

# The contribution of soil, topographic, and vegetation traits to plant water sensitivity

Alexandra G. Konings<sup>1</sup>, Krishna Rao<sup>1</sup>, Meng Zhao<sup>1</sup>  
Park Williams<sup>2</sup>, Noah Diffenbaugh<sup>1</sup>, Marta Yebra<sup>3</sup>

(1) Stanford University

(2) UCLA

(3) The Australian National University



Remote Sensing  
Ecohydrology Group

# Veg response to water stress has widespread effects

Need to understand for:

- 1) Accurate model predictions
- 2) Understanding consequences of global change

## LETTER

<https://doi.org/10.1038/s41586-018-0424-4>

**Sensitivity of atmospheric CO<sub>2</sub> growth rate to observed changes in terrestrial water storage**

## Geophysical Research Letters

### RESEARCH LETTER

10.1029/2018GL078131

**Soil Moisture Stress as a Major Driver of Carbon Cycle Uncertainty**

## Water Resources Research

### RESEARCH ARTICLE

10.1029/2018WR023726

#### Key Points:

- Water-limited and energy-limited

**Satellite and Station Observations Demonstrate Water Availability's Effect on Continental-Scale Evaporative and Photosynthetic Land Surface Dynamics**

nature  
climate change

ARTICLES

<https://doi.org/10.1038/s41558-020-0781-5>

 Check for updates

**Plant hydraulics accentuates the effect of atmospheric moisture stress on transpiration**

ARTICLES

<https://doi.org/10.1038/s41558-020-00945-z>

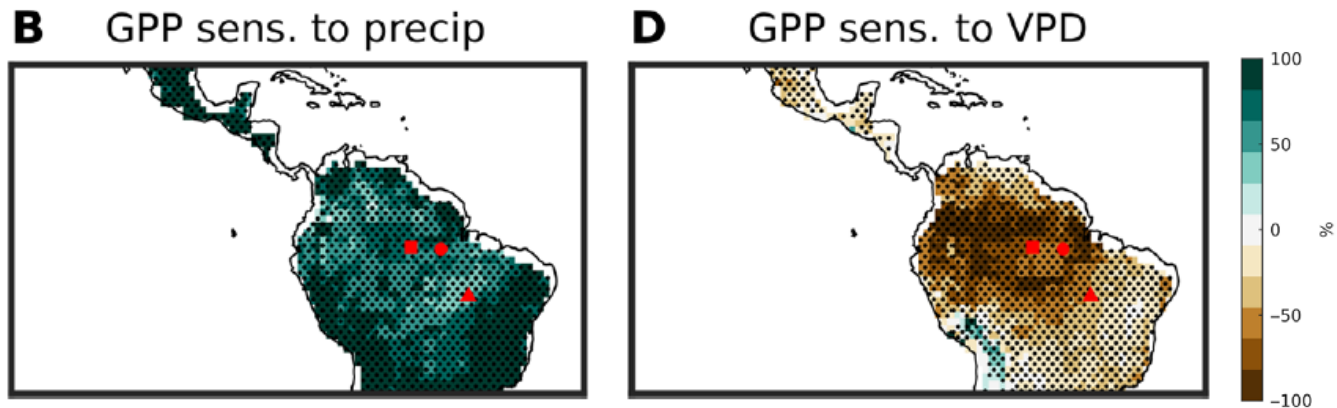
nature  
climate change

 Check for updates

**Soil moisture-atmosphere feedbacks mitigate declining water availability in drylands**

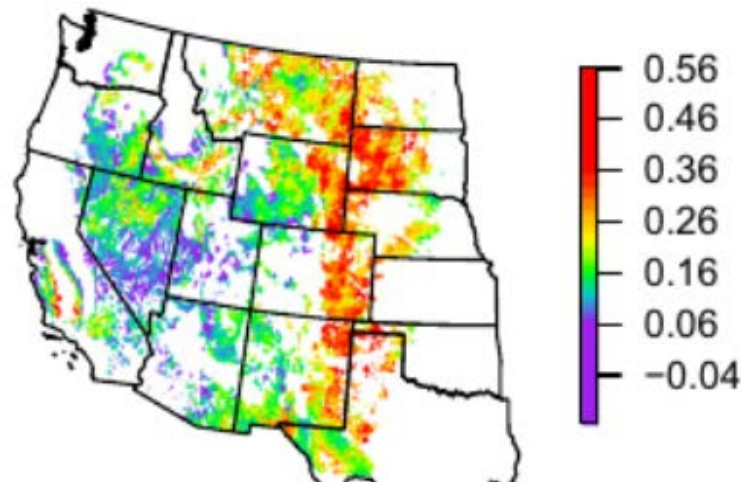
# Veg response to water stress varies considerably

Ex metric 1:



*Green et al, Sci Adv, 2020*

Ex metric 2:



*Felton et al, New Phyto, 2021*

Q: What drives these spatial patterns?

# Many independent explanatory factors: veg type



VS



VS

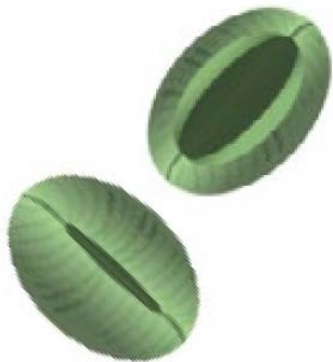


# Specific plant hydraulic traits also matter

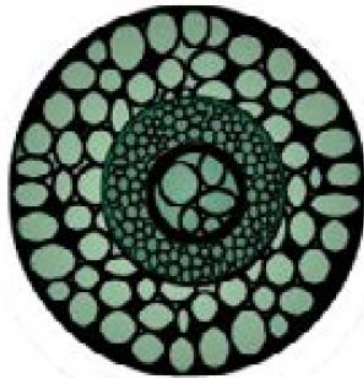
Within broad vegetation types, there is also a range of different plant hydraulic traits that affect drought response.

e.g.:

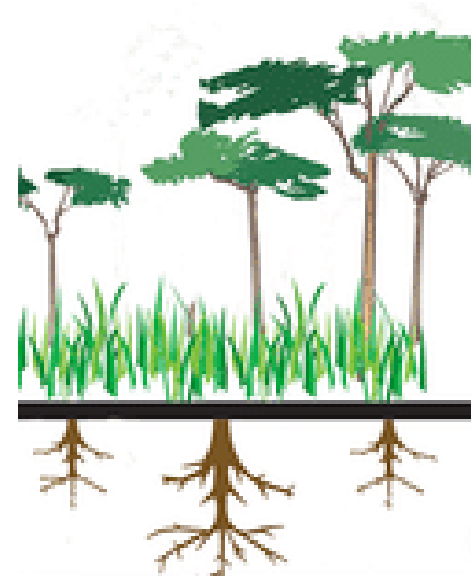
Stomatal traits



Xylem traits



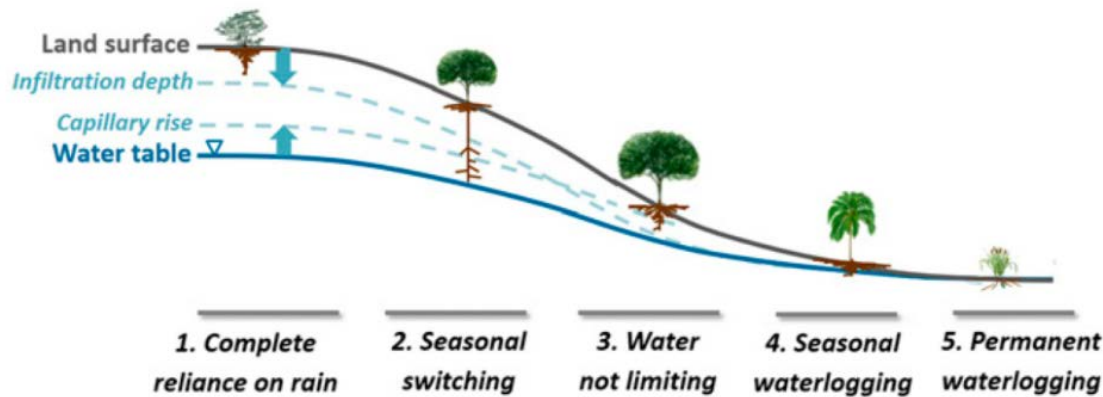
Rooting properties



*Schematics from  
Kannenberget al, Functional Ecology, 2022  
O'Connor et al, HESS, 2019*

# Soil and topography also matter

Rate at which infiltration is moved away from rooting zone affects potential for uptake



*Gao et al HESS 2019*



*Fan et al WRR 2019*

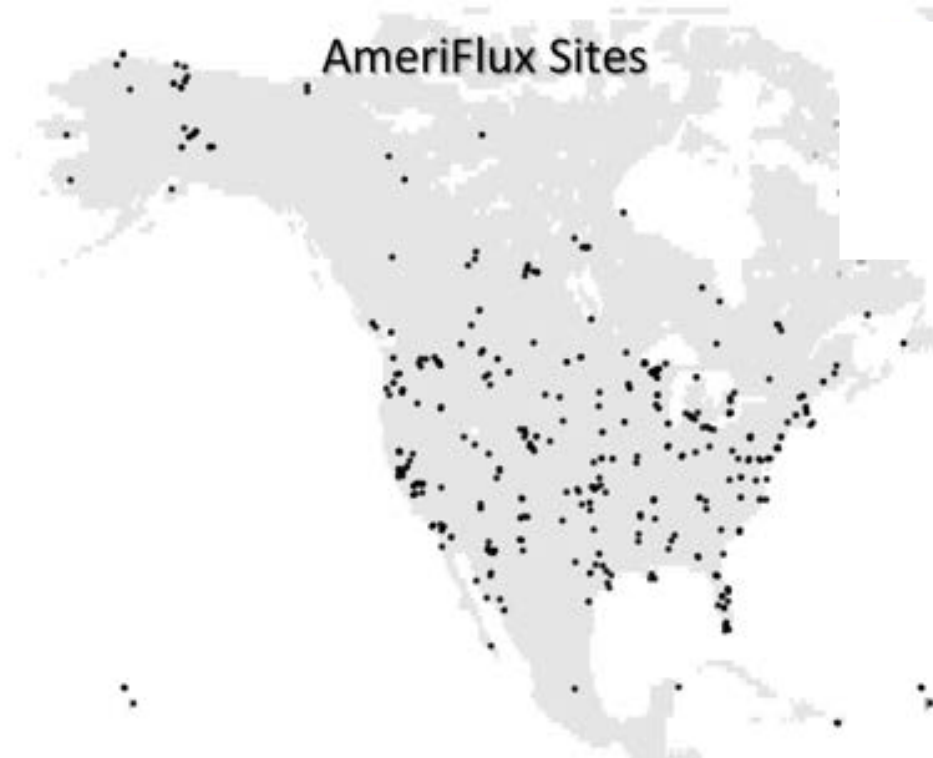
Factors like soil conductivity, topographic slope, capillary rise, water table depth, aspect, etc... all relevant

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How big is the effect of these different factors:  
climate, soil, topography, & vegetation type?



# In situ observations are sparse



*Chu et al, AFM 2021/DoE*

Can we be certain to capture full range of explanatory factors with limited number of datapoints?

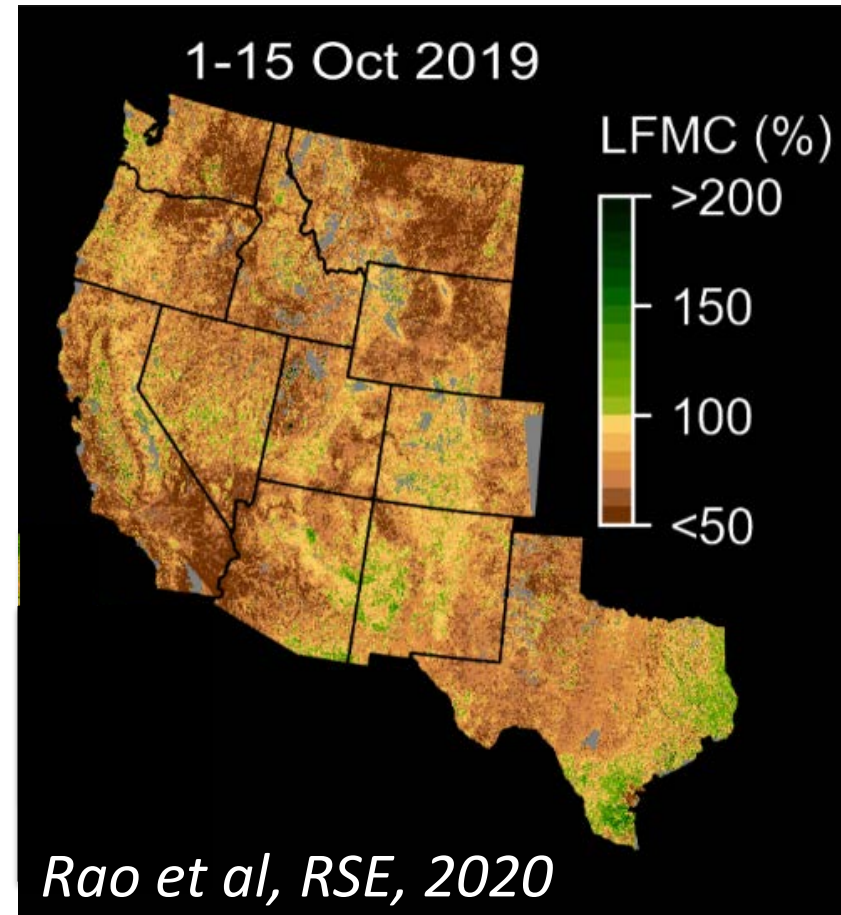


# Use live fuel moisture content (LFMC) across Western US

$$\text{LFMC} = \frac{\text{Vegetation Water}}{\text{Dry Biomass}} \times 100\%$$

250 m, 15-day resolution

Derived from Sentinel-1 SAR  
with RNN

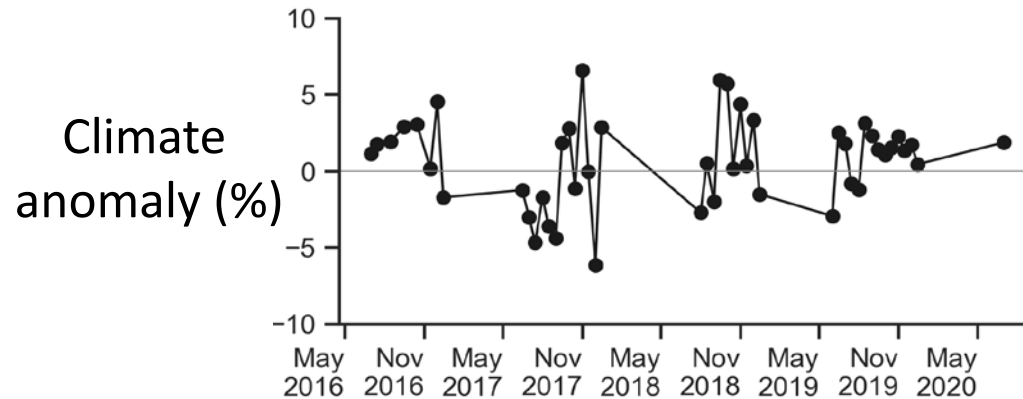


*Key: LFMC measure of actual water stress status of vegetation*  
Balance of water uptake and water loss

# Designing a water stress response metric

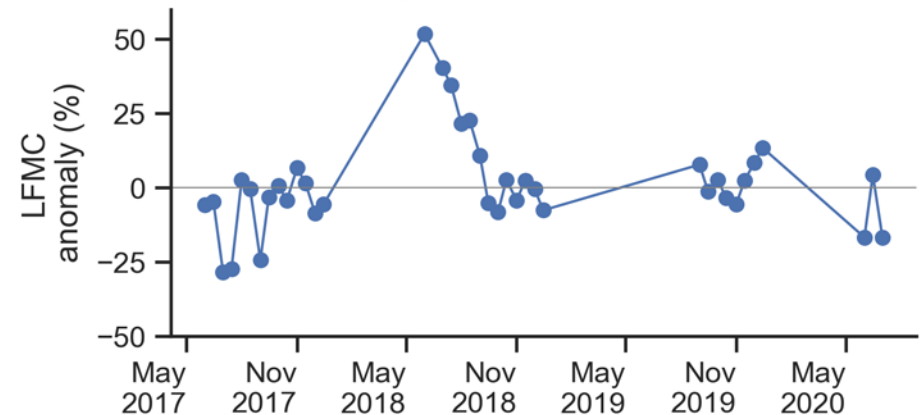
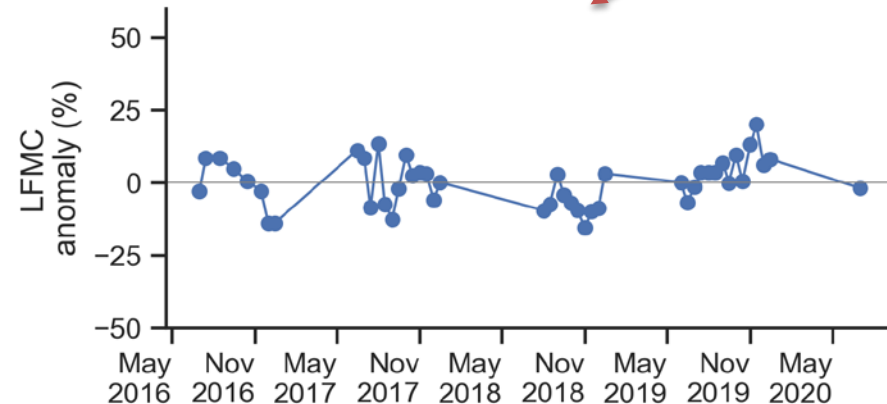
PWS = plant water sensitivity

= how much does LFMC change in response to climate?



?

?



# PWS characterizes water stress response

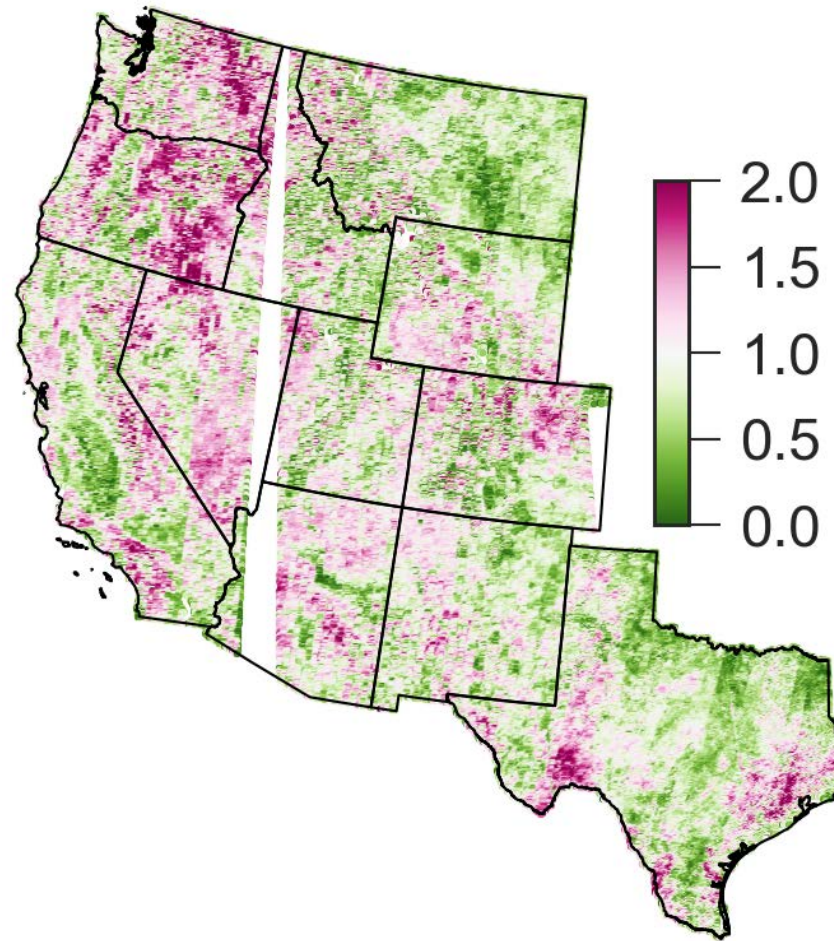
Approach:

- Use DFMC as integrated effect of hydroclimate (supply and demand) on landscape moisture
- Auto-regressive equation for each pixel

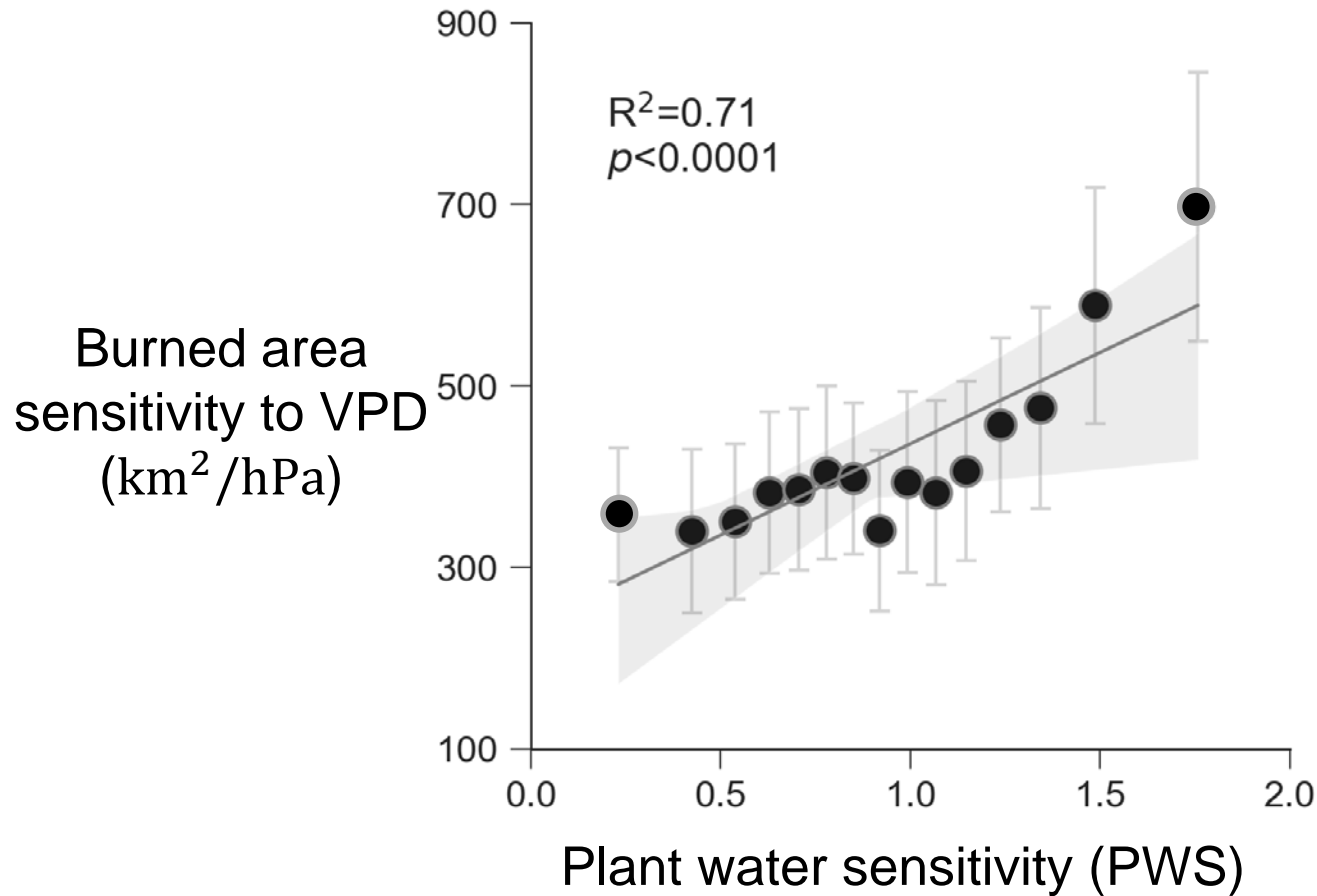
$$LFMC'_t = \sum_{t=0,0.5,\dots}^{5.5} \beta_t DFMC'_t + \gamma$$

$$PWS = \sum_t \beta_t$$

# Resulting PWS map is highly heterogeneous



# PWS has been shown to relate to wildfire risk



*Rao et al, Nat EE, 2022*

# Approach: build explanatory statistical model

Specifically, built random forest model for PWS as a function of several possible explanatory factors

## Plant

- \* Biomass
- \* Plant func.  
type

## Traits

- \* Isohydricity
- \* Medlyn  $g_1$
- \*  $\Psi_{50}$
- \* Max xylem  
conductance
- \* Rooting depth

## Topography

- \* Elevation
- \* Slope
- \* Aspect
- \* Distance to  
water body

## Soil

- \*  $K_{s,max}$
- \* n parameter
- \* Clay %
- \* Silt %

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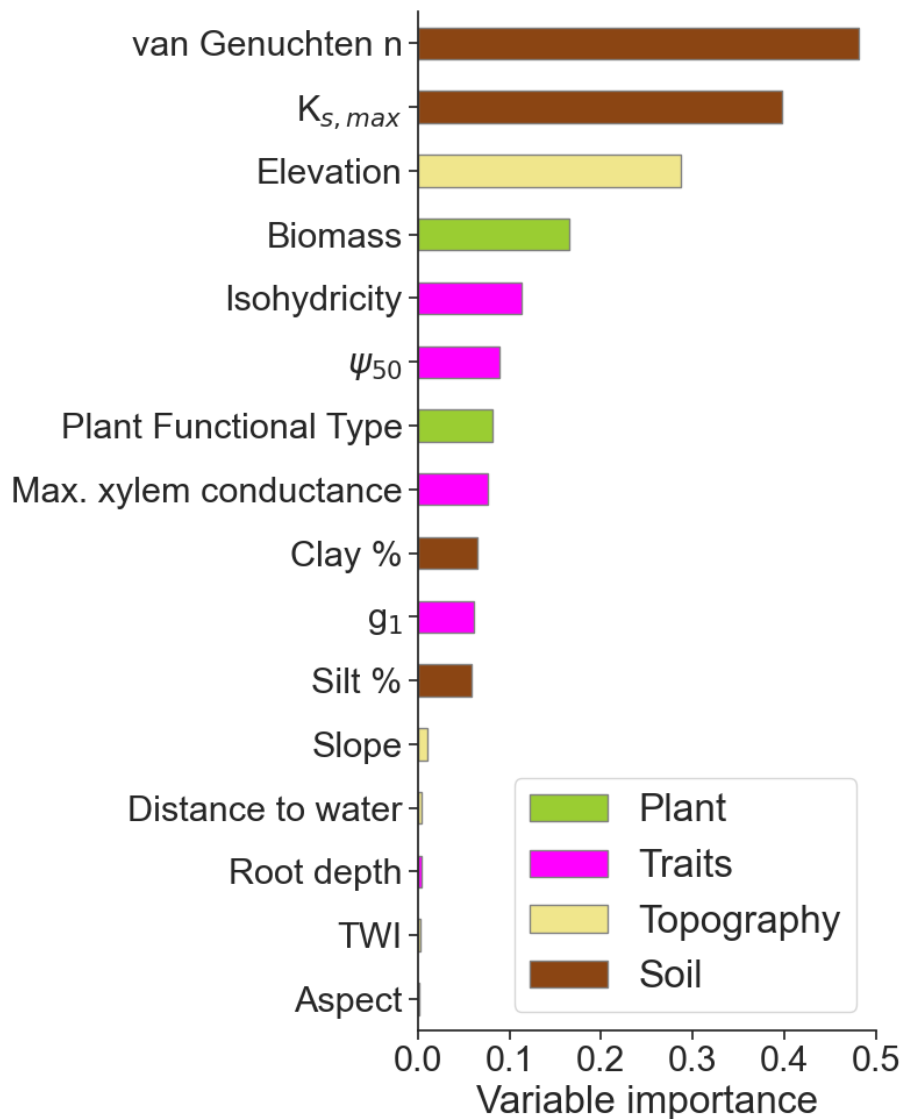
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Model performance ( $R^2 = 0.63$ ) sufficient to test importance

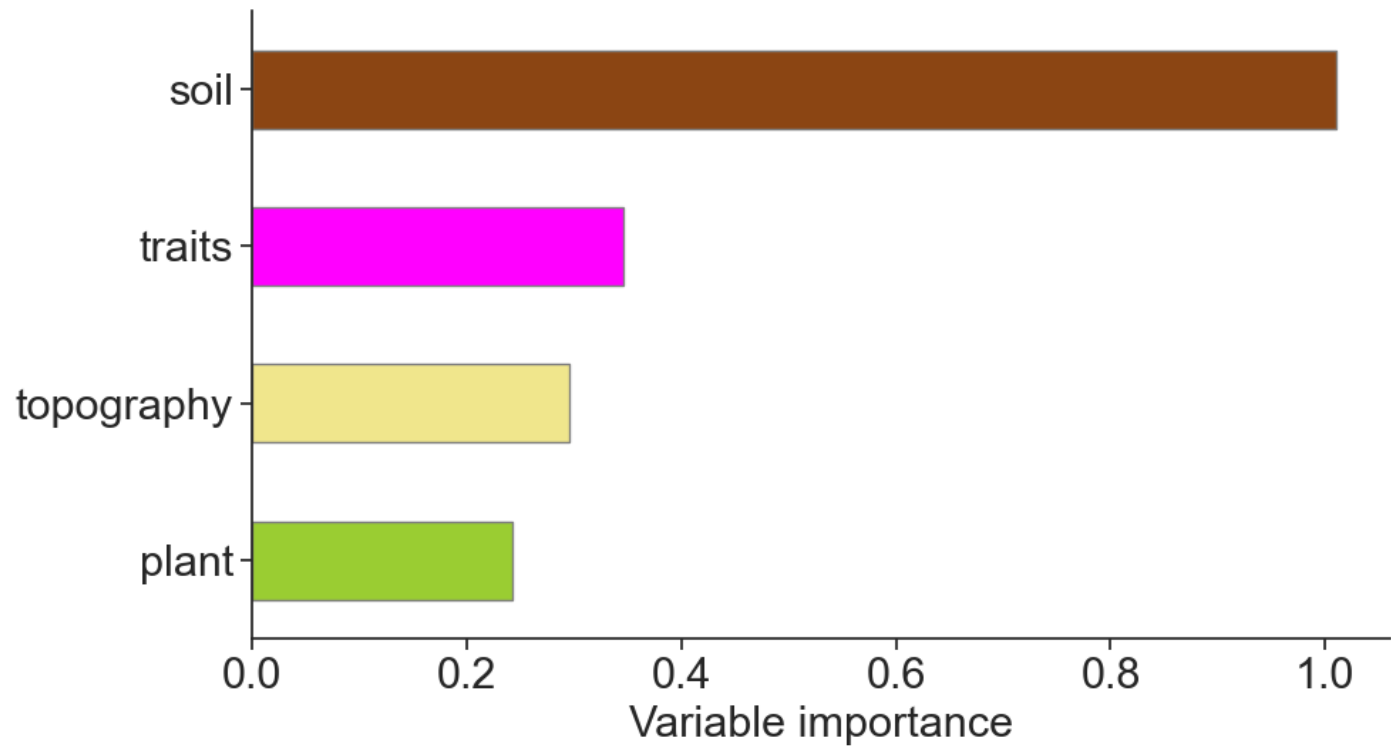


# Plant, soil, climate, and topo all contribute



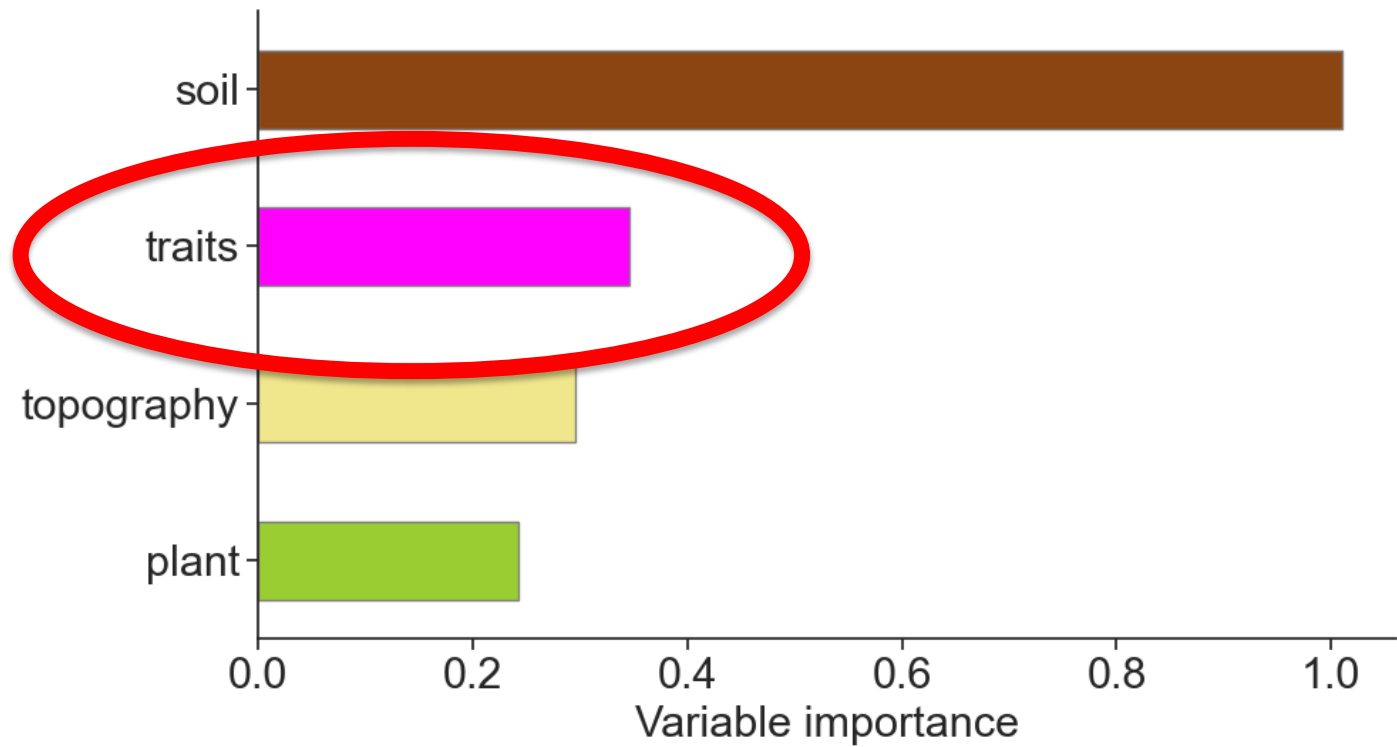
- No single dominant factor
- Two soil traits moist important
- Elevation (in Sierra Nevada) and biomass also important

# Soil more than twice as important as next category



Noteably high influence of soil hydraulic properties is under-discussed in literature

# Why are traits so much less important?



Noteably high influence of soil hydraulic properties is under-discussed in literature

# A closer look at traits data

## Traits

- \* Isohydricity

→ derived from diurnal slopes of VOD, 0.25° resolution

- \* Medlyn  $g_1$

- \*  $\Psi_{50}$

- \* Max xylem conductance

→ from data assimilation with ALEXI ET and VOD, 0.25° resolution

- \* Rooting depth

→ from inverting hydrologic model, assumed = to average water table

All coarse and/or assumption-laden, therefore likely noisy

→ RF model underestimates true effect of traits

# Conclusions

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- Soil hydraulic properties have significant influence. Their relationship to vegetation sensitivity is understudied.
- Plant traits considerably less important, possibly because of coarse trait estimates