

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



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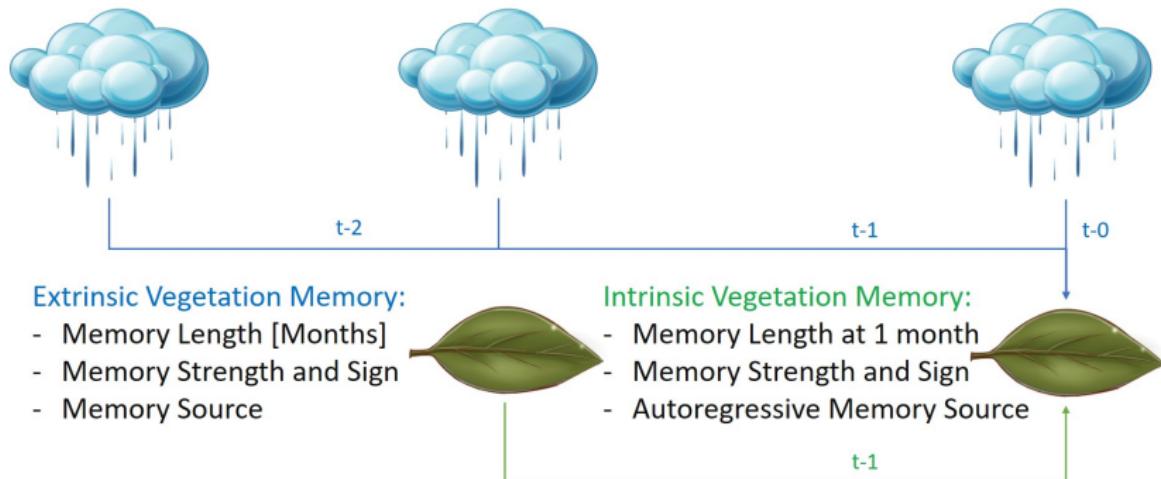
# What is Vegetation Memory?

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

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

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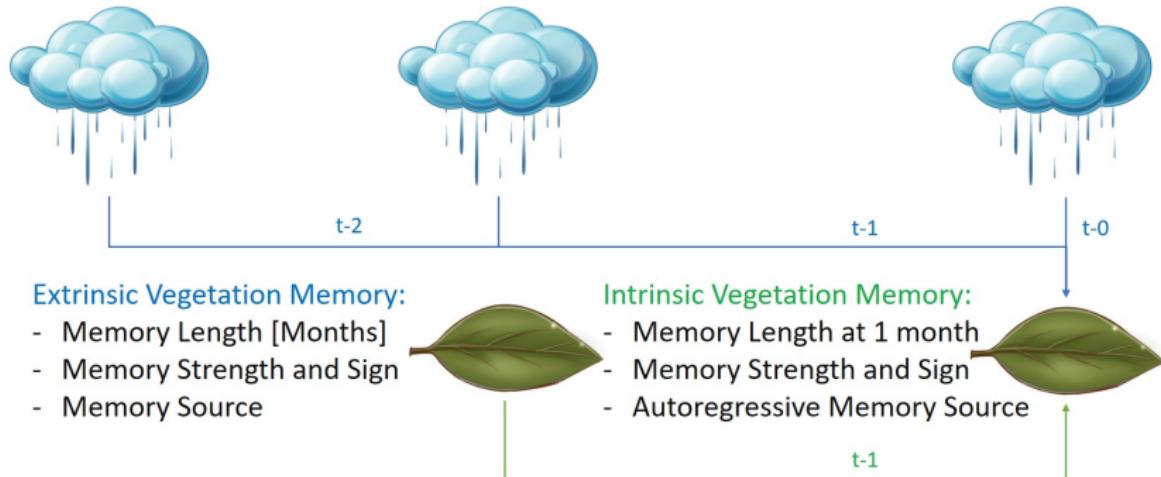
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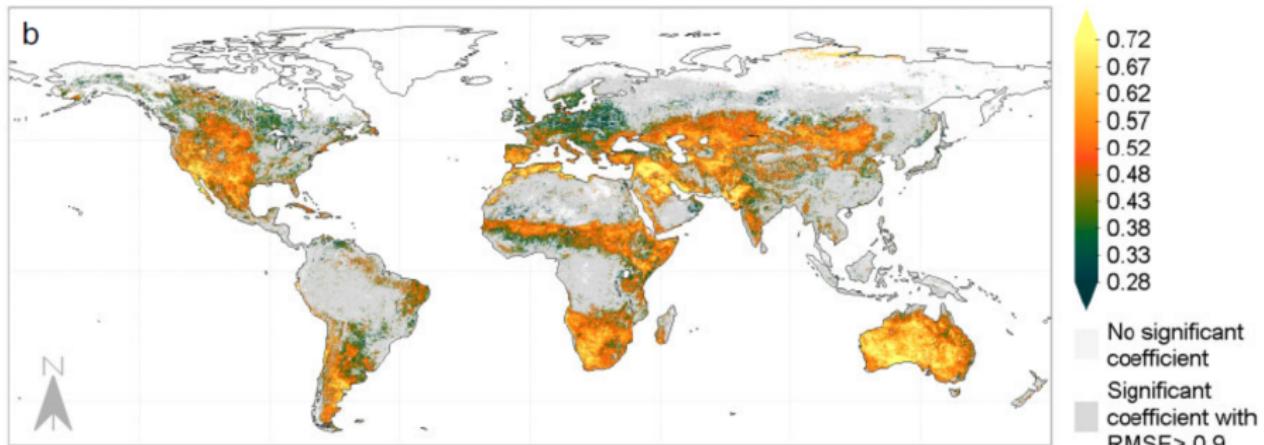
Can we distinguish between **intrinsic** and **extrinsic** memory effects?

# Why do this?

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

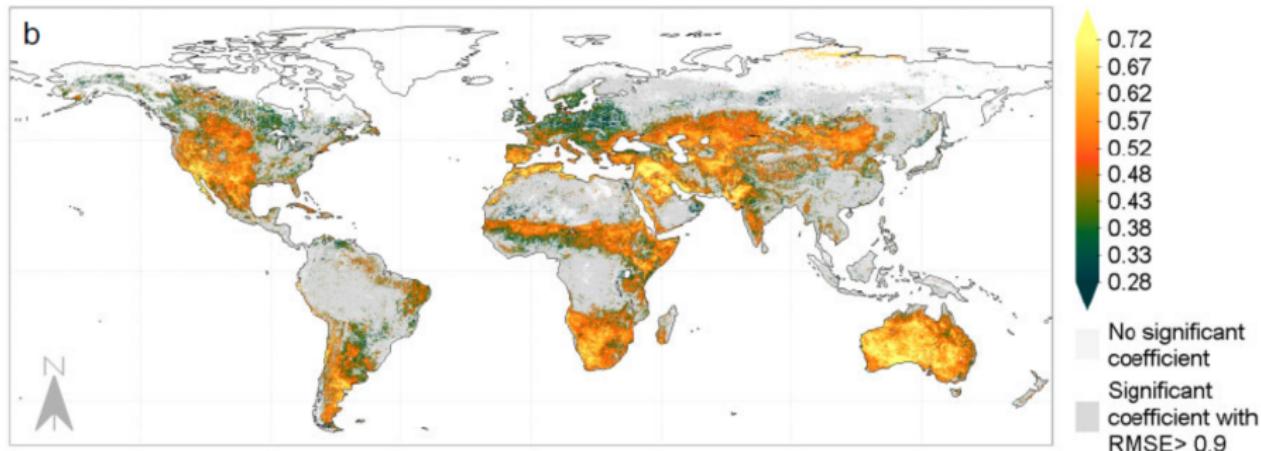
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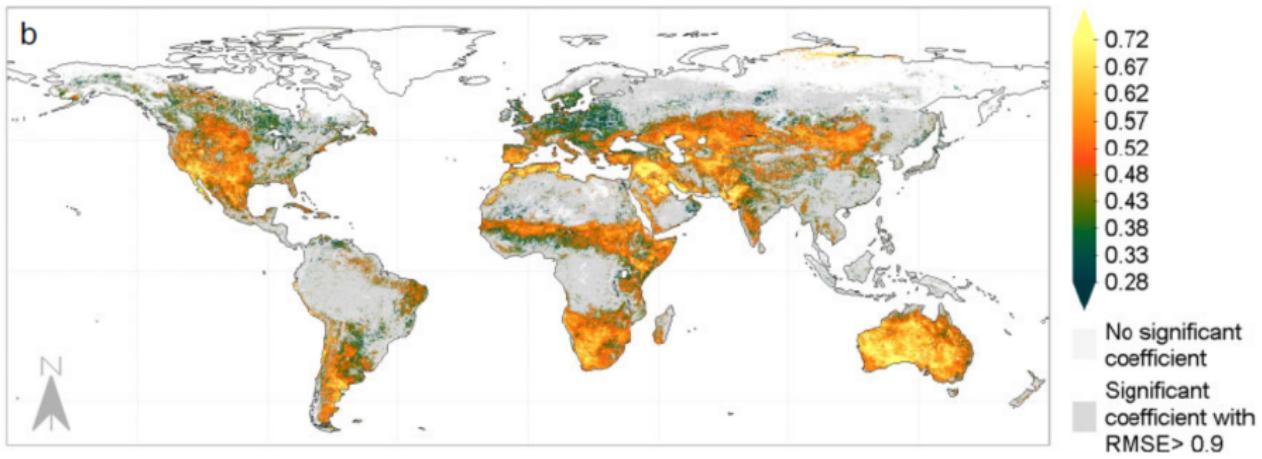
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Big emphasis on **dryland regions** due to demonstrated vegetation memory effects<sup>[1–4]</sup>, and the dependence of dryland vegetation on water regimes<sup>[5]</sup>

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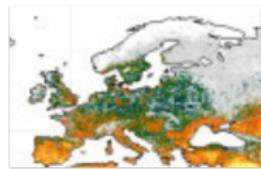


How valid is this assumption?

## Study Regions

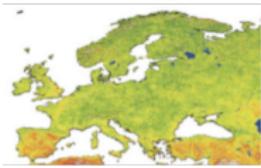
## **South-Western Europe**

## Intrinsic Memory

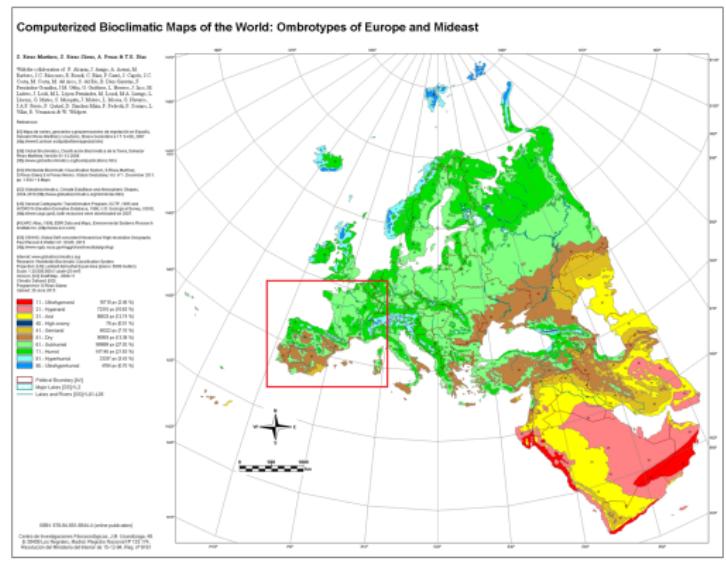


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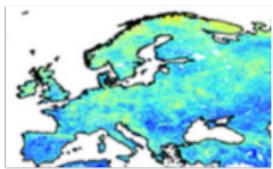
## Intrinsic Memory



Seddon et al. (2016). Sensitivity of global terrestrial ecosystems to climate variability. *Nature*

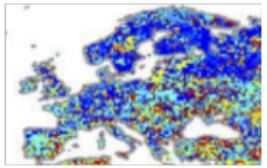


## Water Memory



Vicente-Serrano et al. (2013). Response of vegetation to drought time-scales across global land biomes. *Proceedings of the National Academy of Sciences*

## Water Memory Length



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## Additional Study Regions:

## ■ Caatinga, Brazil

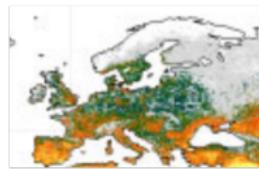
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## ■ Contiguous US

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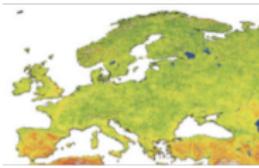
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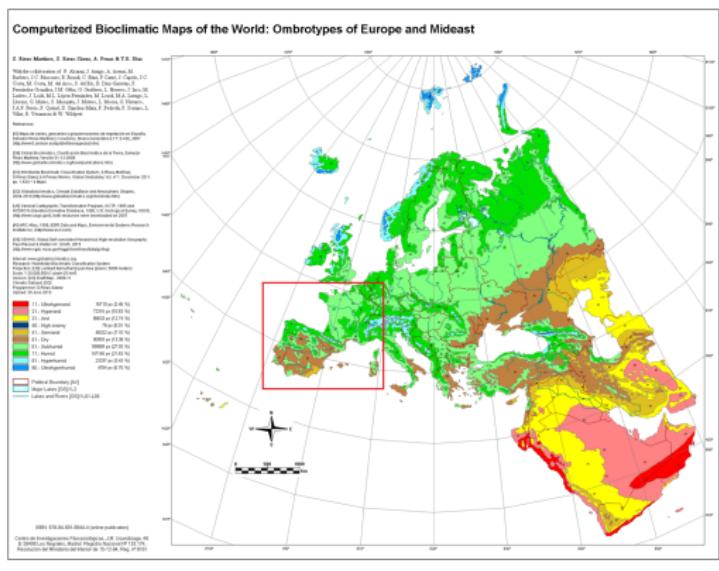


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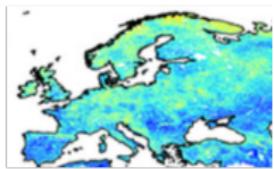
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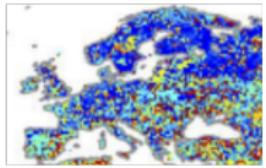


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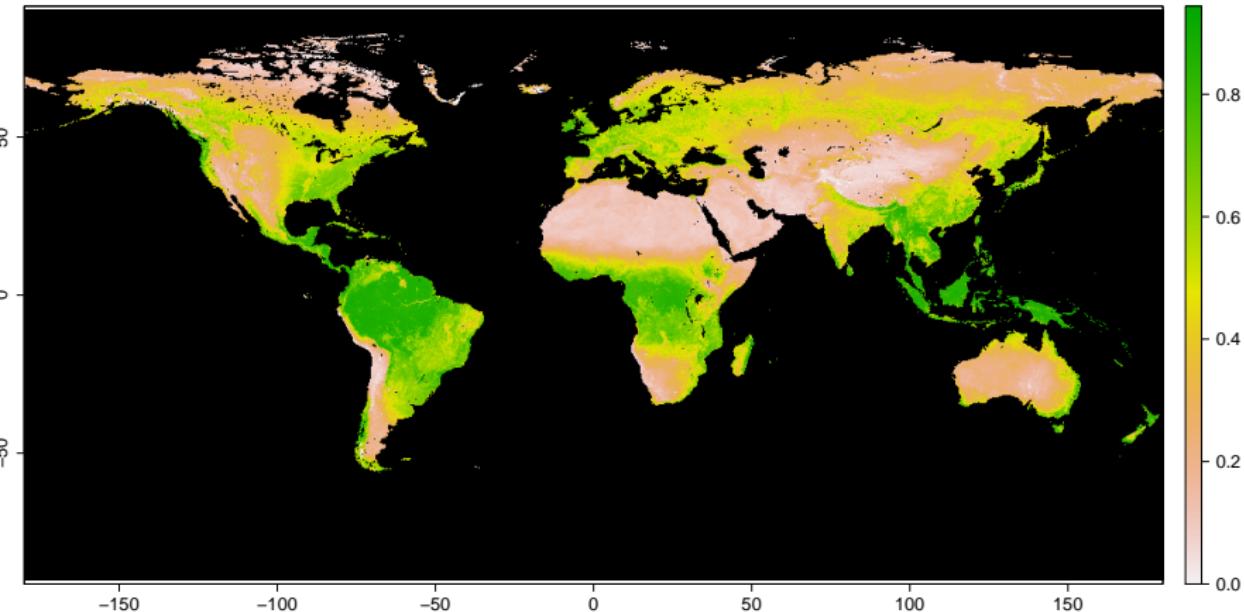
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# Normalised Difference Vegetation Index (NDVI)

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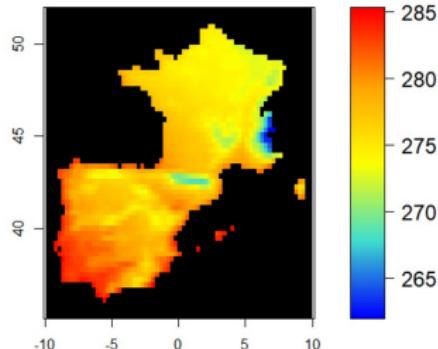
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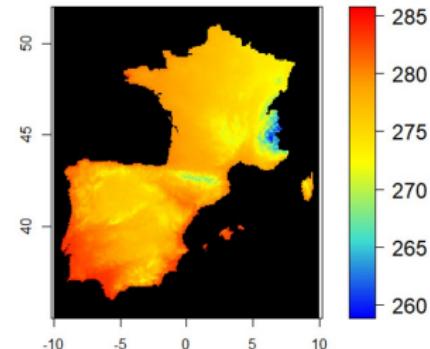
- *Why:* Temperature drives plant physiology and drives levels of aridity<sup>[2,6]</sup>.
- *How:* As one single layer (2m above ground)

# Kriging

Tair January 1981

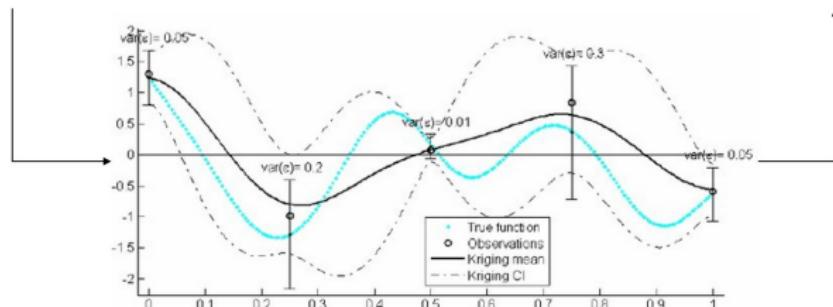


Tair January 1981



+

Covariates  
(Training Resolution)



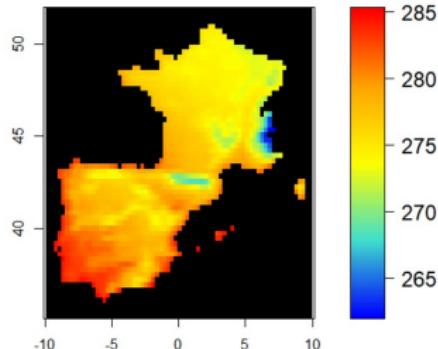
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Covariates  
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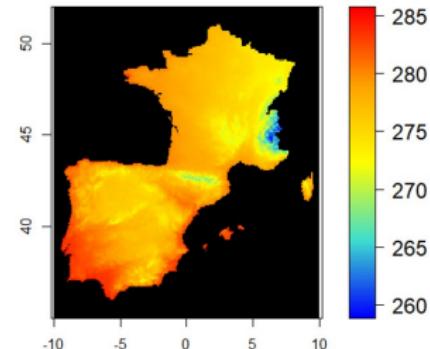
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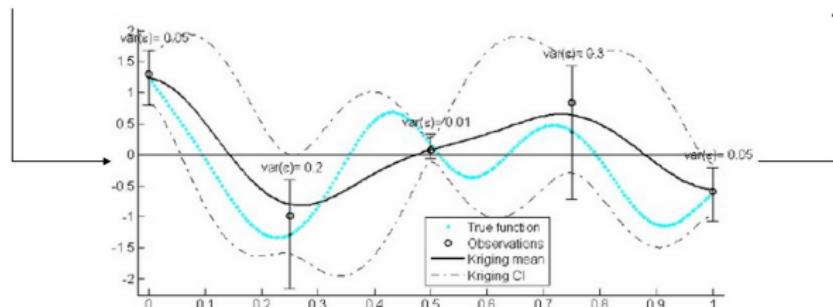
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# Pixel-Wise Model Building

- Linear detrending
- Z-Scores:

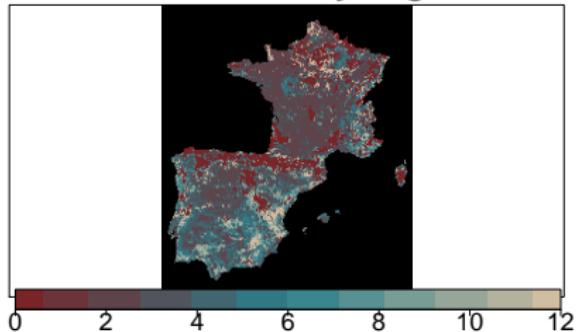
$$Anomaly_i = \frac{Detrended_i - \overline{Detrended}_{month}}{SD_{Detrended,month}} \quad (1)$$

- Calculate:
  - $t - 1$  lag for NDVI
  - Cummulative lags for  $Q_{soil}$  data
- Set NDVI anomalies to 'NA' in months for which  $Thresholds_i < 0.1$  with  
 $Thresholds_i = \overline{Raw_{NDVI,month}}$
- PCA regression and model selection:

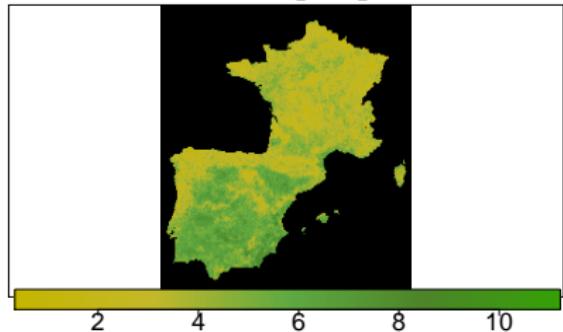
$$NDVI_t = \beta_{t-1} * NDVI_{[t-1]} + \beta_{Q_{soil}} * Q_{soil}_{k;m} + \beta_{Tair} * Tair_t \quad (2)$$

# Vegetation Memory Coefficients

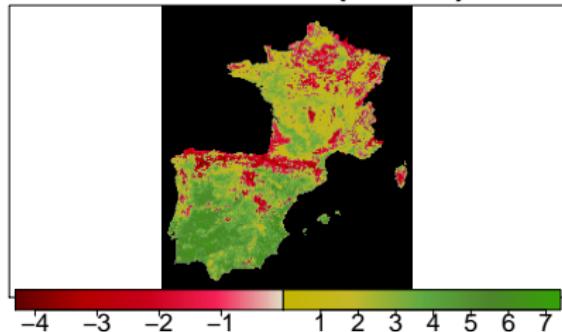
**Soil Memory Lag**



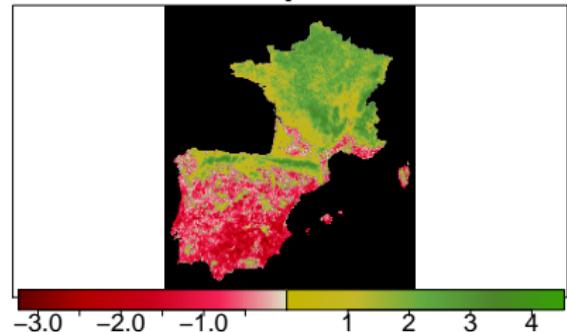
**NDVI [t-1]**



**Soil Moisture (0–7cm)**

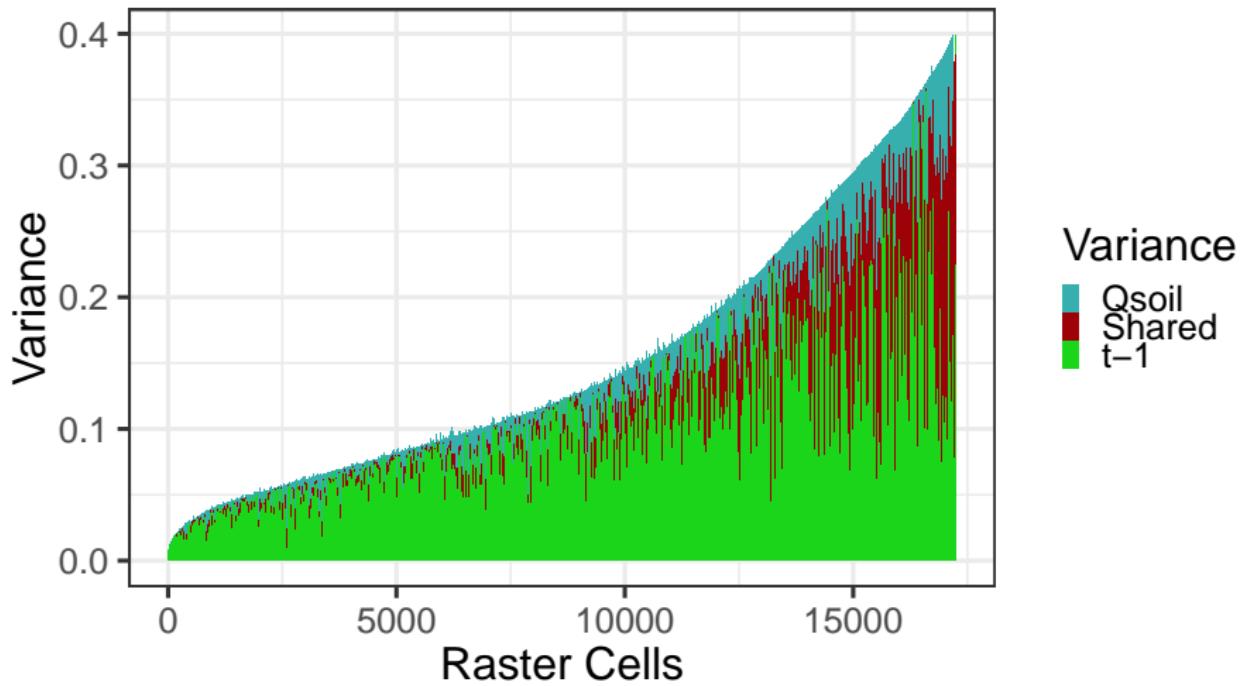


**Air Temperature**



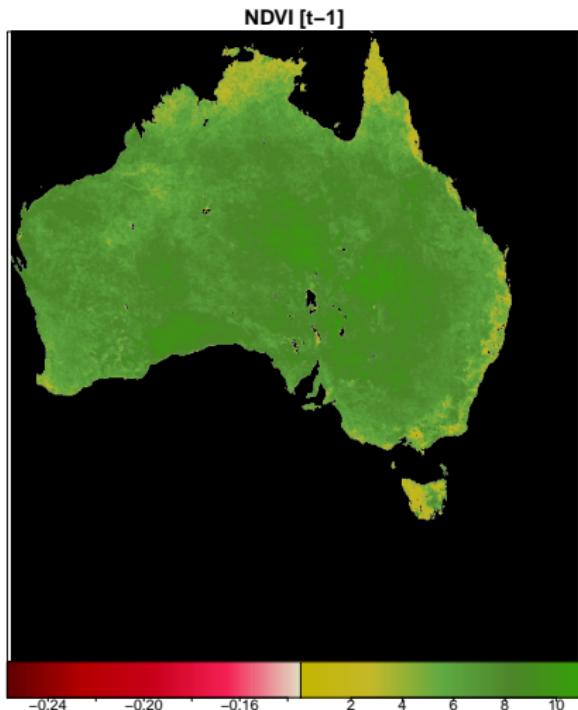
# Distinguishing Intrinsic and Extrinsic Memory

**Qsoil1 is the most informative of the soil moisture layers!**

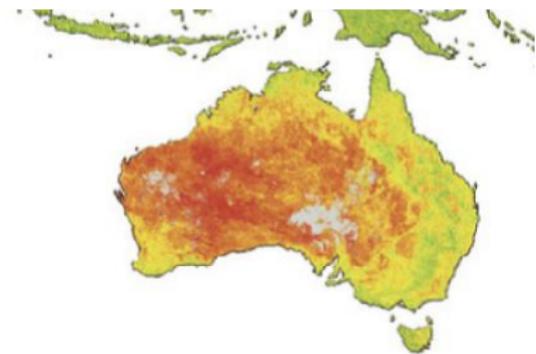


# Identifying Underlying Extrinsic Patterns I

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

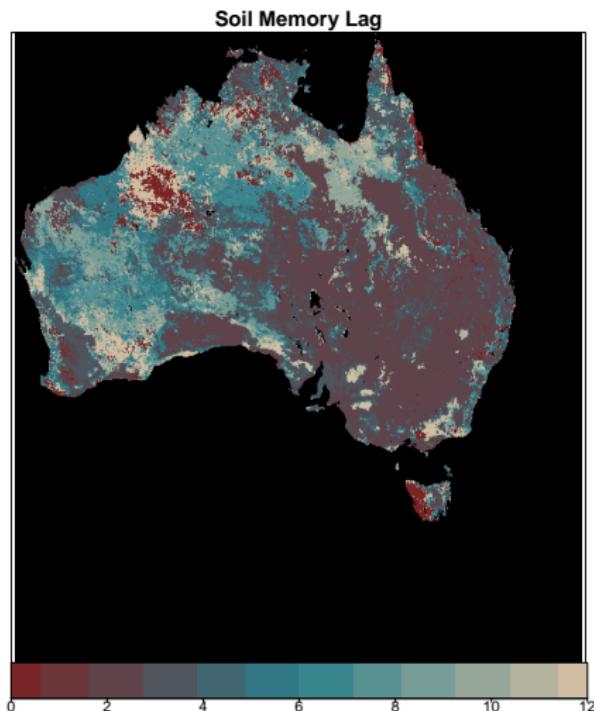


Intrinsic Memory by Seddon et al.<sup>[3]</sup>:

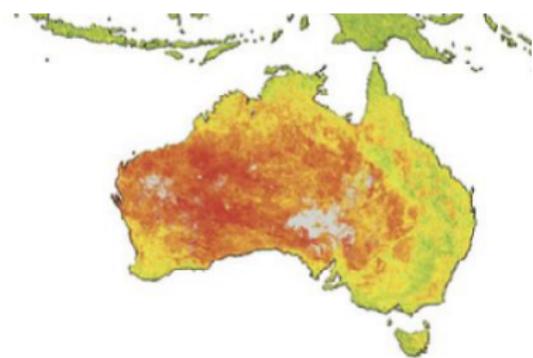


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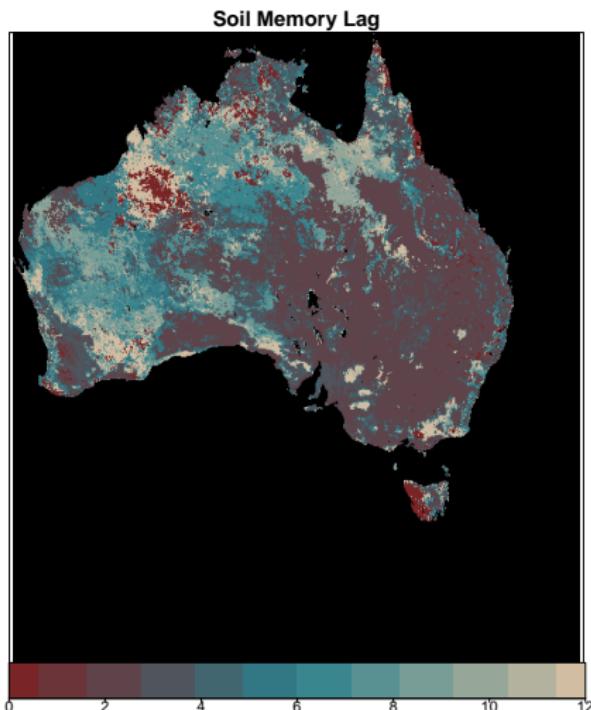


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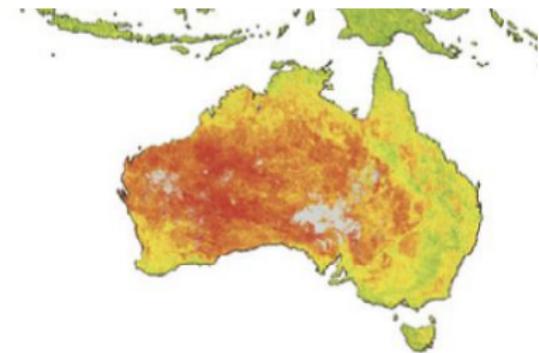


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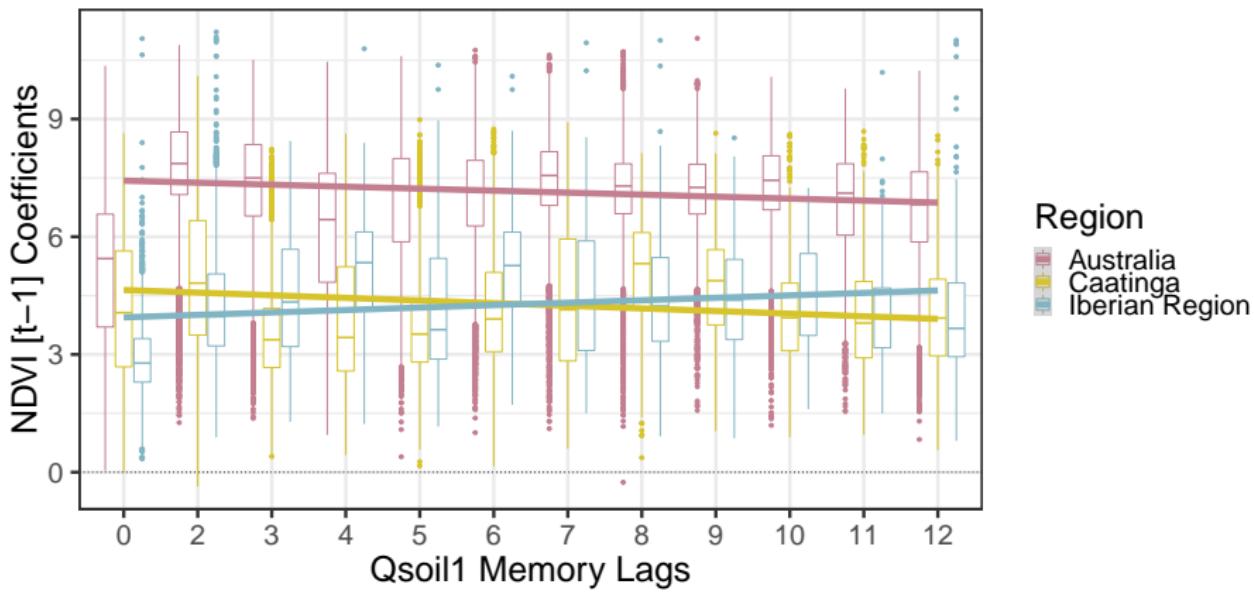


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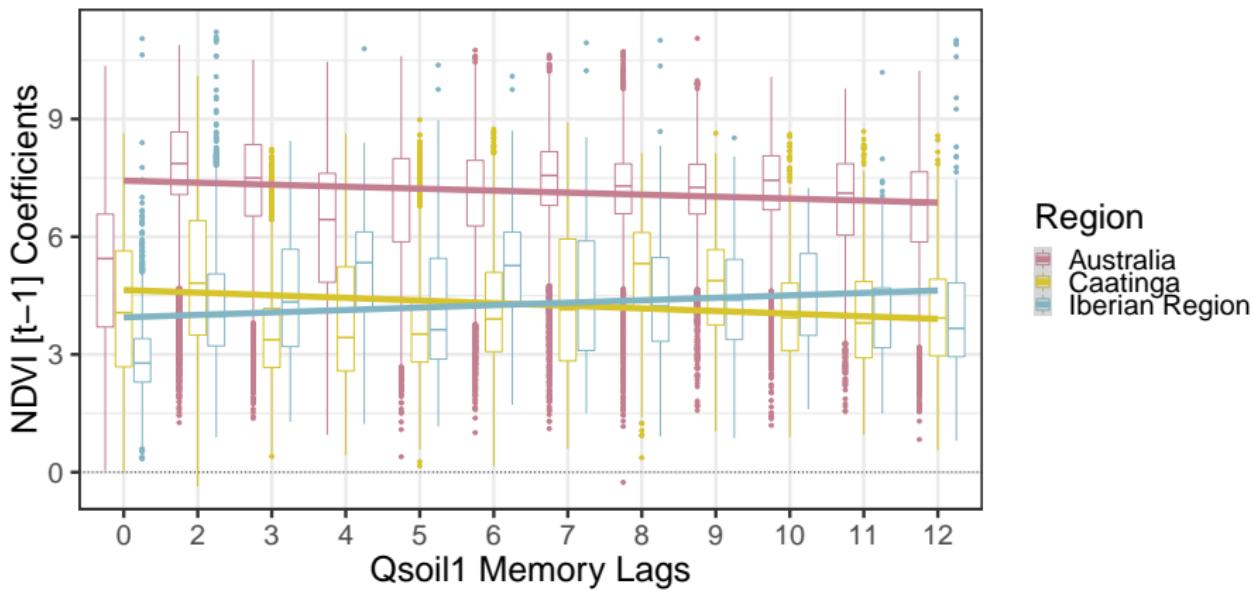
Previous  $t - 1$  variation can  
be understood through  
extrinsic vegetation memory.

# Vegetation Memory Adaptation



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

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# Conclusion

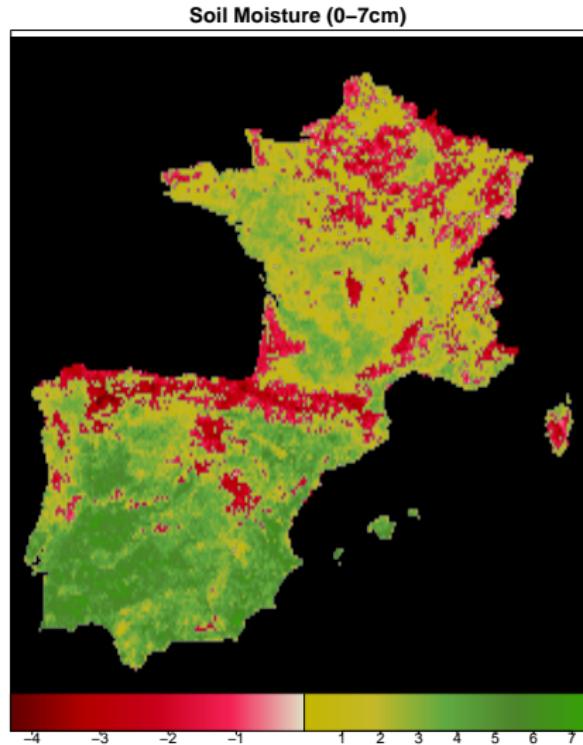
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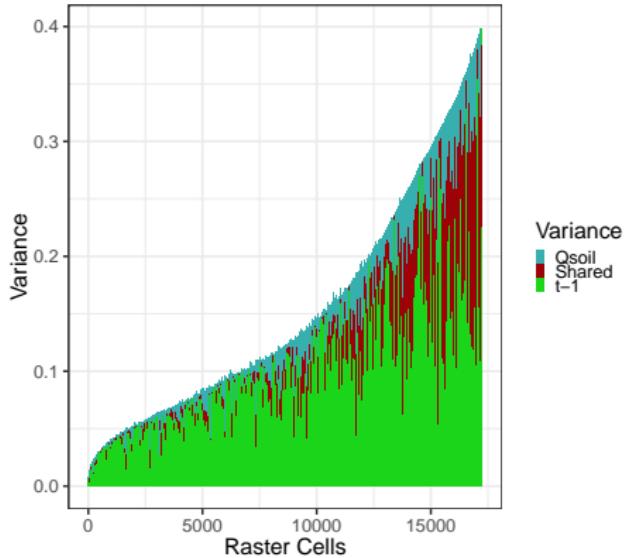
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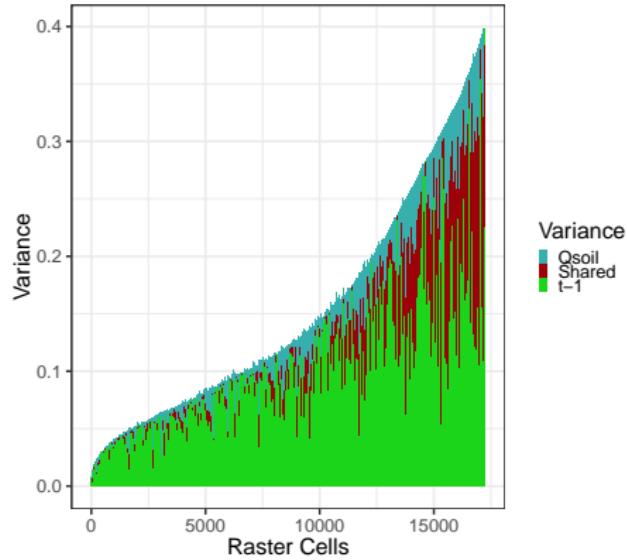
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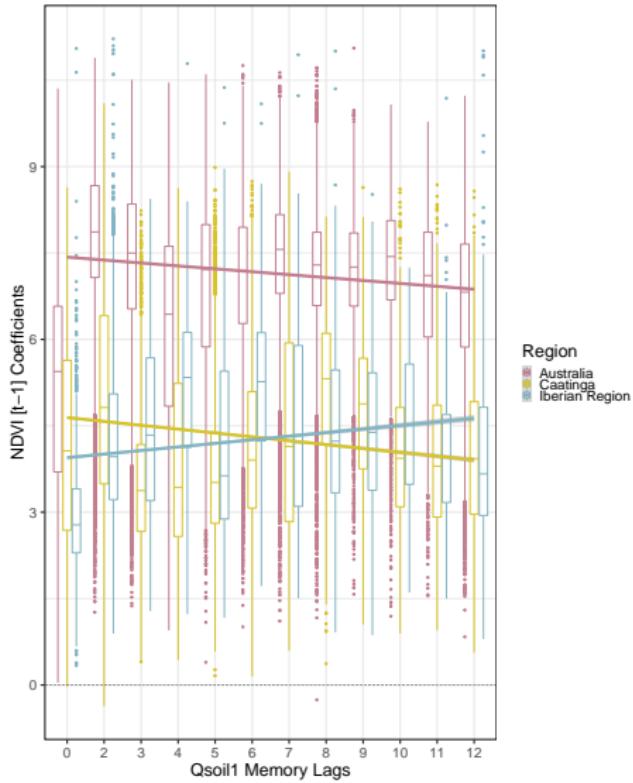
Distinguishing intrinsic and extrinsic memory components remains challenging.

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Interplay of memory characteristics is region-specific.



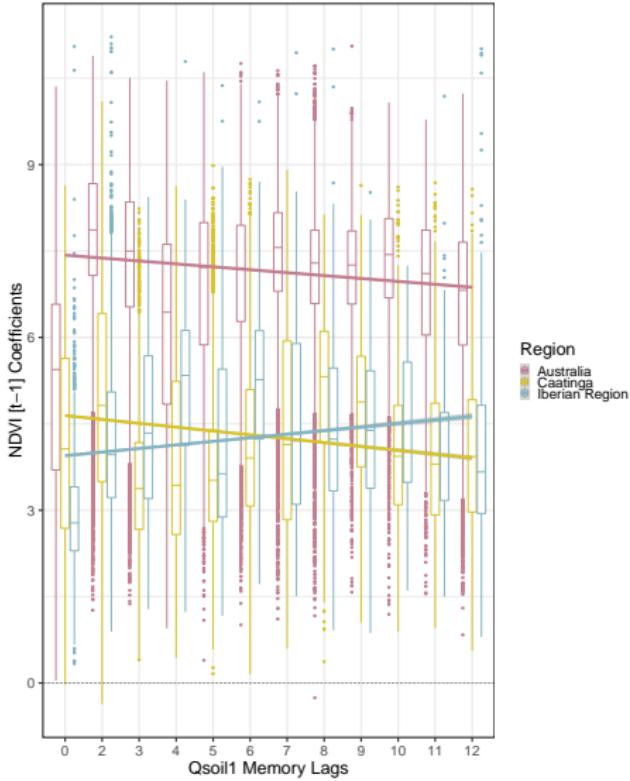
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Interplay of memory characteristics is region-specific.

- 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).