First steps to modeling soil moisture in an oak forest using the FAO-56 dual crop coefficient model

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Introduction

- Soil moisture is an essential variable influencing climatic, hydrological, and ecological conditions (Ochsner et al., 2013).
- Due to the impact of soil moisture on important earth processes, in-situ soil moisture monitoring networks and data are becoming more prevalent.
- The majority of soil moisture monitoring networks consider only one land cover type, limiting the use of these data for applications in other cover types (Patrignani and Ochsner, 2016. In review).
- The Oklahoma Mesonet has soil moisture sensors installed in grasslands across the state, but 12 million acres (28%) of the state are forested (Fig. 1) (Oklahoma Forestry Service).
- Determination of the relationship between soil moisture in grasslands and in forests may allow data from in-situ networks to be used to estimate soil moisture in forested areas.

Objective

- The objective of this preliminary research is to determine a useful model for estimating evapotranspiration (ET) by forests using the FAO-56 dual crop coefficient model in order to include ET in a soil water balance model that will be used to estimate soil moisture in forests.

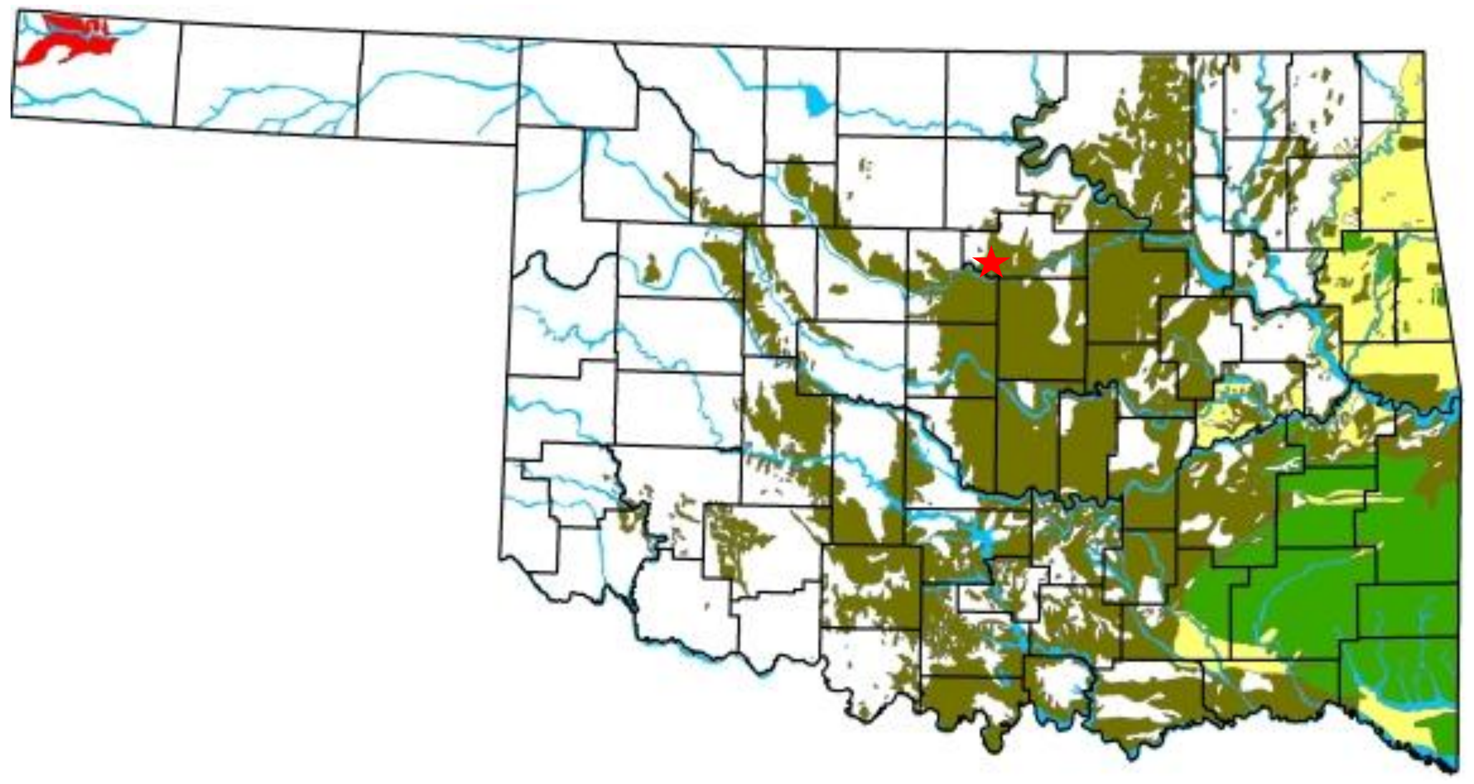

Figure 1. Forested areas of Oklahoma are shown in green, and the Marena, OK Mesonet site is marked by a red star (Oklahoma Forestry Service).

Materials and Methods

Modeled root zone depletion

- The FAO-56 model was used to estimate reference evapotranspiration, ET_o, using weather data, latitude, and elevation data for the Marena Mesonet station (Fig.2) from April 1, 2015 through April 5, 2016.
- To estimate actual ET, ET_o values were used with a preliminary crop coefficient curve for an oak forest (Fig. 2), with growing season and dormancy dates estimated from Johnson and Risser (1974) and Norby et al. (2003).

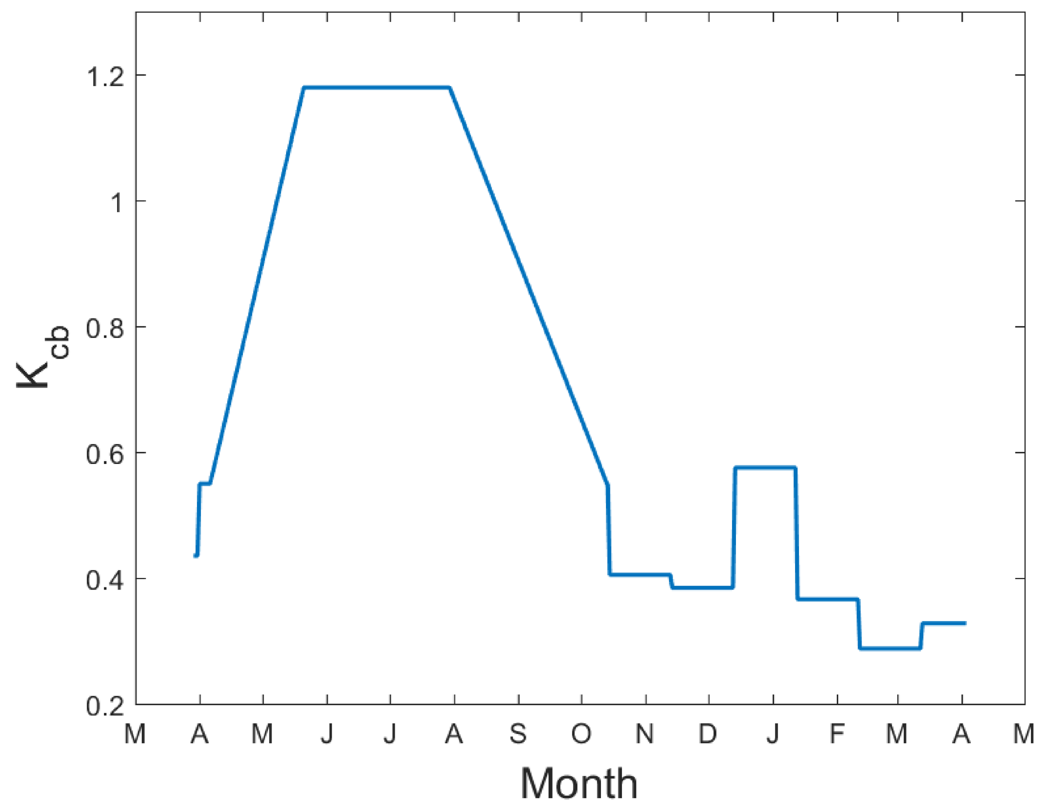

Figure 2. Model-estimated basal crop coefficient (K_{cb}) values for forest.

- Due to the large height of oak forests, the $K_{c\,max}$ value was considered independent of plant height and equal to the daily K_{cb} value + 0.05.
- Daily root zone depletion, D_r, was calculated using modeled soil water balance components.

Calculated root zone depletion

- Using Eq 1., D_r was calculated for soil moisture measurements found using Decagon EC-5 sensors at depths of 5, 20, 45, and 80 cm in an oak forest stand at the CrossTimbers Experimental Range near Marena, OK during the same time period:

$$D_r = 1000(\theta_{fc} - \theta_{obs})*Z_r \qquad (1)$$

where θ_{fc} is the depth-weighted volumetric water content at -33 kPa, θ_{obs} is the depth-weighted, measured volumetric soil moisture under forest, and Z_r is the depth of the rooting zone, which was considered to be 1.0 m.

Results

- Modeled versus calculated root zone depletion dynamics compared favorably after plant height was removed from the FAO-56 model (Fig. 3).
- FAO-56 modeled root zone depletion ranged from 0-189 mm d^{-1}, while calculated depletion ranged from 0-197 mm d^{-1}.
- Both modeled and calculated root depletion had a mean of 97 mm.

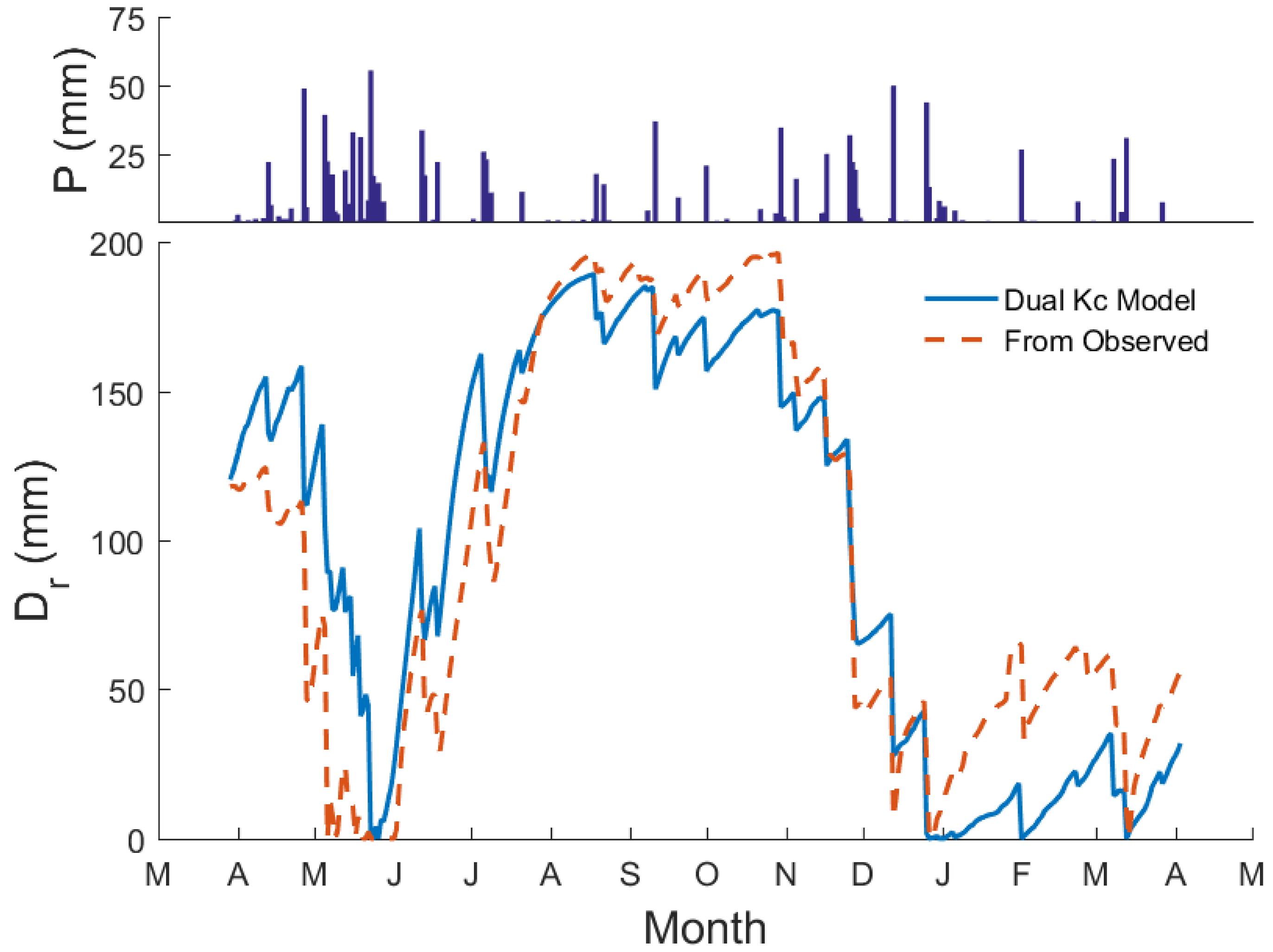

Figure 3. Precipitation (top), daily root zone depletion estimated using the FAO-56 method (bottom, blue solid line) and calculated using observed soil moisture data in an oak forest (bottom, orange dotted line).

Future work

- The final goal of this research is to create a model capable of relating soil moisture under forest to that under grassland and to use that relationship to predict soil moisture for an area of intermixed forest and grassland.
- Additional goals include incorporating estimated soil moisture under forest into a high-resolution statewide map of Oklahoma that includes soil moisture estimates for intermixed grassland, winter wheat, and forest vegetation types.