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Correlation of Plant Available Water to Successive Cumulative Rainfall to better Determine Precipitation Forecasts

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Abstract

While precipitation forecasts in Oklahoma have improved over the years, a more accurate forecast is still needed to enable agricultural producers the ability to better schedule their activities to improve efficient use of resources. Plant available water and precipitation data for 9 counties in Southwestern Oklahoma was collected from Oklahoma Mesonet. This data was evaluated for a possible correlation between plant available water at 3 depths and subsequent cumulative rainfall over the next 21 days. The highest correlations appeared in the dryer parts of the year for Oklahoma; July-October and parts of late winter. The highest correlation was found in the 0-80 cm depth on September 24 with a R^2 of 0.695. These results could prove valuable in enhancing models to forecast precipitation in the dryer parts of the year. These models would be very beneficial to Oklahoman producers.

Introduction

For many years is has been observed by meteorologist that soil moisture plays an important role in predicting weather. The latent heat flux and the sensible heat flux of the soil plays an integral role in the temperature and rainfall of a regional climate. The latent heat flux of a soil is determined by the rate of evaporation that is taking place in a soil as well as the latent heat of vaporization. In a soil with higher moisture content the rate of evaporation as well as the rate of transpiration will be higher. This increase in soil water loss to the atmosphere will increase the humidity and decrease the ambient temperature of the atmosphere (Findell et. al.1997).This higher humidity can act as a greenhouse gas and increase the temperature of the soil through reflection of long-waves. The increased humidity can then increase the chance of rain when atmospheric pressures are favorable (Eltahir, 1998, Wilson et al. 1994).

This brings us to the question at hand. Does soil moisture impact the rainfall in a surrounding regional climate and if so what time of the year does the soil moisture have the most impact? By determining if the soil moisture impacts the amount of rainfall for a given time period in a regional climate, meteorologists may be able to use this to more accurately predict the weather. This information could be used to predict the amount of precipitation, as far in advance as 21 days. If this could be accurately predicted, it could give farmers a better idea of when to schedule planting and harvesting of crops.

Materials and Methods

All of the data utilized in this report was collected from the Oklahoma Mesonet; specifically, the daily data retrieval available free to the public. Soil moisture data for 5, 25, and 60 cm depths and rainfall for 9 counties in southwest Oklahoma was downloaded for years 1998 through 2010. Soil moisture was delivered in the form of a temperature reference value from a Campbell 229-L heat dissipation sensor. This temperature reference value was converted to matric potential using equation 1(Illston et al., 2008):

$$MP = -c*\exp(a*\Delta T_{ref}) \qquad (1)$$

Where

MP = soil matric potential (kPa)
a = calibration constant (1.788 $^{\circ}C^{-1}$)
c = calibration constant (0.717 kPa)
ΔT_{ref} = reference temperature differential (˚C)

To obtain the current volumetric water content at each depth, the calculated matric potential was entered into the van Genuchten equation (van Genuchten):

$$\theta = \theta r + \frac{\theta s - \theta r}{(1+(\alpha h)^n)^{1-\frac{1}{n}}} \qquad (2)$$

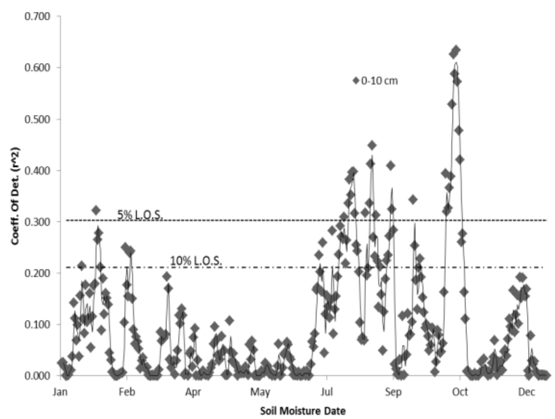
Where θ_r, θ_s, α, and n are soil hydraulic parameters as defined by *ROSETTA*, a USDA-ARS computer program for estimating soil hydraulic parameters. For this project, class average parameters were used for the soil textural class the Mesonet identified at each sensor depth. The permanent wilting point for each sensor depth was then estimated by entering a matric potential of -1500 kPa into the van Genuchten equation. Plant available water could then be estimated by subtracting the volumetric water content at the soil specific permanent wilting point from the current volumetric water content, as calculated from the Mesonet data. In order to convert to a depth of water, the volumetric water content of each sensor's depth was multiplied by a depth of soil around each sensor: 0-10 cm of soil around the 5 cm sensor, 10-40 cm around the 25 cm sensor, and 40-80 cm around the 60 cm sensor.

Correlation between plant available water and subsequent 21 day precipitation was computed using Microsoft Excel's R-Squared function, with the parameters being the sum of precipitation over the next 21 days and plant available water at depths of 0-10, 0-40, and 0-80 centimeters. R^2 values could then be averaged for each day of the year from 1998 through 2010, giving 365 12-year average R^2 values as shown in Figure 1.

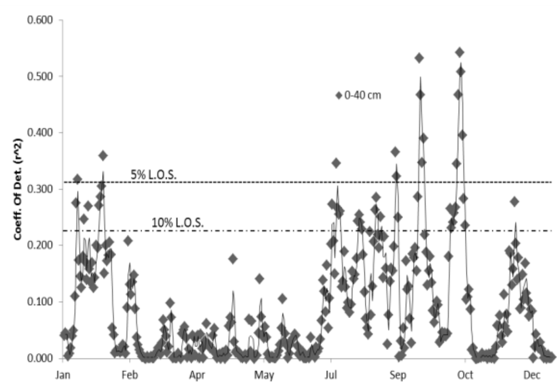
Results and Discussion

Coefficient of Determinations between PAW and subsequent precipitation where graphed across a year. The 5 and 10% level of significance lines were computed as found in Findell et al. (1997).

a)



b)



c)

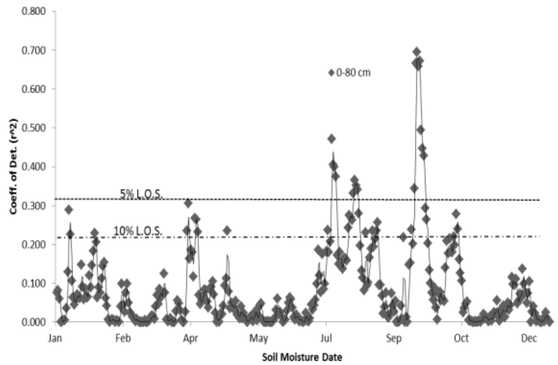


Figure 1. Correlation between PAW and subsequent 21 day precipitation fop (a) 0-10 cm, (b) 0-40 cm, and (c) 0-80 cm depths. Dashed lines indicated 5 and 10% levels of significance.

As indicated in Figure 1 a-c, there is a significant correlation between the first of July and the middle of October for all soil depths. There is also a significant correlation around the end of January for the 0-10 and 0-40 cm depths.

The day and depth with the highest correlation is September 24 in the 0-80 cm depth, with an R^2 of 0.695. The other depths had similar days with their highest correlations. The 0-10 cm depth had an R^2 of 0.634 on October 24 and the 0-40 cm depth had an R^2 of 0.542 on October 23.

Based on these results, a model for predicting precipitation based on PAW would be most useful during the driest times of the year for Oklahoma; the end of the summer and beginning fall and part of winter. Fortunately, models of this kind would be very useful to farmers in scheduling irrigation during the driest times of the year.

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