Modeling transient soil moisture dichotomies arising from anthropogenic land cover alterations

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Introduction

- The majority of the environmental monitoring networks around the world have been installed under surrounding grassland vegetation.
- Typically, soil moisture information recorded under grassland vegetation is used to represent the soil moisture condition at regional level, ignoring the effect of the different land covers.
- However, the distinct vegetative dynamics of the different land covers can impose limitations to extrapolation of soil moisture products, and no methods that bridge the soil moisture regimes from one land cover to another are currently available.

Objectives

- Compare the soil moisture regimes between naturally occurrying sod vegetation surrounding the Oklahoma Mesonet stations and soil moisture under wheat cropland.
- Predict the soil moisture condition under wheat cropland from observed soil moisture under grassland vegetation.

Figure 1. Surroundings of the Oklahoma Mesonet station at Lahoma in June 2013 (left) and November 2013 (right). Both images show the contrasting vegetative dynamics between grassland (front) and wheat cropland (back, red arrows).

Courtesy of the Oklahoma Mesonet.

Materials and Methods

- Observed soil moisture under grassland vegetation was obtained from the Oklahoma Mesonet.
- Soil moisture under the hypothetical scenario of having wheat cropland at each Mesonet station was simulated using the dual crop coefficient (dual Kc) water balance model.
- Root-zone (i.e. top 80 cm) fraction available water capacity (FAW) was estimated for both perennial warm-season grassland and annual winter wheat.
- Soil moisture dynamics were compared for 79 Mesonet stations that monitor soil moisture at 5, 25, and 55 cm depth.
- Ordinary kriging was used for soil moisture spatial interpolation. An artificial neural netwrok was used to predict soil moisture under wheat cropland using soil moisture recorded at the Oklahoma Mesonet.

Results

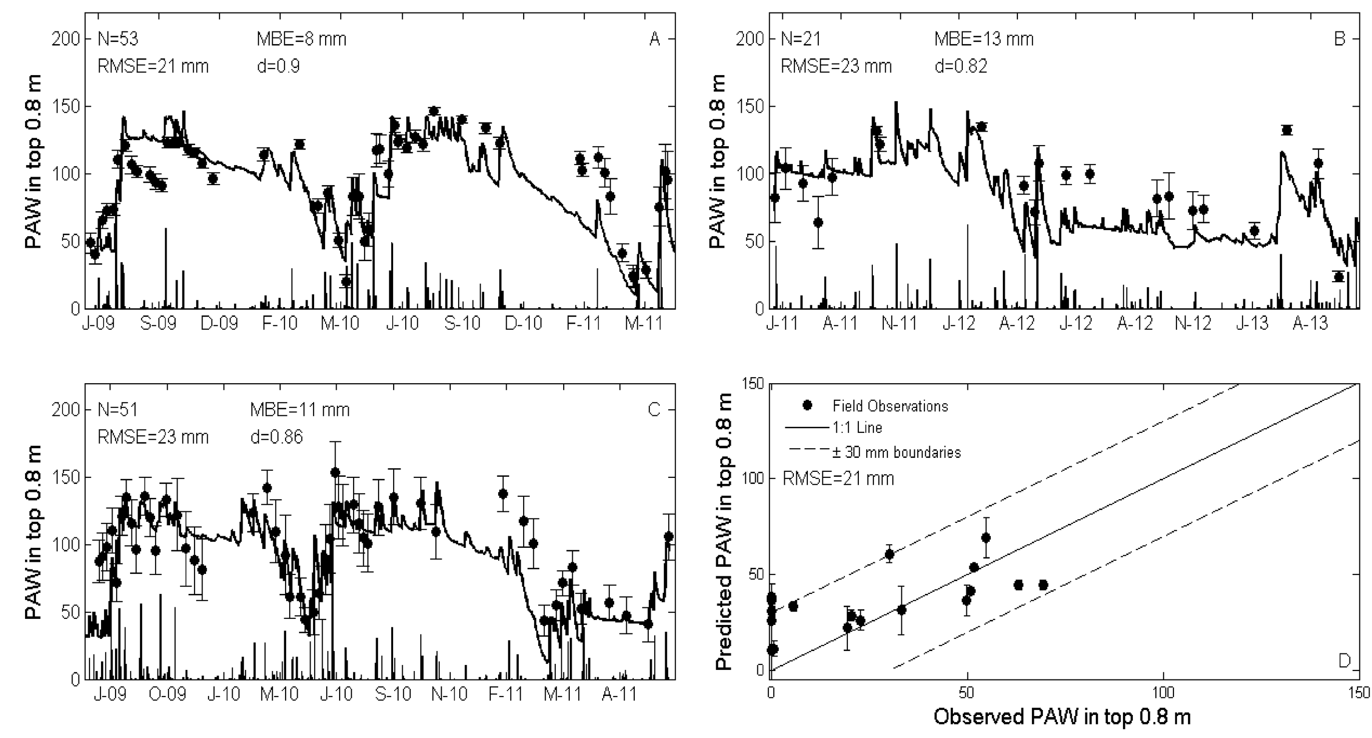

Figure 2. Calibration and validation of the Dual Kc model for winter wheat in Oklahoma.

- Calibration (Fig. 2A) using a soil moisture dataset collected at Lahoma 2009-2011 resulted in root mean squared error (RMSE) of 21 mm, mean bias estimation (MBE) of 8 mm, and Wilmott's index of agreement (d) of 0.9.
- Validation of the dual Kc (Fig. 2B-D) resulted in RMSE ranging from 21 to 23 mm.
- The Dual Kc model was able to capture a wide range of soil moisture scenarios across Oklahoma. The simplicity, robustness, and the low number of input parameters, make the dual Kc model suitable for predicting soil moisture under wheat cropland in Oklahoma.

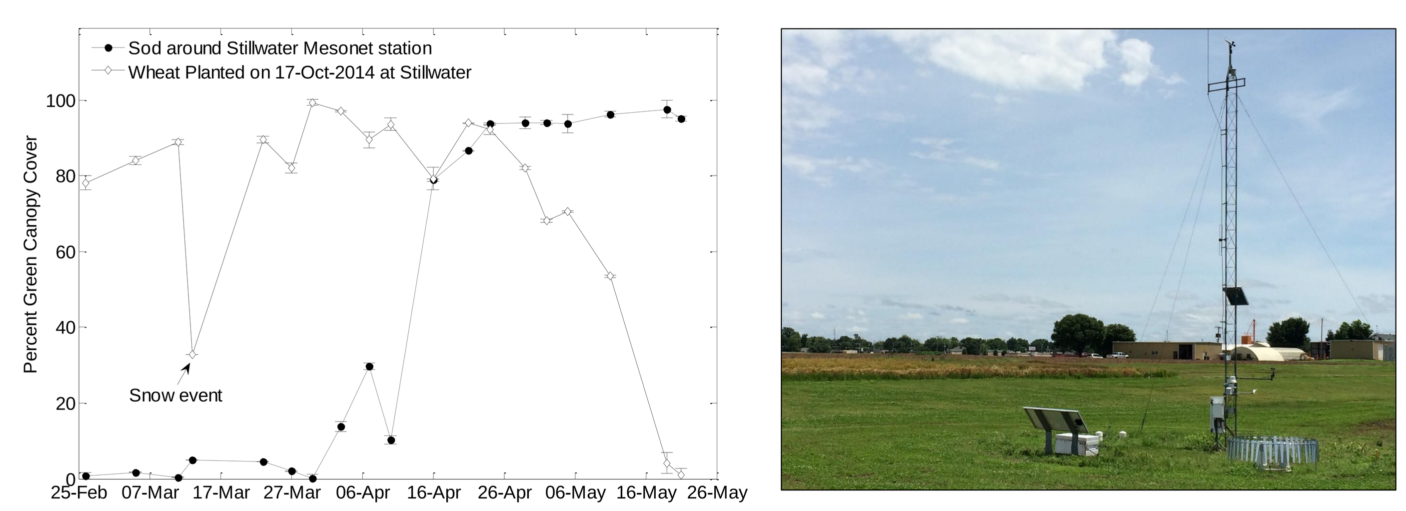

Figure 3. Green canopy cover development (left) for the grassland vegetation surrounding the Stillwater Mesonet station (right) and a nearby (i.e. 25 m) wheat cropland from late February to late May.

- The end of the grassland green-up matched the beginning of the senescing stage of winter wheat in middle April.

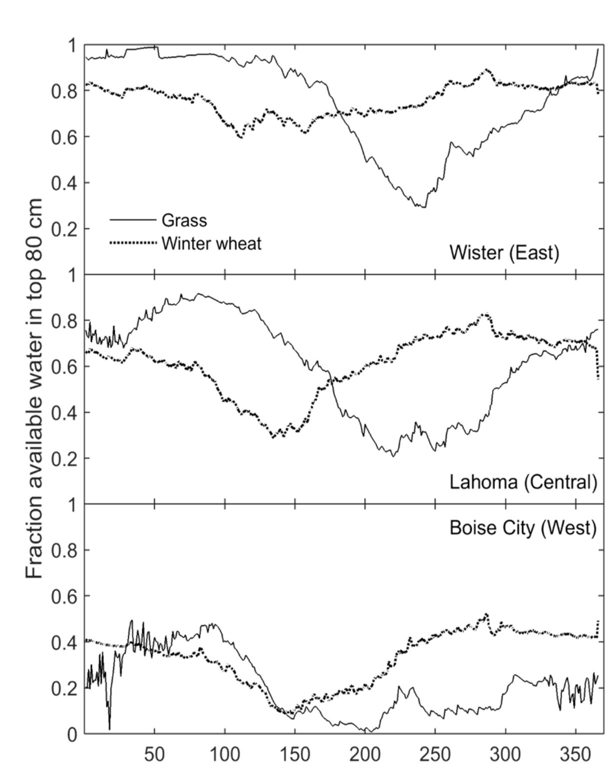

Figure 4. Long-term average FAW for each day of the year (DOY) and for selected Mesonet stations in the east (top), central (center), and west (bottom) part of Oklahoma. Long-term soil moisture patterns were highly associated with the different vegetation dynamics between grassland and wheat cropland, and with the region of the state. Differences were greatest in central Oklahoma

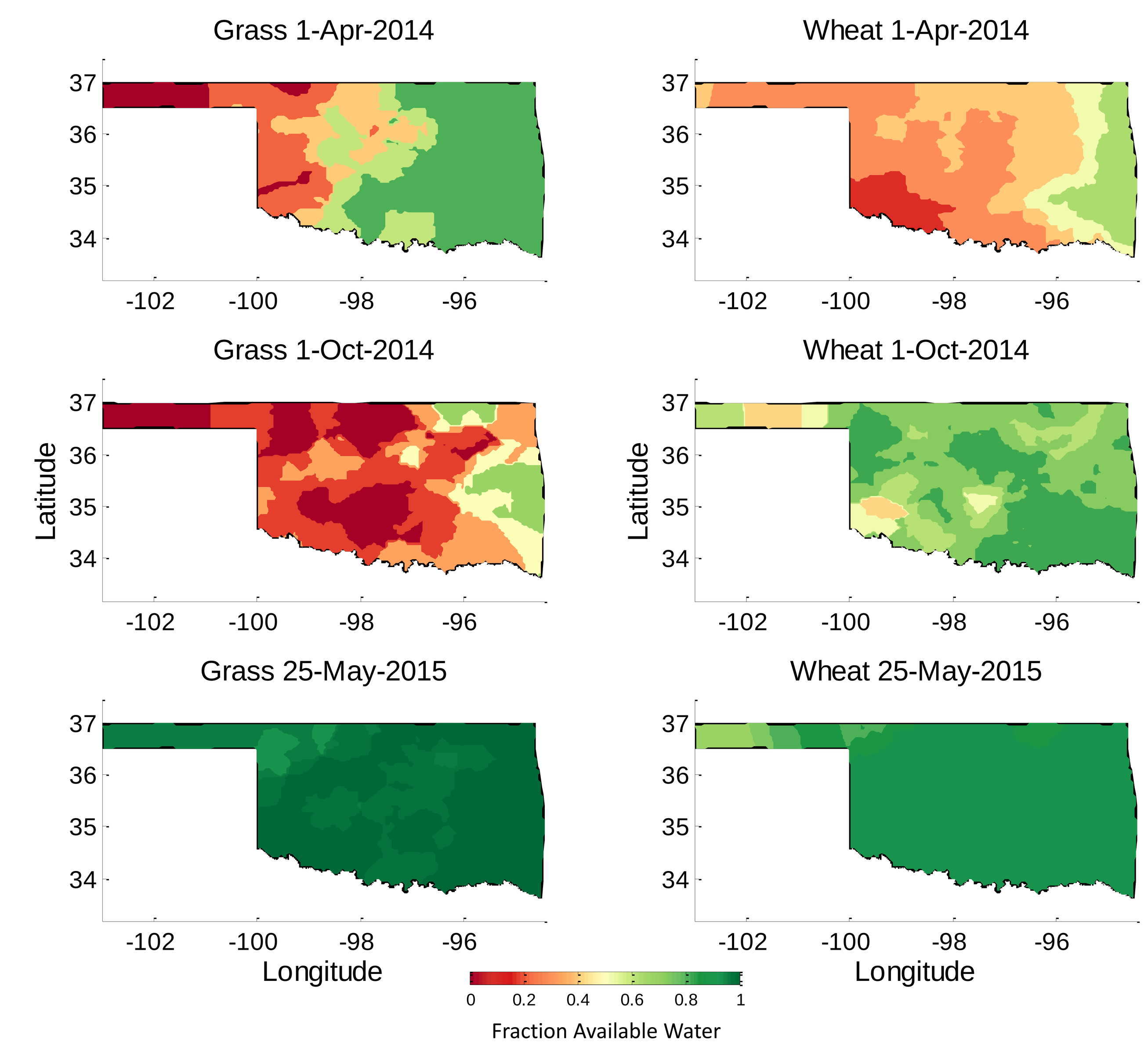

Figure 5. Statewide FAW in top 80 cm for grassland vegetation (left maps, current Oklahoma Mesonet), and wheat cropland (right) at selected dates.

- Representing the state level soil moisture condition using soil moisture recorded at the Oklahoma Mesonet stations resulted in markedly different patterns relative to the soil moisture condition under wheat cropland.

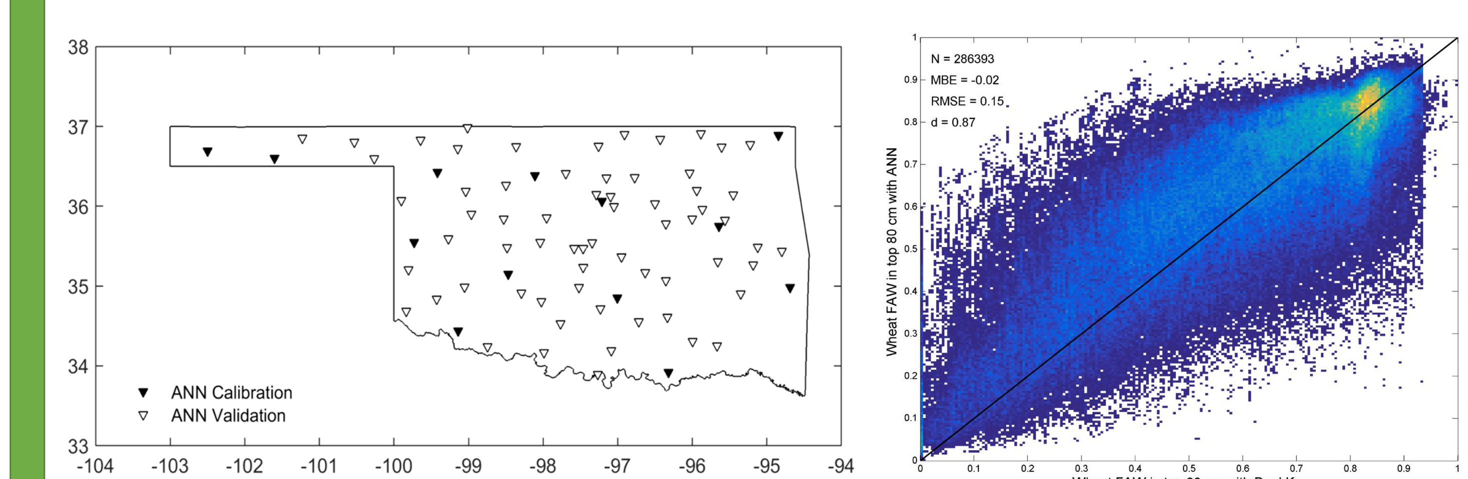

Figure 6. Mesonet stations used for calibration and validation of the Artificial Neural Network (left) and the predicted wheat FAW for the validation set (right).

- Prediction of wheat cropland FAW from observed soil moisture at the Oklahoma Mesonet stations under grassland vegetation resulted in RMSE=0.15.

Conclusions

- Soil moisture regimes of winter wheat and grassland are intermixed at a spatial scale of <1 km, making them difficult to distinguish with existing soil moisture satellites, and limiting Mesonet soil moisture products as a direct surrogate of wheat moisture condition.
- Wheat FAW can be estimated from observed soil moisture under grassland, information that can be assimilated to improve: drought monitoring systems, calibration of remote sensing soil moisture products, and hydrological and crop models.

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