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Drought Decision-Support Tools: Introducing the Keetch Byram Drought Index—KBDI[1]

Clyde W. Fraisse, Norman E. Breuer, and David Zierden[2]

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

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2. Clyde W. Fraisse, assistant professor, Department of Agricultural and Biological Engineering, University of Florida; Norman E. Breuer, associate research scientist, Rosenstiel School of Marine and Atomospheric Science, Univeristy of Miami, Coral Gables, FL, Southeast Climate Consortium affiliate member, and courtesy assistant professor, Department of Agricultural and Biological Engineering, University of Florida; David Zierden, state climatologist, Center for Ocean-Atmospheric Prediction Studies, Florida State University.

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precipitation in January and July will have 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.

Forestlands are affected by drought and are of great economic importance in Florida. Forestlands not only supply timber products but also provide wildlife habitat, watershed protection, and opportunities for recreation and tourism (Roncoli et al. 2006). Drought can greatly increase the risk for wildfires. The Keetch-Byram Drought Index (KBDI) (Keetch and Byram 1968) is generally used to determine potential wildfire hazards across the southeastern United States and is calculated daily by the Florida Department of Agriculture and Consumer Services, Division of Forestry (Figure 1), available at http://flame.fl-dof.com/fire_weather/KBDI/index.html . According to Keetch and Byram (1968), the moisture content of the upper soil, as well as that of the covering layer of duff, has an important effect on the fire suppression effort in forest and wildland areas. In certain forested areas of the country, fires in deep duff fuels are of particular concern to the fire control managers. When these fuels are dry, fires burn deeply, damage is excessive, and extinguishing fires is unduly expensive. KBDI is a continuous reference scale for estimating the dryness of the soil and duff layers. Forest managers have identified several uses for the KBDI in wildfire management (Roncoli et al. 2006).

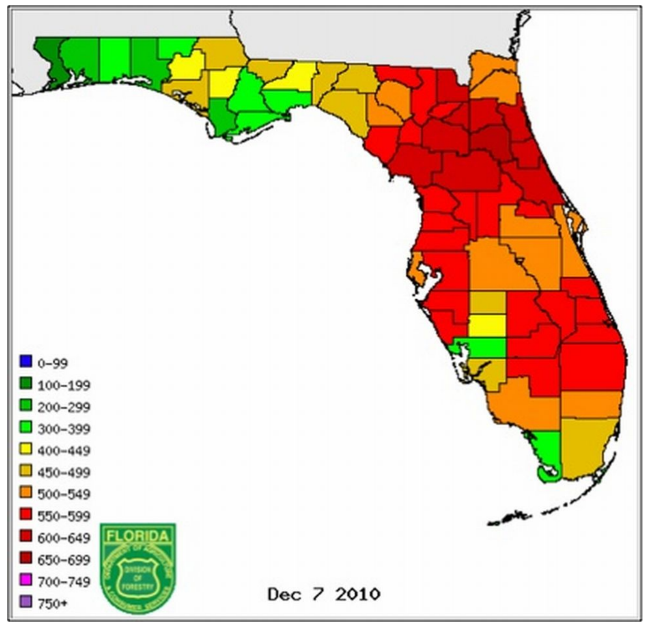

Figure 1. Florida's KBDI provided by the Florida Division of Forestry.

The nuts and bolts of KBDI

KBDI increases for each day without rain (the amount of increase depends on the daily maximum temperature) and decreases when it rains. The scale ranges from 0 (no moisture deficit) to 800. The range of the index is determined by assuming that soil has 8 inches of moisture readily available to the vegetation. For different soil types, the depth of soil required to hold 8 inches of moisture varies (loam=30", clay=25", and sand=80"). A prolonged drought (high KBDI) influences fire intensity largely because more fuel is available for combustion (i.e., fuels have a lower moisture content). In addition, the drying of organic material in the soil can lead to increased difficulty in fire suppression. High KBDI values indicate that conditions are favorable for the occurrence and spread of wildfires, but drought is not

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by itself a prerequisite for wildfires. Other weather factors, such as wind, temperature, relative humidity, and atmospheric stability, play a major role in determining the actual fire danger.

KBDI levels 0-200: Most of the understory prescribed fire work in the South is done at the 0 to 200 levels, which correspond to the early spring dormant season following winter rains. At these levels, soil moisture content and fuel moisture are high.

KBDI levels 200-400: In normal years, the 200-400 levels would represent conditions found in the late spring and early growing season. Rising temperatures and increased levels of plant transpiration reduce soil moisture within the soil and fuel profiles.

KBDI levels 400-600: Typical range during the summer and early fall conditions in the South. These levels represent the upper range at which most normal understory-type burning should be implemented. Very intense fires can be generated with burns ignited in this range of conditions. Under these levels, most of the duff and associated organic layers will be sufficiently dry to ignite, contribute to the fire intensity, and actively burn.

KBDI levels 600-800: The 600-800 KBDI range represents the most severe drought conditions identified within the index and results from an extended period of little or no precipitation combined with high daytime temperatures. Mid- to upper-600 range is the limit of acceptability for igniting prescribed fires of any type unless specific local conditions dictate otherwise. These index levels are normally associated with increased wildfire occurrence, and most states and counties will issue burning bans when KBDI is this high.

KBDI is used by the Florida Division of Forestry to indicate the dryness of the soil and surface fuels. High values of the drought index are associated with severe wildfire outbreaks such as occurred during 1998. However, no threshold point has previously been determined to indicate that conditions are far above normal and warrant concern. Using 35 years of rainfall and temperature measurements from 9 locations throughout the state, average KBDI values were determined for the state on a regional basis. These regions are North (stations used are Pensacola, Tallahassee, and Jacksonville), Central (Daytona, Gainesville, and Orlando) and South (Tampa, Fort Myers, and Miami). The ranges of KBDI values considered normal for each season and region are shown in Table 1. The complete table is available online at http://www.fl-dof.com/fire_weather/information/seasonal.html.

The mean drought conditions show a wide range of variability by region with winter conditions being drier in the South and wetter to the North as the Central and northern regions experience a greater frequency of frontal passages. During the summer, convective activity produces significant rainfall particularly in the southern part of the state. Florida's fire season begins in January and peaks in May and June. All three regions exhibit a peak in their KBDI around May and June. Drought conditions are high during the fall, but fire activity is at a minimum. This shows the need for any threshold values to be determined on a monthly basis to account for the seasonal variation in fire activity.

Forecasting KBDI on AgroClimate.org

The Southeast Climate Consortium provides a forecast of wildfire risk potential on *AgroClimate.org* http://www.agroclimate.org/forestry/wildfire/wildfire.php (Fraisse et al. 2006) based on KBDI (Figure 2). Because of the chaotic nature of weather, the wildfire risk forecast is presented in terms of probabilities. Weather data that drives the forecast are taken from hundreds of National Weather Service (NWS) cooperative observer sites in Florida, Georgia, and Alabama. The large number of weather stations makes it possible to provide the forecast at a county level. It has been shown that increased wildfire activity is linked with the deviation of the KBDI from seasonal normals. The KBDI tends to peak in May, so values around 400 or 500 are not unusual at this time and do not indicate an increased threat. The substantial threat instead comes when KBDI values are 1 to 1.5 (or more) standard deviations (from these seasonal normals) above the seasonal average.

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Table 1. Ranges of KBDI values considered normal for each season and region of Florida

Region	Winter	Spring	Summer	Fall
North	221-390	261-460	301-500	241-420
Central	181-400	281-530	241-460	221-400
South	301-490	341-550	201-350	271-420

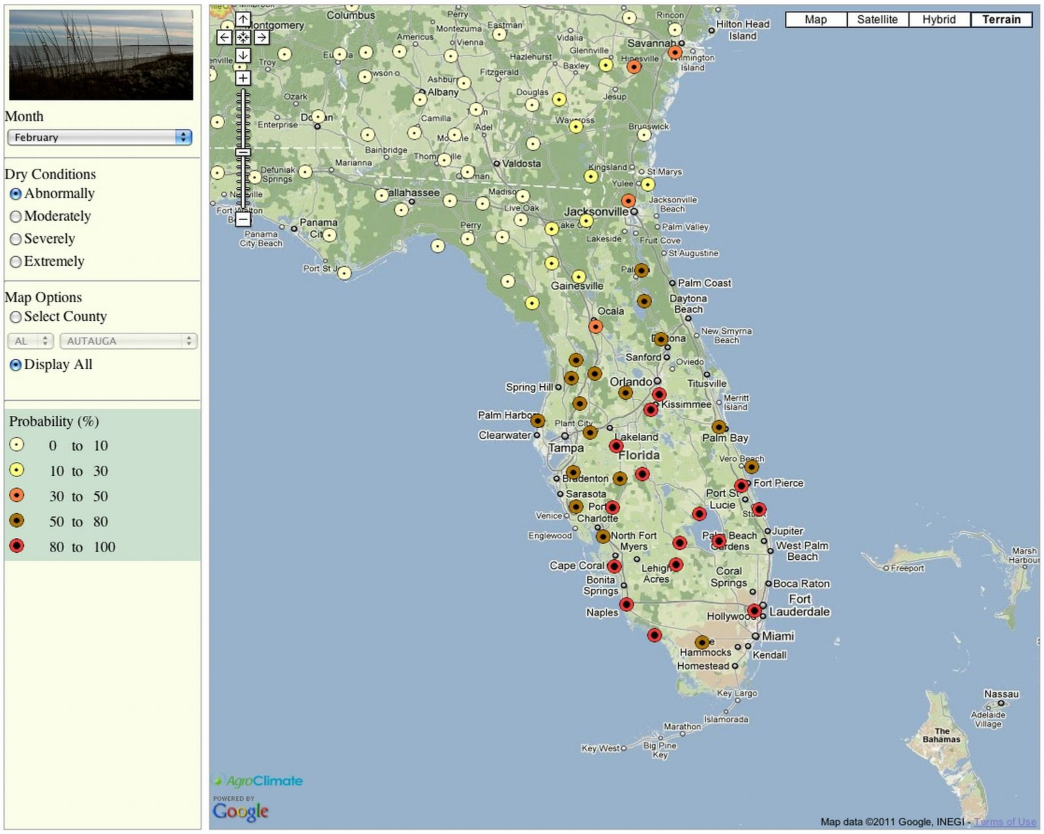

Figure 2. KBDI forecast showing probabilities of abnormally dry conditions expected for February 2011 (http://agroclimate.org/tools/kbdi_forecast)

The wildfire threat forecast is presented in a series of color-coded maps showing the probability of the KBDI being in the following threat categories: 1.) Abnormally dry (450 or above); 2.) Moderately dry (500 or above); 3.) Severely dry (550 or above); or 4.) Extremely dry (650 or above). Since the KBDI is driven by daily weather and can change drastically based on one or more rainfall events, the maps show the probability of exceeding the threat level at least 7 days during the month, rather than for the month as a whole. The forecast is based on both initial conditions (current KBDI values) and expected climate patterns associated with ocean temperatures in the tropical Pacific. For this reason, the forecast is updated monthly throughout the season as conditions change in the field. No forecasts are given for north Alabama and north Georgia due to a lack of skill (no discernible climate signal) in these regions.

While high KBDI values indicate higher probabilities of wildfires, other variables, such as human activities, wind speed, and dry spell lengths, also need to be considered. Previous studies have indicated that climate cycles such as the El Niño - Southern Oscillation (ENSO) phenomenon affect the probability of drought and wildfire in Florida (Brolley et al. 2007). Drought threats are minimal during El Niño winter and spring months but higher during La Niña events when the jet stream is generally far from Florida, bringing reduced rainfall to the state.

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