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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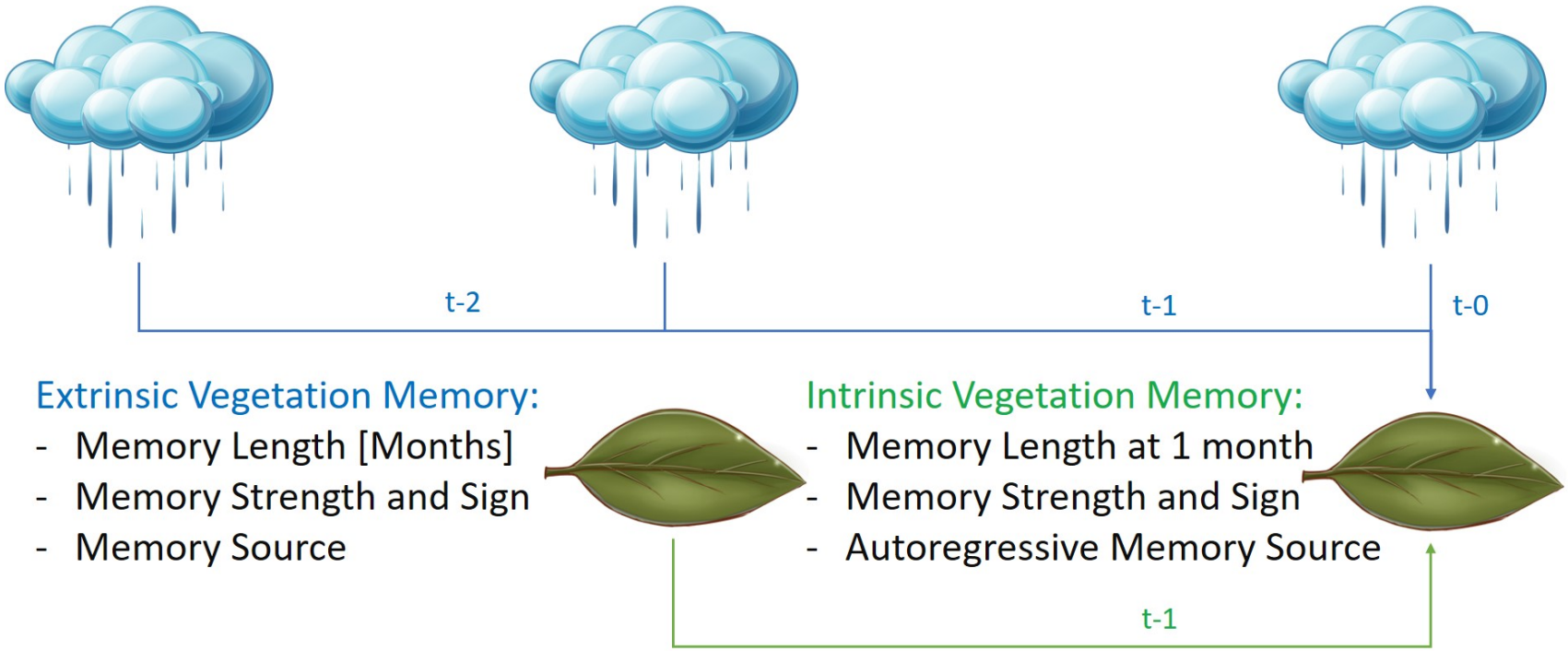

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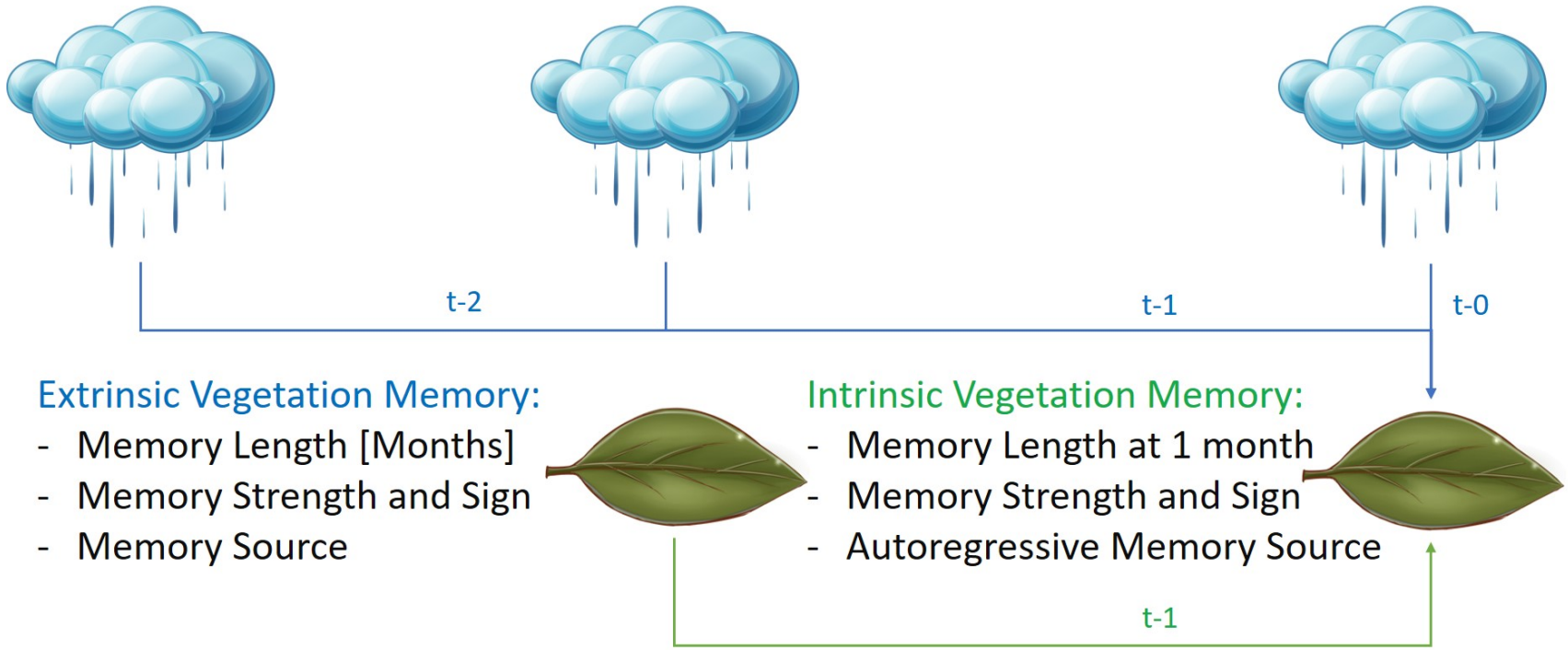

Can we **distinguish** between **intrinsic** and **extrinsic** memory effects?

Why do this?

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

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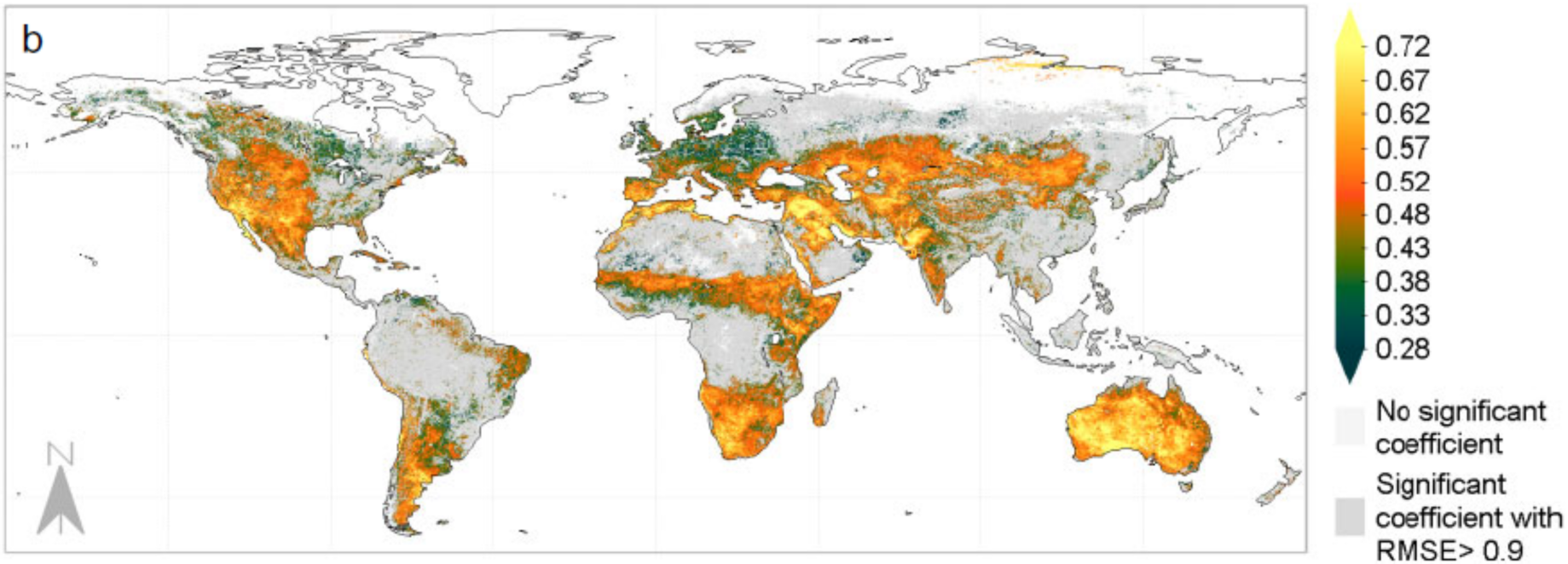

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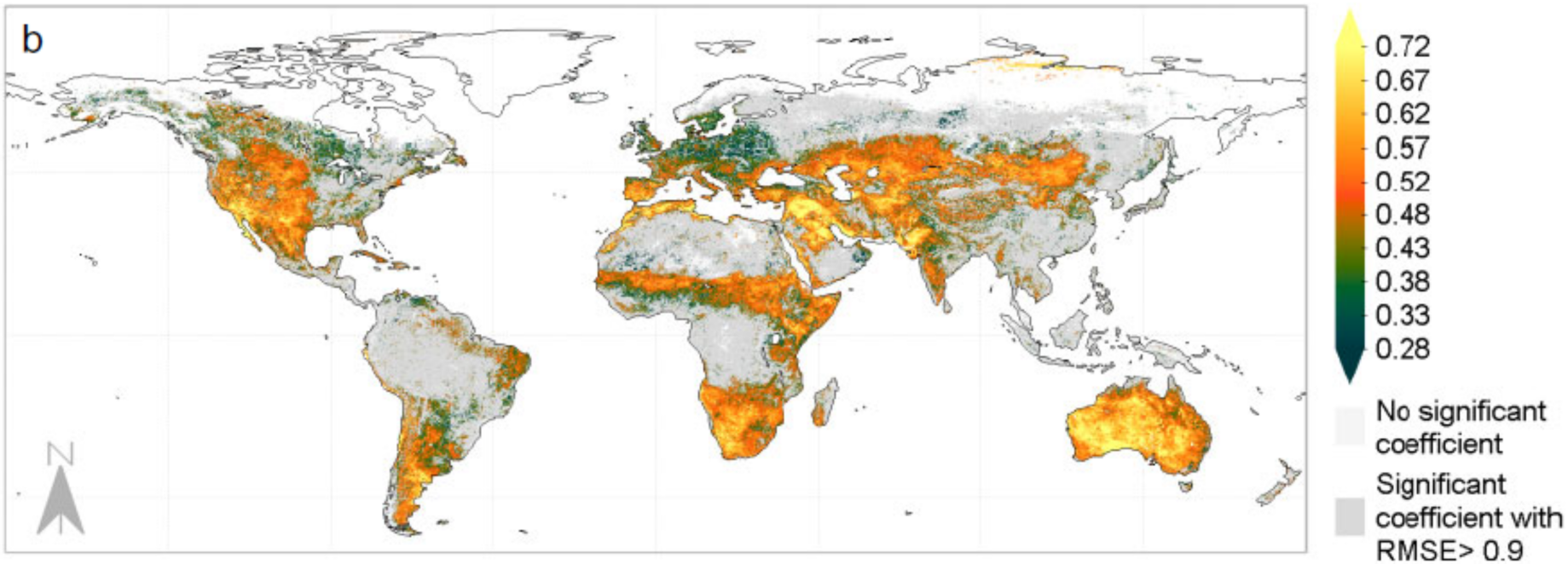

Big emphasis on **dryland regions** due to demonstrated vegetation memory effects[1–4], and the dependence of dryland vegetation on water regimes[5]

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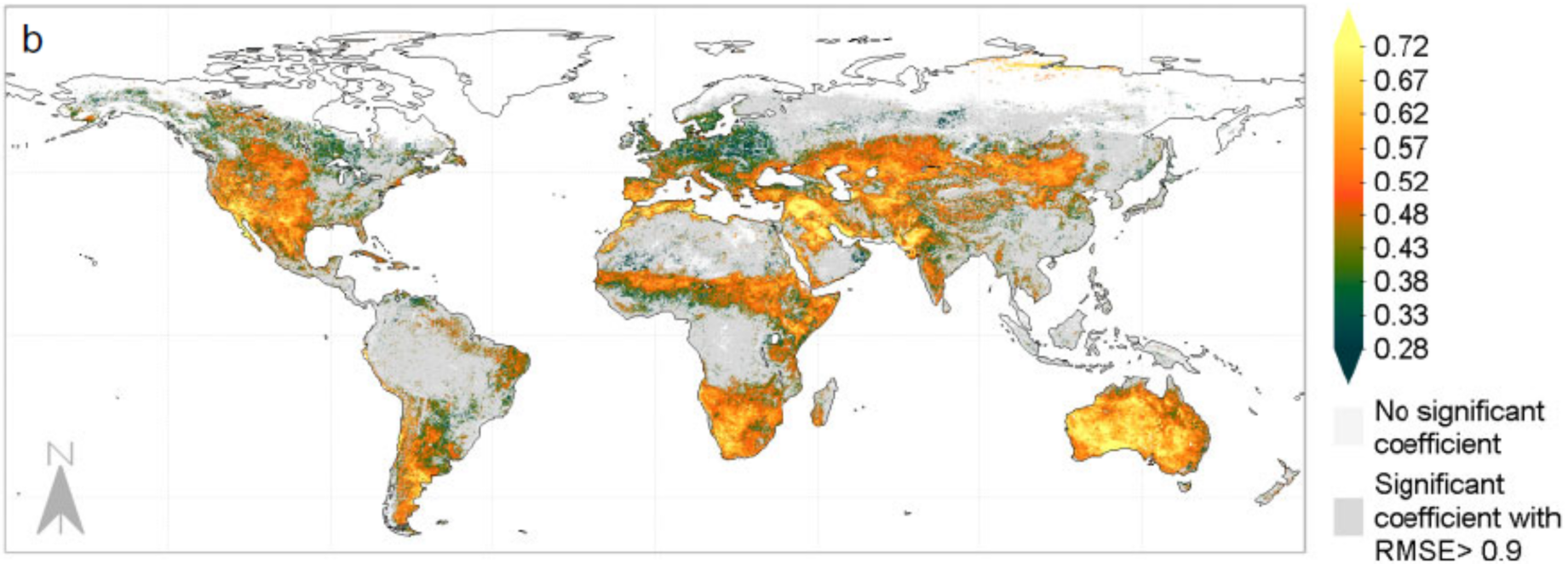
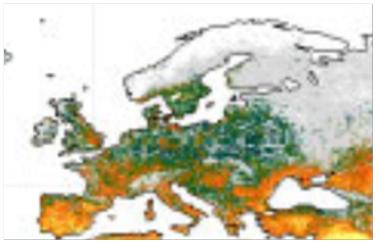


How **valid** is this **assumption?**

Study Regions

South-Western Europe

Intrinsic Memory



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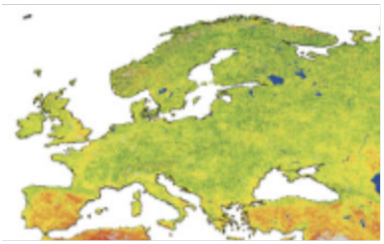

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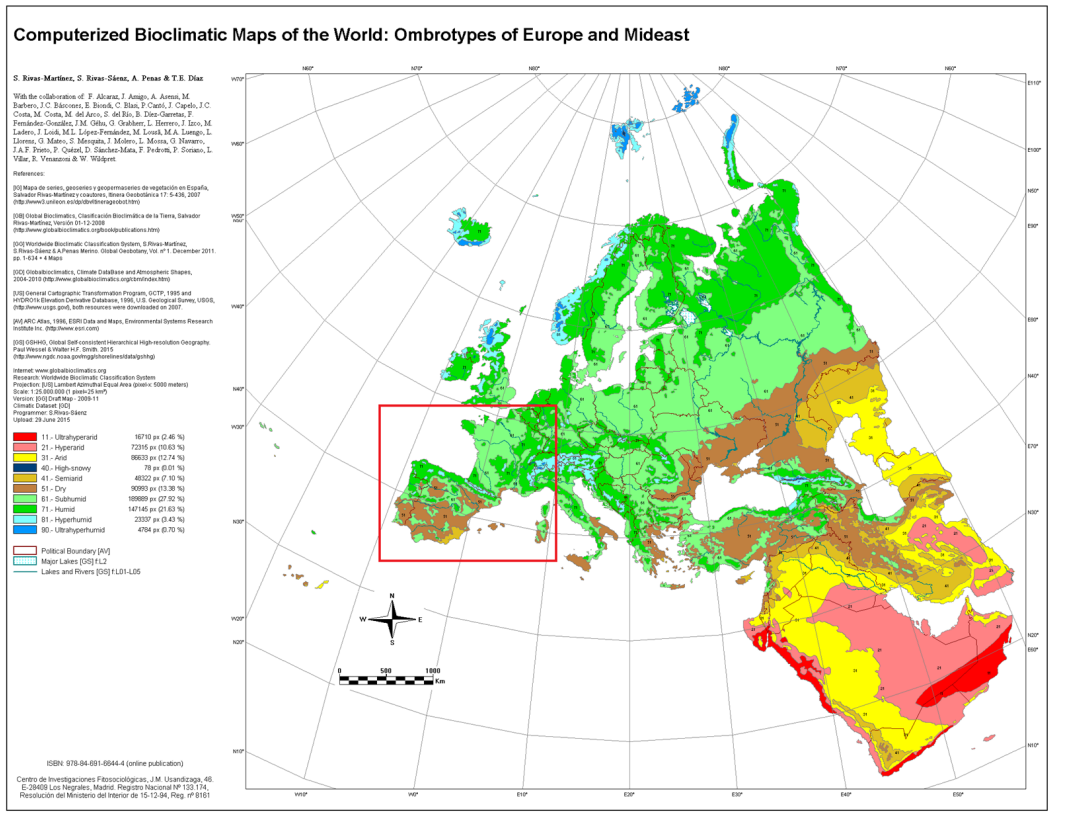
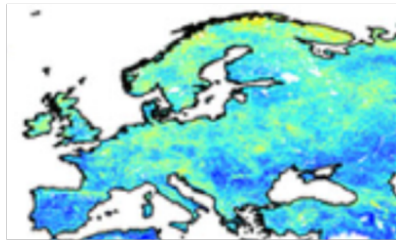


Water Memory



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- Australia
- Contiguous US

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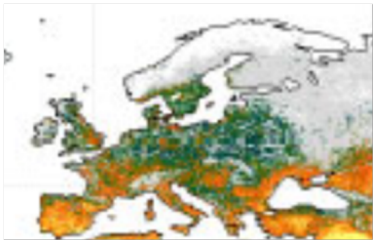

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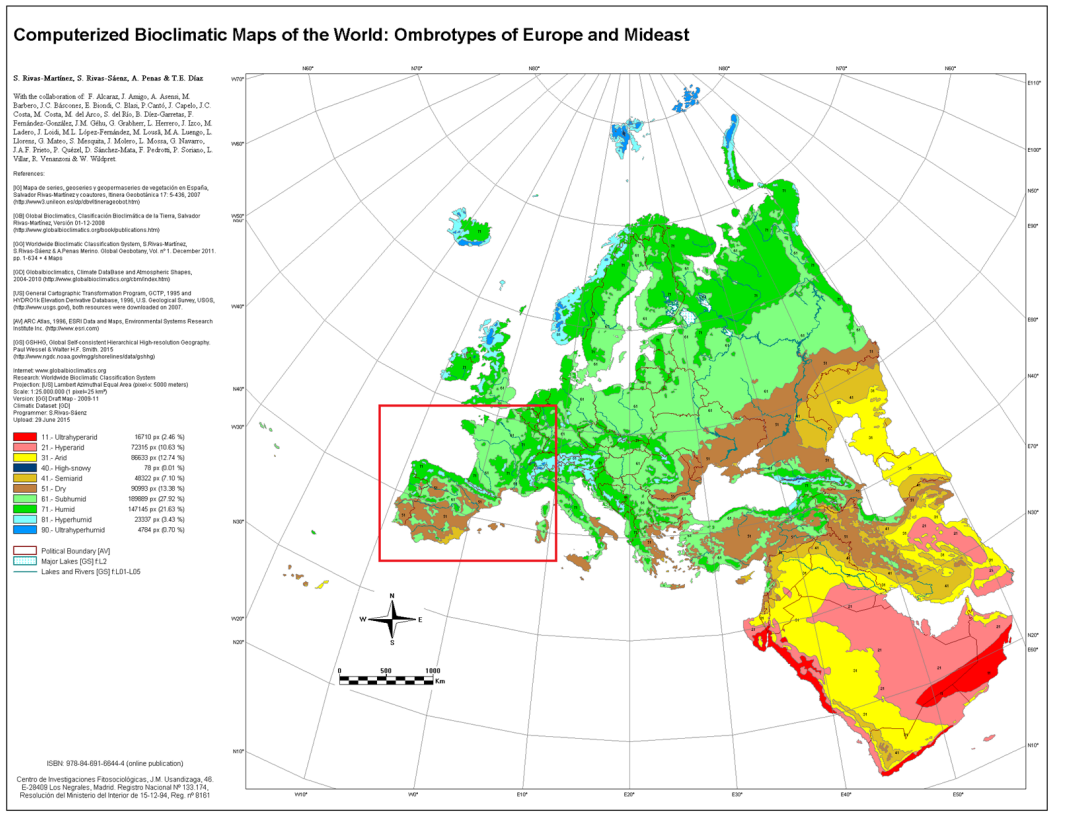

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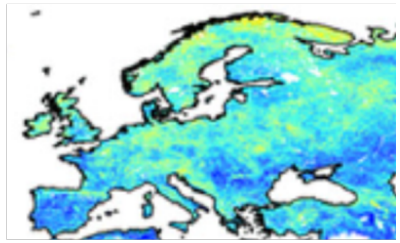

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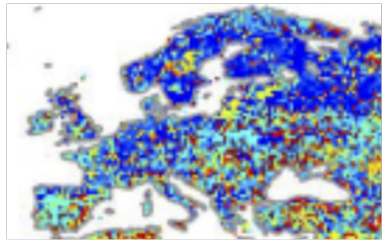

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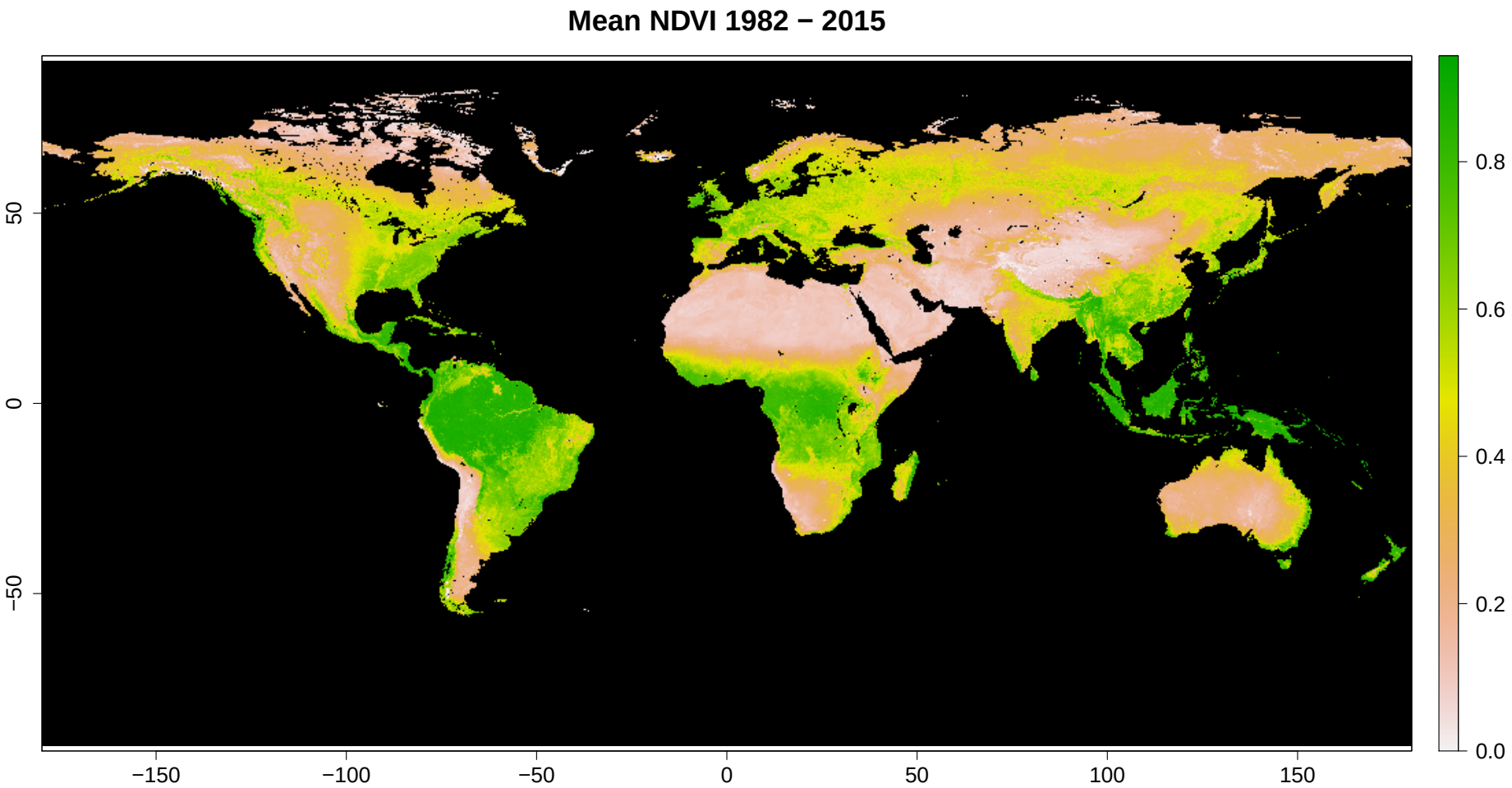
Normalised Difference Vegetation Index (NDVI)

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



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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- **Air Temperature** - $Tair$

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  - *Why:* Soil moisture effects on vegetation may indicate if/how the local ecosystem may deal with drought stress [5–7].
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- **Air Temperature** - $Tair$

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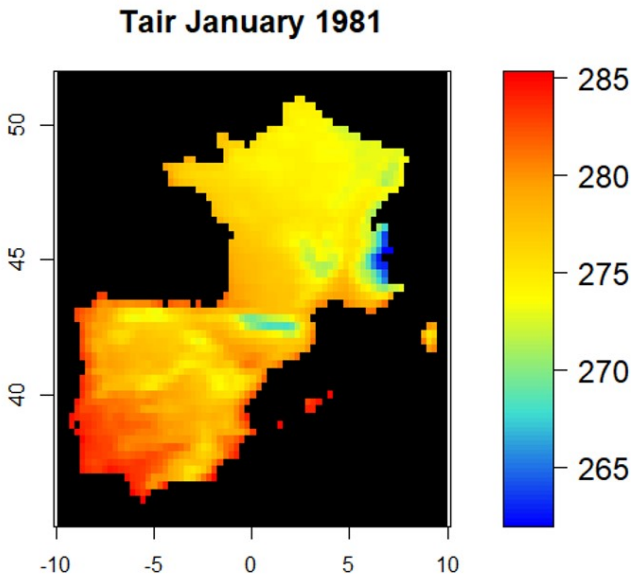
- **Air Temperature** - $Tair$
  - *Why:* Temperature drives plant physiology and drives levels of aridity [2,6].
  - *How:* As one single layer (2m above ground)

Kriging



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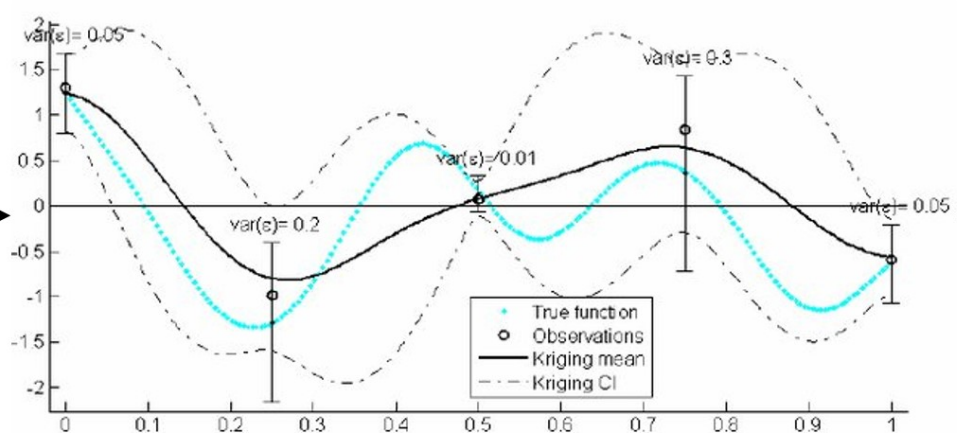
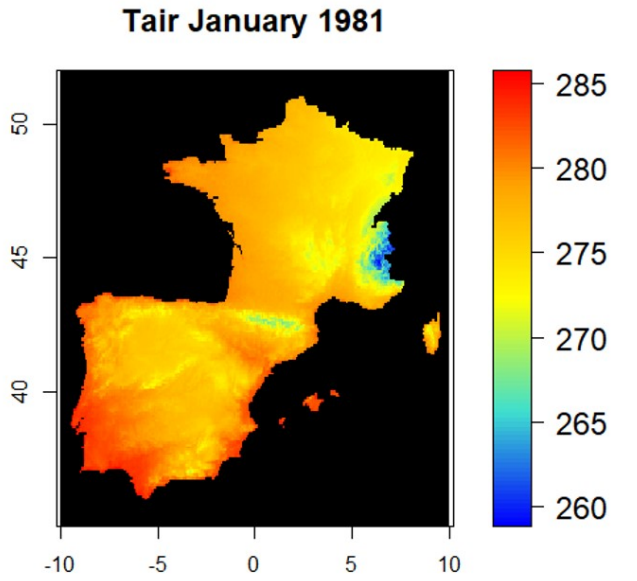
Covariates (Training Resolution)





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Covariates (Target Resolution)

→ RPackage coming soon

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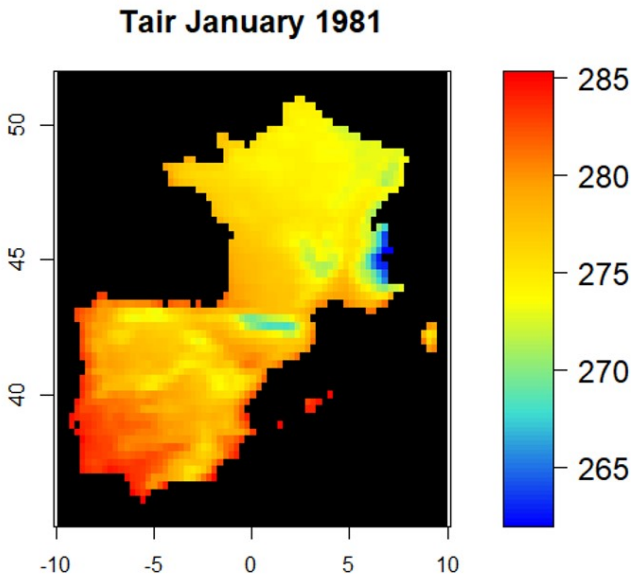

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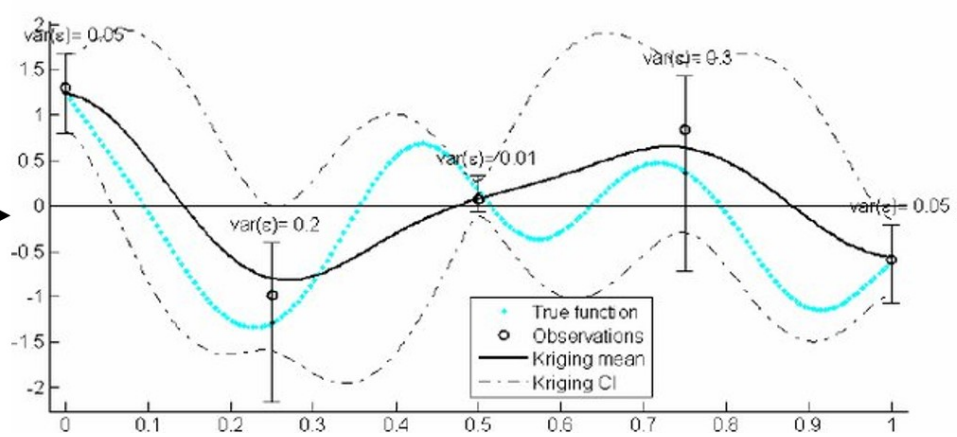

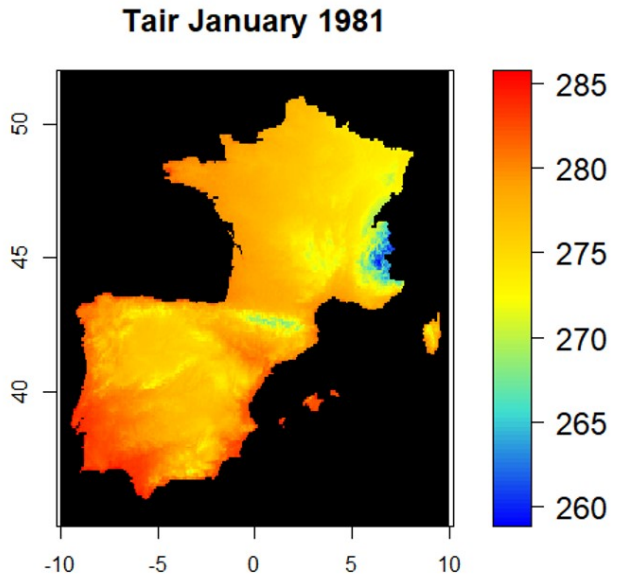

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Pixel-Wise Model Building

- Linear detrending
- Z-Scores:

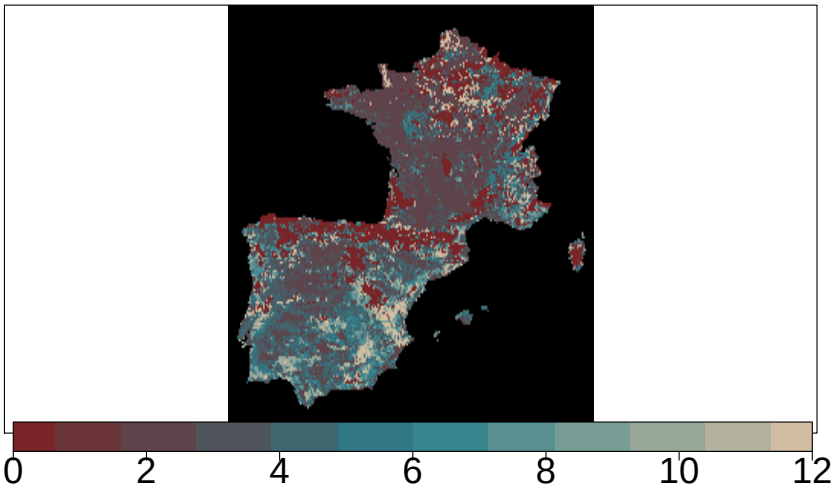
$$Anomaly_i = \frac{Detrended_i - \overline{Detrended_{month}}}{SD_{Detrended,month}} \quad (1)$$

- Calculate:
  - $t-1$ lag for NDVI
  - Cummulative lags for $Qsoil$ 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:

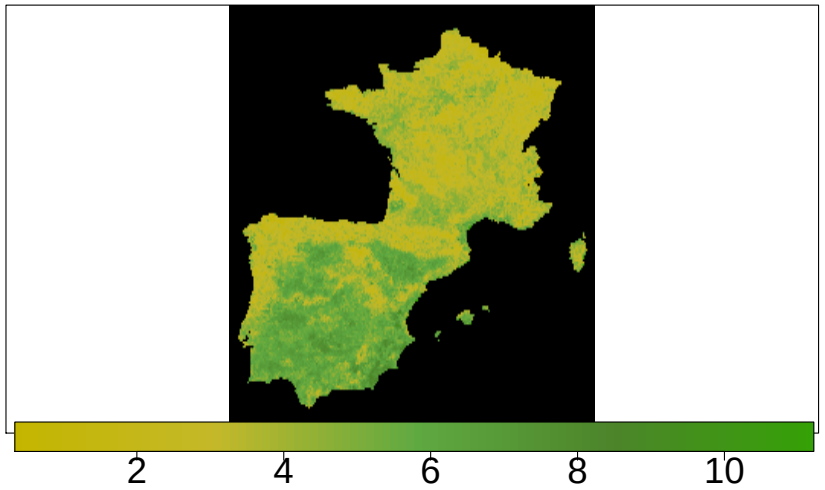
$$NDVI_t = \beta_{t-1} * NDVI_{[t-1]} + \beta_{Qsoil} * Qsoil_{k;m} + \beta_{Tair} * Tair_t \quad (2)$$

Vegetation Memory Coefficients

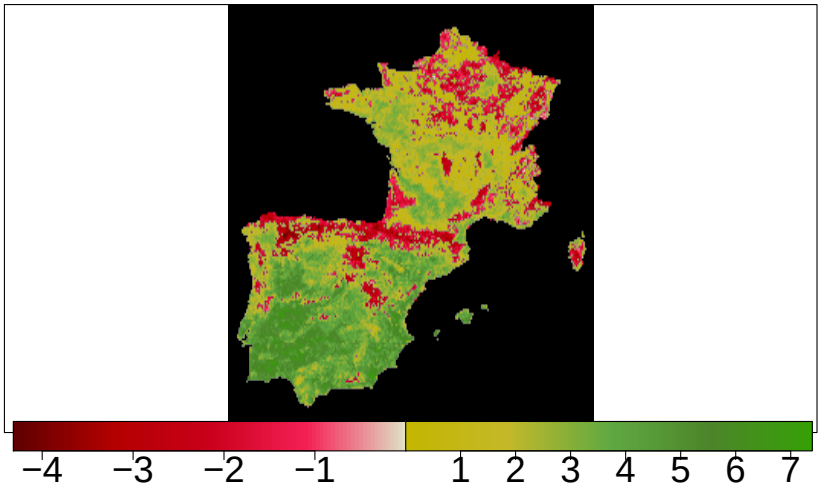
Soil Memory Lag



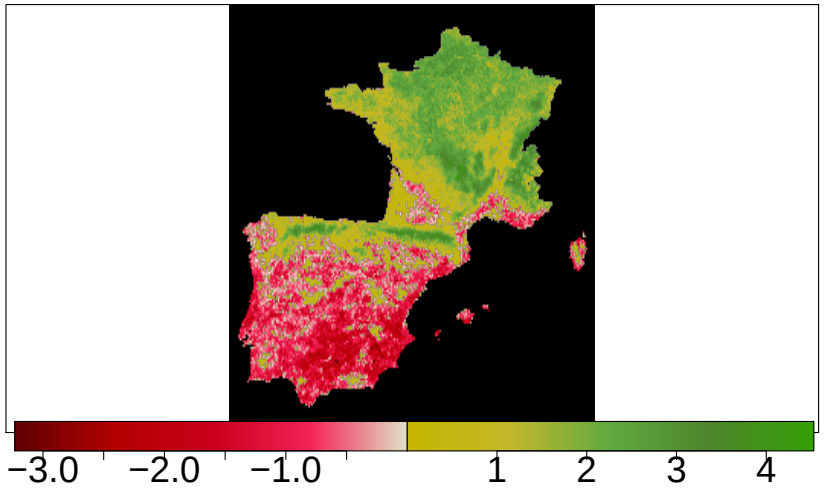
NDVI [t−1]



Soil Moisture (0−7cm)

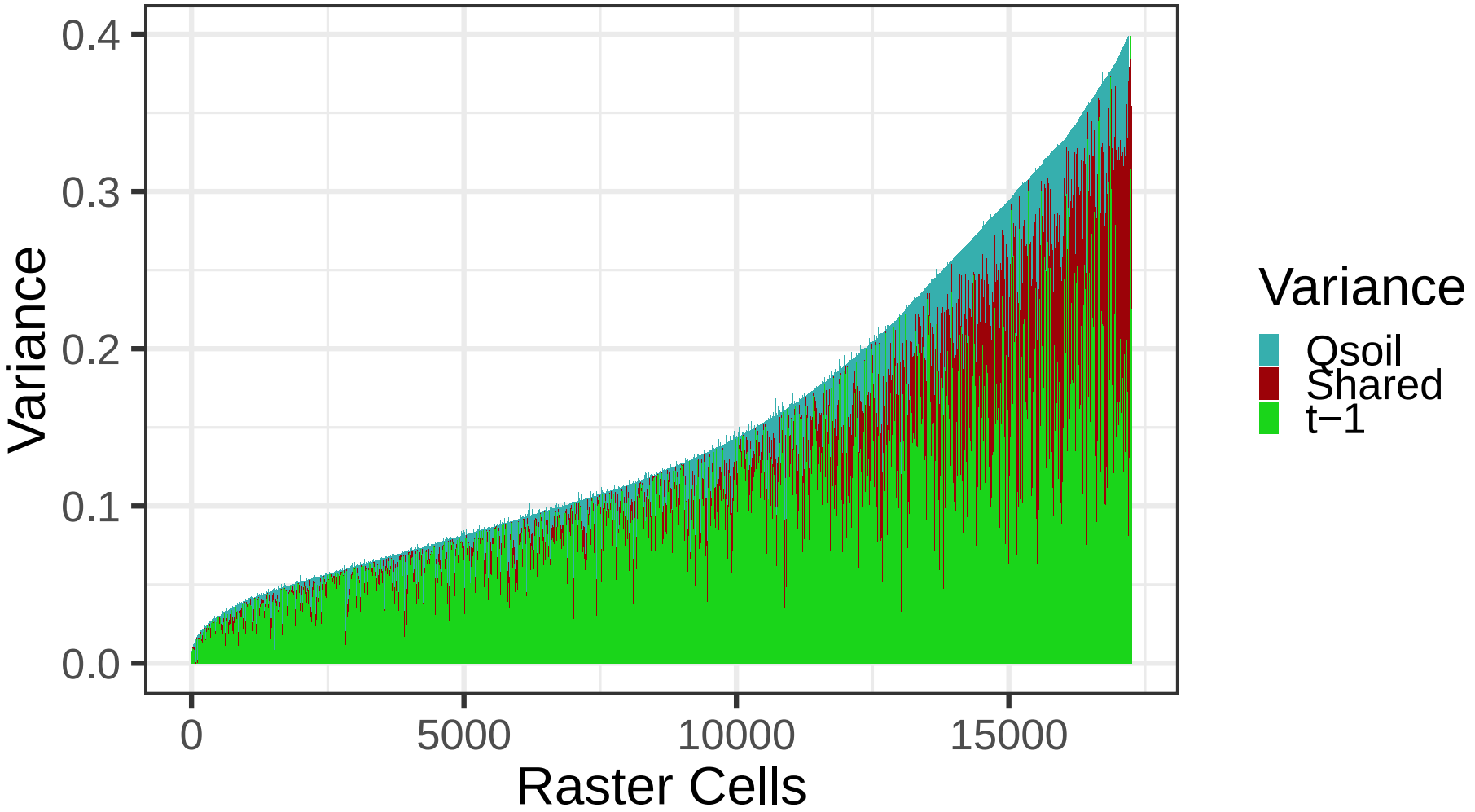


Air Temperature



Distinguishing Intrinsic and Extrinsic Memory

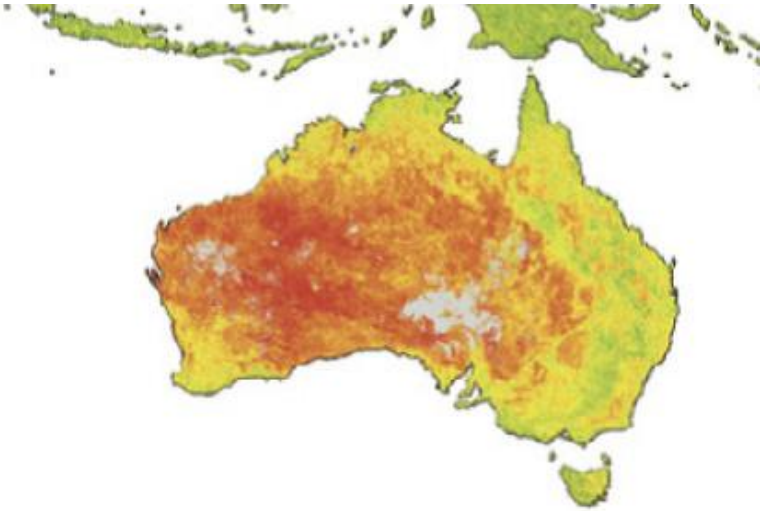
Qsoil1 is the **most informative** of the **soil moisture** layers!



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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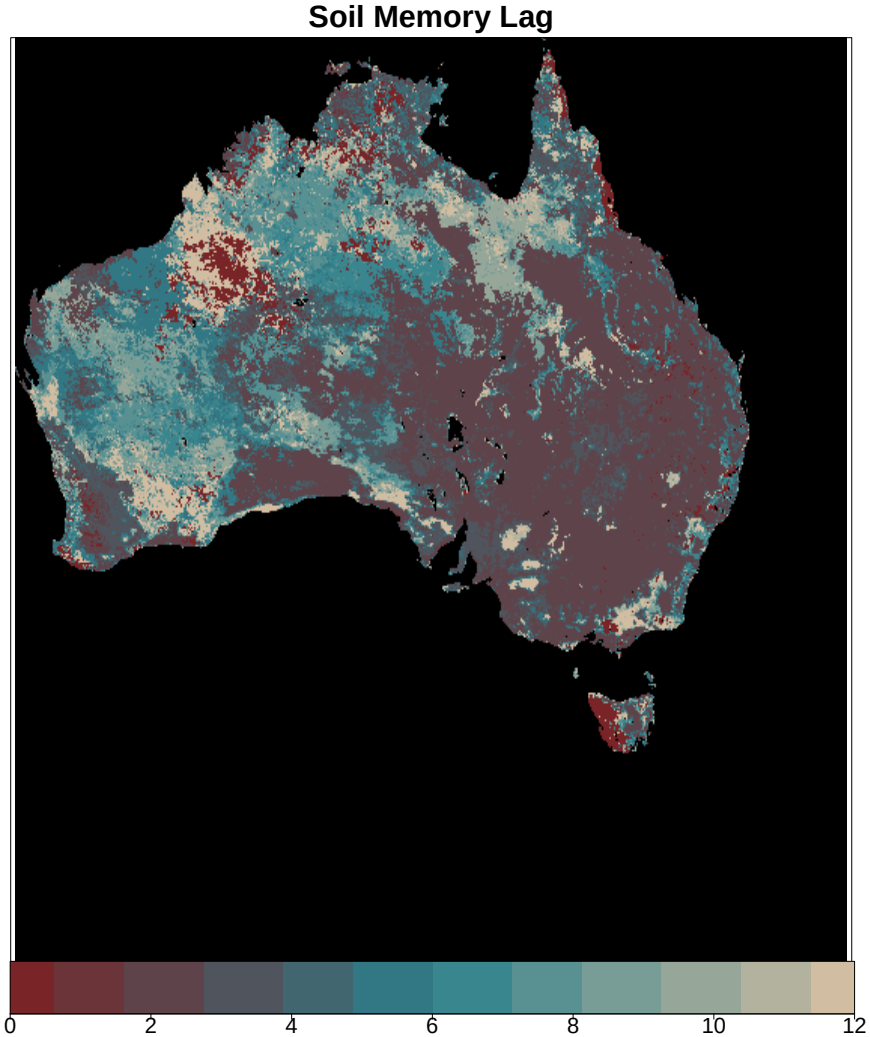

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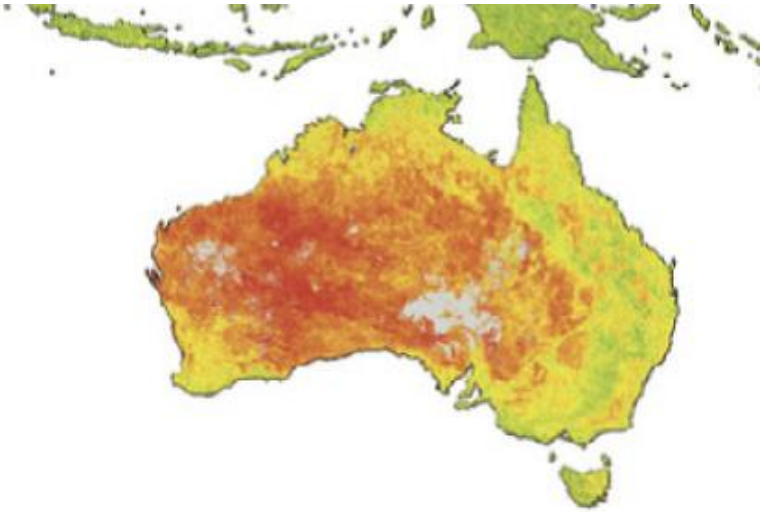

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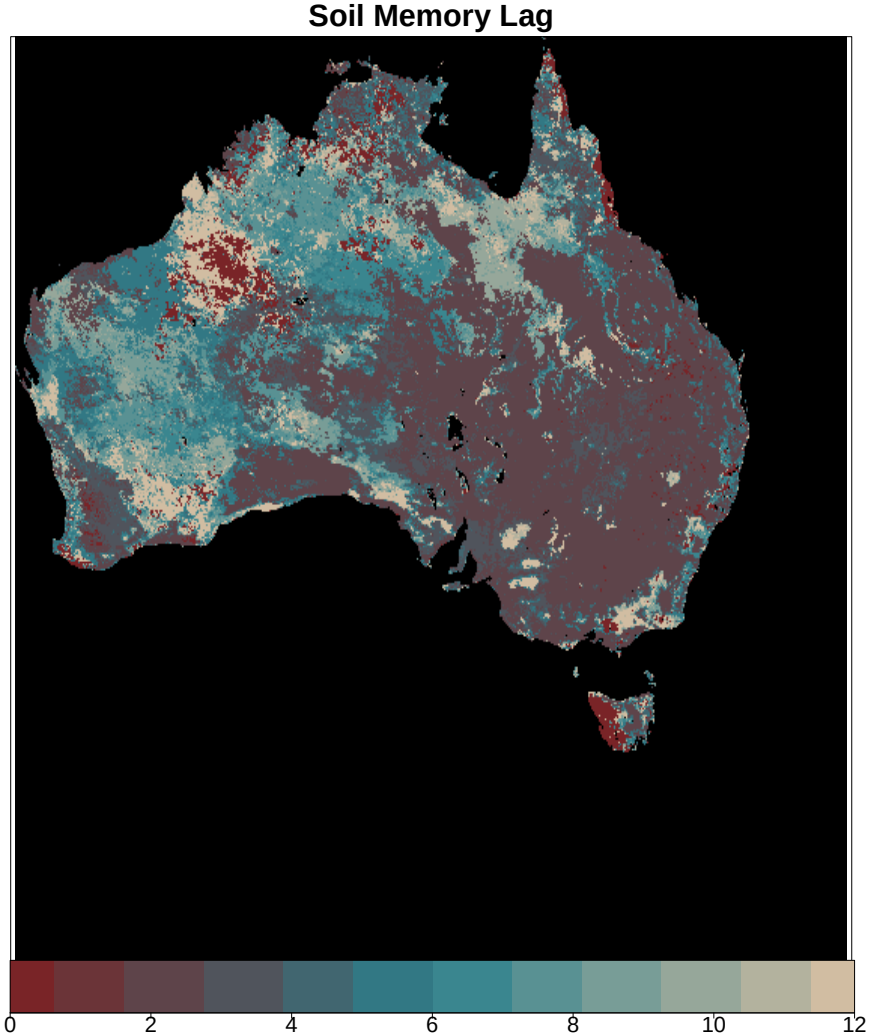

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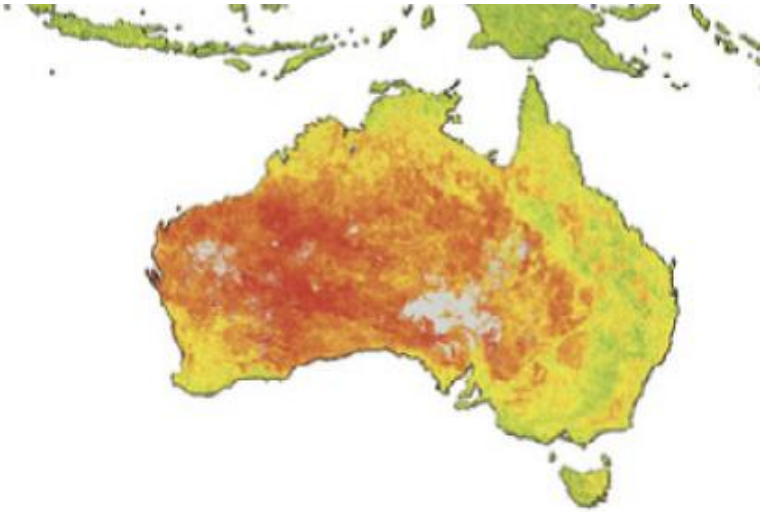
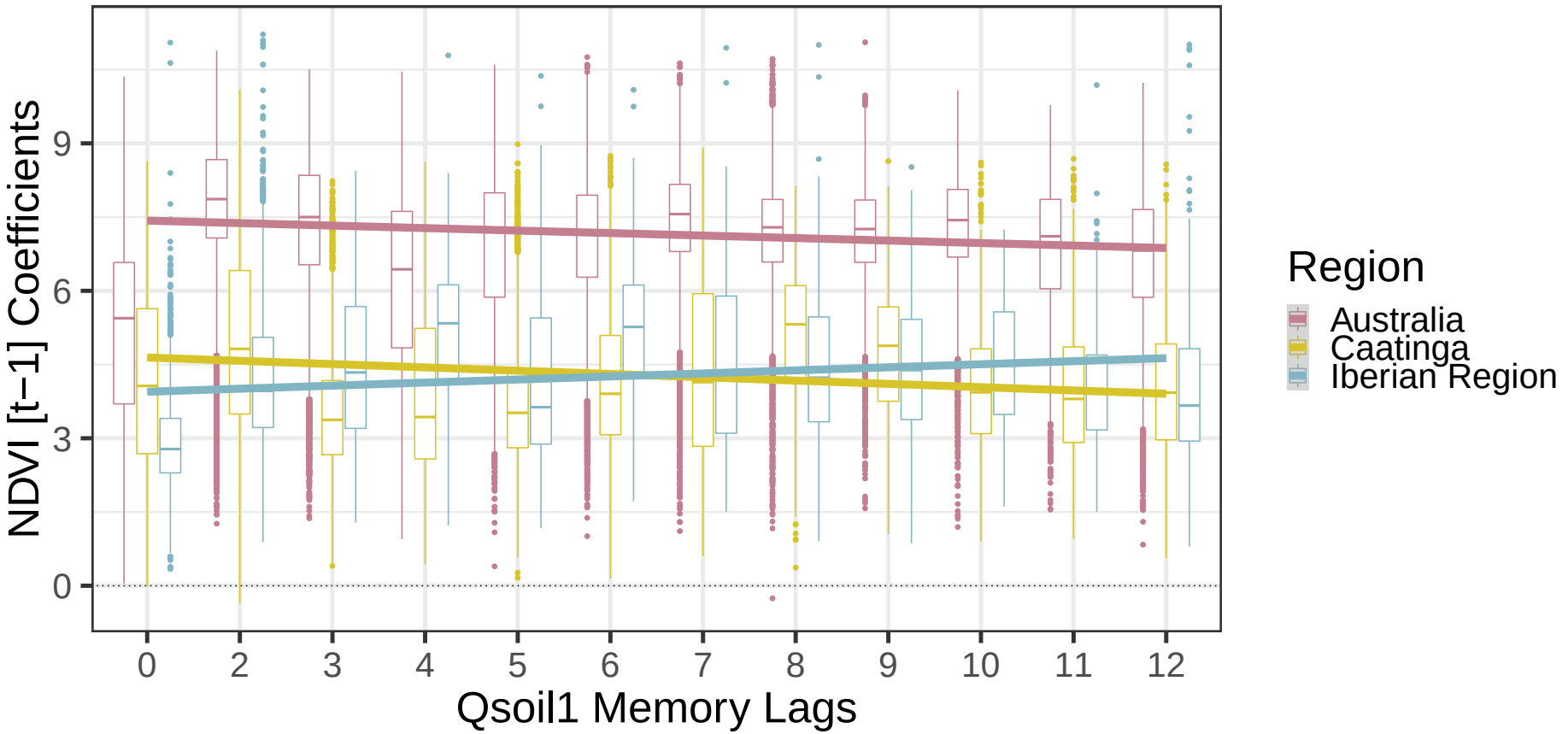


Previous $t-1$ variation can be **understood through extrinsic vegetation memory**.

Vegetation Memory Adaptation



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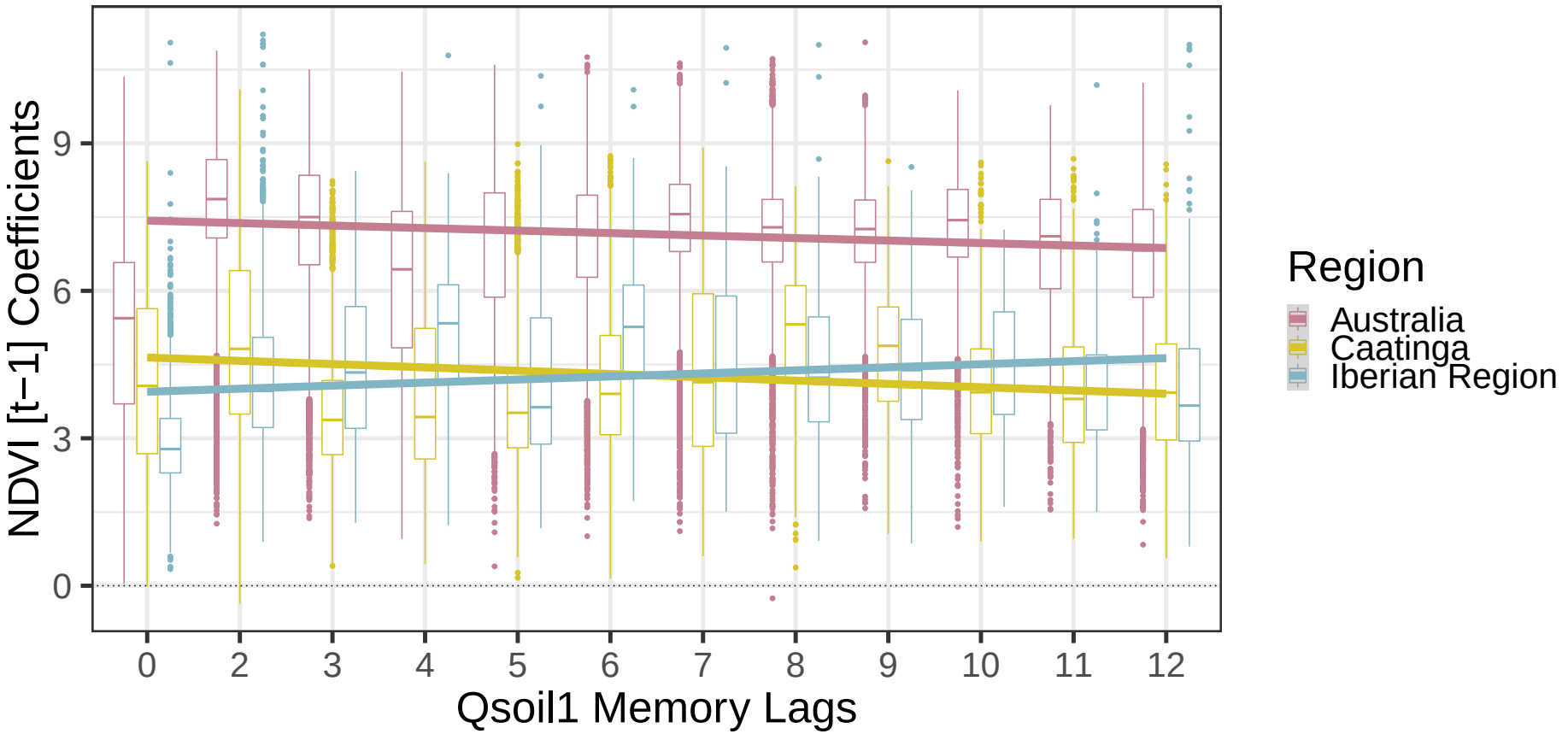

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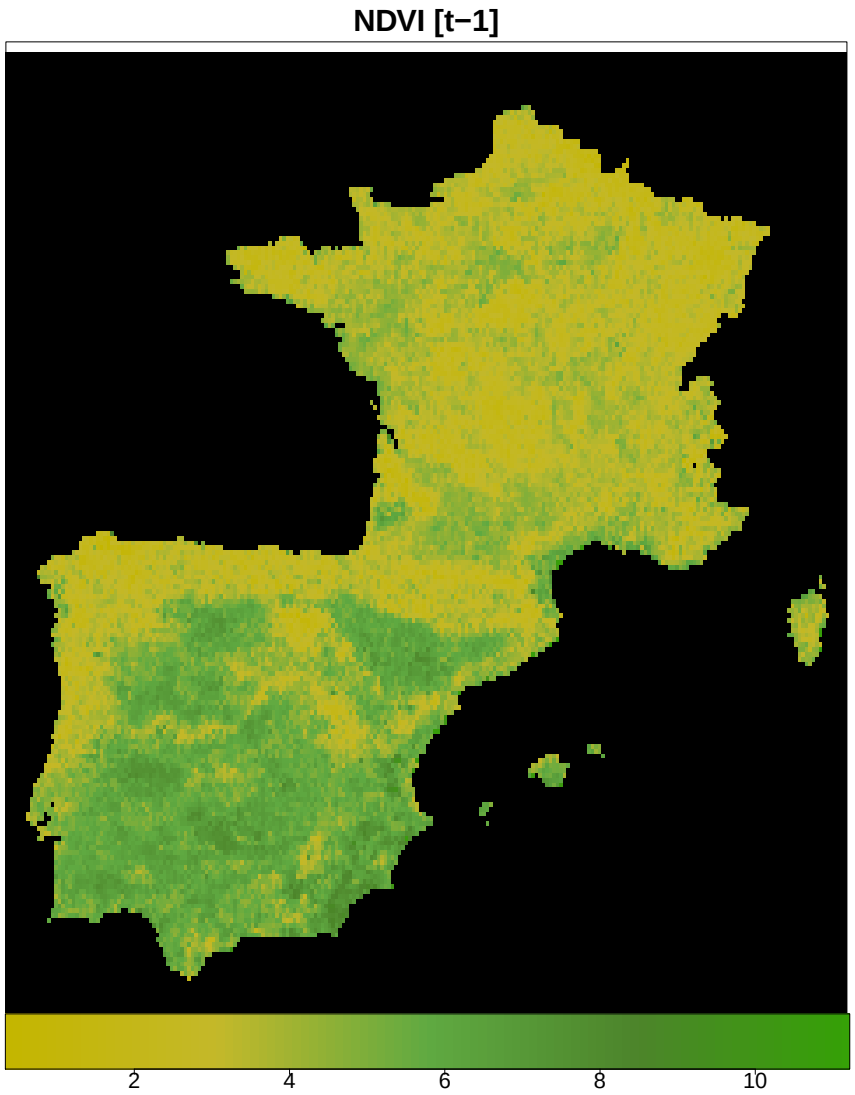

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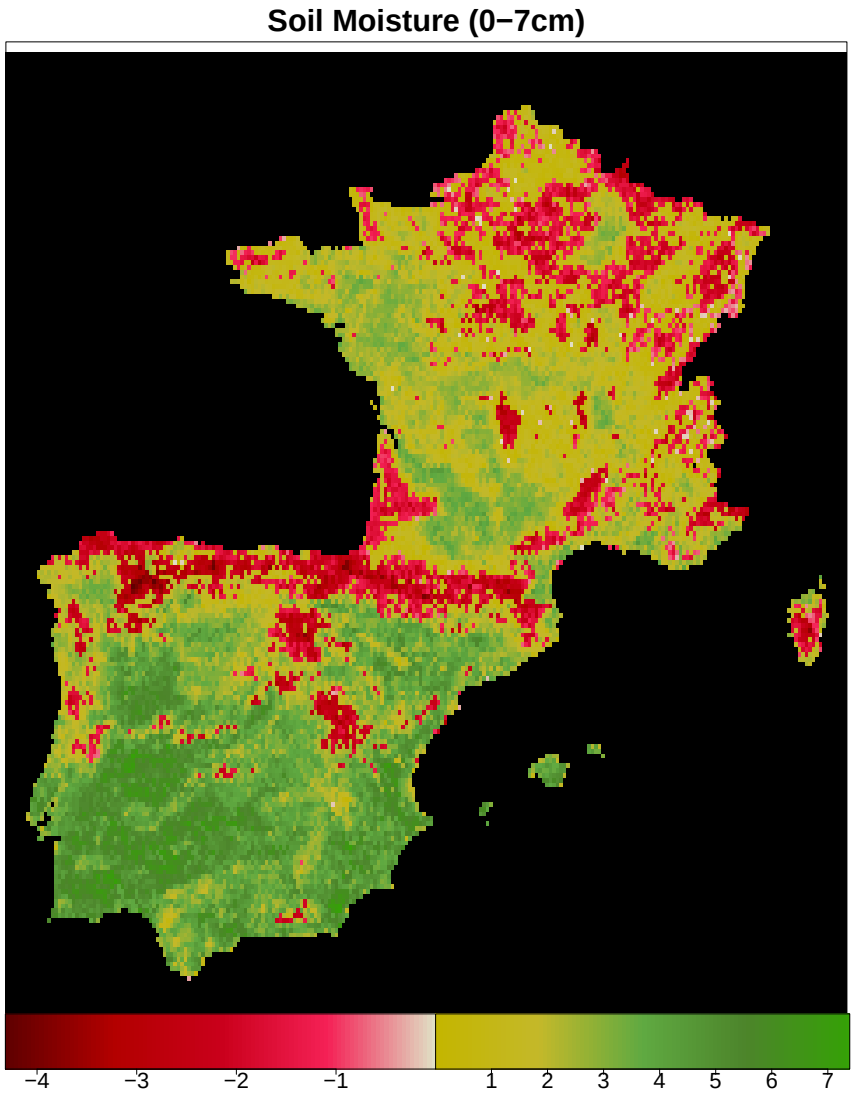

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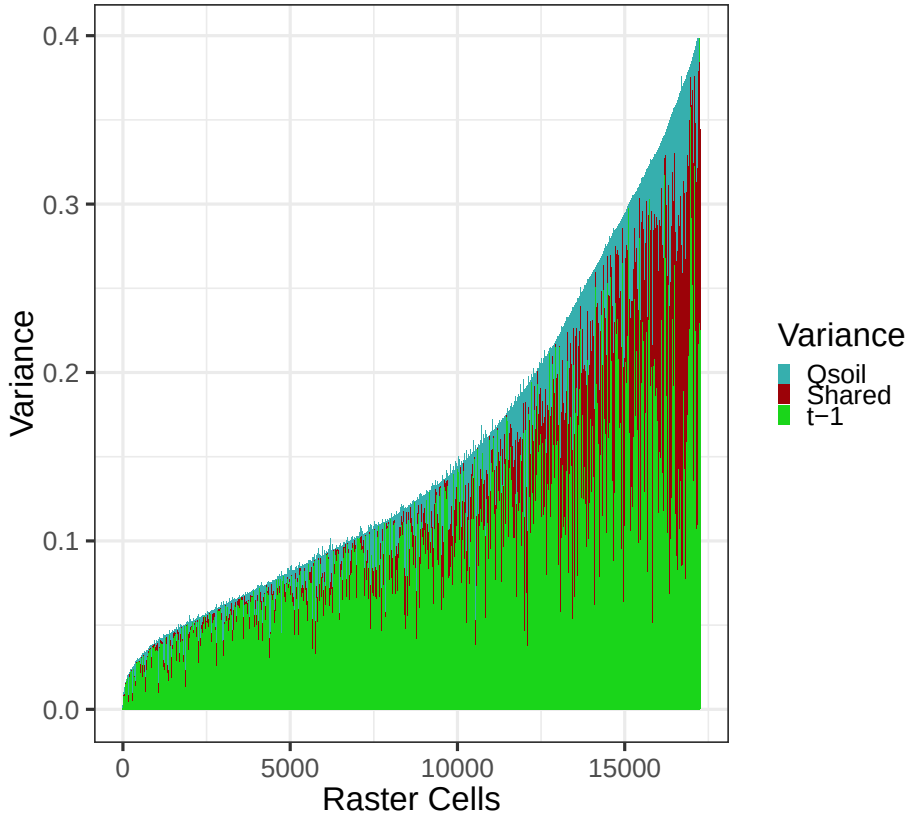

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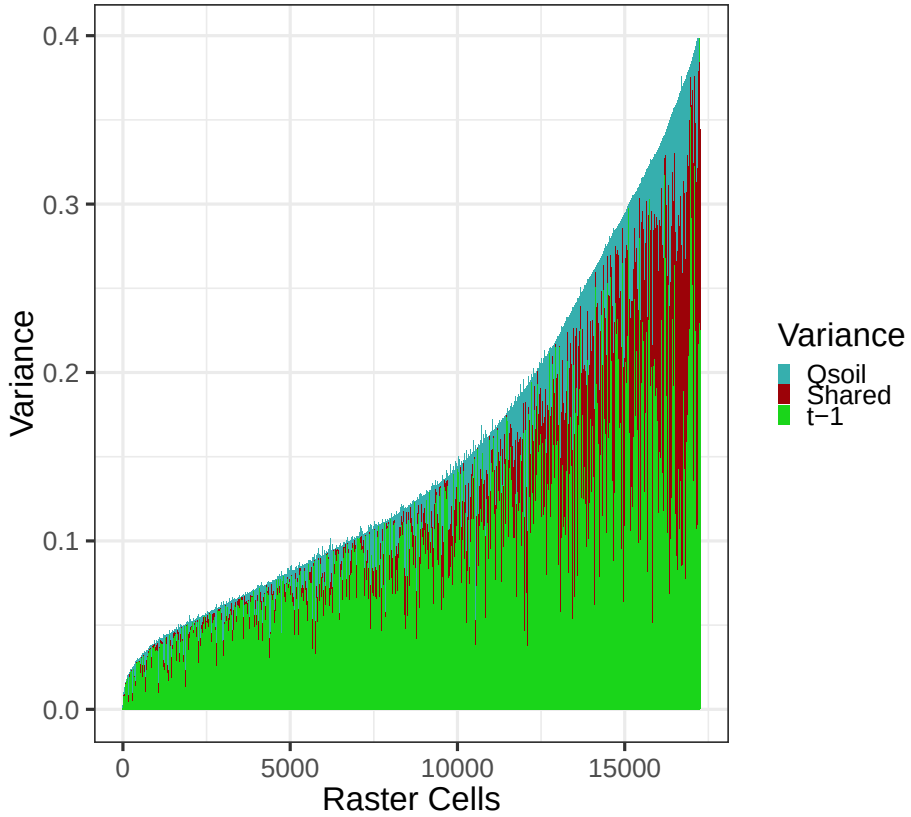

Distinguishing intrinsic and extrinsic memory components remains challenging.

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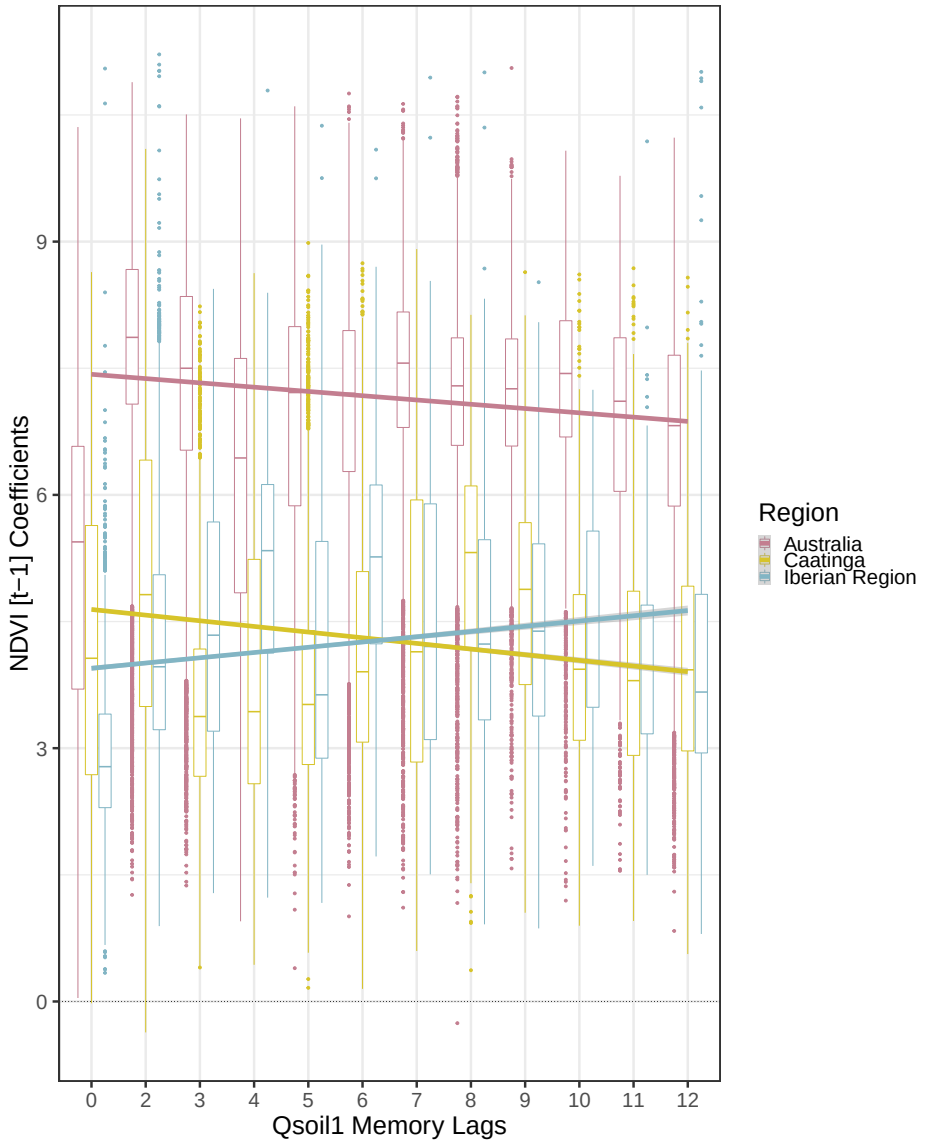
Interplay of memory characteristics is region-specific.



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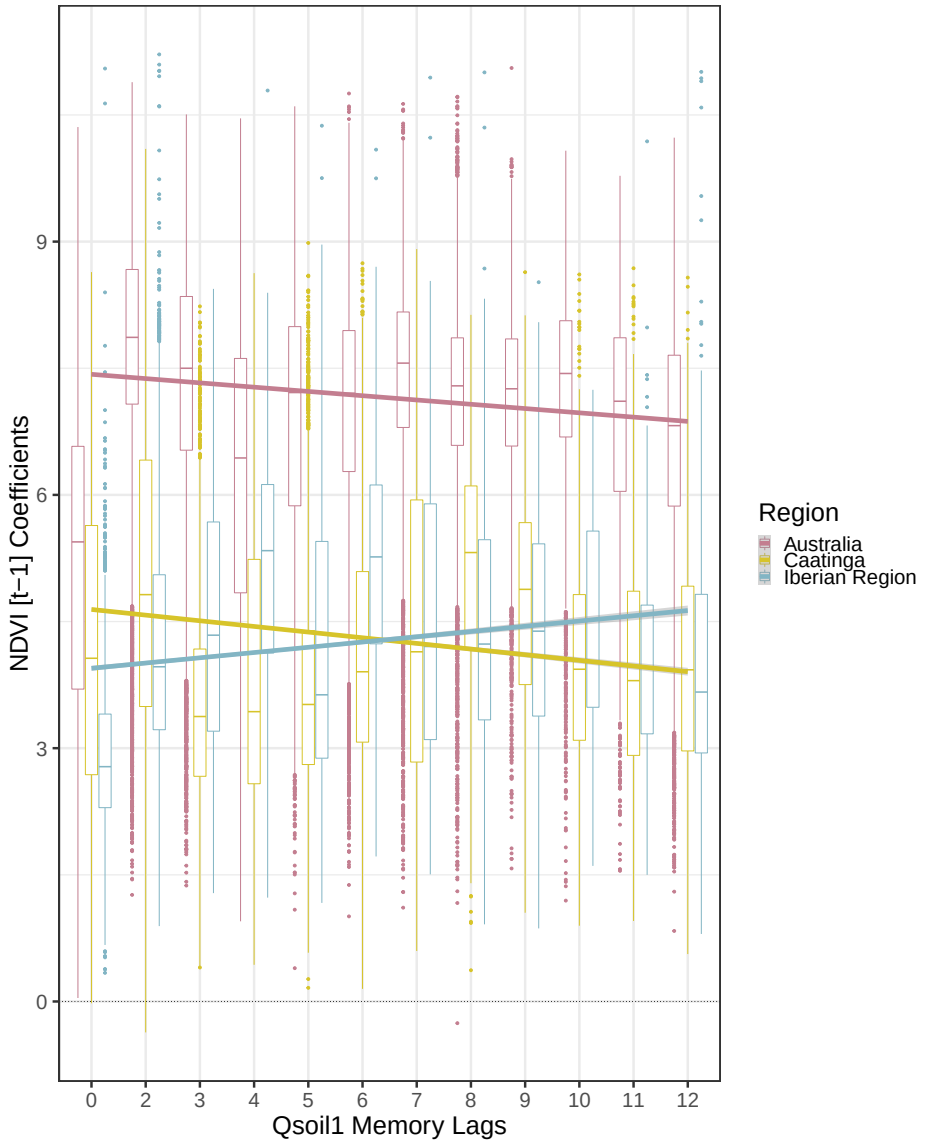
2. **Global generalisations** of **vegetation response to soil moisture aspects not possible**.



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).

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[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).

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[7] Papagiannopoulou, C. *et al.* Vegetation anomalies caused by antecedent precipitation in most of the world. *Environmental Research Letters* **12**, 074016 (2017).