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Modeling the Effects of Throughfall Reduction on Soil Water Content in a Loblolly Pine Plantation of the Southeast US

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Introduction

- In the Southeast US, changing climate conditions are predicted to be warmer and drier, resulting in more severe drought and drier soil moisture conditions.
- Access to water reserves in deep soil during drought periods helps the forest buffer the deleterious effects of water deficits.
- Objective: To model soil moisture dynamics under a throughfall reduction experiment to better predict the future hydrologic effects of a drier climate.



Fig. 1 (above left) Experimental treatments and blocks for a throughfall exclusion study in 8-yr-old loblolly pine plantation in Taliaferro County, GA. Note blocks (indicated by different colors) were established by tree height and basal area; (above right) Throughfall exclusion structure.

Methods

- Loblolly pine (*Pinus taeda*) were planted in Taliaferro County, Georgia in 2006 (Fig. 1).
- Soil samples at eight depths: 0-10, 10-20, 20-50 and 50-300cm in 50 cm increments (Fig 3) to test for texture, Ksat, and van Genuchten parameters (Table 1).
- Soil texture was determined using the hydrometer method.
- Soil water retention curves were estimated using Tempe cells (0-0.1 Mpa) and Decagon WP4C DewPoint Potentiometer (>0.1MPa). Curves were then fit to estimate van Genuchten parameters (Table 1).
- Precipitation and evapotranspiration (Fig. 2) data were collected from a nearby weather station.
- Root distributions were adapted from Parker and Van Lear (1996) (Fig.4).
- Soil volumetric water content were measured using time domain reflectometry (TDR).

Table 1 Soil physical attributes

Depth (cm)	Texture	Ksat (cm/day)	θ_r (cm ³ /cm ³)	θ_s (cm ³ /cm ³)	α (cm ⁻¹)	n
0-10	loam	164.7	0.034	0.33	0.00082	1.45
10-20	clay loam	164.7	0.034	0.40	0.00306	1.28
20-50	clay	91.8	0.069	0.39	0.00160	1.39
50-100	clay	28.0	0.085	0.41	0.00034	1.41
100-150	clay	19.2	0.076	0.48	0.00070	1.38
150-200	clay loam	3.5	0.081	0.43	0.01825	1.28
200-250	clay loam	3.9	0.083	0.39	0.01924	1.22
250-300	loam	3.4	0.051	0.50	0.00313	1.36

Model Structure and Inputs

- The model was designed to simulate daily changes (March 2013 to present) in the vertical distribution of soil water using HYDRUS 1-D.
- This model consists of 8 soil material layers with respective soil hydraulic parameters (Fig 3).
- The hydraulic model is the van Genuchten-Mualem single porosity model.
- Upper boundary condition was set as atmospheric boundary with surface run off; Lower boundary condition was set as free drainage.
- Precipitation inputs determine water flux to the soil surface and evapotranspiration water removal (Fig 2).
- Root water uptake was modeled using Feddes' plant water stress response function, with root distribution fitted to a power function (Fig. 4).

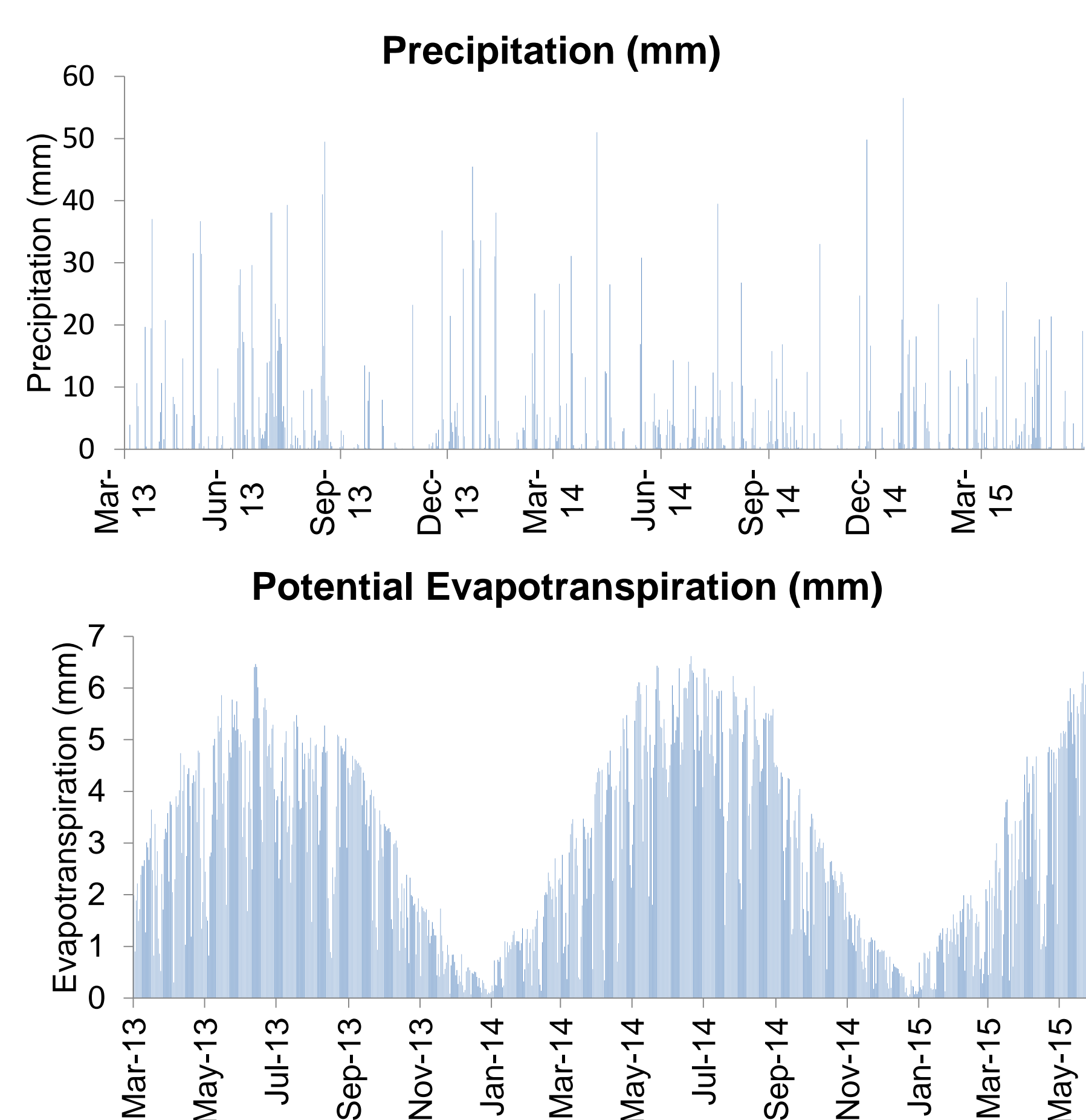


Figure 2. Precipitation input (above top) and potential evapotranspiration input (above bottom) for March 2013 to May 2015

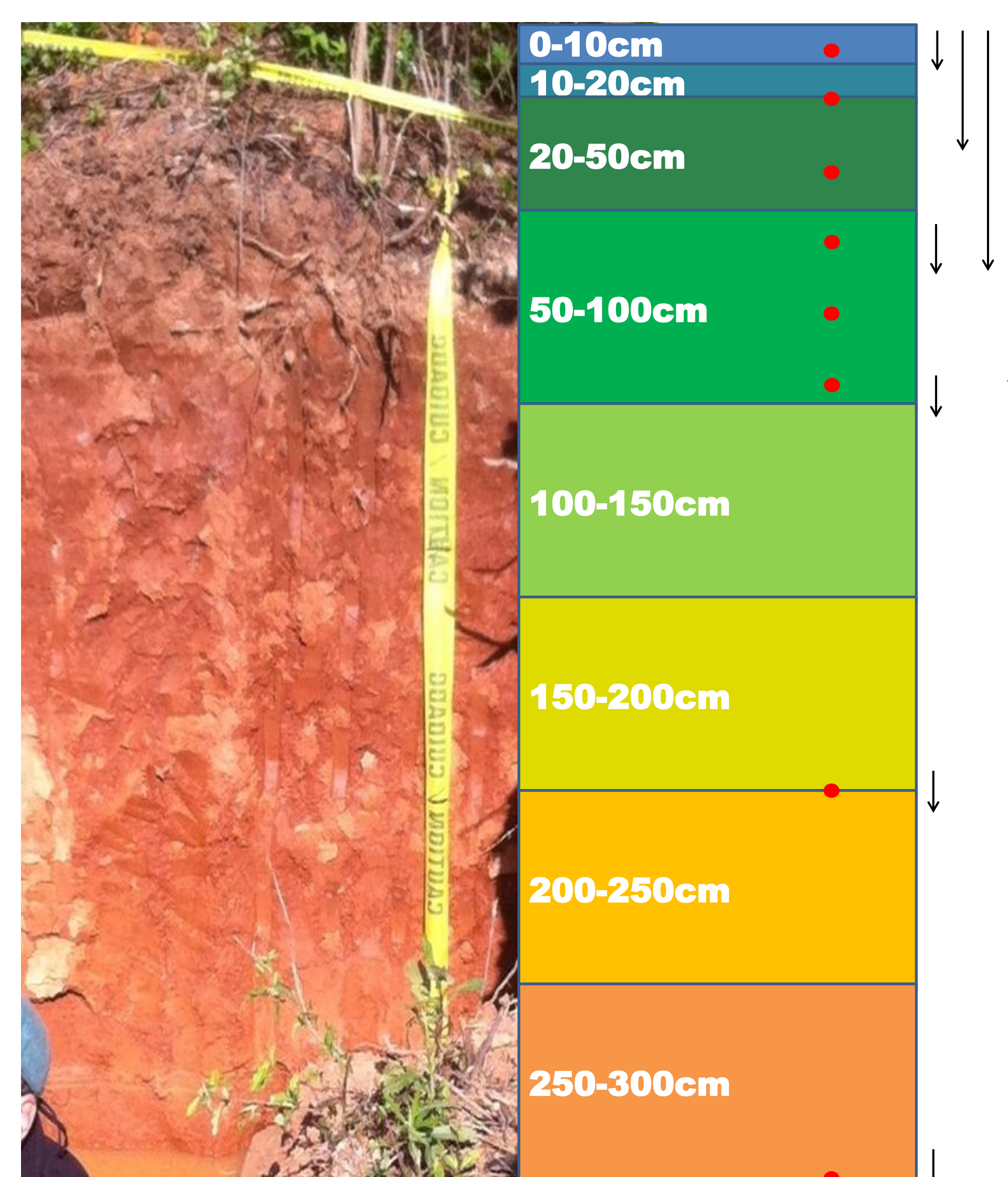


Figure 3. (left) Soil profile picture of the research site (right). Model structure: Different colors indicate soil layers; Arrows indicate TDR measurements; and red dots indicating observation nodes.

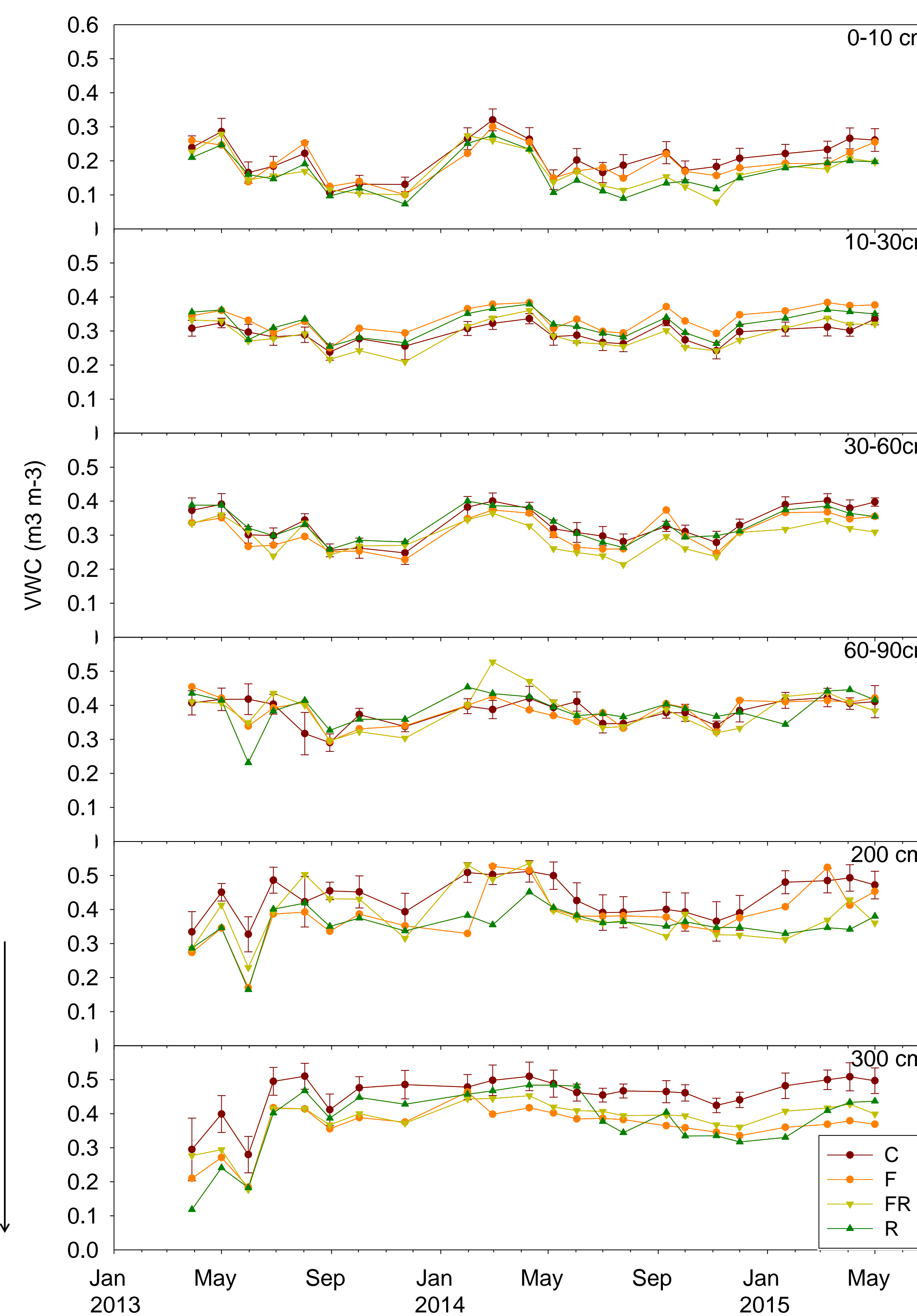


Figure 6. Mean soil VWC of six depths (0-10, 10-30, 30-60, 60-90, 200 and 300cm) for March 2013 to May 2015. Bars representing SEM for four replicates are given only for C to maintain clarity.

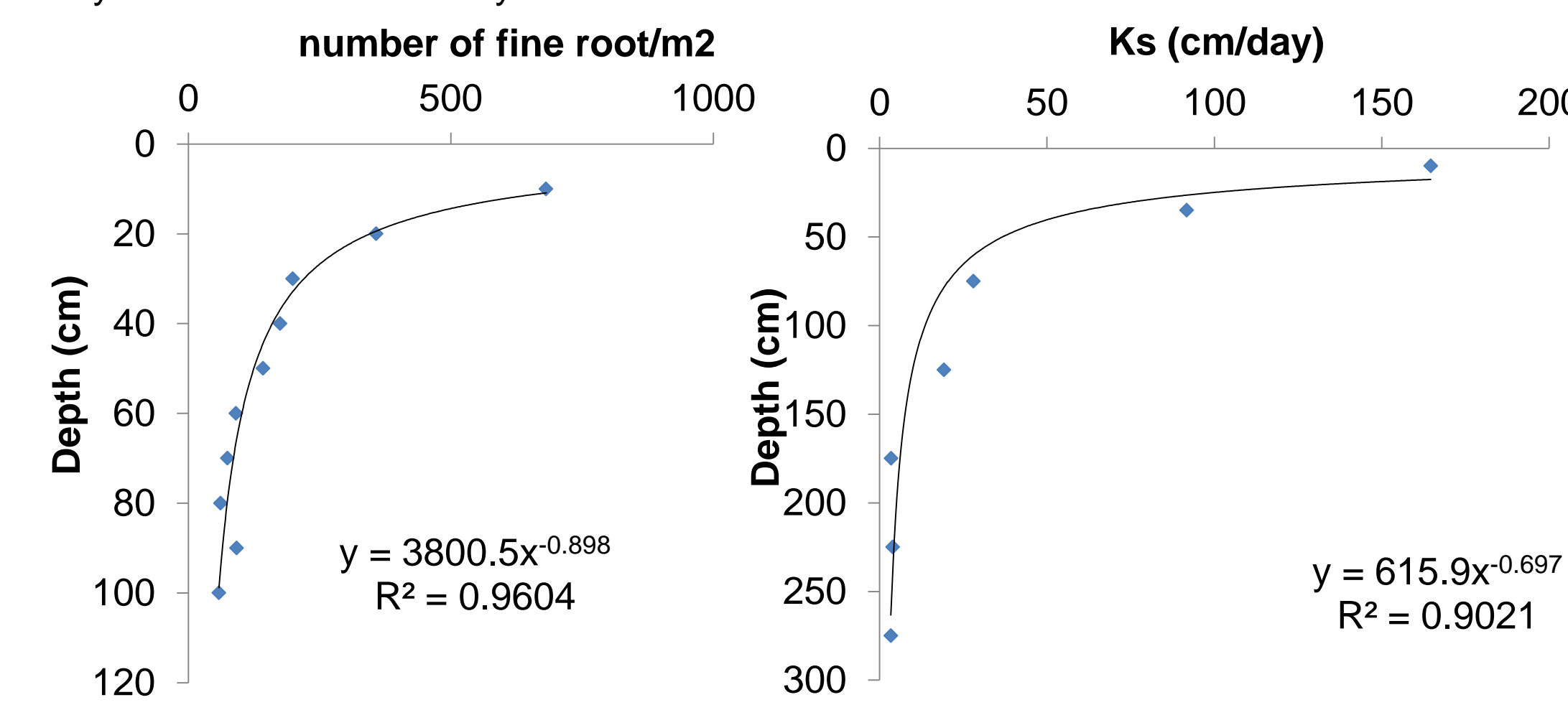


Figure 4. Root distribution fitted with a power function. Adapted from Parker and Van Lear (1996) Soil heterogeneity and root distribution of mature loblolly pine in piedmont soil. SSSAJ 60(6):1920-25.

Model Outputs

- Presently, simulations are presented for the control plot with no reduction in water inputs.
- Soil VWC were measured approximately monthly in the control plots from March 2013 to present at: 0-10, 0-30, 0-60, 0-90, 200 and 300 cm (Fig 6.). They were also collected every 30 minutes from Feb 2014 to present at ~60 and ~90 cm.
- The model explained 47.9% of the variance in measured values (Fig. 7).

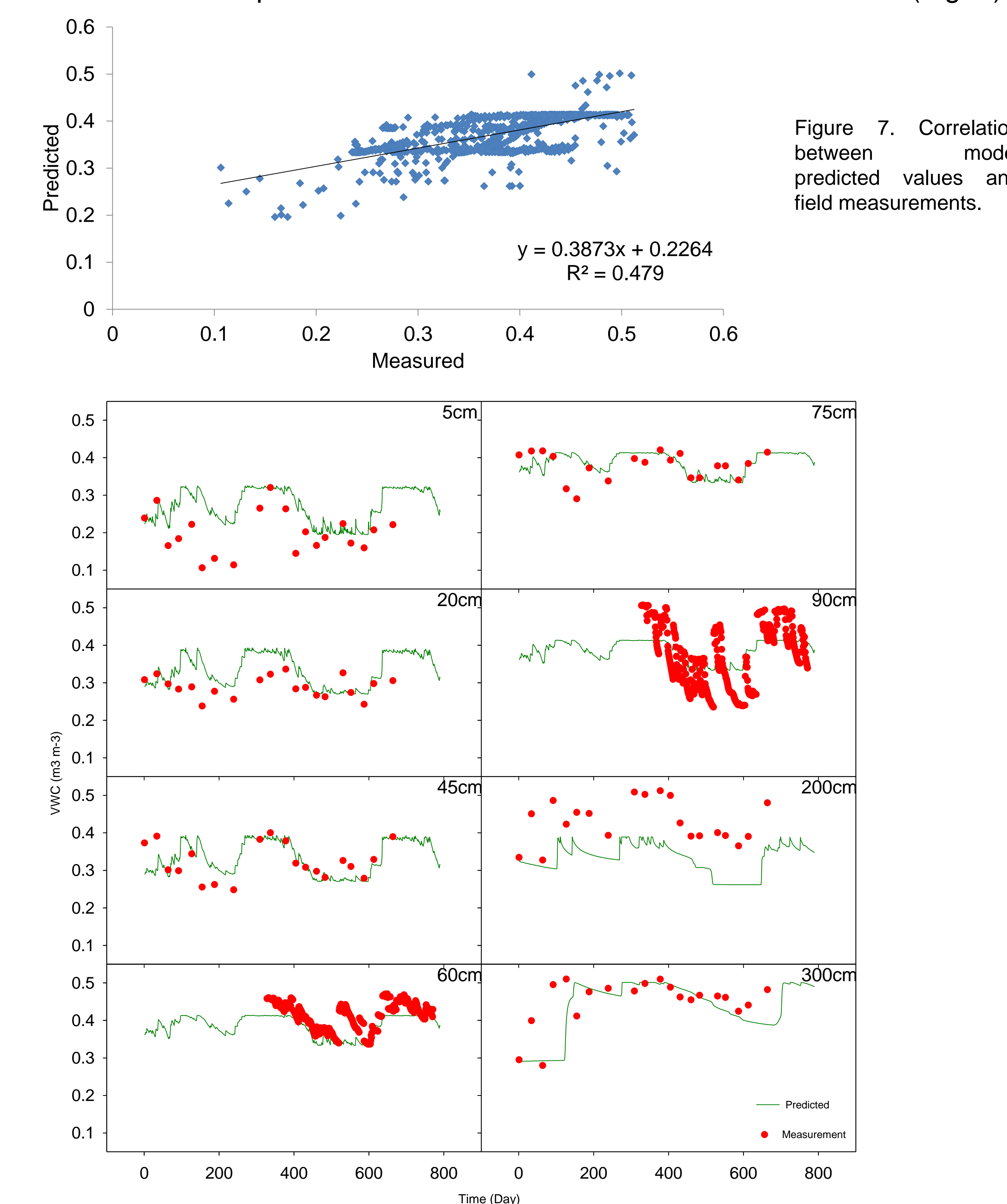


Figure 7. Correlation between model predicted values and field measurements.

Future Plan

- Model Calibration**
 - Field data of the control plots will be used for model calibration.
 - Calibration observation nodes were placed at 5, 20, 45, 60, 75, 90, 200 and 300cm. Model output generated from these nodes will be used to compare with field measurements.
- Model validation**
 - Soil VWC were measured at the same intervals in the throughfall exclusion plots. These data will be used for model validation and to assess changes in the depth of root water uptake with drying.

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