Better modeling of root-soil interactions by explicit representation of soil hardness

Christopher K Black[1], Ernst D Schäfer[1,2], Jonathan P Lynch[1,2]

[1]Pennsylvania State University, [2]University of Nottingham

ckb23@psu.edu, @infotroph

Context

- Deeper-rooted crops may ease soil carbon debt while enhancing drought tolerance and N use efficiency. Testing this requires that we observe a lot of roots.
- Roots are hard to observe, so it is useful to stretch our datapoints as far as possible using models. This only works if the model structure is realistic for the question we're asking!
- Most root growth models ignore soil structure and assume growth in a uniform, nonrestrictive medium.
- That's fine when parameterizing from pot experiments, but **ignoring soil structure limits our inferences when modeling field experiments.**

Soil penetration resistance

Gao et al. 2016, Soil & Tillage Res

$$Q = \rho \left(A^* \frac{(F-e)^2}{1+e} ({\sigma_s}^p - \psi S^*)^f \right)^2$$

Where

ρ = soil bulk density, measured

e = porosity, measured or calculate from bulk

σ = net stress, calculated from weight of overlying soil layers:

$$\sigma_i = \sum_{k=0}^{i-1} \rho_k$$

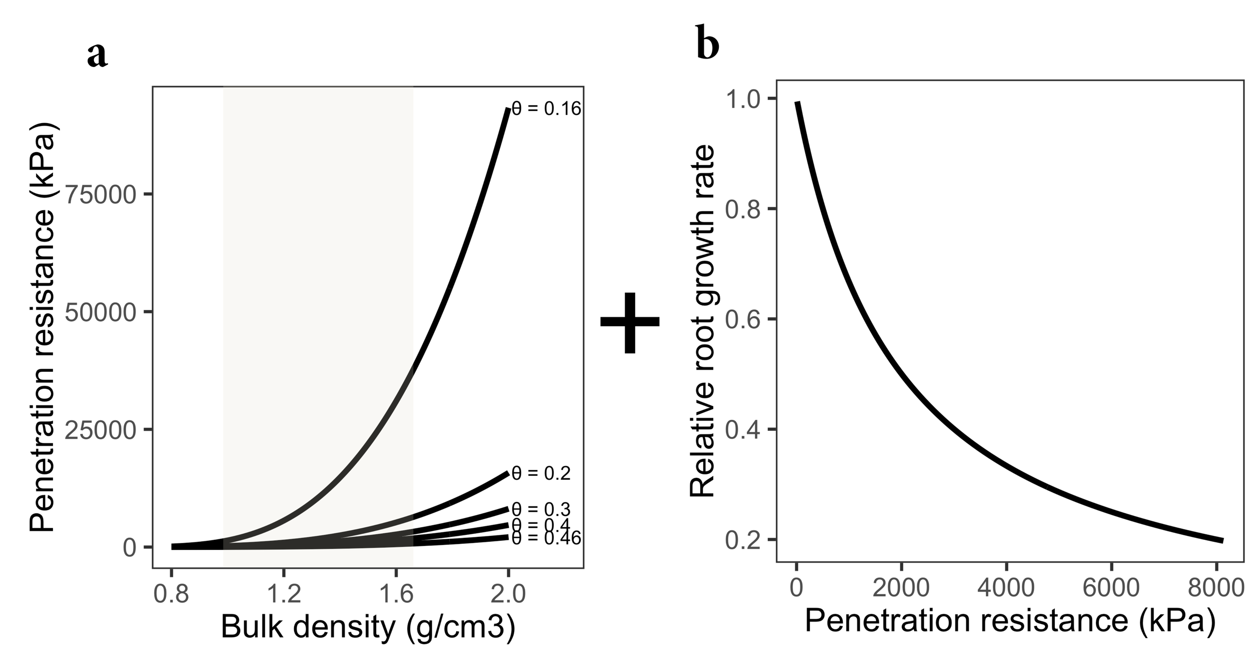
ψ = matric potential, calculated from van Genuchten

S^* = effective saturation, calculated from van Genuchten

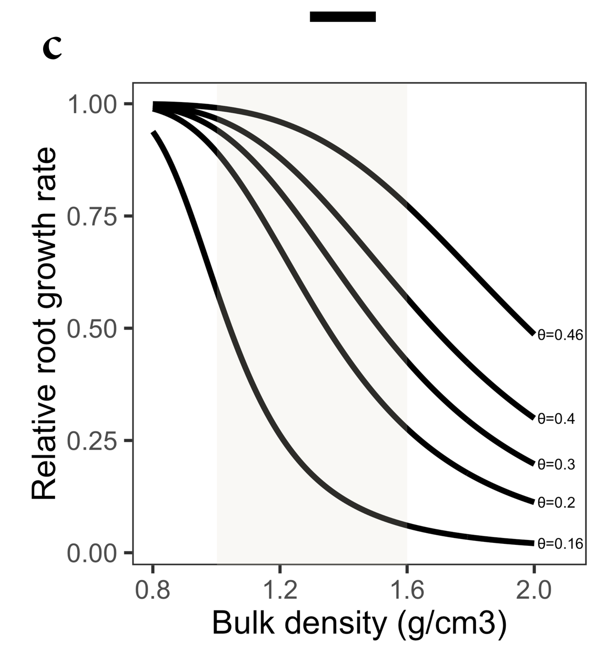
A^*, F, p, f = fitted constants

Contribution

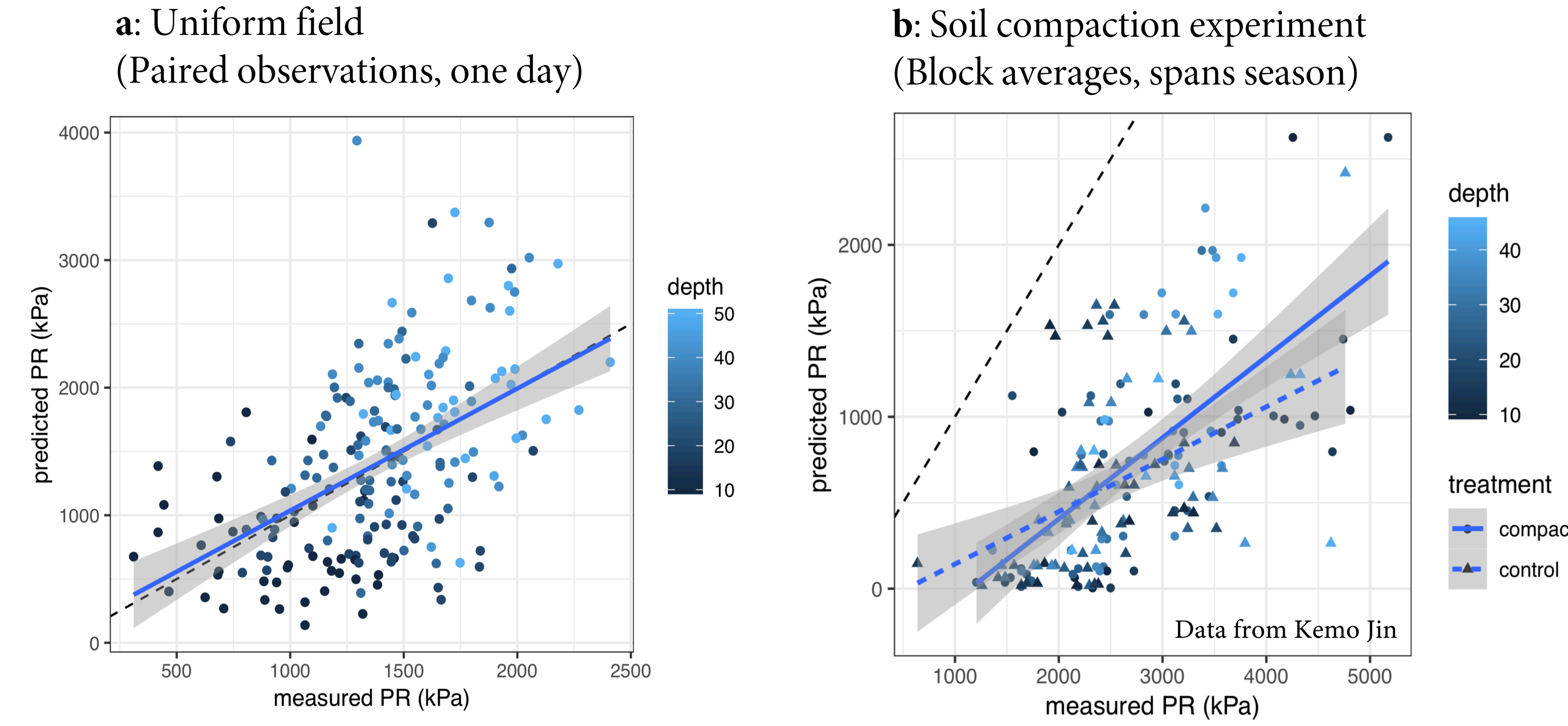
- We updated the structural-functional root growth model *OpenSimRoot* (Postma et al. 2017, New Phyt) to include a physical model of soil impedance.
- Models with realistic soil impedance predict shallower- and shorter-rooted phenotypes than do models with uniform impedance.
- Adding a plowpan increases sensitivity to root branching angle.
- **Accounting for soil physical structure changes model predictions of root architecture.**
- Next steps: Validate against field data.

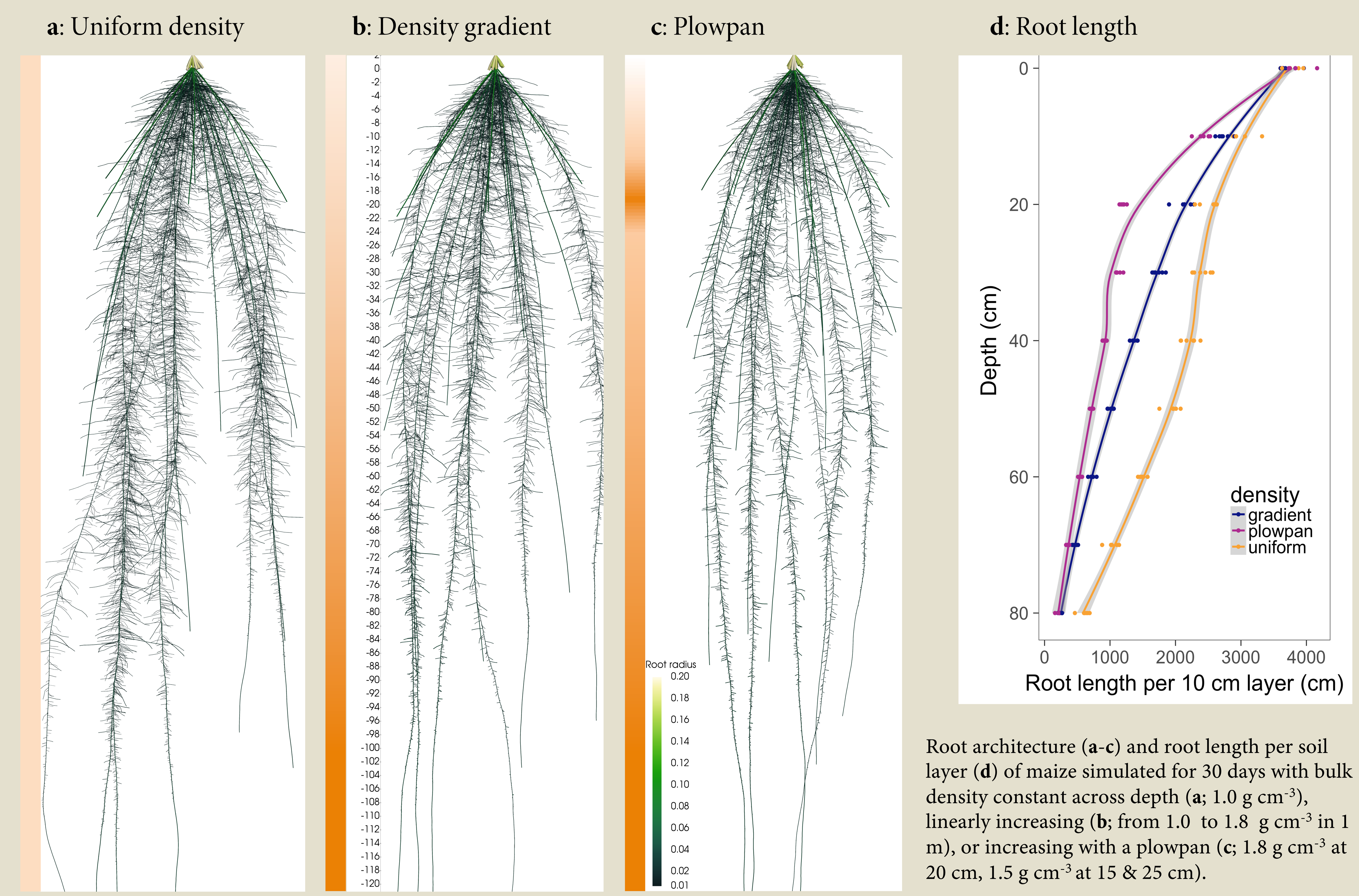


Calculation of relative growth rate in OpenSimRoot: Penetration resistance (**a**) is estimated from bulk density and water status according to the pedotransfer function of Gao et al (2016), then converted to relative growth rate (**b**) according to a user-specified root impedance function; here, we use a decreasing Michaelis-Menten with Km=2000. The resulting effect of bulk density on relative growth (c) is roughly sigmoid, with a quasi-linear portion in the range typical of agricultural soils (shaded).

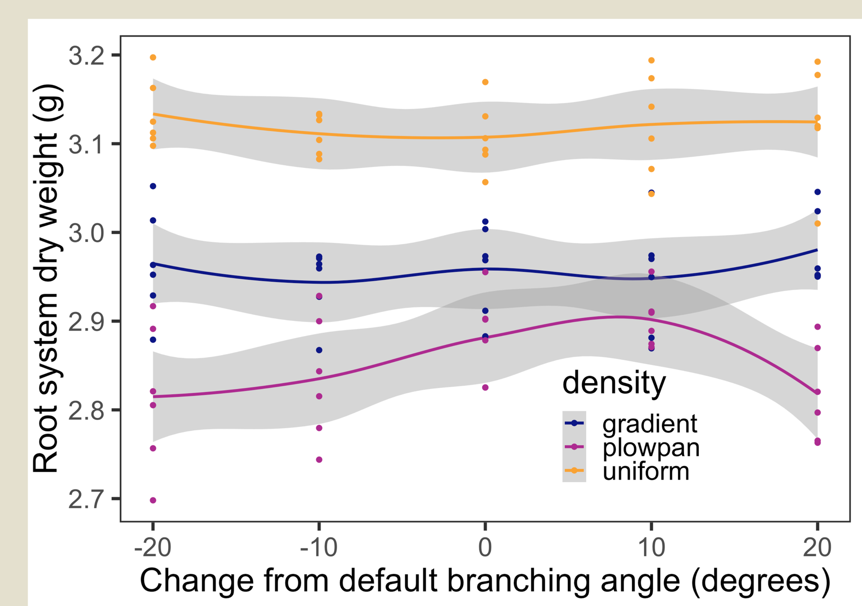


Comparison of penetration resistance observed vs. predicted from bulk density and water status of a silt loam soil at Rock Springs, PA, measured as (**a**) 10-cm layers from paired 0-50 cm coring and penetrometry in a single maize field on 2017-06-27, and (**b**) daily block averages of 2.5 cm layers (7.5-50 cm) across the 2017 growing season in a soil compaction experiment.

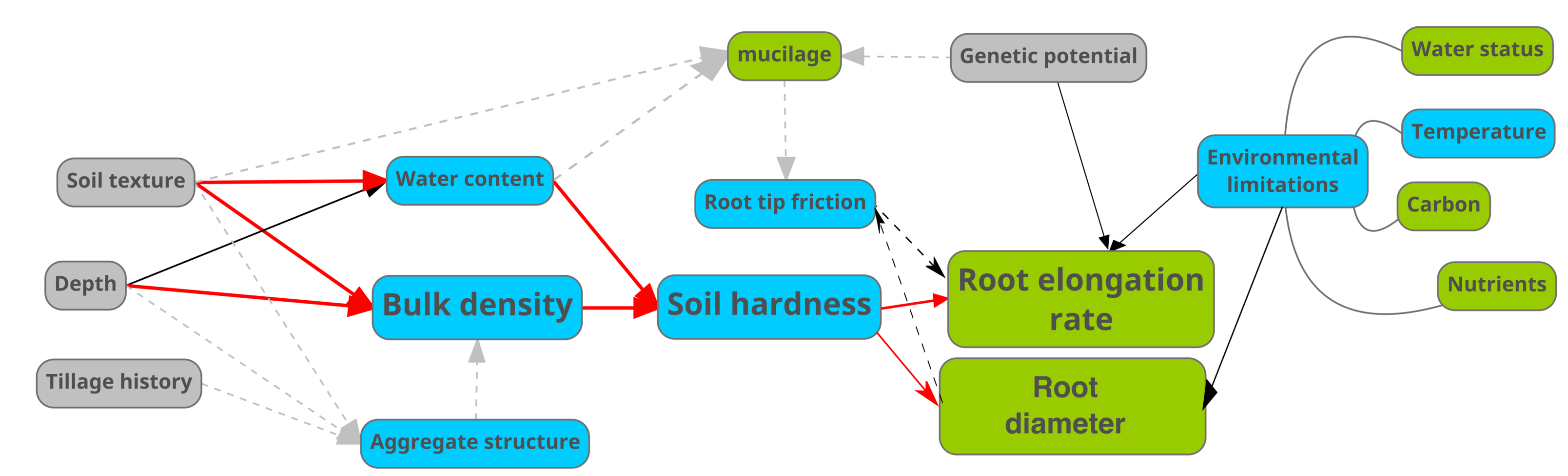




Root architecture (**a-c**) and root length per soil layer (**d**) of maize simulated for 30 days with bulk density constant across depth (**a**; 1.0 g cm^{-3}), linearly increasing (**b**; from 1.0 to 1.8 g cm^{-3} in 1 m), or increasing with a plowpan (**c**; 1.8 g cm^{-3} at 20 cm, 1.5 g cm^{-3} at 15 & 25 cm).



Effect of altering root branching angle on predicted maize root mass after 30 days.



Conceptual diagram of factors affecting root growth rate in OpenSimRoot. Red arrows are links newly implemented in this study; dashed lines are planned but not yet implemented.

PennState

arpa·e