A Simple Water Deficit Index (WDI) For Quantifying Agricultural Drought

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CONCLUSIONS

- WDI is more realistic and reliable because its transpiration function is dynamic and it accounts for drainage and run-off.
- Although WDI needs more inputs for computation, it is conceptually simple because it is based on simple water balance.
- Like LGMI, WDI can quantify water deficit at high resolution.

INTRODUCTION

Many current agricultural drought indices have limited value as they give no proper consideration to meteorology, crop physiology, and soil conditions (Lourens and Jager, 1997), or because they are too complex. Thus, a drought index is needed that is simple yet can approximate crop water deficit.

The SECC region is using the Lawn-and-Garden Moisture Index (LGMI) for monitoring drought. Although LGMI is more informative with respect to spatial resolution, it has some shortcomings: its ET function is constant and it does not consider run-off or soil water holding capacity. Thus, there is a need for improving the index to better reflect the water status in soil-plant system.

OBJECTIVES

- To develop a simple yet reliable index that can quantify crop water deficit.
- To compare the new index with LGMI.

METHODOLOGY

1. Developing Index:

- Water deficit index (WDI) is a function of actual transpiration (T) to potential transpiration (TP) ratio (Hiler and Clark 1971):
  WDI = 1 – T/TP
- T (mm/day) is the product of an uptake coefficient (α, mm/day) and available water (θ – θWP) when T is less than TP (mm/day) (Dardanelli et al. 2004):
  If T < TP, T = α(θ – θWP)
  If T ≥ TP, T = TP
- TP occurs when the availability of soil water does not limit transpiration. It is estimated using the FAO 56 Penman-Monteith model (Allen et al. 1998).
- In soil layer, water content exceeding field capacity (θFC) is subject to drainage (Ritchie, 1998).
  If θ > θFC, D = βZ(θ - θFC)
  If θ ≤ θFC, D = 0
  Where, D = drainage (mm/day), θ = soil moisture content, β = drainage coefficient (1/day), and Z = soil layer depth (mm).
- Run-off (R, mm/day) is estimated using the USDA NRCS curve number technique (USDA, 2004).
- The amount of water (W, mm) in soil layer is computed daily based on inflows (precipitation, P) and outflows (transpiration, T; drainage, D; and runoff, R).
  W = P – (T + D + R)
- Inputs required (daily): precipitation, solar radiation, minimum and maximum temperature, and wind speed.

2. Simulation:

Using historical weather data of 105 years, daily values of WDI and LGMI were calculated for a reference crop, grass. Two locations were selected to see the geographical variation: Floyd County in north GA and Lee County in south FL. To see the effect of soil layer depth on WDI and to compare it with LGMI, two soil depths – 25 cm and 40 cm – were chosen.

3. Comparison:

Daily values of both WDI and LGMI were split into months and averaged, which then were used to compare the two indices in terms of the departure of WDI from LGMI, mean absolute difference of WDI from LGMI, and the correlation between WDI and LGMI. The comparison was made for two soil depths and two locations.

RESULTS AND DISCUSSION

In both locations, LGMI was mostly greater than WDI (Figure 1), which was because the ET function of LGMI is constant for all locations and seasons and was always higher than that of WDI (Figure 2). Differences between locations were mainly because of temperature and precipitation differences (Figure 3).

Figure 1. Monthly values of WDI and LGMI (25 cm layer)

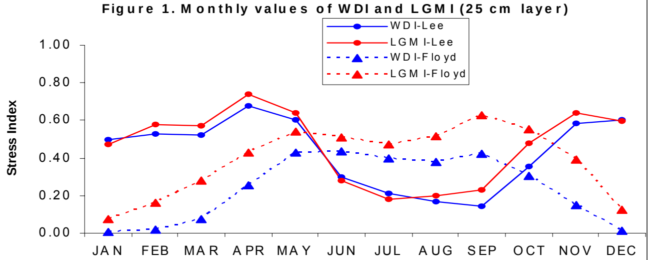


Figure 2. Daily mean evapotranspiration

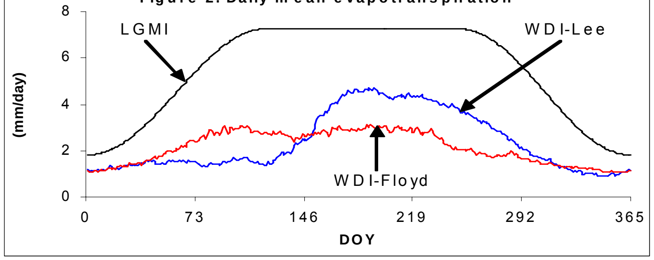
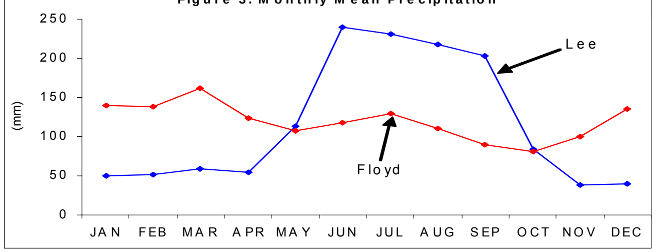
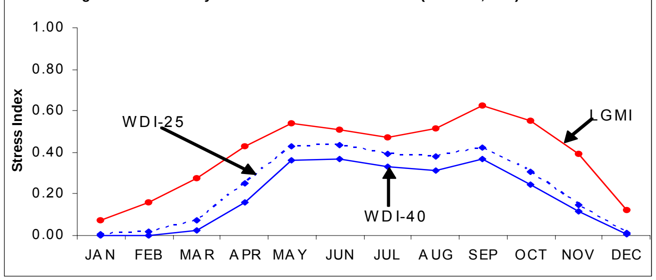


Figure 3. Monthly Mean Precipitation



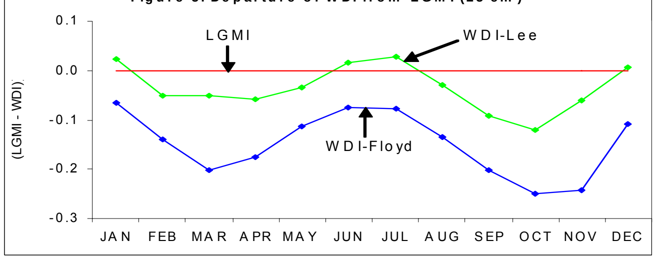
For a shallow rooted soil depth of 25 cm, WDI increased approaching LGMI (Figure 4). This increase was because of the reduced amount of water, which was insufficient to meet the plant need. This result also confirmed that LGMI predicts stronger water deficit than WDI, which is because LGMI assumes more transpiration loss.

Figure 4. Monthly values of WDI and LGMI (FLOYD, GA)



The departure of WDI from LGMI was greater in Floyd than in Lee (Figure 5) because transpiration was greater in Lee as a result of higher temperature. Because LGMI assumed the same evapotranspiration for the two locations, and WDI varied with meteorological conditions, this difference existed over the two locations. Spring and fall months had the greatest differences, whereas winter and summer had the least. This variation was because of the corresponding transpiration difference (Figure 2).

Figure 5. Departure of WDI from LGMI (25 cm)



The overall correlation between LGMI and WDI was greater in Lee (r ~ 0.84) than in Floyd (r ~0.70). This difference was due to more water loss estimated by WDI for Lee, where the total amount of transpiration was greater because of higher temperature. For Lee, correlations were weaker in the summer; whereas for Floyd, the weaker correlations were in the winter. The correlation was greater in 25-cm layer than in 40-cm.

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