materials and Method section.

Table 3 contains the average peanut crop yield per county in both 2007 and 2009 along with corresponding average soil moisture content. The table also has the average percentage change of soil moisture from 2007 to 2009 along with average percentage change of yield. It shows that there was considerable difference in soil moisture from 2007 to 2009. All 12 counties had positive change in soil moisture content in the wet year of 2009. Terrell County had more than 65% gains in soil moisture amount in 2009. Six counties including Terrell had more than 13% gains in soil moisture. We also observed that the peanut yield increased by more than 20% in three counties. Three counties for some reasons unknown had negative yield. Rest six counties had gain of 5 to 17% in peanut crop yield. It suggested that there is very good relationship between soil moisture and peanut crop yield, which was also established by many other researchers (Songri et al., 2009; Vorasoot et al., 2004; Nageswar Rao et al., 1988).

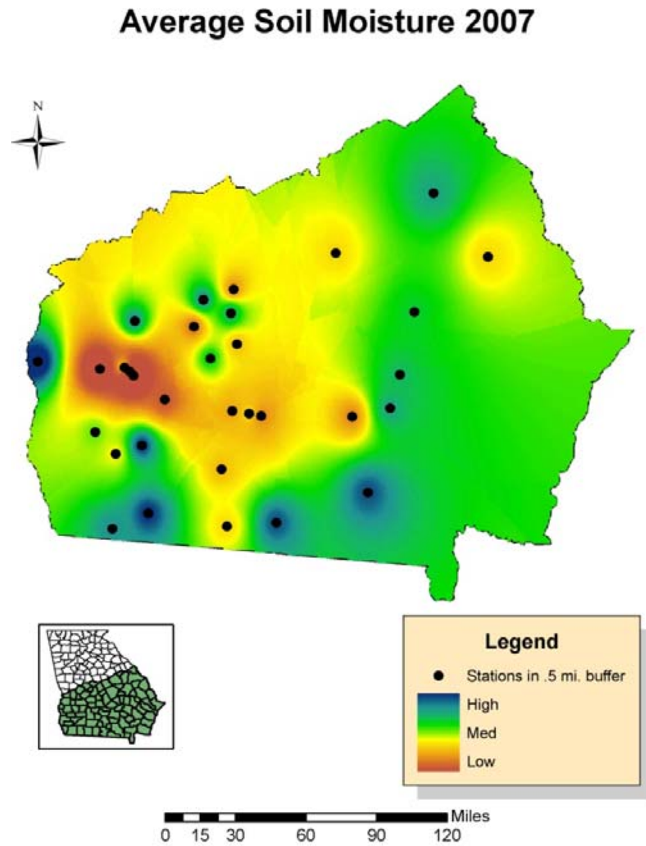

Figure 3. Soil moisture distribution map of South Georgia in Year 2007 created by IDW interpolation of the soil moisture data collected from AEMN weather stations.

With the linear regressionanalysis of 12 counties' average peanut crop season soil moisture data (in) versus peanut yield (Bu/ac), a coefficient of determination (R^2) of 0.21 was obtained for the 2007 soil moisture and peanut yield data. The relationship chart with equation and R^2 value is shown in Figure 4a. However, there were two clear outliers present in the data in the form of Baker and Brooks County. There was not much correlation existed in Baker and Brooks Counties' soil moisture and peanut yield data. It could be attributed to other factors like possible irrigation, nutrient application, and availability of quality soil in the county, which was not considered in this study. We also observed that Yield decreased in Brooks County from 2007 to 2009 even if there was an increase in soil moisture amount in the county over the years. Once, these two outliers were deleted, an increased coefficient of determinant (R^2) of 0.69 was obtained with ten counties dataset. It suggests that there is a strong relationship exists between soil moisture and yield for peanut crop.

.

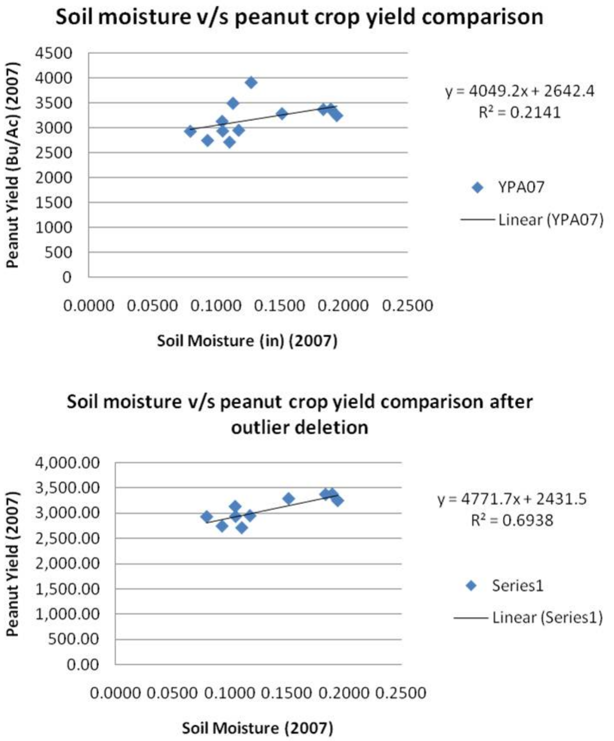

Figure 4: Soil moisture v/s. peanut crop yield relationship comparison in year 2007.

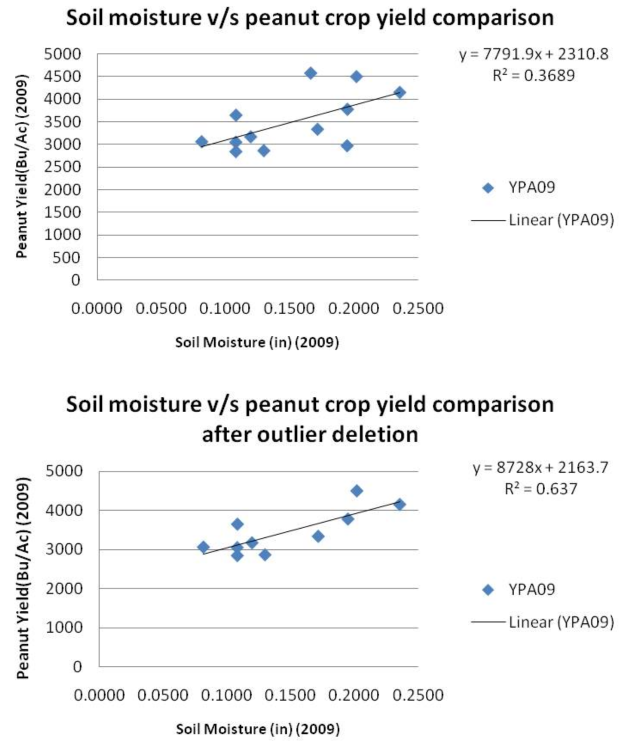

Figure 5: Soil moisture v/s. peanut crop yield relationship comparison in year 2009

Similar relationship was established for the 2009 soil moisture and peanut yield data per county. With the linear regression analysis of 12 counties' average peanut crop season soil moisture data (in) versus peanut yield (Bu/ac), a coefficient of determination (R^2) of 0.37 was obtained. The increase of R^2 from the water deficient year of 2007 may attributed to the fact that good soil moisture amount can produce good yield. Figure 5a shows the relationship chart with the regression equation and R^2 value. Once, the outliers data in the form of Baker and Burke Counties were deleted and with ten counties data, the coefficient of determinant (R^2) increased to 0.64. Thus, we come to conclusion that soil moisture clearly has a strong relationship with peanut crop yield.

We did not find any statistically significant variation in peanut yield due to changing soil moisture content in 2009 from this study but found that several other factors as described above may have been altered by farmers to offset the damage in 2007 by drought condition. We did not use the irrigation information as most of the study area was rainfed to prove this point but a future study will be conducted to find the amount of increased irrigation in the drought year (2007) if any to offset the soil moisture requirement during a drought season.

CONCLUSION

The study was conducted to find a relationship between soil moisture content and peanut crop yield. The help of geospatial technology was taken to make the study efficient. As crop production is a spatial phenomenon, geospatial technology has a big role to play in crop yield analysis. The study provided a good deal of geospatial technology application for other users to follow. The study found sufficient evidence of a relationship between soil moisture and peanut crop yield in rainfed condition. The linear regression model analysis for 2007 and 2009 provided coefficient of determinant values of 0.21 and 0.37, respectively. With outlier deletion, the coefficient of determinant values increased to 0.69 and 0.63 for the years 2007 and 2009, respectively. Other peanut crop growth factors like soil attributes and irrigation amount (if any) were not considered in the analysis. We expect the correlation will be stronger if these factors are included in the analysis.

REFERENCES

Georgia Peanut Commission. 2010. Georgia Peanut Commission: Working for farmers. http://www.gapeanuts.com/index.asp. Accessed on November 20, 2010.

Nageswar Rao, R.C., Singh, S., Sivakumar, M.V.K., Srivastava, K.L., and William, J.H. 1988. Effect of water deficit at different growth phase of peanut. Agronomy Journal, 80: 431 – 438.

Nesbitt, J. and Panda, S.S. 2011. Cotton crop rotation suitability analysis for southwest Georgia using geospatial technology. To be presented in 2011 Georgia Water Resources Conference, Athens, GA.

Perlman, H. 2011. Ground water depletion. http://ga.water.usgs.gov/edu/gwdepletion.html. Accessed on March 14, 2011.

Songri, P., Vorasoot, N., Jogloy, S., Kesmala, T., Akkasaeng, C., Patanothai, A., and Holbrook, C.C. 2009. Evaluation of yield and reproductive efficiency in peanut (Arachis hypogaea L.) underdifferent available soil water. Asian Journal of Plant Sciences, 8(7): 465-473.

Vorasoot, N., Songri, P., Akkasaeng, C., and Patanothai, A. 2004. Effects of water stress on yield and agronomic characters of peanut (Arachis hypogaea L.). Songlanakarin Journal of Science and Technology, 26: 787-794.

Wright, G.C. and Rao, N.R.C. 1994. Peanut water relations. In: The Peanut Crop, Smartt, J. (Ed.), Chapman and Hall, London, pp: 281 – 325.