Exploring the links between soil moisture and wildfire

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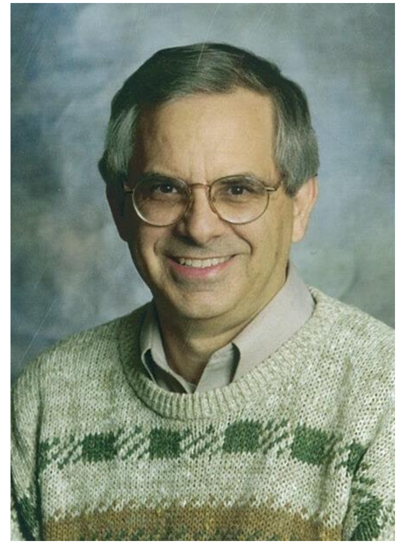
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Our motivating question:

- How can increasingly available information on soil moisture and related soil properties help us reduce the negative impacts of wildfire on people and ecosystems?

Our journey so far:

- Soil moisture affects growing-season wildfire size in the southern Great Plains.
- Concurrent and antecedent soil moisture related differently to wildfire in different seasons.
- Soil moisture is a better growing-season wildfire predictor than KBDI.
- Grassland fuelbed conditions are strongly linked to soil moisture.

Oklahoma wildfires

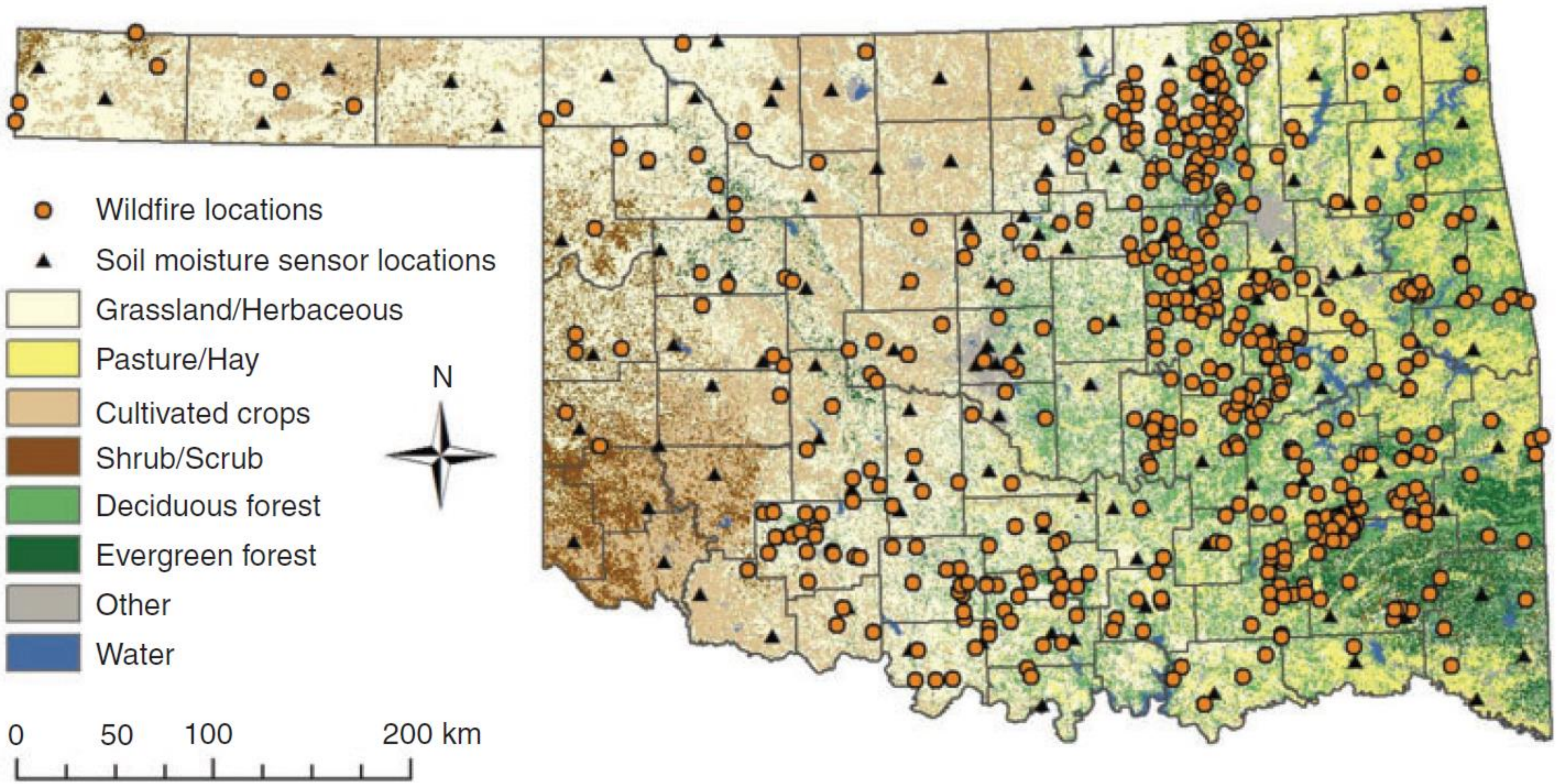
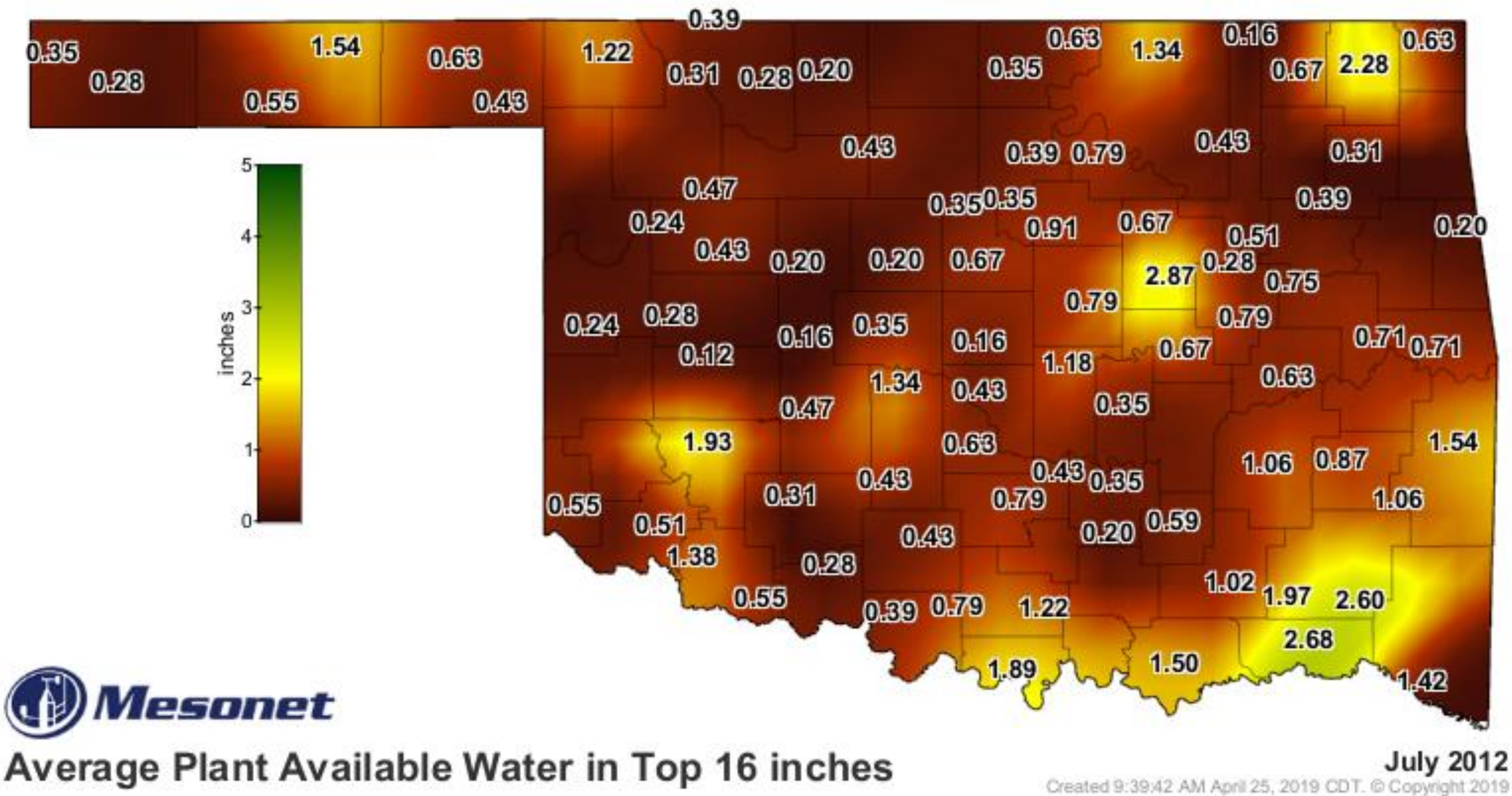


Fig. 1. Oklahoma land cover (Homer *et al.* 2015), locations of Oklahoma Mesonet soil moisture sensors used for the calculation of fraction of available water capacity (FAW), and locations of 501 wildfires ≥405 ha from 2000 to 2012. (For colour figure, see online version available at http://www.publish.csiro.au/nid/17.htm.)

Oklahoma soil moisture data



Soil moisture affects growing season wildfire size

- FAW = fraction of available water capacity
- Large growing season wildfires only occurred when FAW was low.
- Large dormant season wildfires occurred at all levels of FAW.

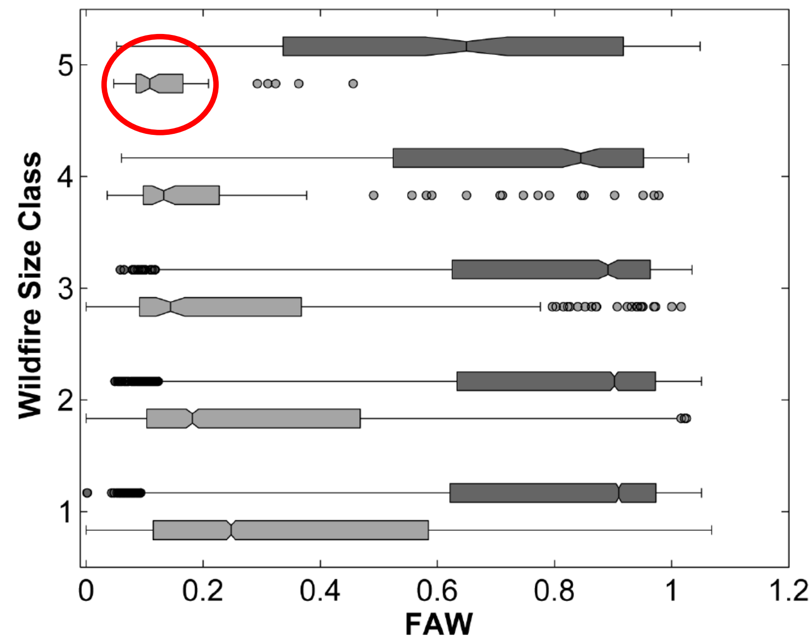


Fig. 1. Fraction of available water capacity (FAW) for fires in wildfire size Classes 1 (smallest) through 5 (largest) during the dormant season (dark gray boxes) and growing season (light gray boxes) for Oklahoma wildfires from 2000–2012. Median values are the black lines near the middle of each box, and notches are 95% confidence intervals on the medians. Median values are roughly significantly different ($P < 0.05$) if notches do not overlap. The 25th and 75th percentile values are the left and right sides of boxes, respectively; the data range excluding outliers is indicated by whiskers extending from each box; and outliers are individual points. All growing season size Class 5 fires ($\geq$405 ha) occurred at FAW < 0.5 and the great majority occurred at FAW < 0.2.

Soil moisture affects growing season wildfire size

- Many plants experience water stress when FAW < 0.5.
- 91% of growing season wildfires >121 ha occurred when FAW < 0.5.
- 77% occurred when FAW < 0.2.

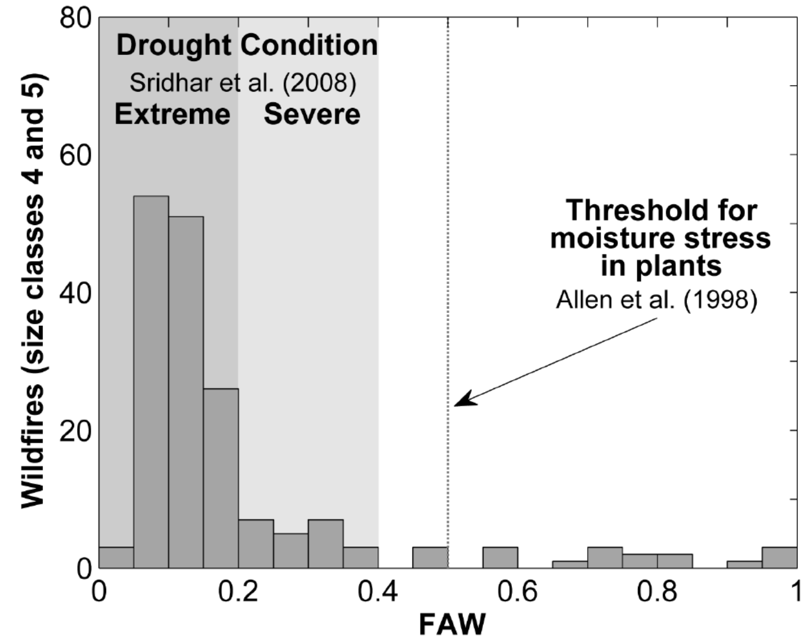


Fig. 2. Frequency distribution of fraction of available water capacity (FAW) for growing-season wildfires in size Class 4 (≥121 and <405 ha) and 5 (≥405 ha) combined in Oklahoma from 2000–2012. Most fires (159 of 174 fires for which soil moisture data were available) occurred at FAW < 0.5, with some occurring under severe drought (22 fires) and most occurring under extreme drought (134 fires).

Concurrent and antecedent soil moisture related differently to wildfire in different seasons

- Large growing season fires reach a maximum when soil moisture reaches a minimum.
- Dormant season fires reach a maximum when soil moisture is near maximum

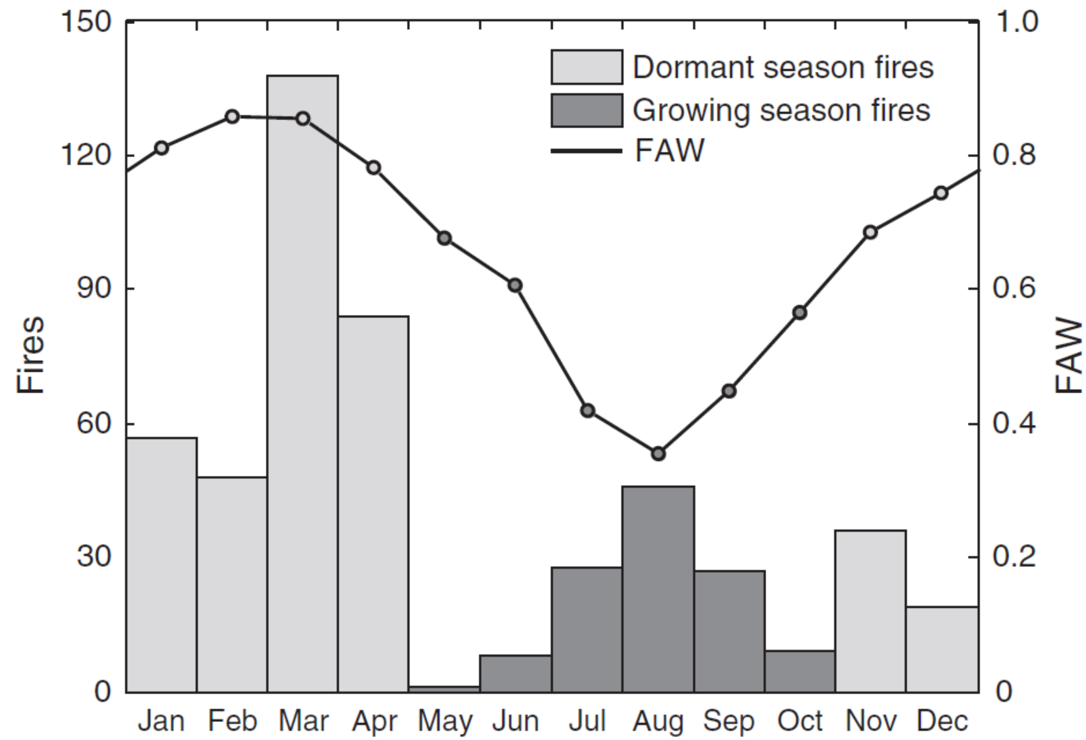


Fig. 2. State-wide average monthly fraction of available water capacity (FAW) and monthly distribution of 501 wildfires ≥405 ha in Oklahoma from 2000 to 2012.

Concurrent and antecedent soil moisture related differently to wildfire in different seasons

- *<u>But</u>*, FAW anomalies were associated with high wildfire occurrence across seasons

- A lag effect of FAW on dormant season wildfire occurrence was apparent

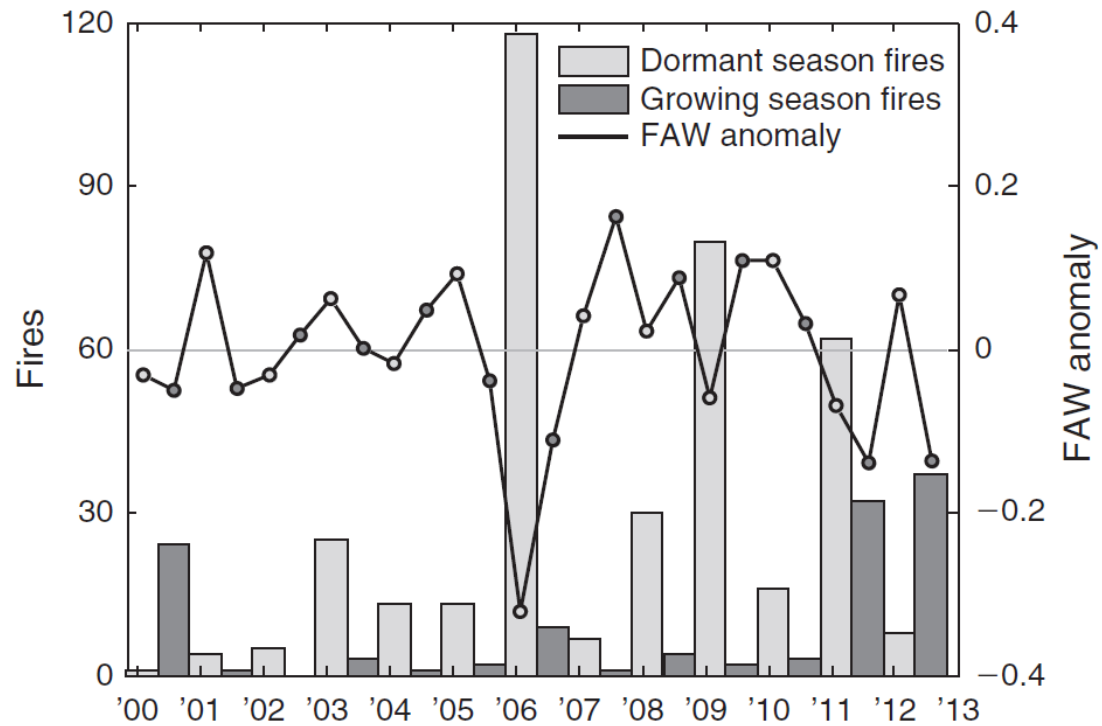


Fig. 3. State-wide average seasonal fraction of available water capacity (FAW) anomaly and growing (May–October) and dormant season (November–April) wildfires ≥405 ha in Oklahoma from 2000 to 2012. Year labels are positioned at the first day of each year (1 January).

Concurrent and antecedent soil moisture related differently to wildfire in different seasons

- Logistic regression model correctly predicted large fire presence/absence on 83% of growing season days over 13 years.

- Current soil moisture, wind speed, and humidity were all important predictors.

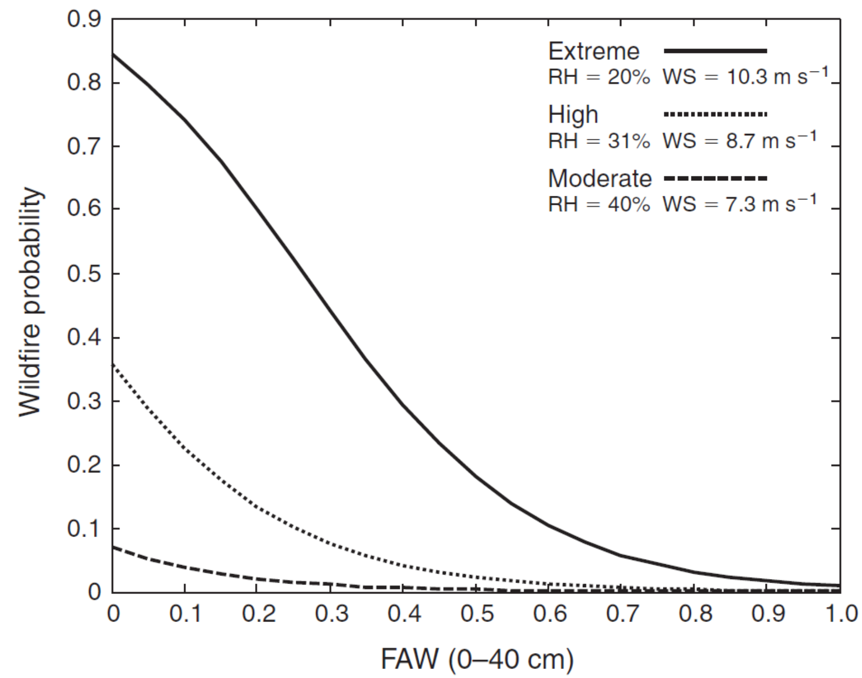


Fig. 4. Daily probability of wildfire occurrence during the growing season as a function of fraction of available water capacity (FAW) and three levels of wildfire conditions (extreme, high, and moderate). Data are based on 119 growing-season wildfires ≥405 ha in Oklahoma from 2000 to 2012. Under 'extreme' wildfire conditions, minimum relative humidity (RH) and maximum wind speed (WS) approximate criteria for the US National Weather Service fire weather warnings in central and western Oklahoma. Under 'high' wildfire conditions, RH and WS corresponded to their respective 25th (low) and 75th (high) percentile values, and moderate RH and WS were their medians over the 13-year period. Daily wildfire probability markedly increased for FAW <0.5, the threshold for water stress in plants.

Concurrent and antecedent soil moisture related differently to wildfire in different seasons

- Logistic regression model correctly predicted large fire presence/absence on 77% of dormant season days over 13 years.

- Antecedent and current soil moisture, wind speed, humidity, and temperature were all important predictors.

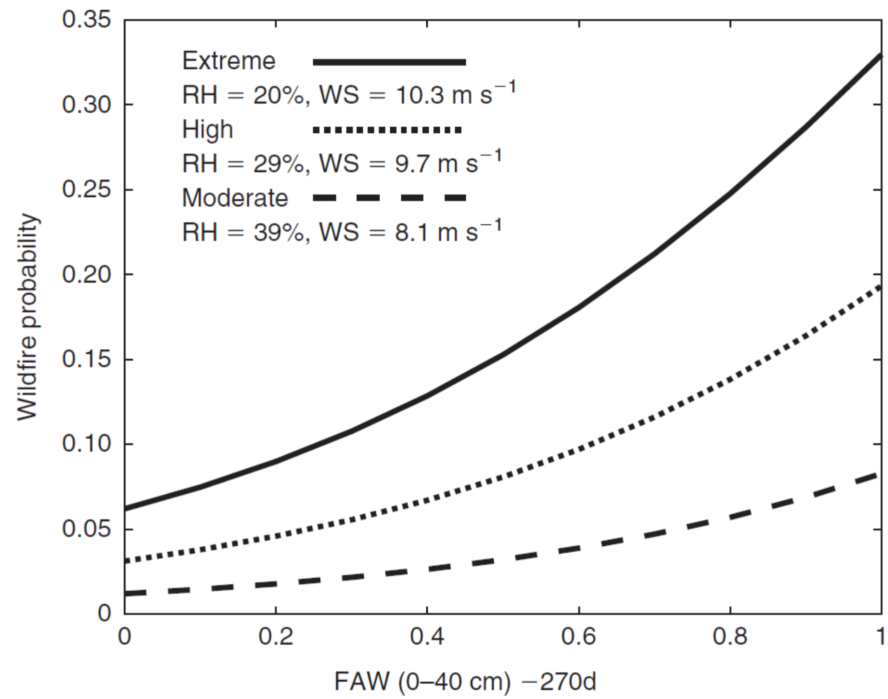


Fig. 5. Daily probability of wildfire occurrence during the dormant season as a function of fraction of available water capacity (FAW) −270d and three levels of wildfire conditions (extreme, high, and moderate). Data are based on 382 dormant season wildfires ≥405 ha in Oklahoma from 2000 to 2012. Under 'extreme' wildfire conditions, minimum relative humidity (RH) and maximum wind speed (WS) approximate criteria for the US National Weather Service fire weather warnings in central and western Oklahoma. Under 'high' wildfire conditions, RH and WS corresponded to their respective 25th (low) and 75th (high) percentile values, and moderate RH and WS were their medians over the 13-year period. Daily wildfire probability markedly increased for FAW −270d >0.5, the threshold for water stress in plants.

Soil moisture is a better growing-season wildfire predictor than KBDI

- 66% of growing season fires >121 ha occurred under extreme KBDI
- 81% of growing season fires >121 ha occurred under extreme FAW

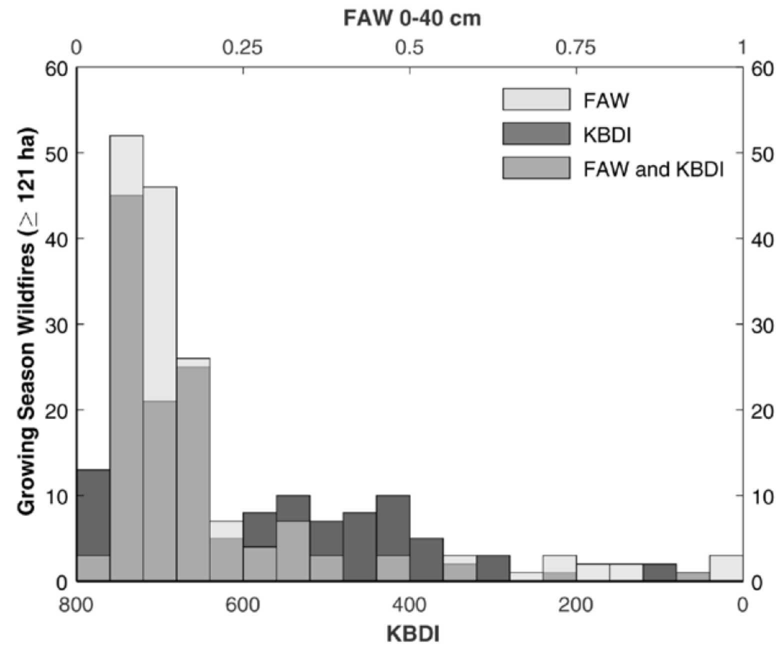


Fig. 2. Frequency distribution of fraction of available water capacity (FAW) from 0 to 40 cm and Keetch–Byram Drought Index (KBDI) for growing-season wildfires combined in size classes 4 (≥ 121 and < 405 ha) and 5 (≥ 405 ha) in Oklahoma from 2000 to 2012. Most fires occurred under dry conditions, with 151 of 166 fires occurring when FAW was < 0.5 and 152 occurring when KBDI was > 400. Peak wildfire potential was more narrowly defined by FAW, with a smaller number of fires (109 vs. 134) occurring at extreme KBDI (600–800) than for equivalent FAW (0.0–0.25) and a larger number of fires (43 vs. 17) occurring at high KBDI (400–600) than for equivalent FAW (0.25–0.5).

Soil moisture is a better growing-season wildfire predictor than KBDI

- Soil moisture conditions indicated extreme drought for 3 weeks preceding the fire
- KBDI was <400 only 10 days before the fire
- On average soil moisture indicated fire danger 10 days earlier than KBDI

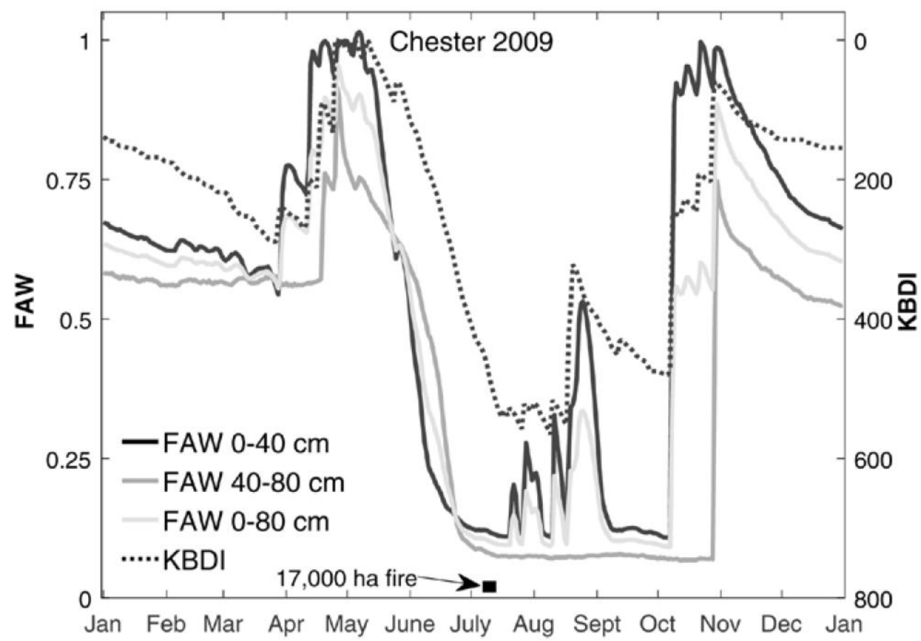
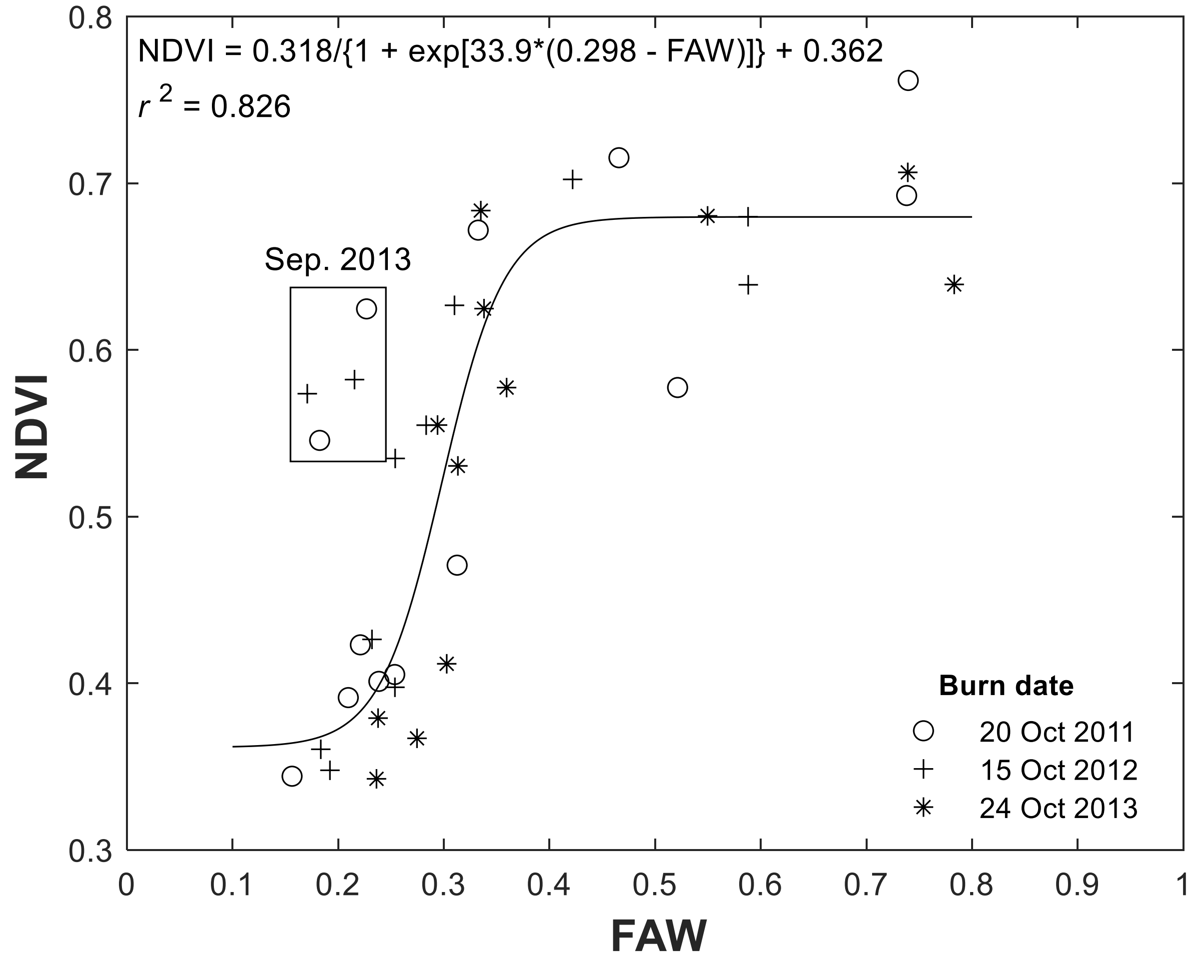


Fig. 6. Fraction of available water capacity (FAW) for the 0- to 40-, 40- to 80-, and 0- to 80-cm soil layers as well as the Keetch–Byram Drought Index (KBDI) near Chester, OK in 2009. Also displayed is the 17,000 ha Chester wildfire that occurred near Chester, OK on 10 July 2009. FAW and KBDI display a similar temporal trend, but differ during periods of soil drying in June and soil moisture recharge thereafter. KBDI provided little warning of increased wildfire danger leading up to the Chester fire, with values indicating only moderate wildfire potential (KBDI < 400) just 2 wk before the fire. In contrast, FAW 0 to 40 cm indicated extreme drought during the 2 wk leading up to the fire.

Grassland fuelbed conditions are strongly linked to soil moisture

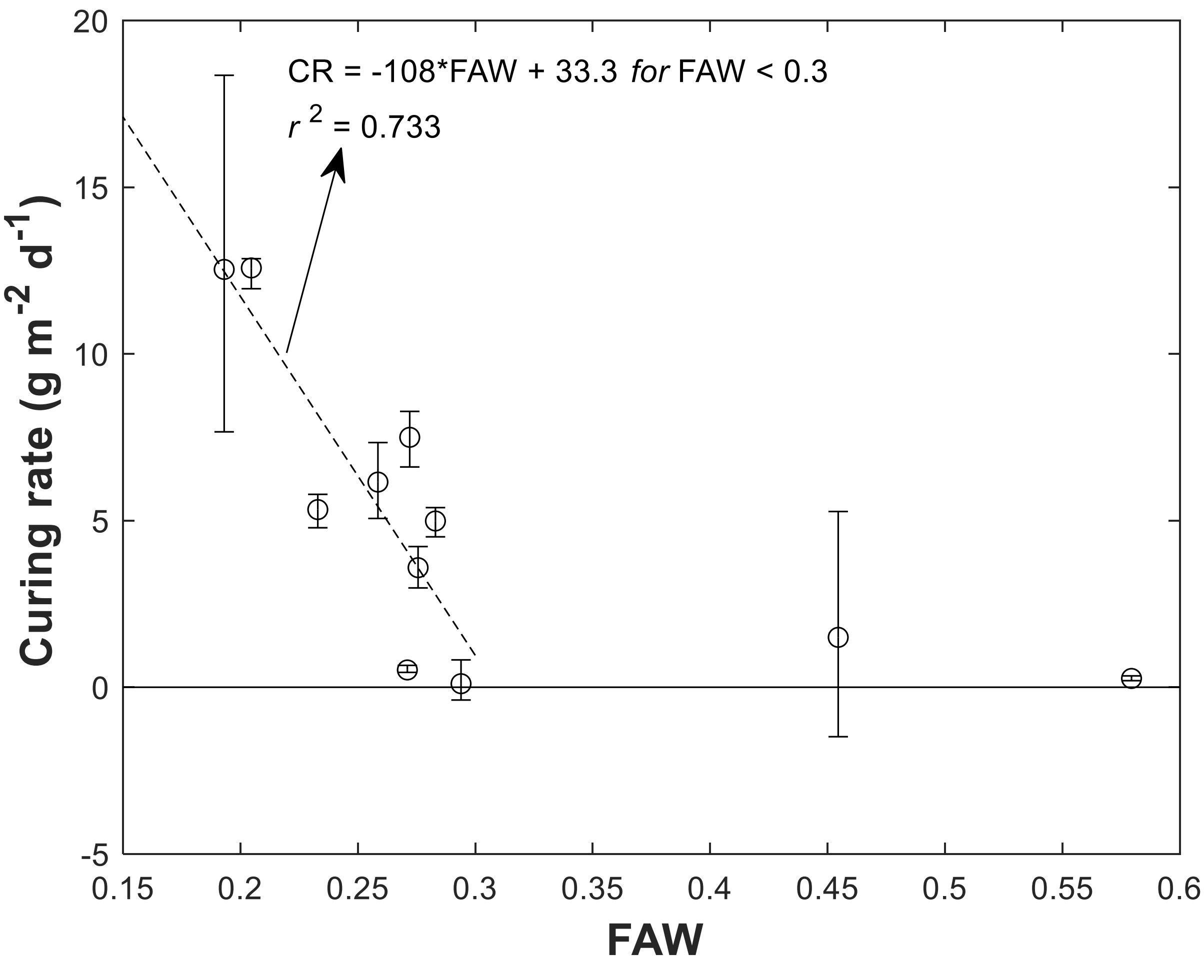
- Logistic relationship between soil moisture and greenness
- Steepest slope at FAW = 0.3



Grassland fuelbed conditions are strongly linked to soil moisture

- Fuel curing rate linearly related to soil moisture at FAW < 0.3

- Maximum curing rates ~13 g m^{-2} d^{-1}



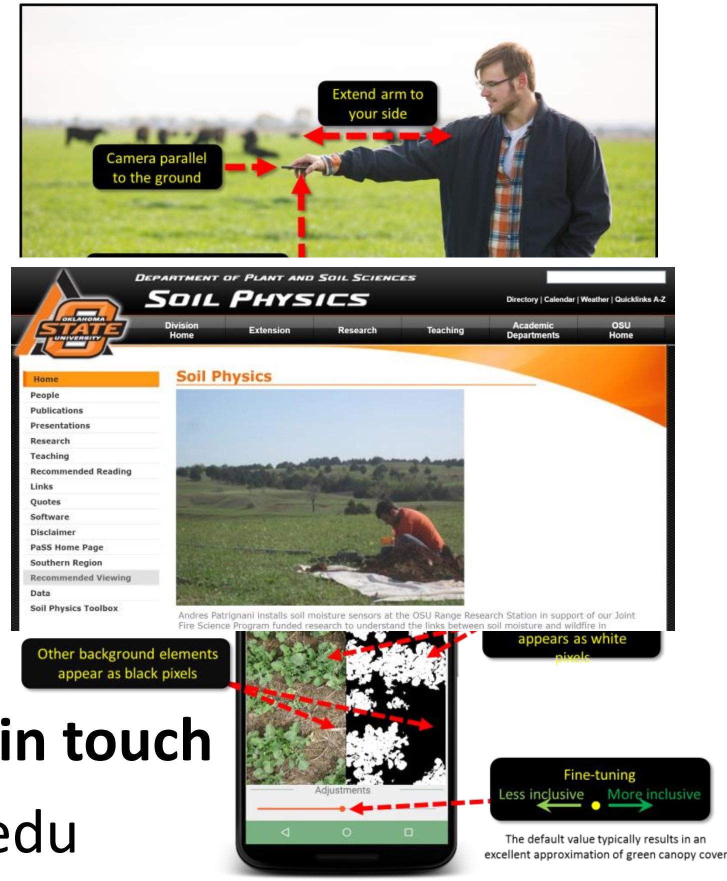
Summary

- Soil moisture affects growing-season wildfire size in the southern Great Plains.
- Concurrent and antecedent soil moisture related differently to wildfire in different seasons.
- Soil moisture is a better growing-season wildfire predictor than KBDI.
- Grassland fuelbed conditions are strongly linked to soil moisture.

Acknowledgments and invitations

- Supported by:

- Special thanks to:
  - Oklahoma Mesonet staff



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