

IDENTIFYING ECOLOGICAL-MEMORY PATTERNS IN DRYLANDS USING REMOTE SENSING AND STATE-OF-THE-ART CLIMATE-REANALYSIS PRODUCTS



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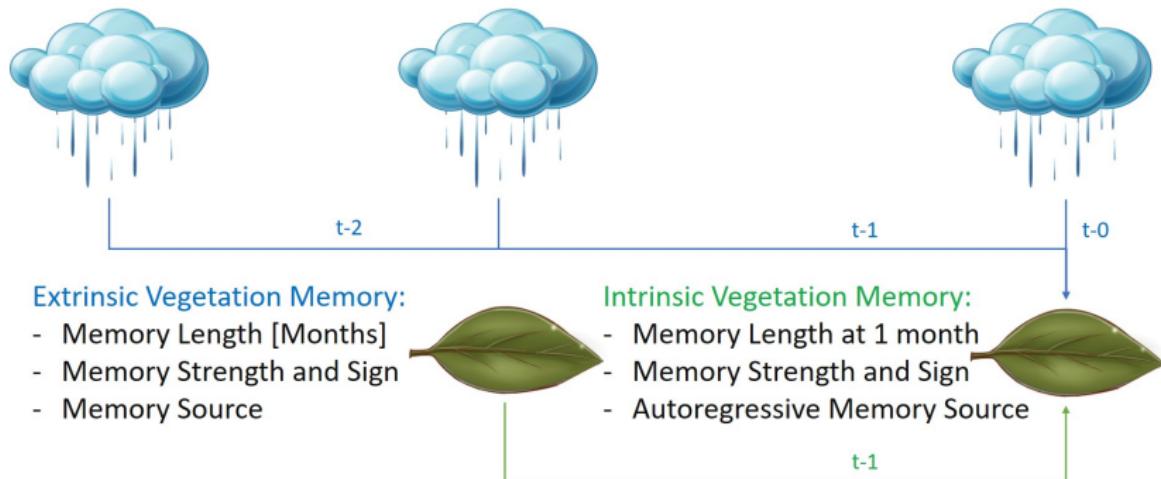
What is Vegetation Memory?

Vegetation Memory is the effect of **antecedent ecosystem and environmental states** on **current vegetation performance**^[1].

Can we distinguish between **intrinsic** and **extrinsic** memory effects?

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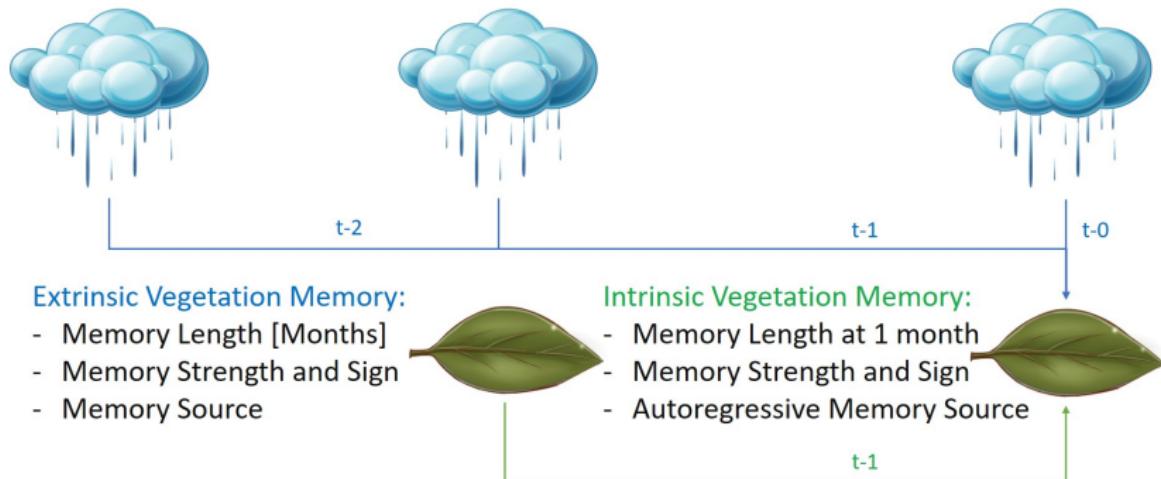
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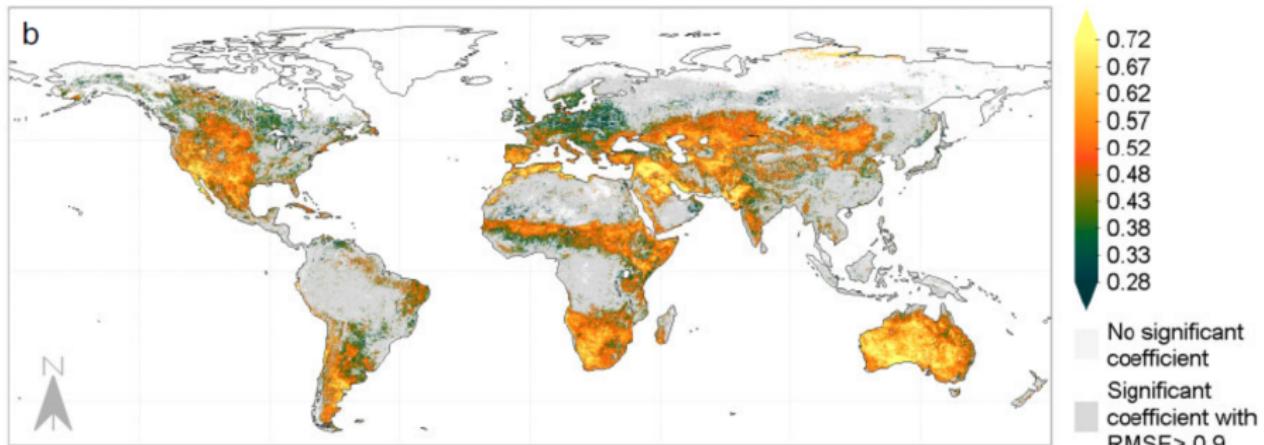
Can we distinguish between **intrinsic** and **extrinsic** memory effects?

Why do this?

Intrinsic Vegetation Memory proposed to be a proxy of **engineering resilience in ecosystems** (*high memory ~ low resilience*)^[2].

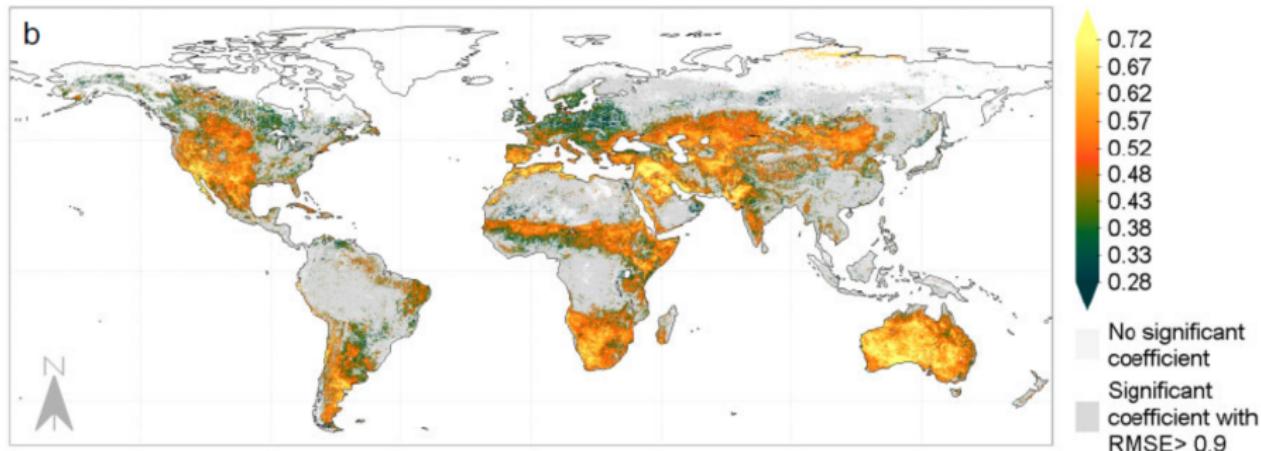
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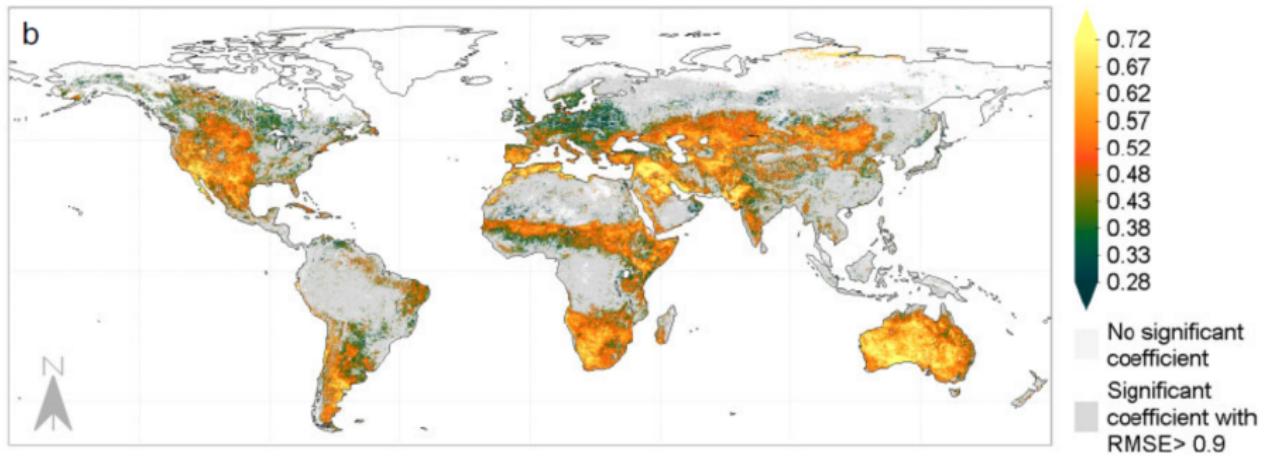
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Big emphasis on **dryland regions** due to demonstrated vegetation memory effects^[1–4], and the dependence of dryland vegetation on water regimes^[5]

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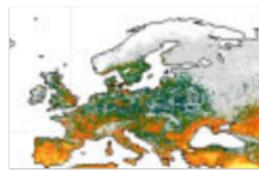


How valid is this assumption?

Study Regions

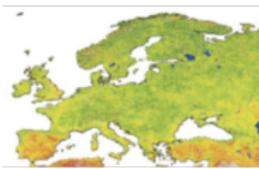
South-Western Europe

Intrinsic Memory

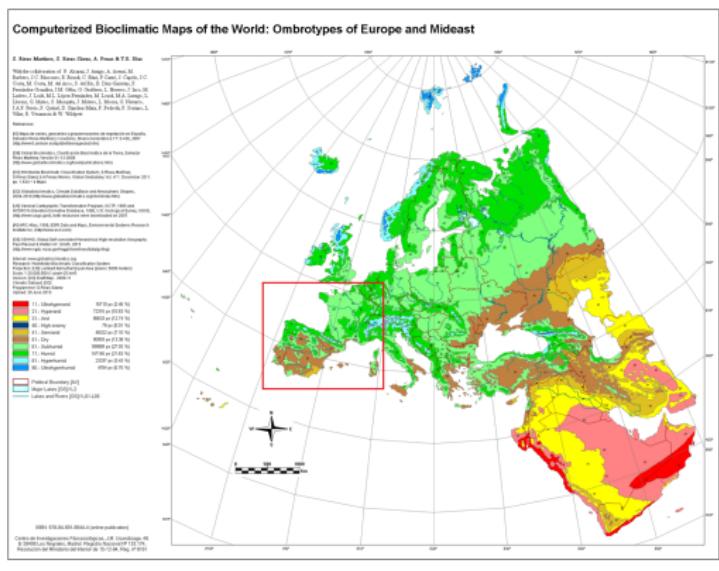


De Keersmaecker et al. (2015). A model quantifying global vegetation resistance and resilience to short term climate anomalies and their relationship with vegetation cover. *Global Ecology and Biogeography*

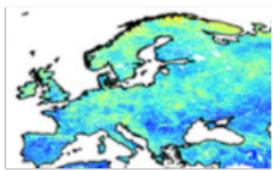
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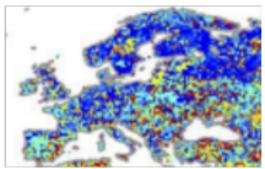


Water Memory



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Water Memory Length



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Additional Study Regions:

■ Caatinga, Brazil

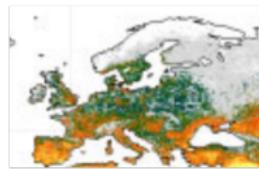
■ Australia

■ Contiguous US

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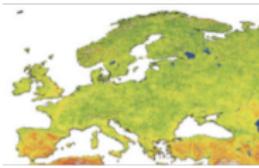
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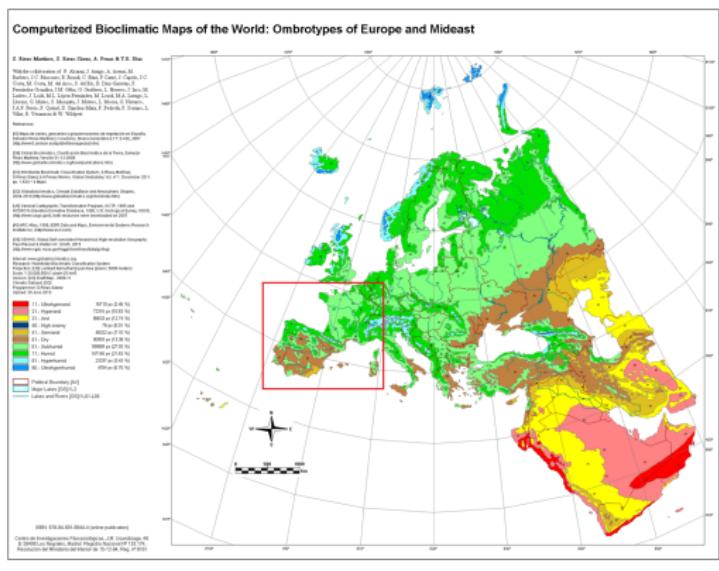


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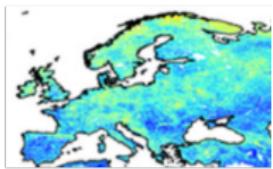
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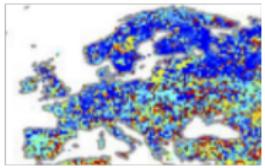


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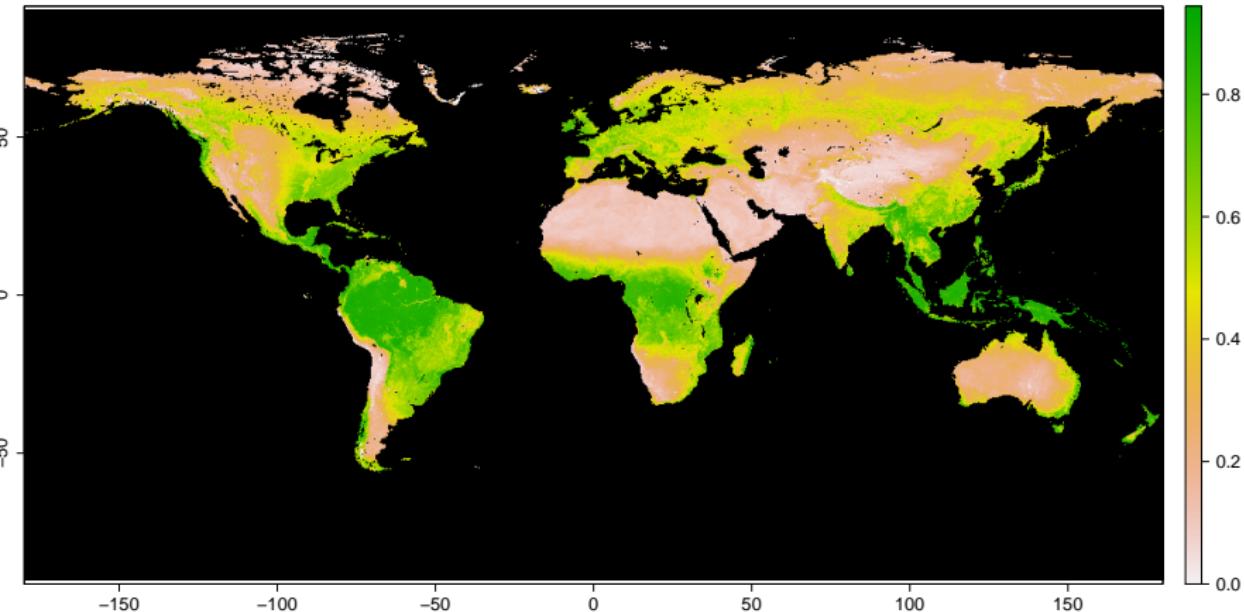
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Normalised Difference Vegetation Index (NDVI)

- *Biological Relevance:* Proxy of biomass and vegetation cover
- *Comparability:* Has been used in other studies of vegetation memory

Mean NDVI 1982 – 2015



ERA5 & Climate Variables

■ Why:

- Applicable globally
- Gap-less time series
- More sophisticated approach than previously utilised:
 - Worldclim - Superior Temporal Resolution (superior resolving of climate extremes)
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- Assessment of climate uncertainty possible
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■ Air Temperature - T_{air}

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- *Why:* Soil moisture effects on vegetation may indicate if/how the local ecosystem may deal with drought stress^[5–7].
- *How:* as different layers of depth (Q_{soil1} - Q_{soil4})

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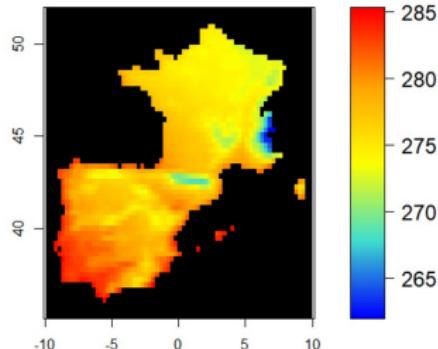
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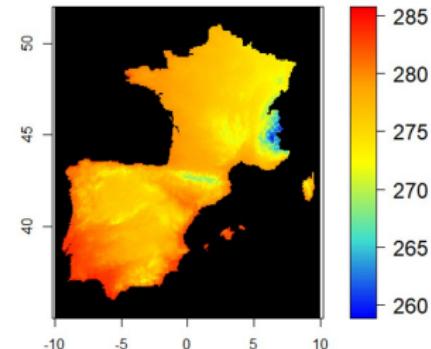
- *Why:* Temperature drives plant physiology and drives levels of aridity^[2,6].
- *How:* As one single layer (2m above ground)

Kriging

Tair January 1981

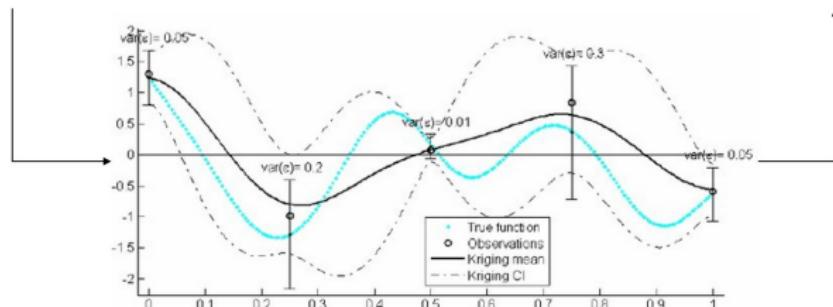


Tair January 1981



+

Covariates
(Training Resolution)



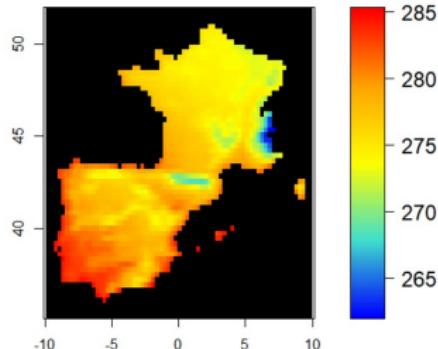
+

Covariates
(Target Resolution)

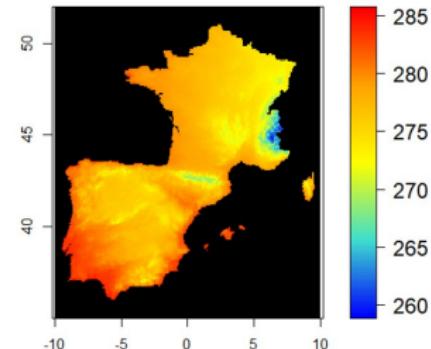
→ RPackage coming soon

Kriging

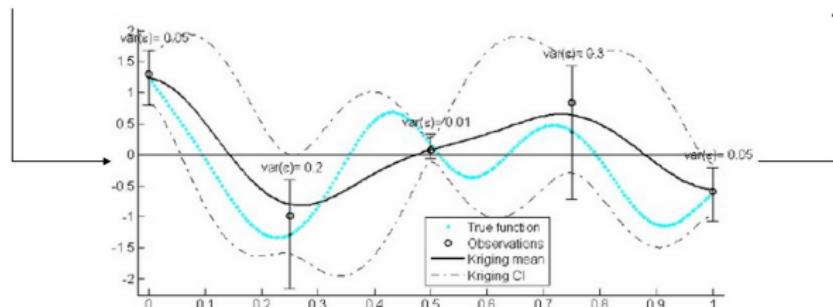
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Pixel-Wise Model Building

- Linear detrending
- Z-Scores:

$$\text{Anomaly}_i = \frac{\text{Detrended}_i - \overline{\text{Detrended}}_{\text{month}}}{\text{SD}_{\text{Detrended}, \text{month}}} \quad (1)$$

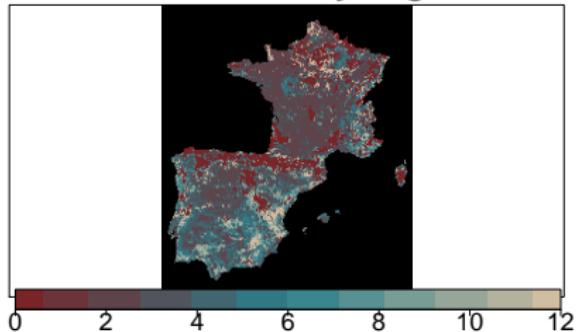
- Calculate:
 - $t - 1$ lag for NDVI
 - Cummulative lags for Q_{soil} data
- Set NDVI anomalies to 'NA' in months for which $\text{Thresholds}_i < 0.1$ with

$$\text{Thresholds}_i = \overline{\text{RawNDVI}, \text{month}}$$
- PCA regression and model selection:

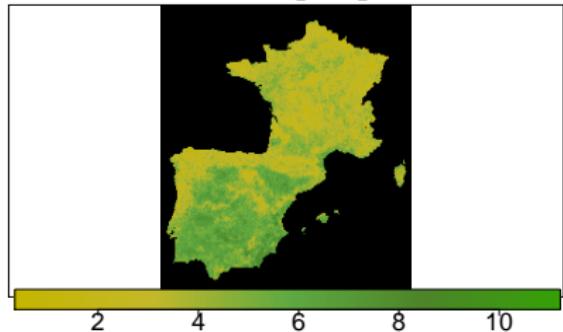
$$\text{NDVI}_t = \beta_{t-1} * \text{NDVI}_{[t-1]} + \beta_{Q_{soil}} * Q_{soil}_{k;m} + \beta_{Tair} * Tair_t \quad (2)$$

Vegetation Memory Coefficients

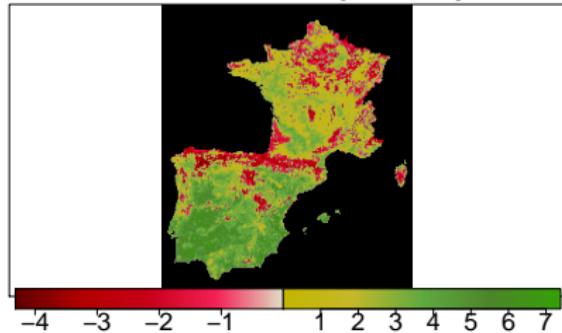
Soil Memory Lag



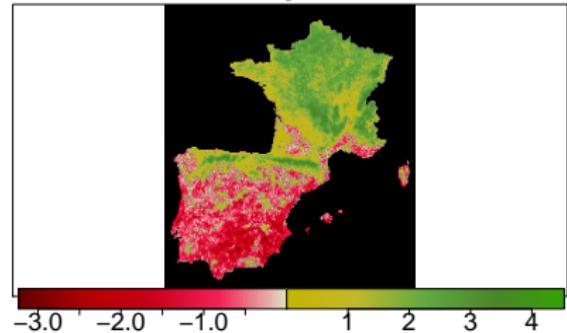
NDVI [t-1]



Soil Moisture (0–7cm)

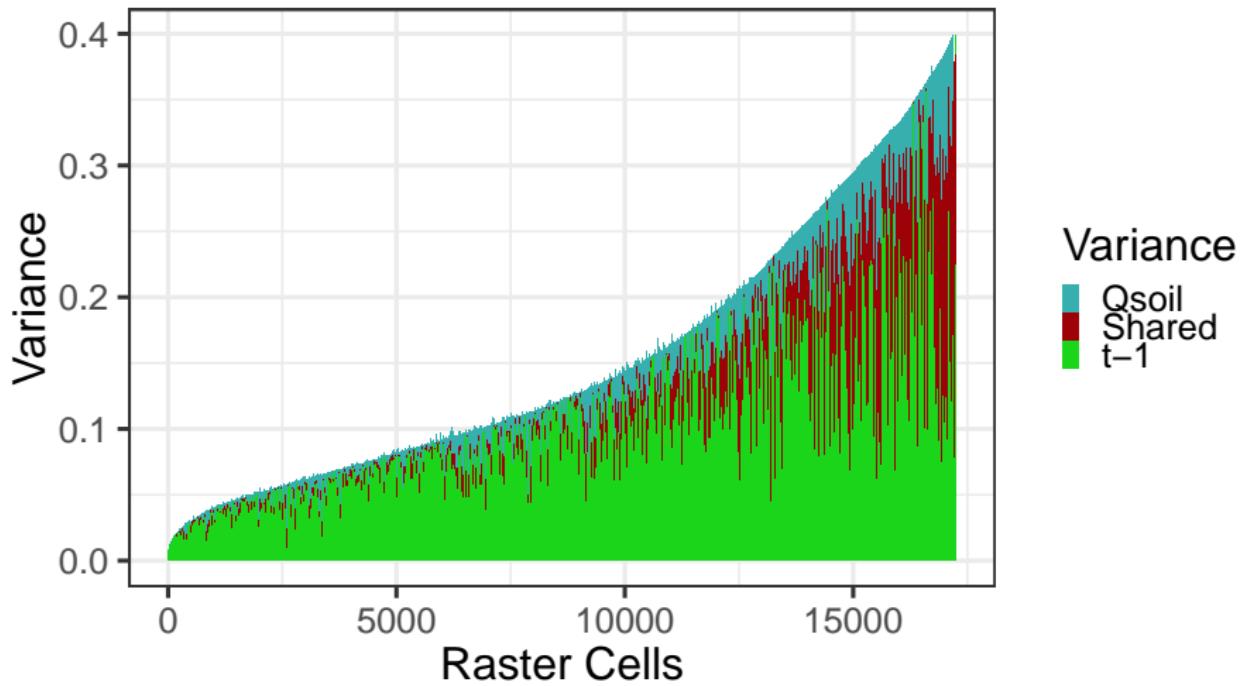


Air Temperature



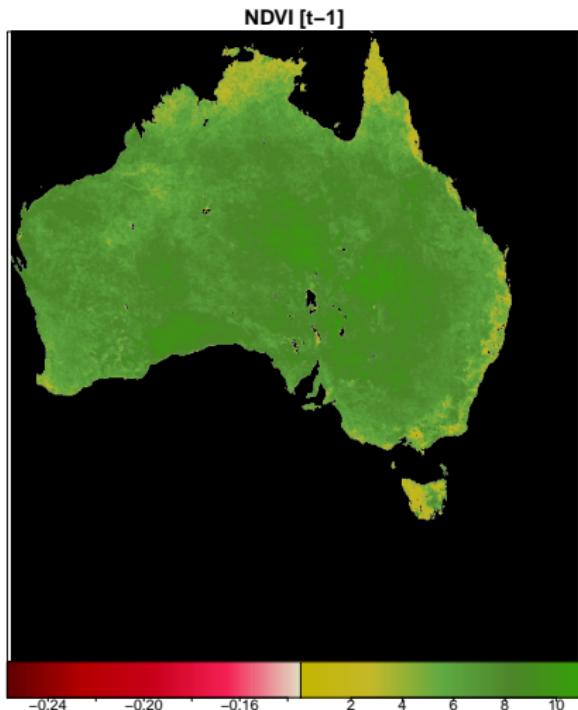
Distinguishing Intrinsic and Extrinsic Memory

Qsoil1 is the most informative of the soil moisture layers!

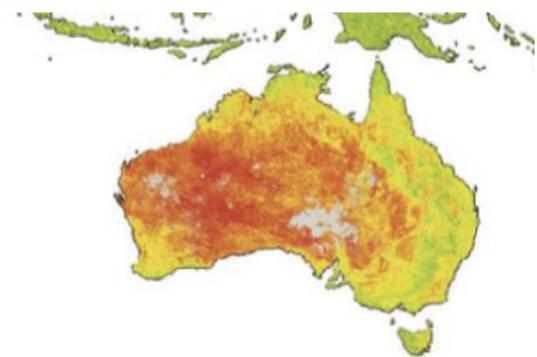


Identifying Underlying Extrinsic Patterns I

Uniform $NDVI[t - 1]$ effect across Australia **contrasts** with **other studies**.

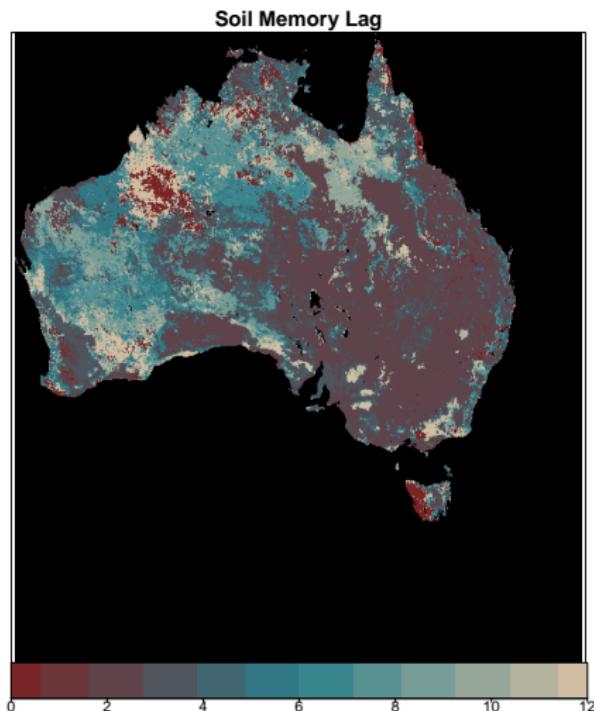


Intrinsic Memory by Seddon et al.^[3]:

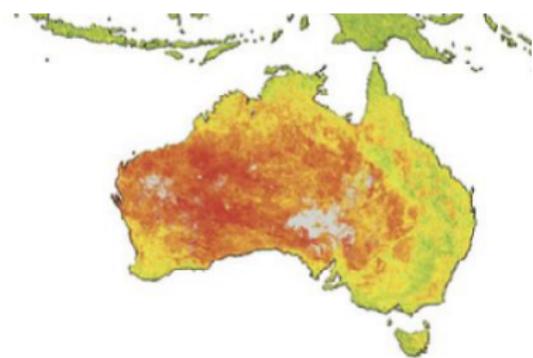


Identifying Underlying Extrinsic Patterns II

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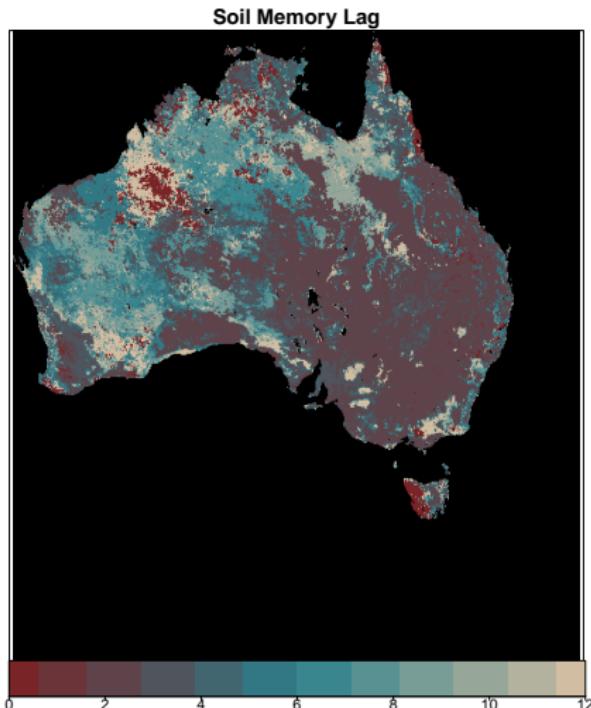


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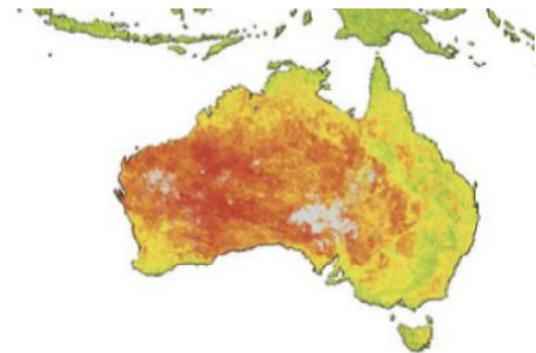


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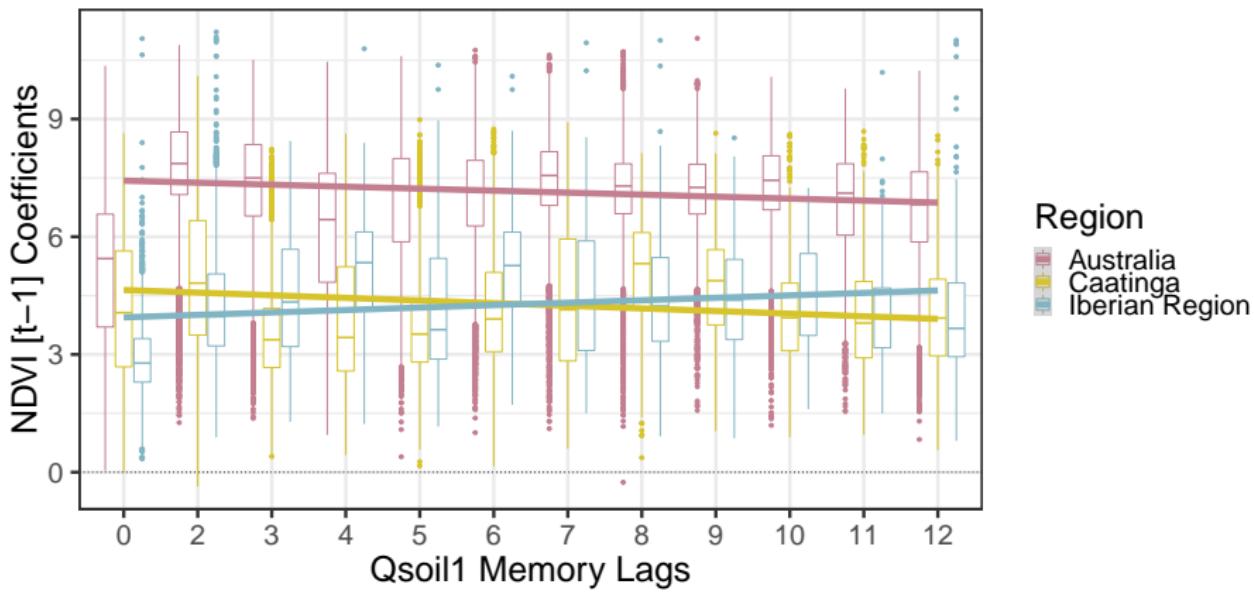


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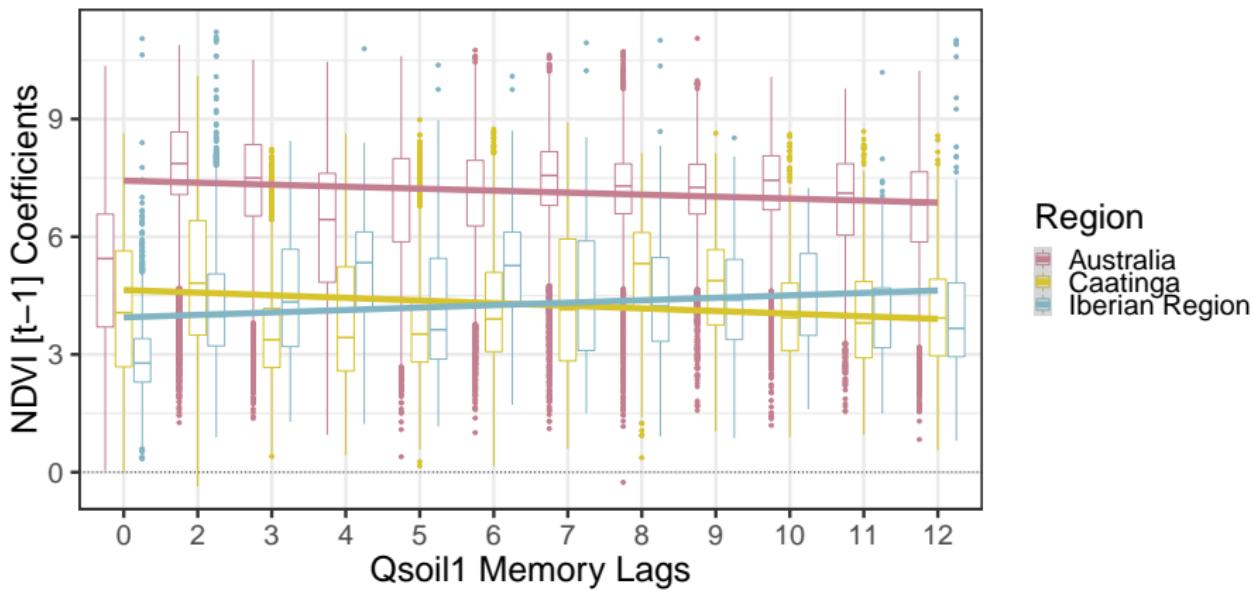
Previous $t - 1$ variation can
be understood through
extrinsic vegetation memory.

Vegetation Memory Adaptation



Relationship of intrinsic coefficient and extrinsic vegetation memory length is not uniform across study regions.

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Conclusion

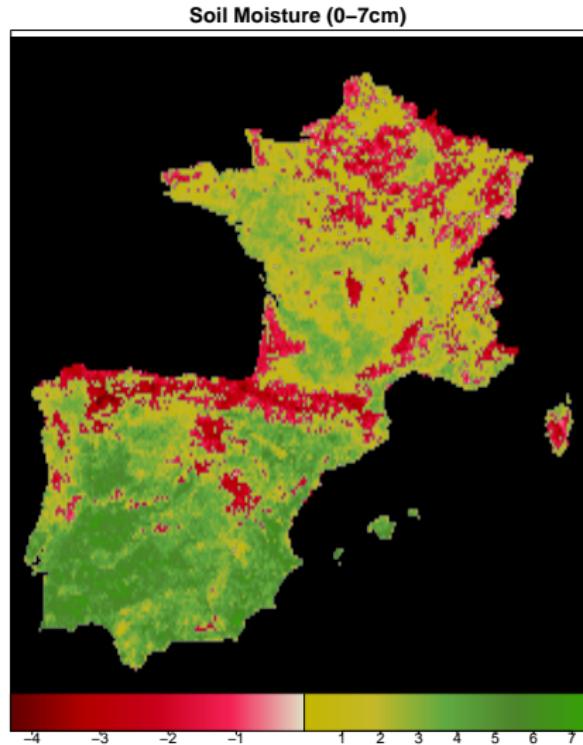
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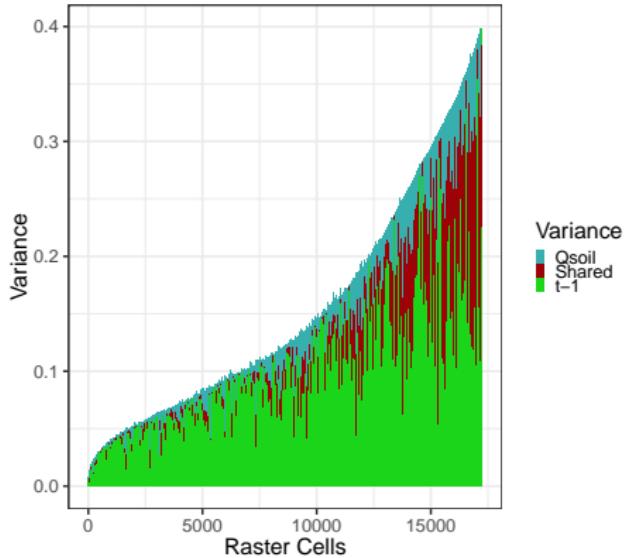
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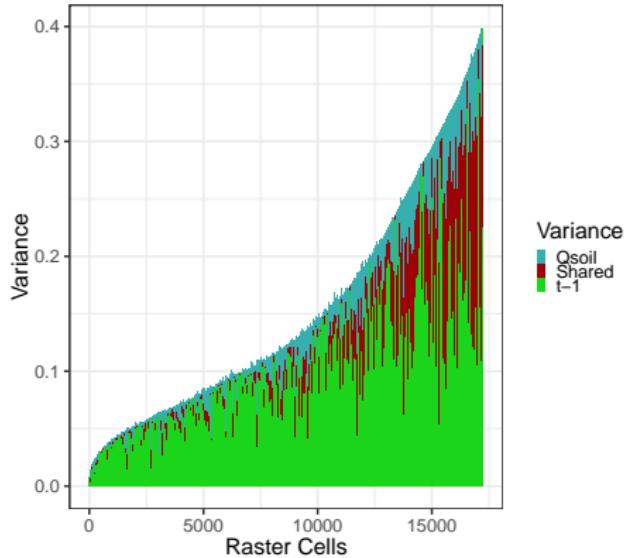
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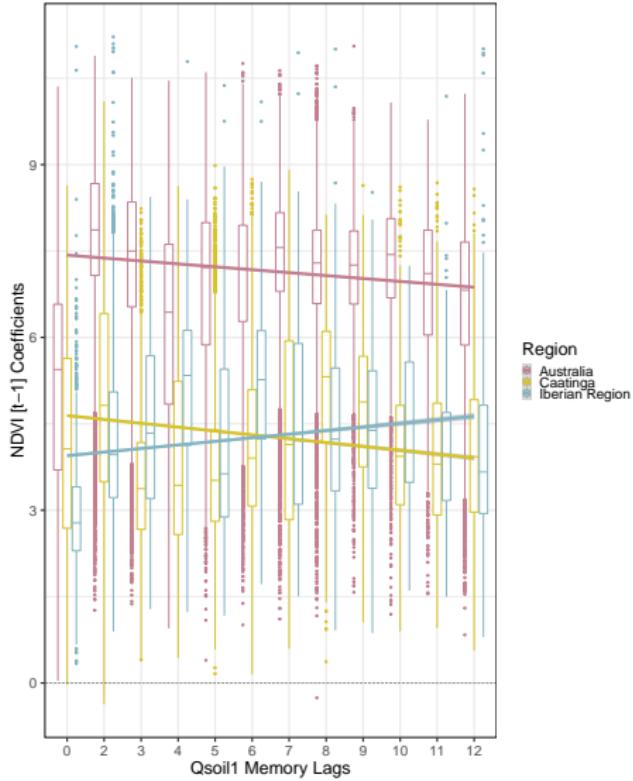
Distinguishing intrinsic and extrinsic memory components remains challenging.

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Interplay of memory characteristics is region-specific.



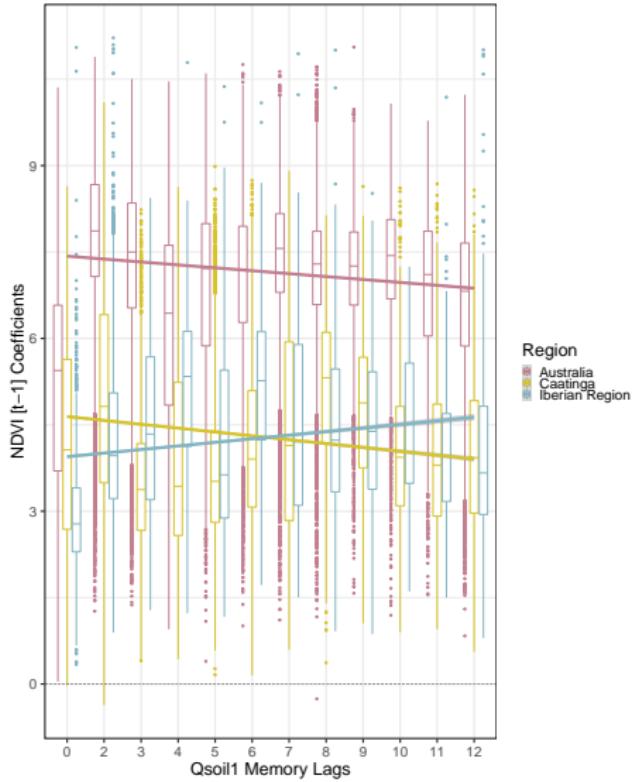
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Interplay of memory characteristics is region-specific.

- 2 Global generalisations of vegetation response to soil moisture aspects not possible.**



Sources

- [1] Liu, L., Zhang, Y., Wu, S., Li, S. & Qin, D. Water memory effects and their impacts on global vegetation productivity and resilience. *Scientific Reports* **8**, 1–9 (2018).
- [2] De Keersmaecker, W. *et al.* A model quantifying global vegetation resistance and resilience to short-term climate anomalies and their relationship with vegetation cover. *Global Ecology and Biogeography* **24**, 539–548 (2015).
- [3] Seddon, A. W. R., Macias-Fauria, M., Long, P. R., Benz, D. & Willis, K. J. Sensitivity of global terrestrial ecosystems to climate variability. *Nature* **531**, 229–232 (2016).
- [4] Vicente-Serrano, S. M. *et al.* Response of vegetation to drought time-scales across global land biomes. *Proceedings of the National Academy of Sciences* **110**, 52–57 (2013).
- [5] Smith, A. P. *et al.* Shifts in pore connectivity from precipitation versus groundwater rewetting increases soil carbon loss after drought. *Nature Communications* **8**, 1335 (2017).
- [6] Rudgers, J. A. *et al.* Climate sensitivity functions and net primary production: A framework for incorporating climate mean and variability. *Ecology* **99**, 576–582 (2018). [0608246v3](#).
- [7] Papagiannopoulou, C. *et al.* Vegetation anomalies caused by antecedent precipitation in most of the world. *Environmental Research Letters* **12**, 074016 (2017).