Weather Data Based Drought Risk Assessment for Summer Annual Crops

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Abstract

Water deficit is a strong limiting factor on crop yields worldwide. Tools to assess drought-risk are essential towards optimizing water use by cropping plants. Weather data ranging from 14-16 years was evaluated to assess the potential for drought avoidance for Woodward, Oklahoma. For each day when the probability (P) of occurrence of minimum temperatures below 0ºC was <0.05, the soil water deficit was estimated by subtracting the actual soil water content from the water content at field capacity. A water deficit > 50mm was considered a drought, and found to be a production constraint on cropping systems in Northwest Oklahoma. The growing season was determined to begin on DOY 102, and end on DOY 293. Only the first 37 days held a P of drought < 0.20, resulting in drought-risk for approximately 80% of the site's growing season. An approach for assessing drought-risk through analysis of meteorological records may provide resource managers with a useful tool for improving water efficiency in agronomic applications.

Introduction

Drought is a major cause of limited productivity in agricultural systems worldwide, accounting for a large proportion of the yearly variation in the yield of summer annual crops (Boyer 1982). The definition of drought has historically been problematic for water deficit monitoring and analysis (McKee et al., 1993). Meteorological drought, a persistent precipitation deficit, can alter the seasonal recharge of soil water, which may lead to an agricultural drought. Thus, an agricultural drought is soil water deficit that stresses rangelands, pastures, dryland crops, and by extension any land cover (Garbrecht et al., 2007).

Either form of drought may be avoided by matching crop phenology with periods of the cropping season when water supply is likely to be more abundant (Purcell et al, 2003). Although the technology for determining potential periods of drought is available, it is not widely used.

The goal of this research was to evaluate the likelihood of drought occurrence with readily available weather data. Our findings may end in the development of a toll for use in cropping system decisions with regards to seasonal planting date.

Materials and Methods

Obtaining the Data Set

Historical weather data was obtained using the Oklahoma Mesonet, an automated network of 116 remote meteorological stations across the state of Oklahoma (McPherson, et al., 2007). The study site was Woodward, located in northwest Oklahoma, where the average annual rainfall was roughly 620mm for the period among 1914-1995 *(http://www.worldclimate.com/cgibin/data.pl?ref=N36W099+2200+349760C).*

The data collected ranged from 14 to 16 years, and contained daily values for minimum daily temperatures (T_{min}) and soil moisture calibrated delta – T (ΔT_{ref}) for three different depths in the soil: 5cm, 25cm and 60cm. These ΔT_{ref}'s, or temperature differences, were estimated with the Campbell Scientific 229-L sensor (Basara et al., 2000).

Missing data were eliminated from the data sets, and month and day format were replaced with day-of-the-year (DOY) format, and DOY 366 values were not used (Purcell et al., 2003).

Estimation of Environmental Parameters

A growing season for the summer period was defined as the period when probability (P) of occurrence of T_{min} below 0ºC ≤ 0.05 (Purcell et al, 2003). The P was calculated by counting the number of years where values below 0ºC were observed in each DOY, and dividing it by the total number of observations. The DOY in spring and fall when P≤0.05 for T_{min} was less than 0ºC were determined using trend line equations from both the decreasing P in spring and the increasing P in the fall.

Soil texture per depth for the studied location was obtained from the mesonet website *(www.mesonet.org/index.php/ sites/site_description/wood).* The soil hydraulic parameters such as residual water content (θr), saturated water content (θs), a, n and m used on this study derived from the USDA ROSETTA (Schaap et al, 2001).

Variables for soil moisture as matric potential (MP) and actual soil volumetric water content (θ_a), were derived from the ΔT_{ref}'s according to Illston, 2008. These variables were estimated for each DOY and for each soil depth.

The θ for field capacity (θ_{fc}), needed to estimate the soil water deficit, was calculated using a soil matric potential of -33kPa (Jamison and Kroth, 1958; Colman, 1947) in the van Genuchten equation (Illston et al, 2008).

Soil water deficit (D) was estimated for each depth by multiplying the difference between the θ_{fc} and the θ_a, by the thickness of the soil layer (∆Z):

$$D = (\theta_{fc} – \theta) \times \Delta Z$$

The thicknesses of the layers used in these calculations were 10cm, 30cm and 40cm for ∆T05, ∆T25 and ∆T60, respectively. The total soil water deficit was estimated for each DOY by the summation of the three distinct D.

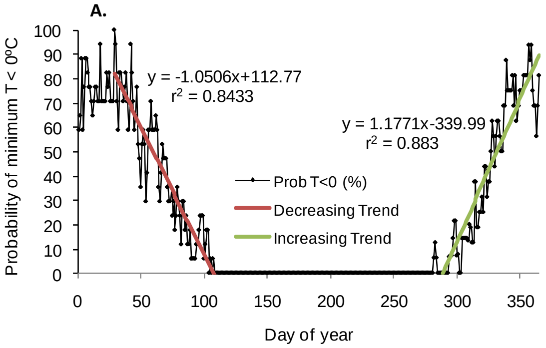
A value of 50mm soil water deficit was considered the critical value for drought assessment (Purcell et al., 2003). The P≥0.20 for D>50mm was calculated for each DOY within the growing season using the same method previously used when estimating the growing season.

Results and Discussion

The growing season for Woodward OK was found to begin on DOY 102, and to end on DOY 293, totaling 190 days. During the first 37 days of the growing season the P that the soil water deficit would exceed 50 mm was lower than 20%. Within this time frame plants would not be likely to experience drought stress. After this DOY, the P of water deficit occurrence was > 0.20, and persisted through the final 154 days of the growing season (Figure 1).

Our findings support previous work that demonstrates high drought-risk probability for sites within the Northern Great Plains Region, where a *P* of drought >0.20 persists for more than half of the growing season (Purcell, et al. 2003).

For semi-arid regions such as western Oklahoma, water is a leading limiting factor in agricultural production. Resource managers and farmers in regions dependent on rainfall for the sustaining of non-irrigated summer crops are in critical need of crop management methods that capitalize on seasonal fluctuations in available soil moisture. Systematic meteorological analysis of climatic patterns and rainfall events may prove critical towards the maximization of production efficiencies (Purcell, et al. 2003).



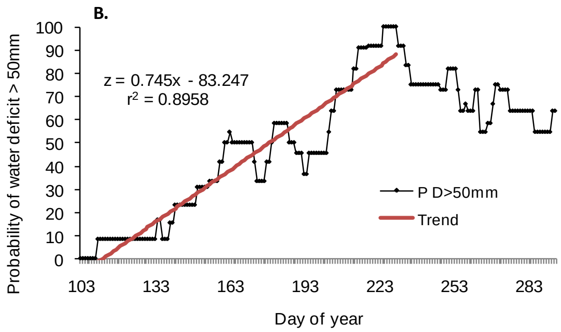


Fig.1. Probability (*P*) of (A) Minimum Temperature being less than 0° for each day of the year (DOY), and (B) soil water deficit (D) exceeding 50mm for each DOY at Woodward, OK.

By planting early within the 37-day timeframe, crops most dependent on water may be ensured of their needs. This window of available moisture comprises nearly 20% the total growing season, presenting a common challenge for growers in semi-arid regions.

One shortcoming in this particular analysis is the variability in the number of years comprising the meteorological record of a particular measurement site. Our site began collection in 1994 - 1996; larger variability in weather patterns is a possibility for sites within northwestern Oklahoma.

Such findings could have implications for modeling drought-risk based on soil specific parameters, helping prevent decreases in yield. Further research may provide land managers with an increased understanding of soil, water, and weather in agronomic applications.

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