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Drought Decision-Support Tools: Introducing the Lawn and Garden Moisture Index—LGMI[1]

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Introduction

Agriculture is inherently risky. Drought is a recurring phenomenon that has plagued civilization throughout history (Heim 2002). Agriculture is often the first sector affected by the onset of drought because it depends on precipitation and soil moisture reserve during various growth stages (Narasimhan and Srinivasan 2005). In fact, drought takes a bigger economic toll in the United States than other natural disasters. Drought was the predominant source of crop insurance indemnities paid because of crop losses between 1999 and 2009, totaling $15.3 billion or an average 37% of the indemnities paid during that time (USDA/RMA 2010).

Drought differs from other natural hazards in several ways. First, drought is a slow-onset natural hazard often referred to as a creeping phenomenon (Gillette 1950). Because of drought's creeping nature, its effects accumulate slowly over a substantial period of time, making its beginning and end difficult to determine. The first evidence of drought is based on rainfall records, while the next piece of evidence to appear is often an effect on vegetation. The capacity of soil to store water affects the period of time until a drought starts affecting crops. The effects of a drought on flow in streams and rivers may not be evident for several weeks or months. Drought impacts are non-structural and generally spread over a larger geographical area than damages resulting from other natural hazards such as floods and hurricanes. Also, drought does not have a precise and universally accepted definition. Over the years, drought has been defined in many ways. However, droughts are generally classified into four categories, including meteorological, agricultural, hydrological, and socio-economic droughts (Wilhite and Buchanan-Smith 2005).

Meteorological drought is characterized by a situation in which the precipitation (rainfall or snow) is significantly lower than the climatologically expected rainfall over a wide area. Drought onset generally occurs with a meteorological drought.

Agricultural drought is characterized by a shortage of moisture in the root zone of crops and does not depend only on the amount of precipitation. The same amount of precipitation in January and July will have

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different impacts. A drought occurring in the winter may have little or no observable effects on crops. However, during the summer, when temperatures are warmer and days are longer, plants will extract more water from the root zone. Consequently, summer droughts are more apparent and cause more damage. Moderate drought during crop growth periods can result in stunted growth of the crop and reduced crop yields. A severe drought during the same period may result in a total crop failure.

Hydrological drought is characterized by decreased flows in rivers and streams and below-average water levels in lakes, reservoirs, and groundwater.

Socio-economic drought differs from the other types because it associates the supply and demand of economic goods (e.g., water, grains, hydro-electrical power) with elements of meteorological, hydrological, or agricultural droughts.

Several products can help managers and stakeholders understand and monitor drought conditions, including the Palmer Drought Severity Index (PDSI) and the Standardized Precipitation Index (SPI). Early warning and decision-support tools are also available online, such as the U.S. Drought Monitor available at http://drought.unl.edu/dm/monitor.html. Recently, researchers at the University of Alabama developed another index, called the Lawn and Garden Moisture Index or LGMI (http://nsstc.uah.edu/aosc/lawn_garden2.htm), which monitors the capacity of current soil moisture to sustain healthy lawns and gardens.

The nuts and bolts of LGMI

The LGMI is a weighted estimate of the difference between available soil water and evaporative demand of shallow-rooted plants. Positive values indicate adequate precipitation or water surplus, while negative values indicate water deficit (Woli 2010).

$$LGMI_i = SM_i - ET_i$$

Where

-$LGMI_i$ is the Lawn and Garden Moisture Index for the i-th day (mm);

-SM_i is the available soil moisture (SM) for the i-th day (mm);

-ET_i is the evapotranspiration (ET) of shallow-rooted plants for the i-th day (mm).

The SM is calculated as the weighted sum of precipitation over the previous three weeks (Figure 2). For the previous week, all precipitation is considered to be effective; for the two weeks before the last, effective precipitation is reduced from actual precipitation by a linear scale:

$$\mathrm{SM}i = \sum_{b=1}^{7} P_{\text{i-b}} + \frac{1}{14} \sum_{b=8}^{21} P_{\text{i-b}}\,(21.5 - \mathrm{b})$$

Figure 1.

Where

-b is the previous day, whose values range from 1 to 21;

-"i" is the current day;

- P_i is the amount of precipitation on the i-th day (mm).

For instance, if precipitation in each day was 0.1 inches and uniform throughout the previous 21-day period, the total precipitation amount for the period would be 2.1 inches, and the SM for day i would be 1.4 inches, comprised of 0.7 inches for the 7 days before the present day and 0.7 inches for 8 to 21 days before present.

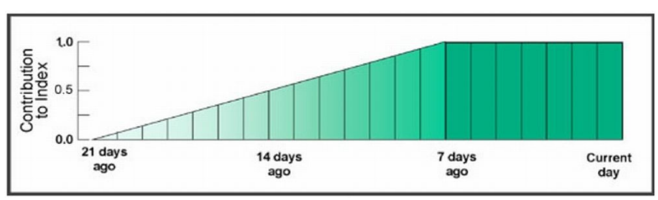

Figure 2. The sliding scale used to determine the contribution of recent rainfall to LGMI (Source: The Alabama office of the state climatologist)

While SM changes daily in response to precipitation amount, ET does not change with precipitation or environmental conditions. To keep LGMI simple and allow it to be computed from daily rainfall data, LGMI assumes the same ET function for every location, year, crop, and soil type:

$$ET_i = \begin{cases} 31.75 - 19.05 \cos[(\pi/120)\,(DOY - 1)] & \text{for } 1 \le DOY \le 120 \\ 50.80 & \text{for } 121 \le DOY \le 250 \\ 31.75 + 19.05 \cos[(\pi/115)\,(DOY - 250)] & \text{for } 251 \le DOY \le 365 \end{cases}$$

Figure 3.

Where

-ET_i is the ET of plants on the i-th day (mm);

-DOY is the day of the year.

Monitoring and forecasting LGMI on AgroClimate.org

AgroClimate.org is a web-based climate forecast and decision-support system (http://www.agroclimate.org) (Fraisse et al. 2006) developed to provide Extension agents, producers, and natural resource managers with tools to aid their decision-making to reduce risks associated with climate variability. It was designed and implemented by the Southeast Climate Consortium (SECC - http://seclimate.org) in partnership with the Florida Cooperative State Extension Service, and is updated and maintained periodically to ensure the relevance of the information and decision-support tools contained in the system. *AgroClimate.org* provides LGMI monitoring (http://www.agroclimate.org/tools/lawnGarden/) and forecasting (http://www.agroclimate.org/forecasts/LGMI/map) for the southeastern United States.

Doppler radar estimates of precipitation with a 4 km x 4 km (2.5 miles x 2.5 miles) are used to calculate LGMI on *AgroClimate.org* (Figure 4). Generally, a good agricultural drought index should be both easily computed and relevant for agricultural management. To make rational decisions based on an index, it is important to understand its predictability (Chen et al. 1997) and also the assumptions made during its computation. LGMI is not explicitly based

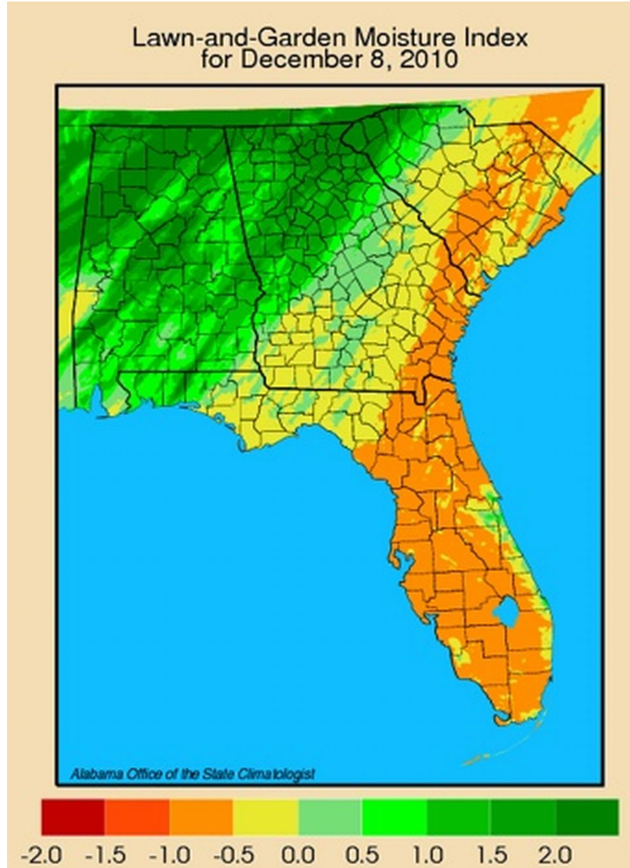

Figure 4. LGMI map showing values calculated for December 8, 2010

on plant transpiration and soil water storage, yet it takes into account the evapotranspiration process by using the concept of effective precipitation, meaning rainfall that is sufficient to offset evapotranspiration and maintain soil water above the wilting point. Similarly, LGMI also considers soil water losses by assuming that all precipitation that occurred in the previous week is available to plants while precipitation from the previous 1 to 3 weeks declines linearly in availability. Nevertheless, the simplicity, high temporal (daily), and spatial (4 km x 4 km) resolutions, as well as the potential to forecast LGMI, make it attractive as a tool for monitoring agricultural drought.

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