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

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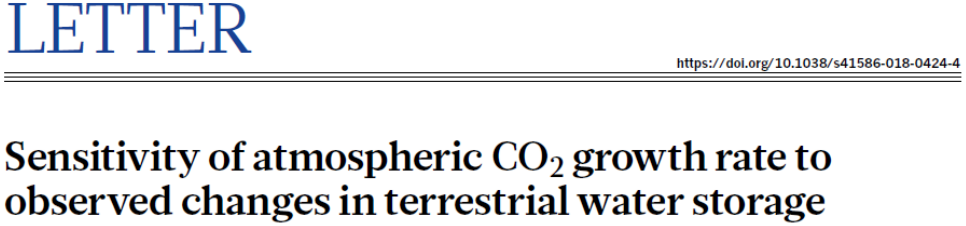
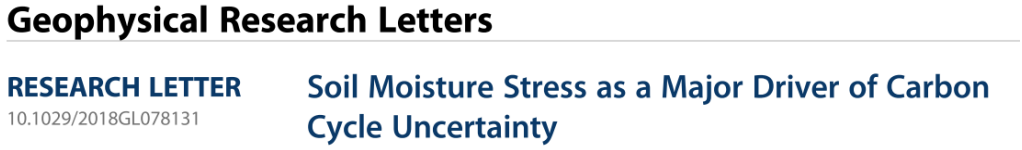
Veg response to water stress has widespread effects

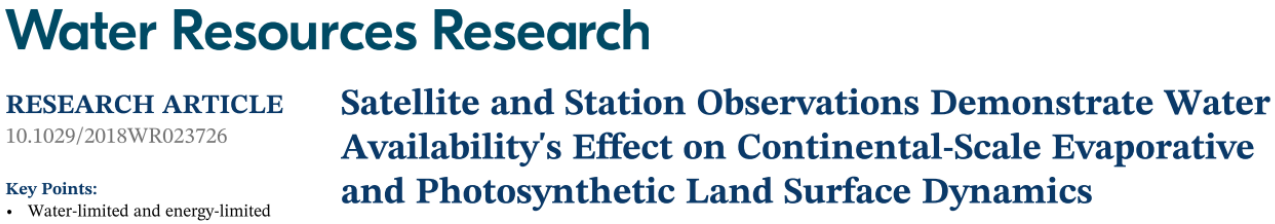
Need to understand for:

1) Accurate model predictions

2) Understanding consequences of global change

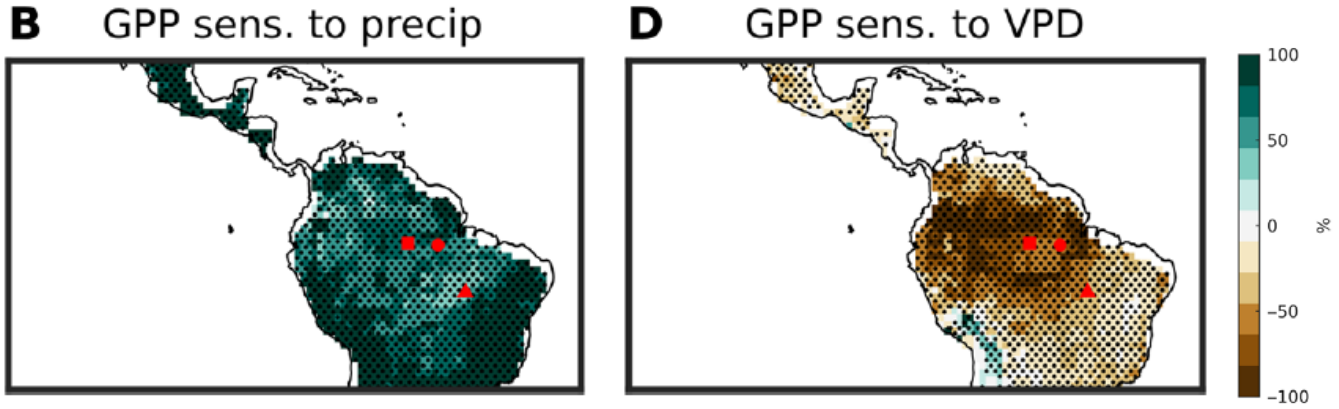






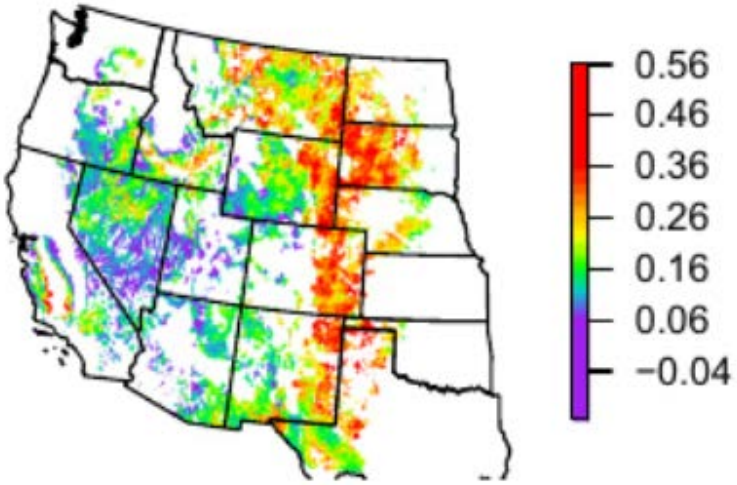
Veg response to water stress varies considerably

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

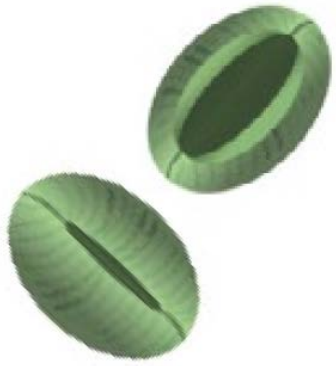
vs

Specific plant hydraulic traits also matter

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

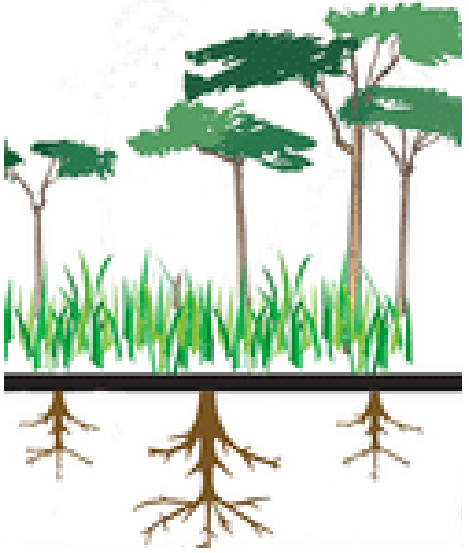
e.g.:

Stomatal traits



Xylem traits

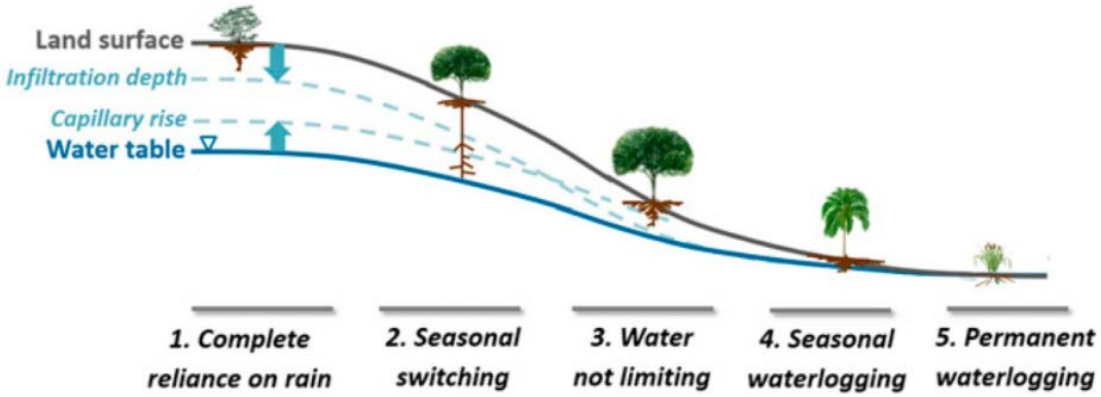
Rooting properties



Schematics from
Kannenberg et 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



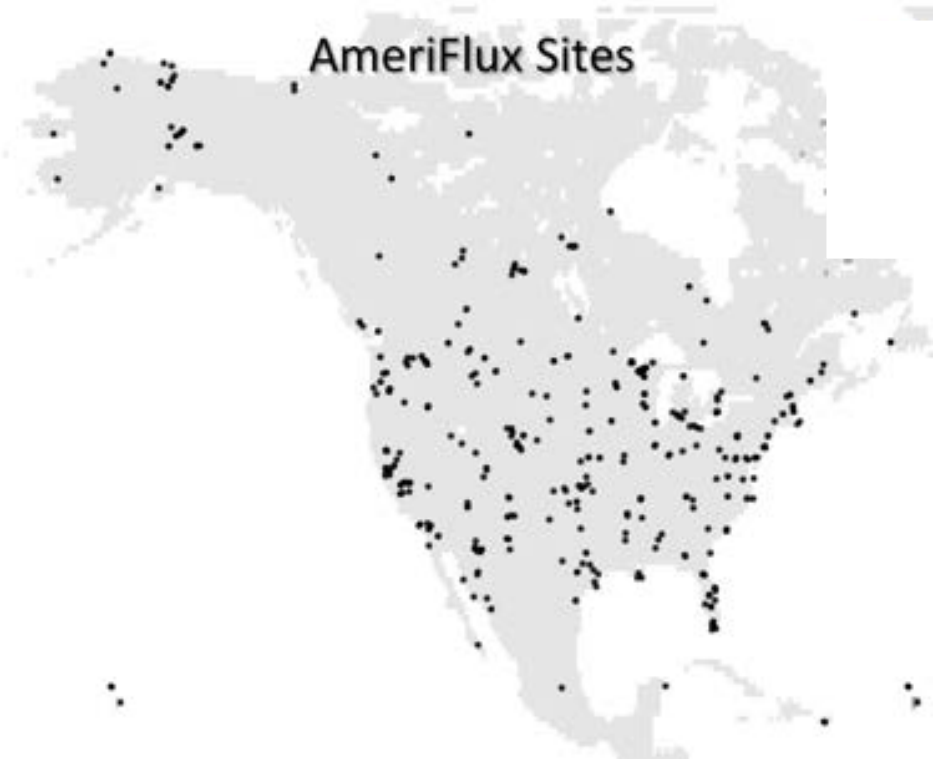
Gao et al HESS 2019

Fan et al WRR 2019

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

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

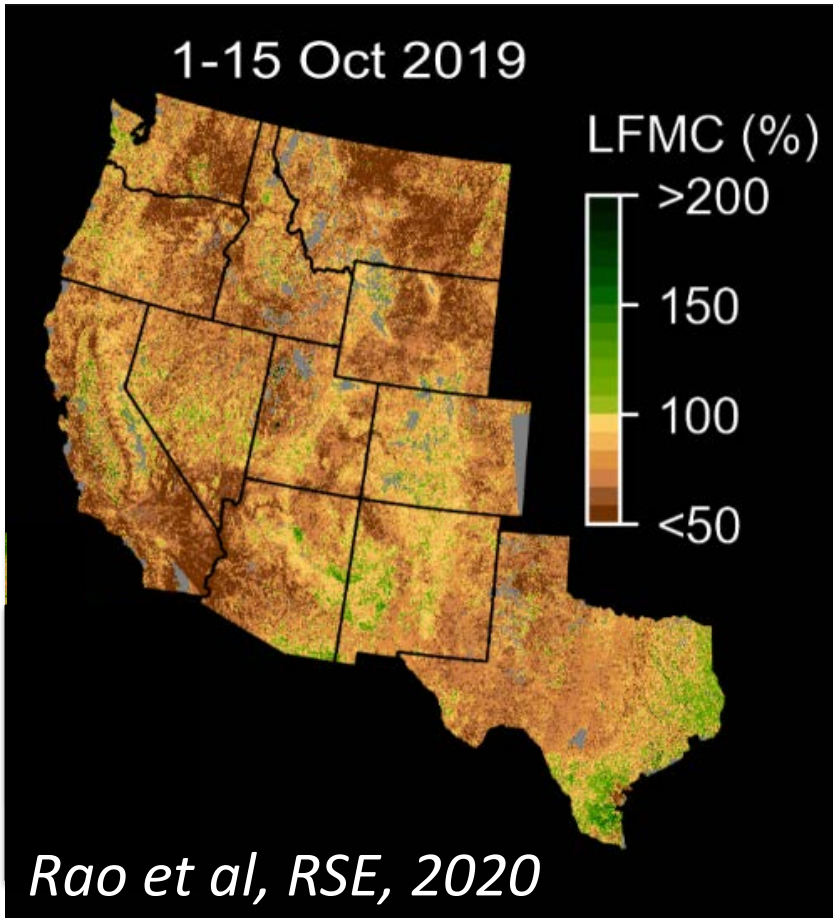
Can we be certain to capture full range of explanatory factors with limited number of datapoints?

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



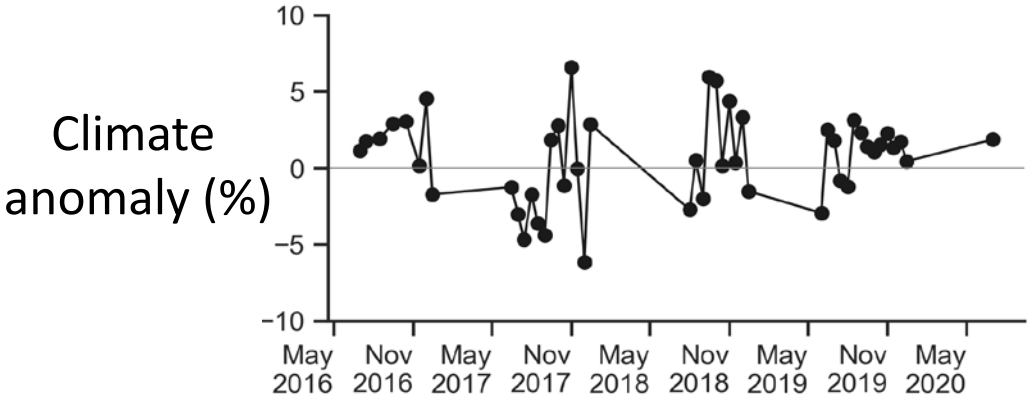
Key: LFMC measure of actual water stress status of vegetation

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?



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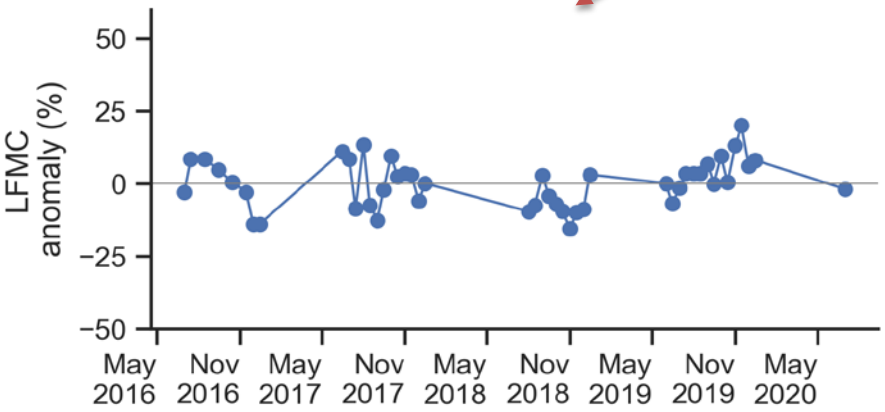
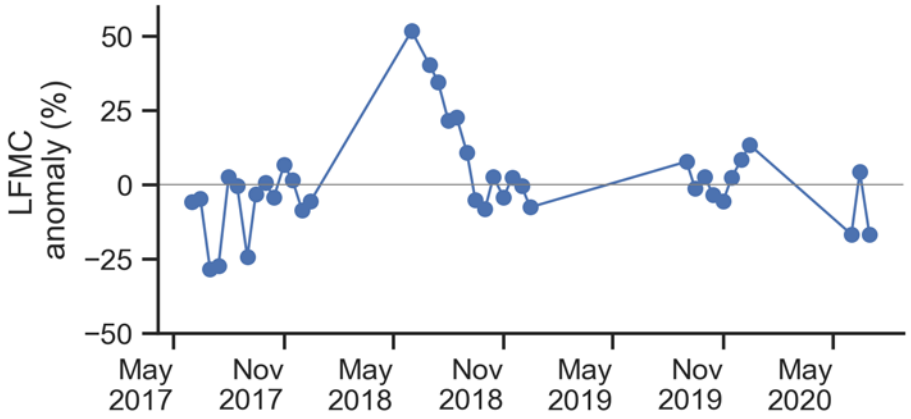




PWS characterizes water stress response

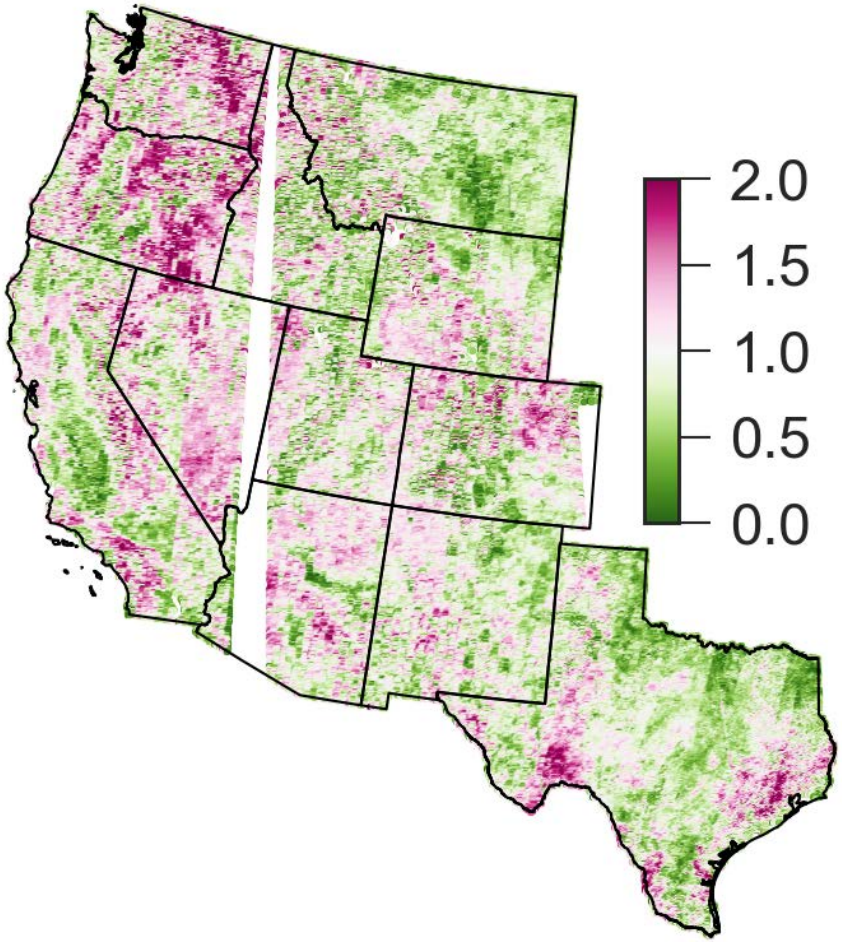
Approach:

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

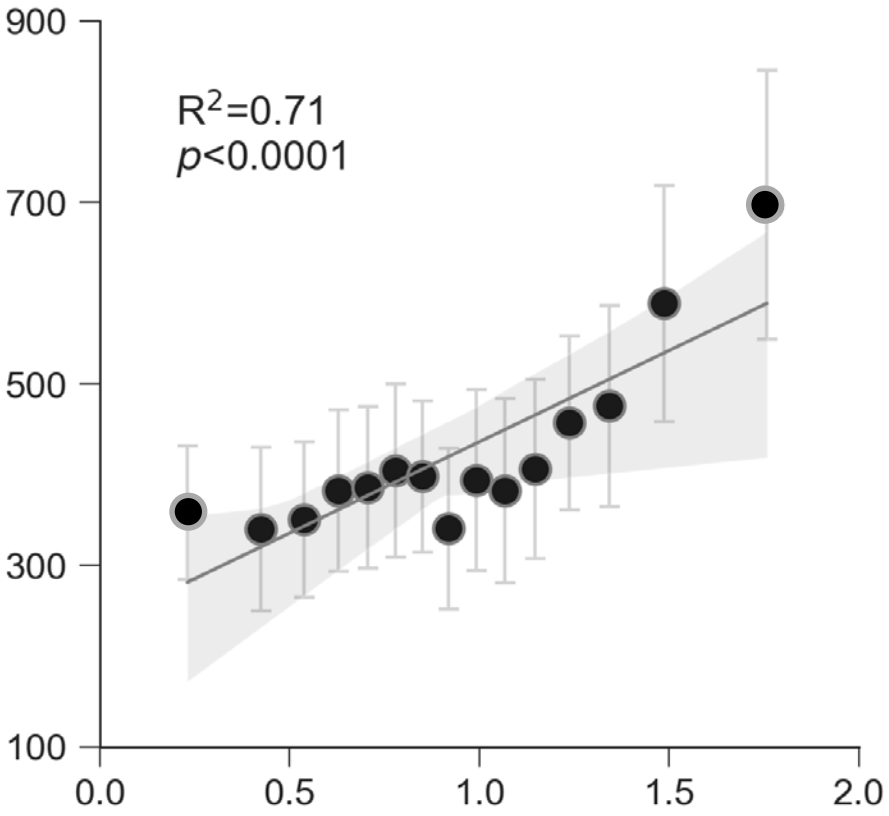
$$LFMC'_t = \sum_{t=0,0.5,\ldots}^{5.5} \beta_t DFMC'_t + \gamma$$

$$PWS = \sum_t \beta_t$$

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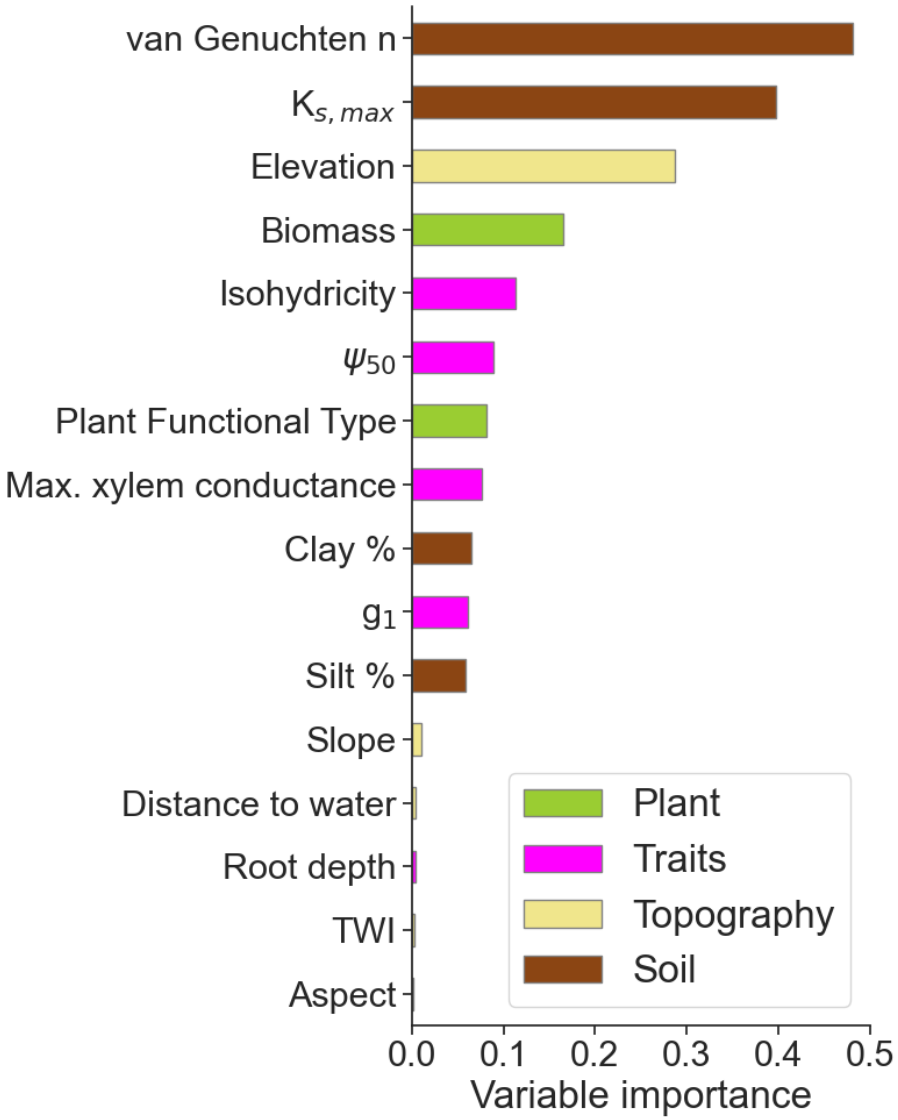
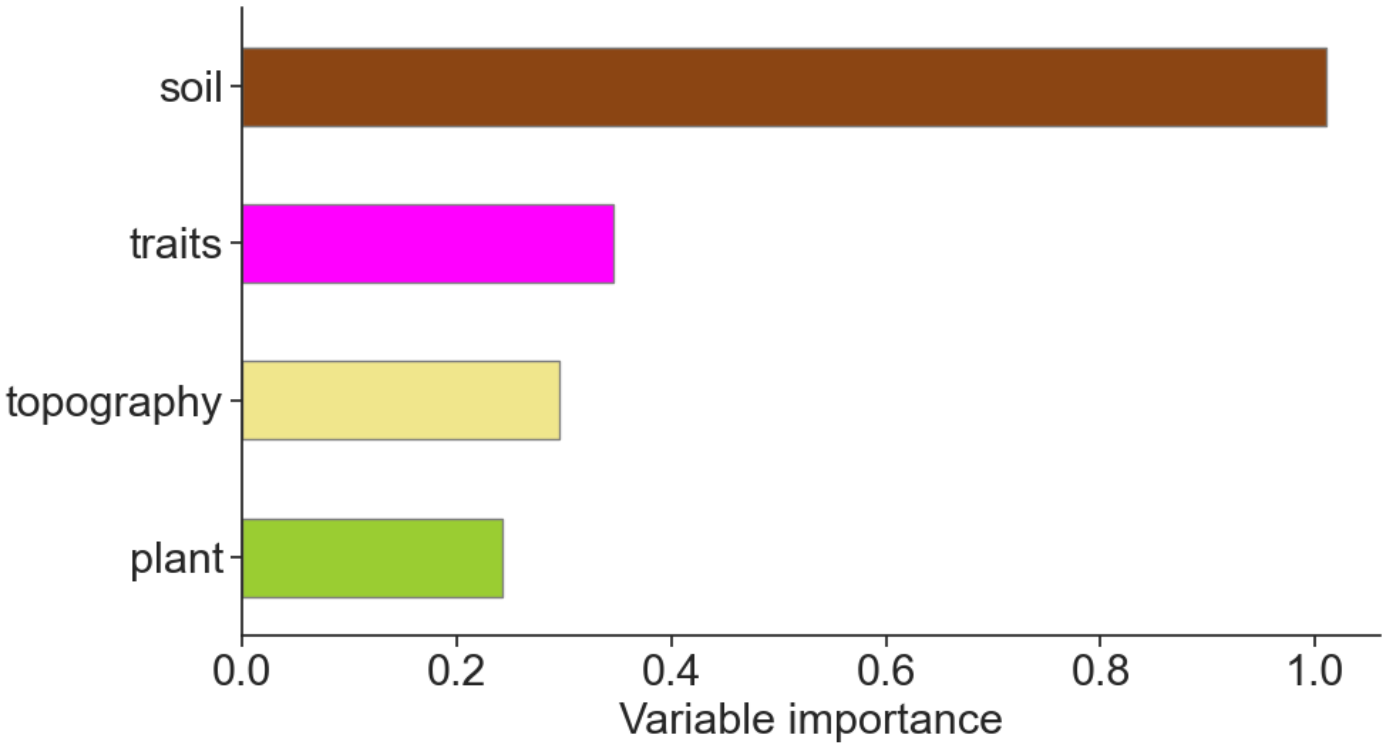
Model performance ($R^2 = 0.63$) sufficient to test importance

Plant, soil, climate, and topo all contribute



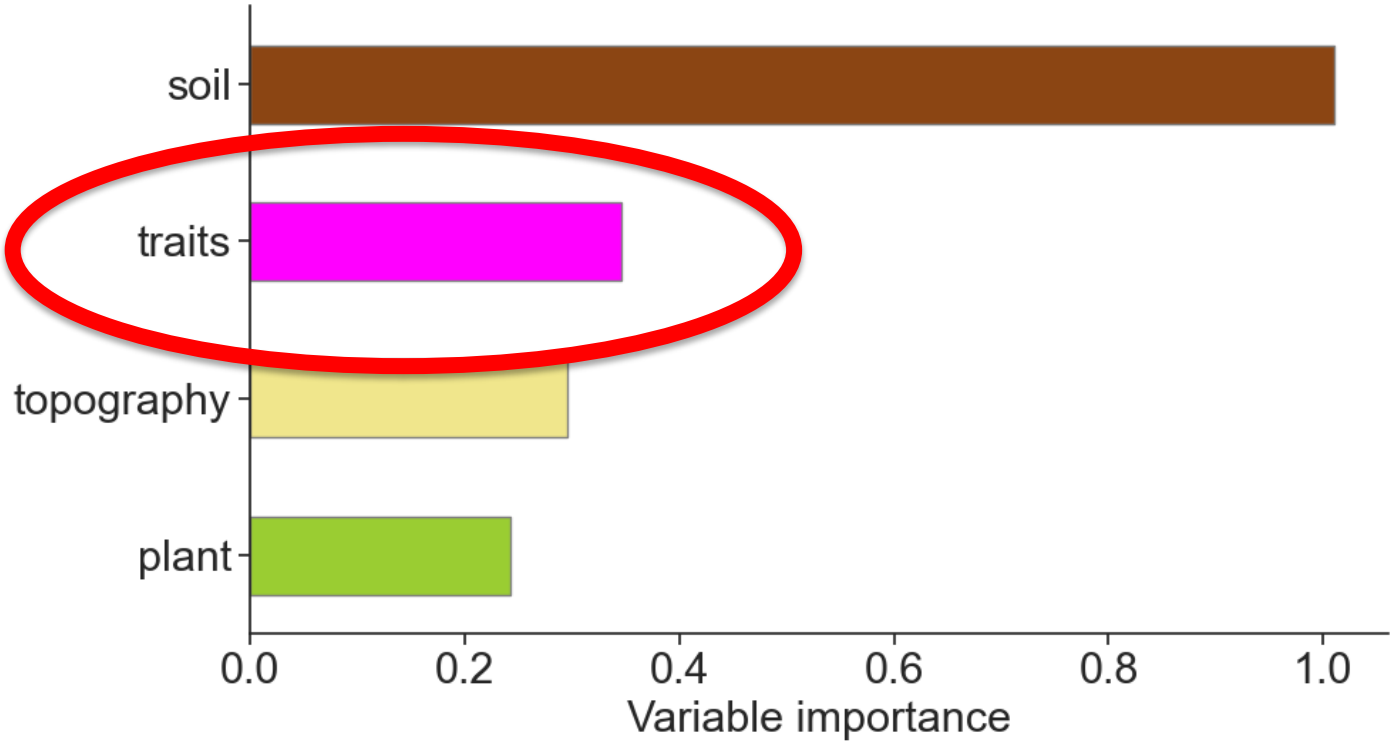
- No single dominant factor
- Two soil traits moist important
- Elevation (in Sierra Nevada) and biomass also important

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?



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A closer look at traits data

Traits

* Isohydricity → derived from diurnal slopes of VOD, 0.25° resolution

* Medlyn g_1
* Ψ_{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

- Soil hydraulic properties have significant influence. Their relationship to vegetation sensitivity is understudied.

- Plant traits considerably less important, possibly because of coarse trait estimates