

# Meta-analysis reveals that releasing a Scots pine forest from water stress by irrigation can shift the boundary condition to a new dynamic-equilibrium

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# Dynamic Equilibrium

2<sup>nd</sup> Law of Thermodynamics



Ecology  
(open systems):

Balance in Vegetation Development



Chemistry/Biology  
(close systems):  
Reversible Reactions

(von Bertalanffy 1950, *Science*; Simberloff 1974, *Annual review of Ecology and Systematics*; Payette et al. 1984, *Nature*; Levin 1999, *Conservation Ecology*; Pachepsky et al. 2001, *Nature*; Yu et al. 2015, *Ecology*)

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(open systems):  
Balance in Vegetation Development

Chemistry/Biology  
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**Negative feedback loops maintain the dynamic equilibrium or homeostatic state in a system**

(von Bertalanffy 1950, *Science*; Simberloff 1974, *Annual review of Ecology and Systematics*; Payette et al. 1984, *Nature*; Levin 1999, *Conservation Ecology*; Pachepsky et al. 2001, *Nature*; Yu et al. 2015, *Ecology*)

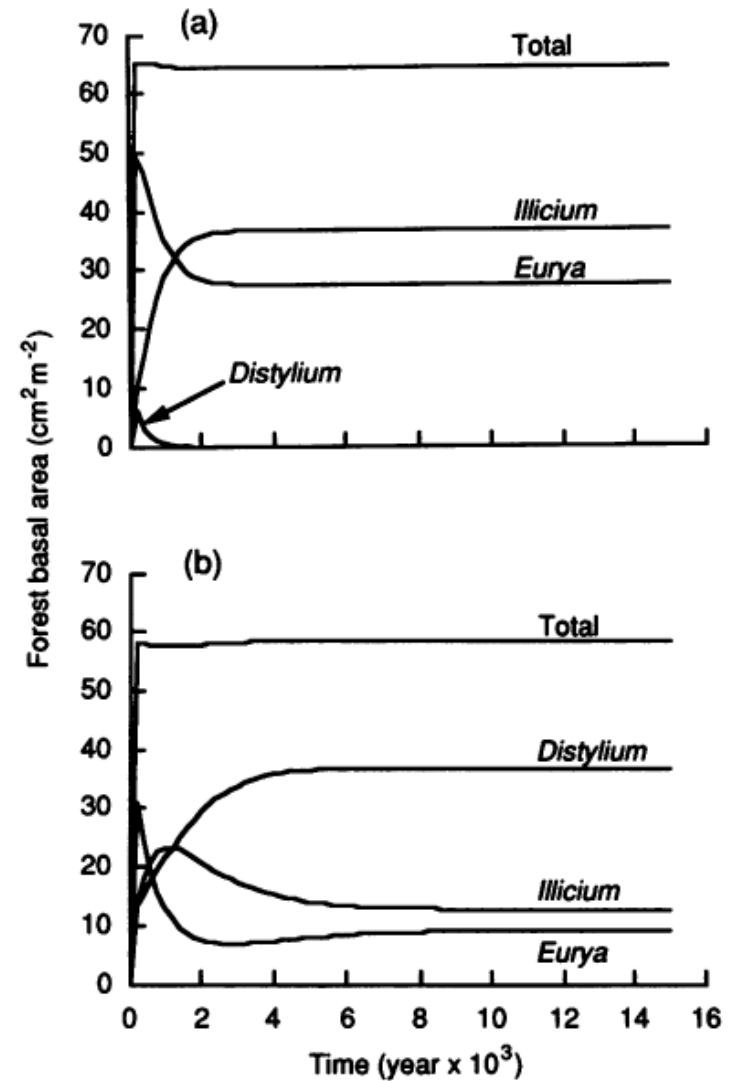
# Dynamic equilibrium in the open ecosystems

- ✓ **Dynamic**, it is constantly adjusting to the changes that it encounters.
- ✓ **Equilibrium**, functions are kept within a normal range



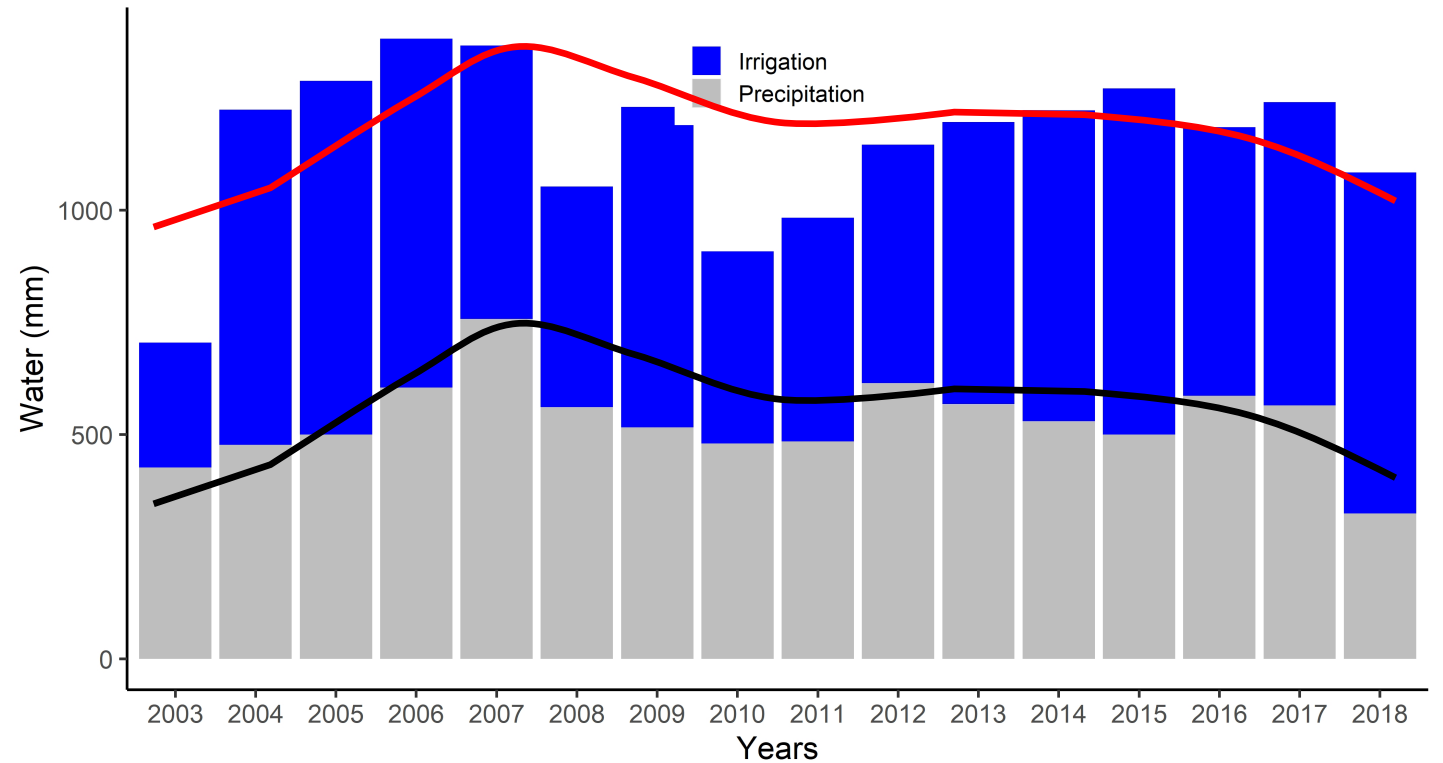
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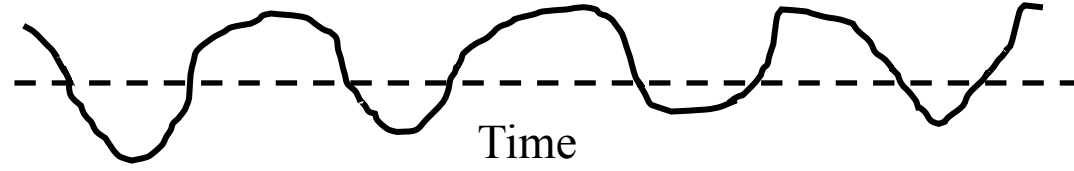


Kohyama 1993, Journal of Ecology

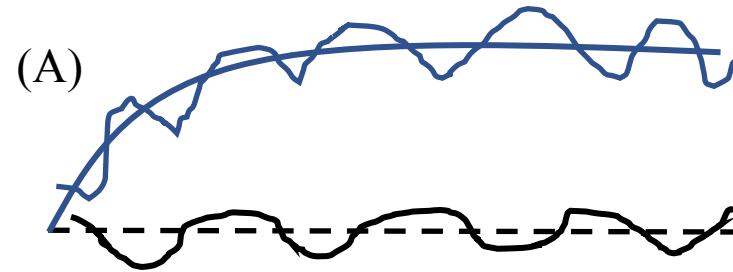
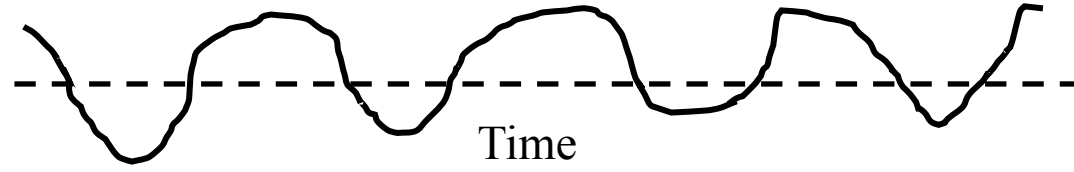
# Scots pine forests of Valais, Switzerland



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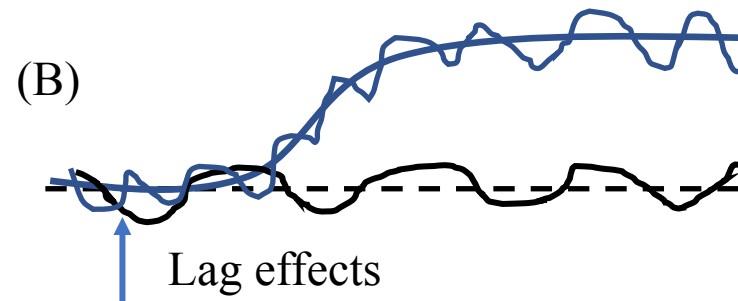
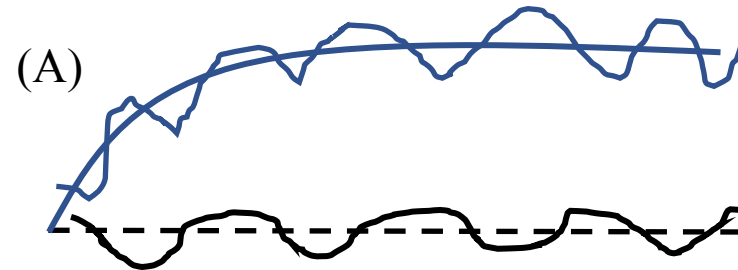
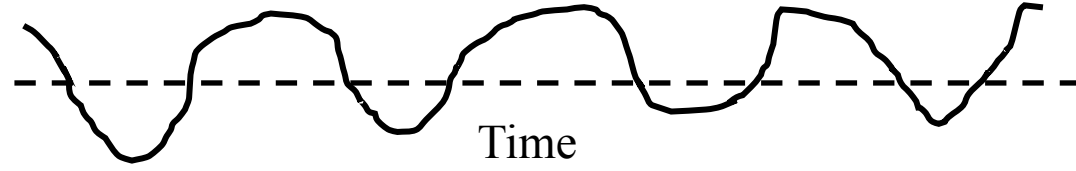


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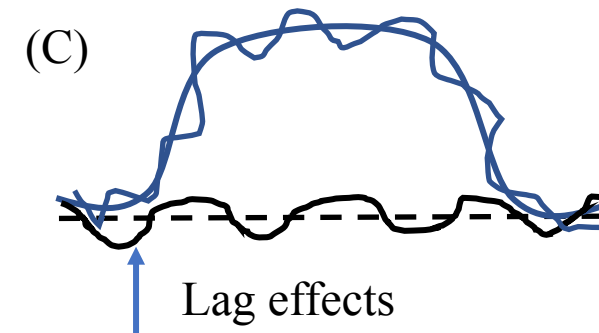
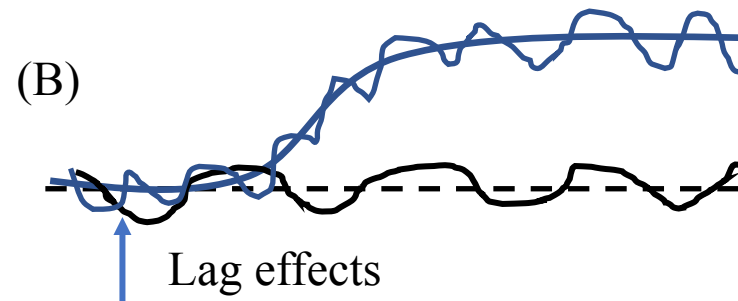
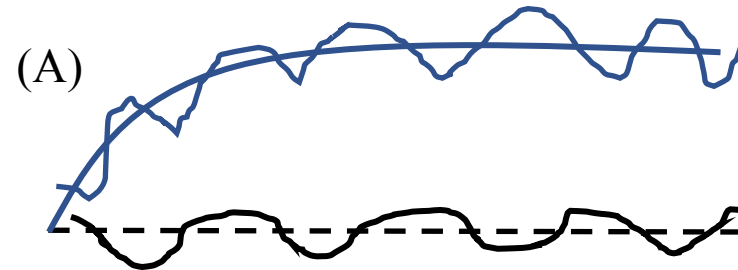
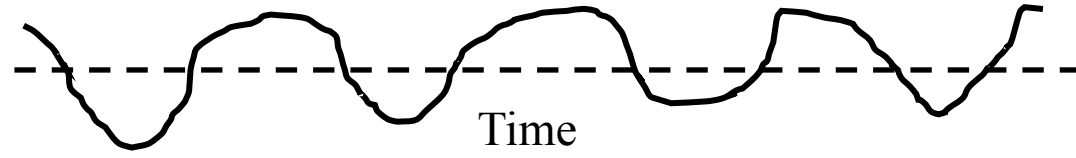




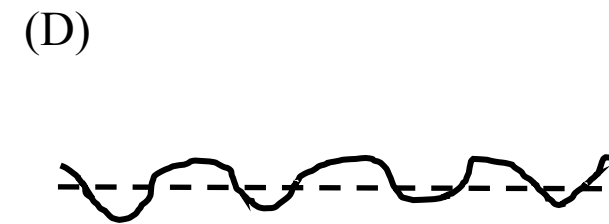
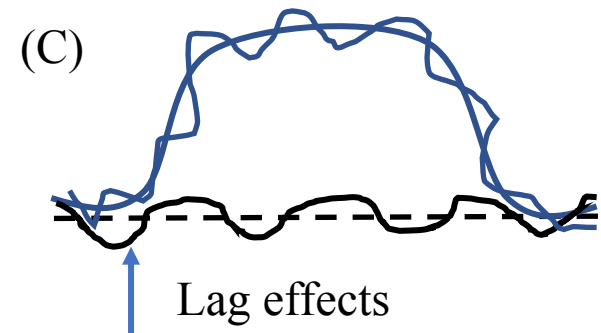
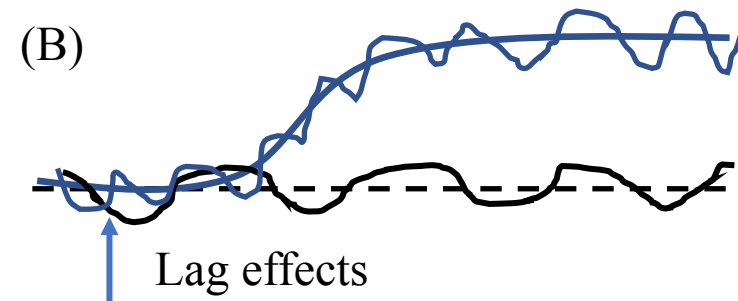
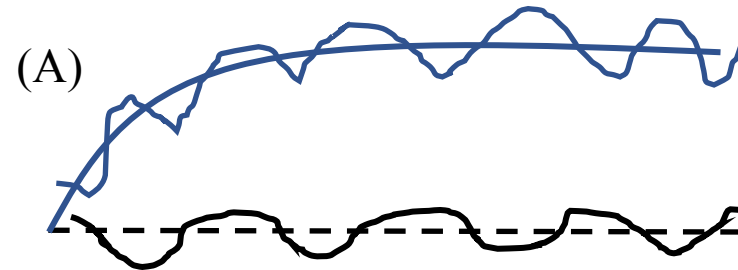
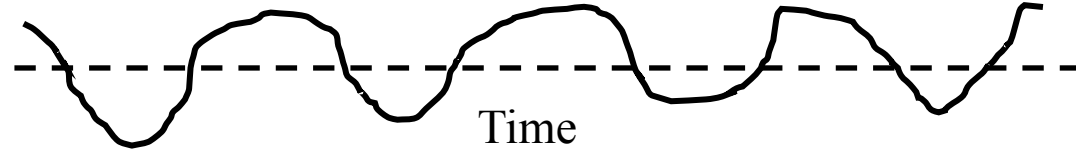
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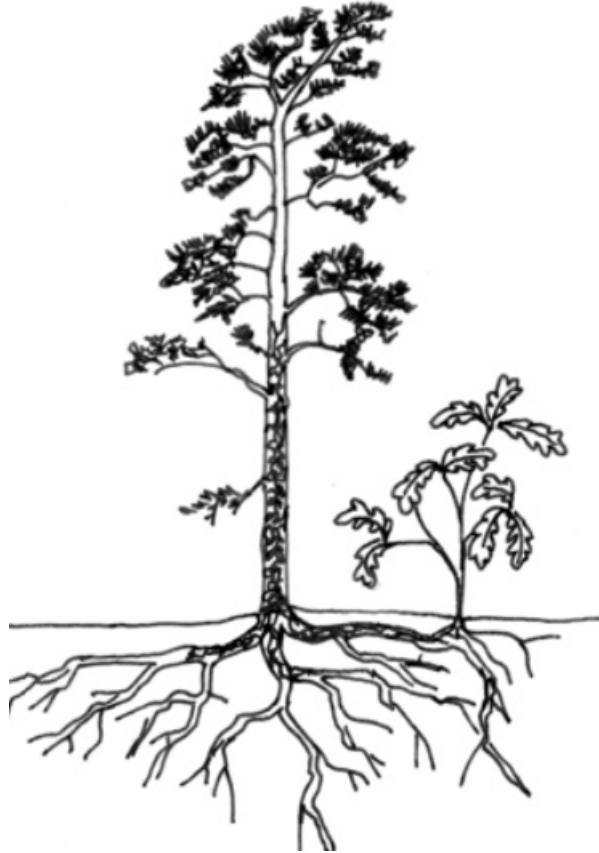


# Observations



## Tree-level

- ✓ Needle length
- ✓ Shoot length
- ✓ Crown transparency
- ✓ Radial growth
- ✓  $\delta^{13}\text{C}$  in tree ring
- ✓ Fine root biomass
- ✓ Tree survival

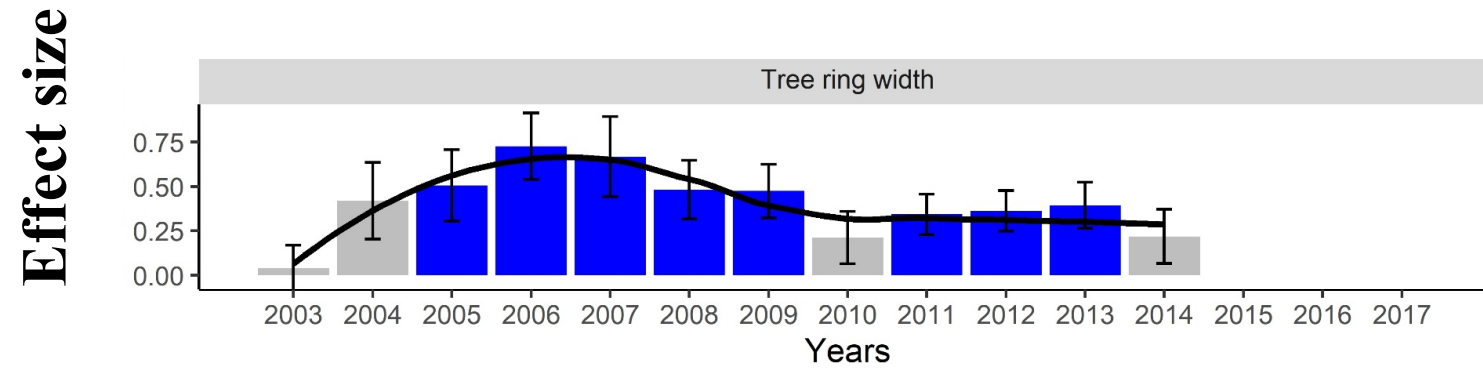


## Ecosystem-level

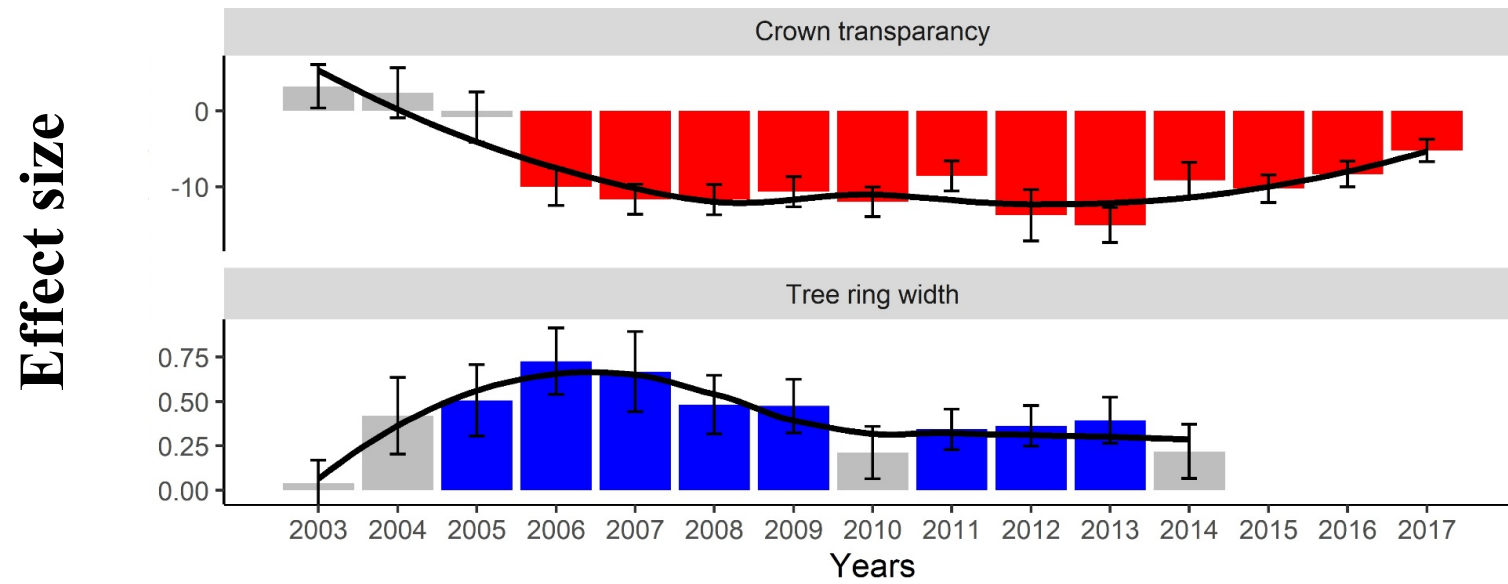
- ✓ Volumetric soil water
- ✓ Tree juvenile abundances
- ✓ Litter decomposition rate
- ✓ *Tomicus* abundances
- ✓ Fungal fruit body abundances



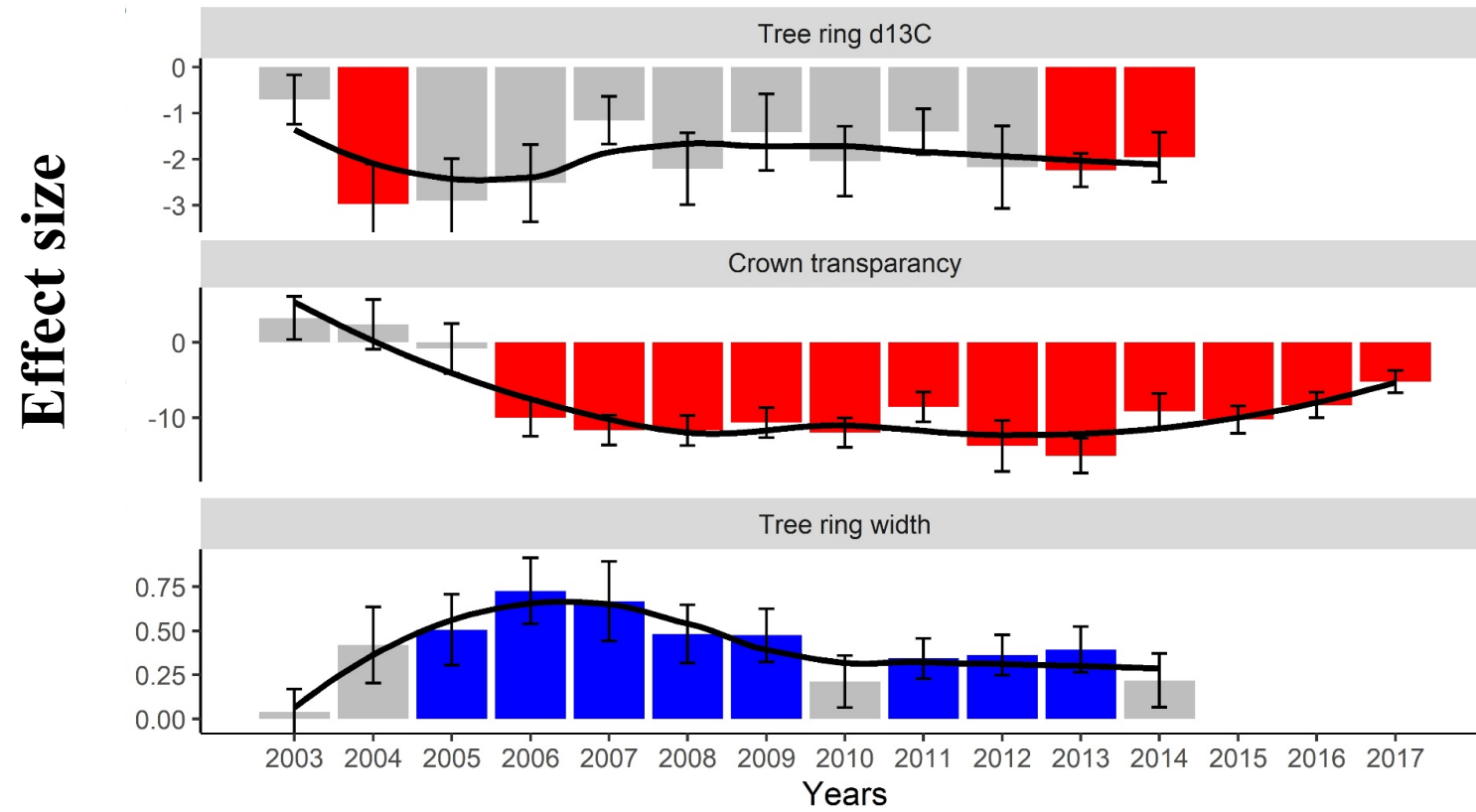
# Results, Tree-level



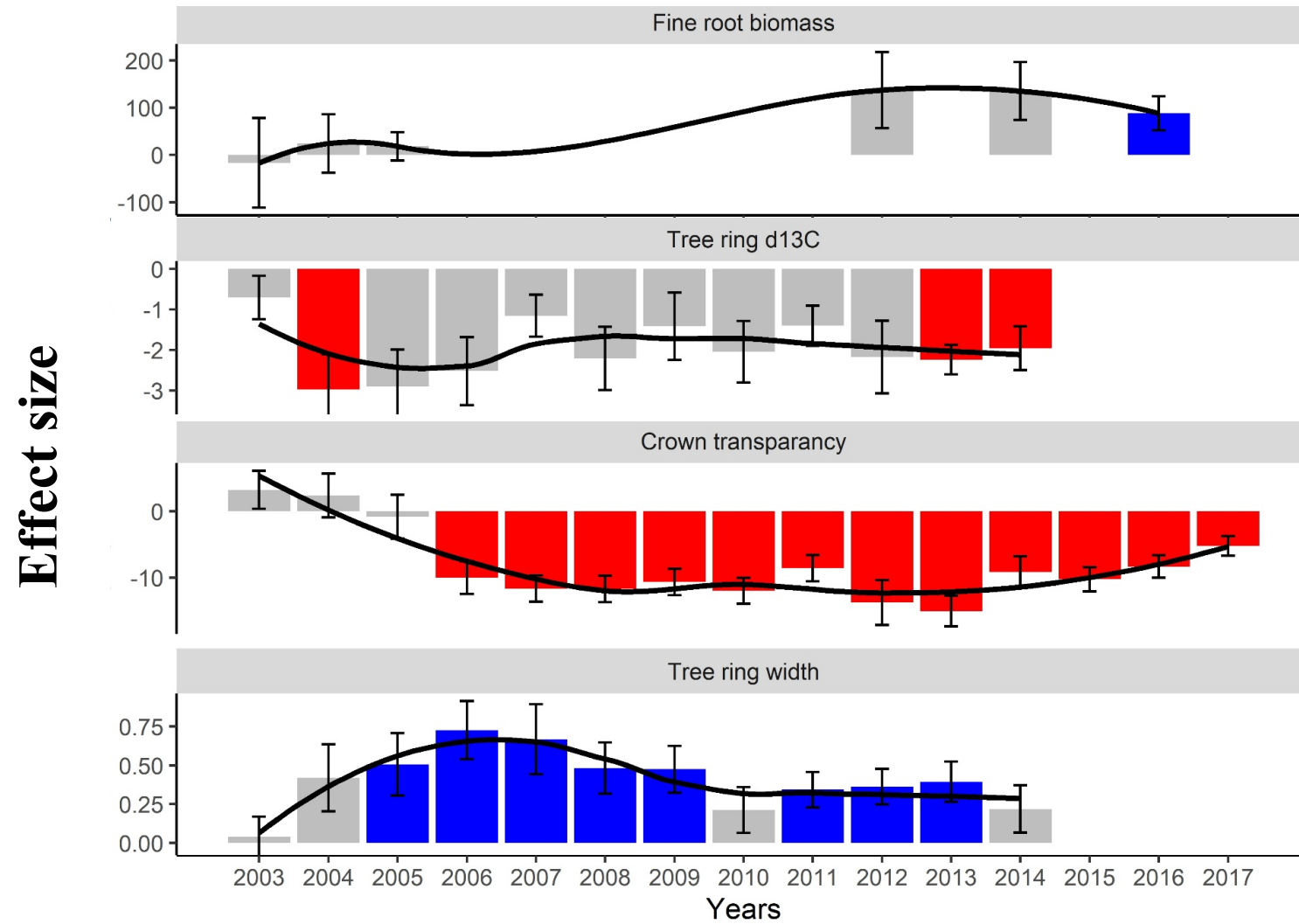
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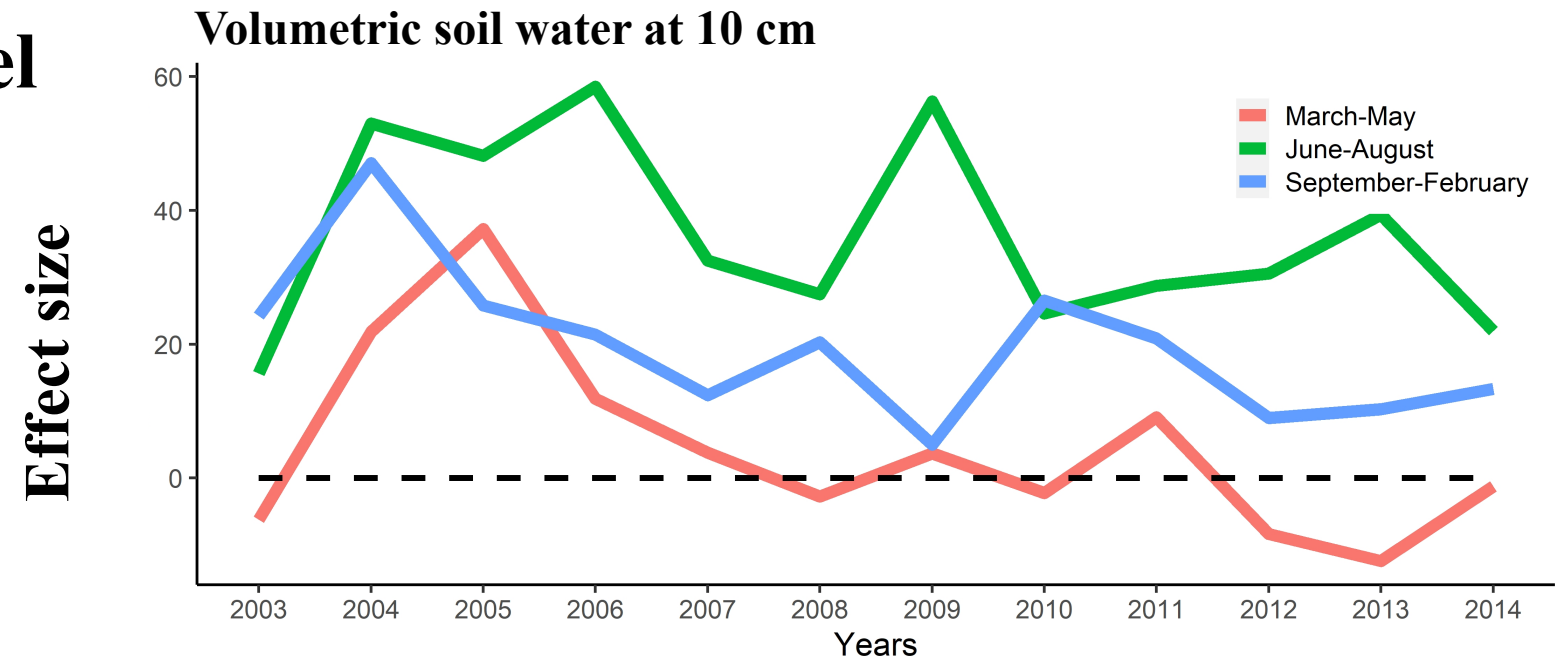
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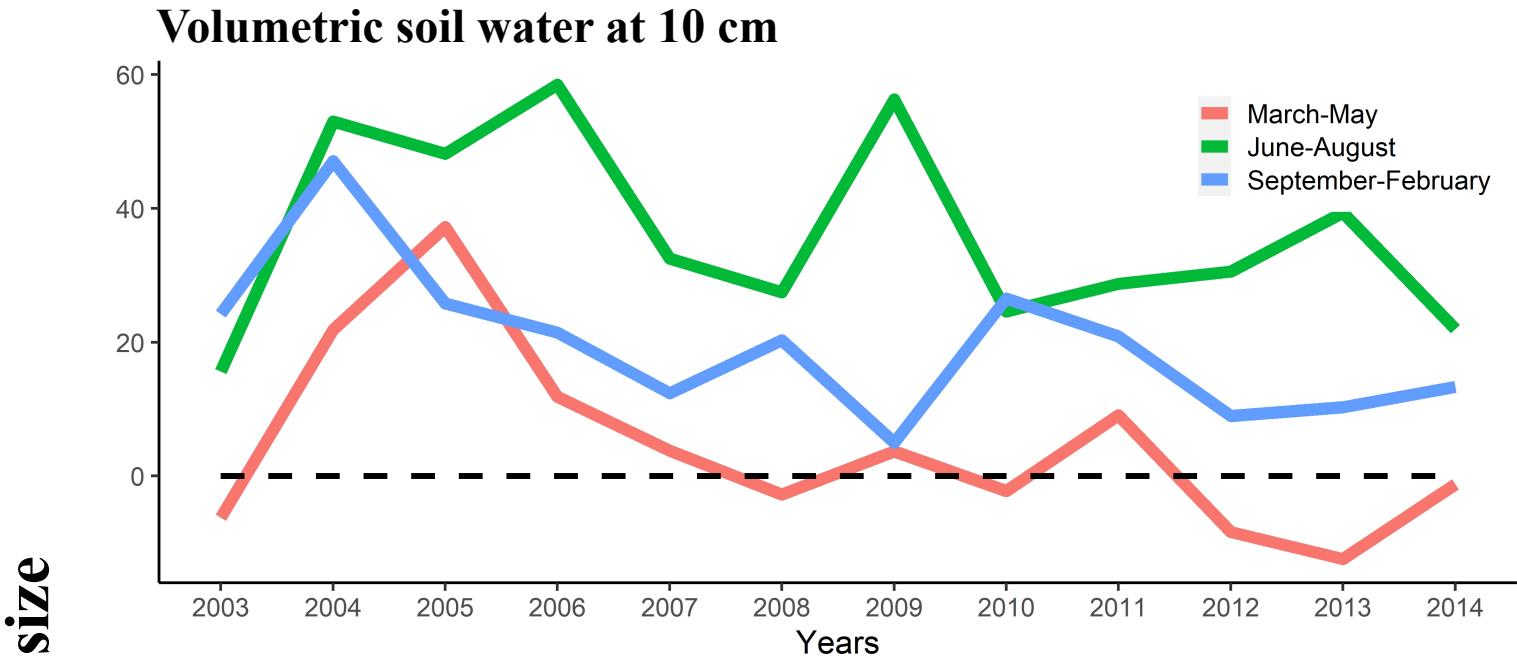
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# Results, Ecosystem-level

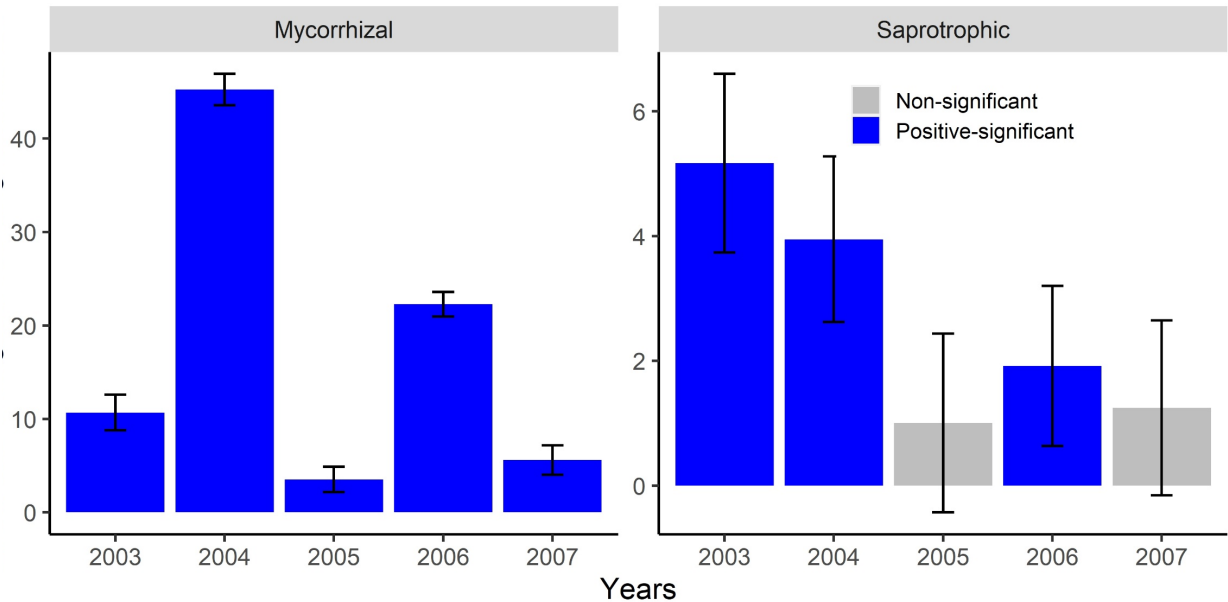


# Results, Ecosystem-level



Effect size

### Fungal fruit body abundances



# Take home:

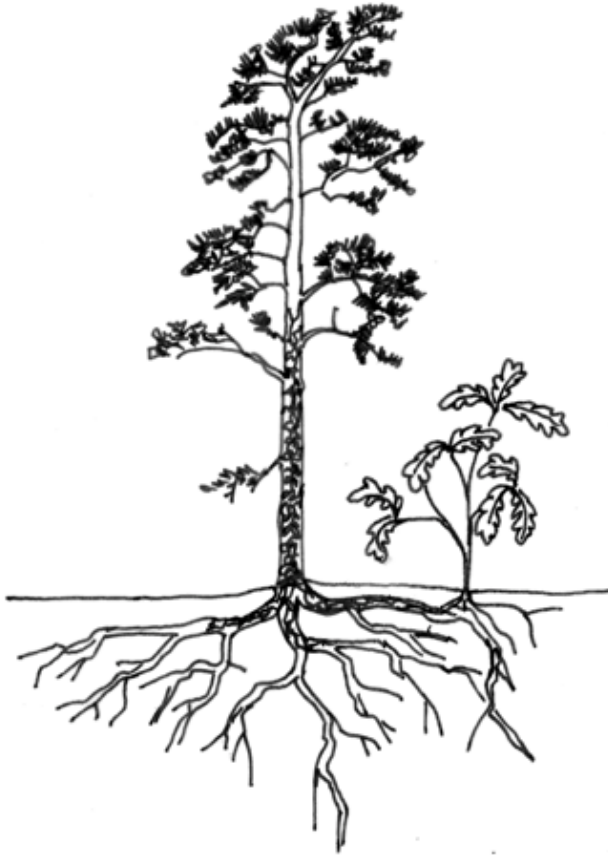
(A)

## Fast responses: 1-5 yrs

- a** Crown transparency<sup>P, T</sup> ↓
- b** *Tomicus* abundance<sup>E, \*</sup> ↓
- c** Needle length<sup>P, T</sup> ↑
- d** Shoot length<sup>P, T</sup> ↑
- e** Radial growth<sup>P, T</sup> ↑
- f** Tree ring  $\delta^{13}C$ <sup>P, T</sup> ↓
- g** NSC insoluble<sup>P, T</sup> ↓
- h** Fungal fruit bodies<sup>E</sup> ↑

## Slow responses: >5 yrs

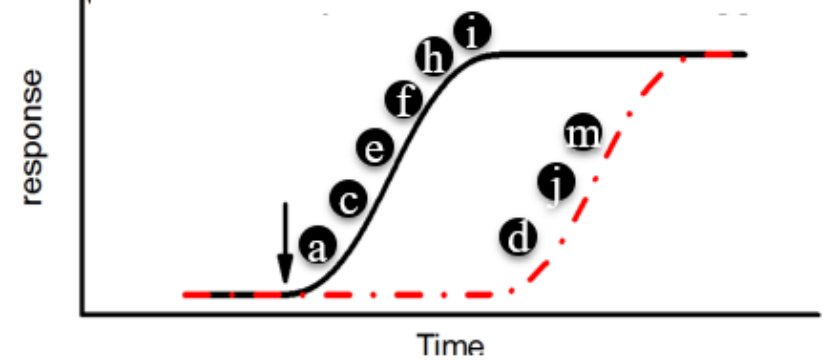
- i** Soil moisture<sup>E</sup> ↑
- j** Tree survival<sup>P, T</sup> ↑
- k** Shrubs & *Quercus*<sup>E, \*</sup> sapling abundance ↑
- l** Litter decomposition<sup>E, \*</sup> ↑
- m** Fine root biomass<sup>P, T</sup> ↑
- n** Soil organic matter (SOM) stocks<sup>E, \*</sup> ↑



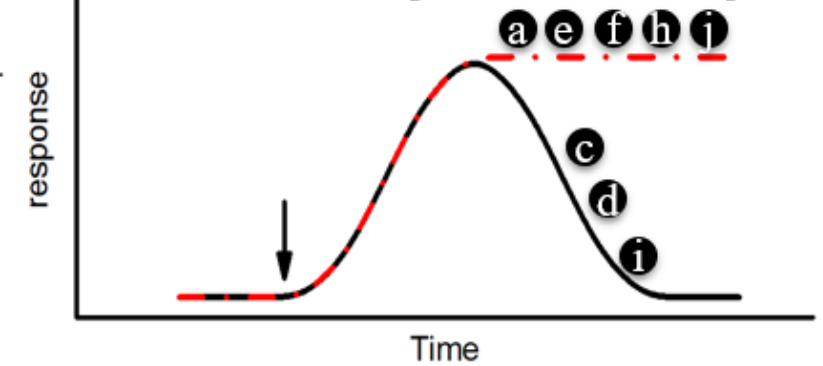
(B)

## Response patterns

Start of the responses: Immediate vs. lagged



Duration of the responses: Transient vs. persisting



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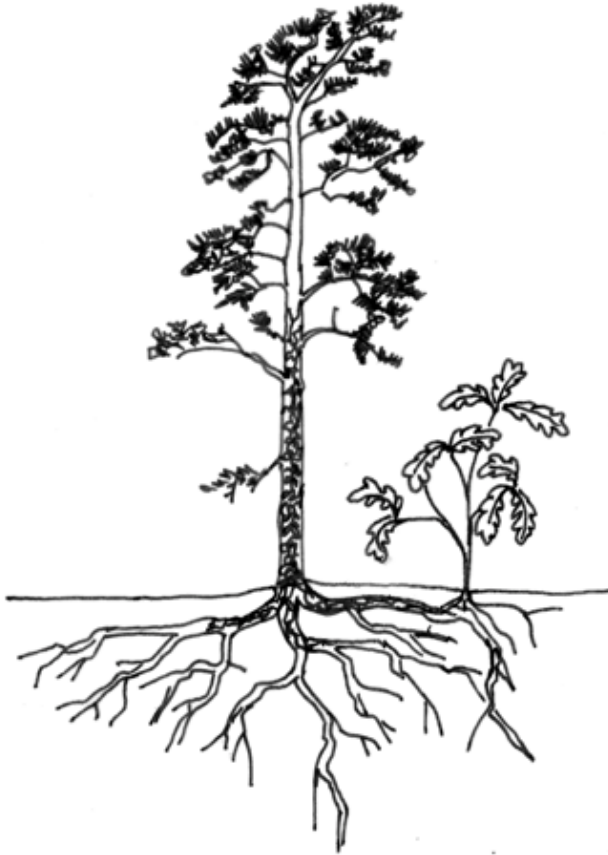
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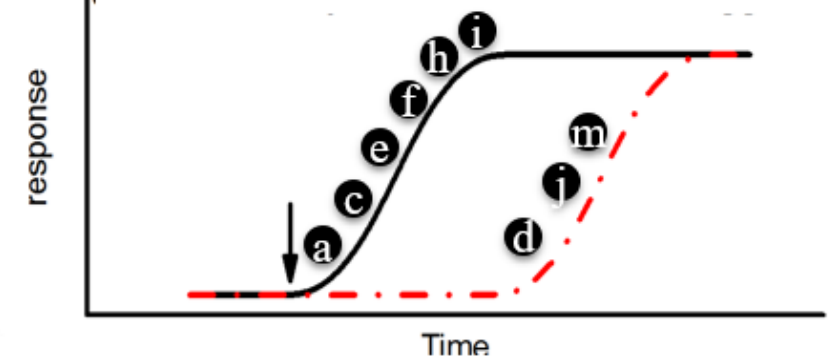
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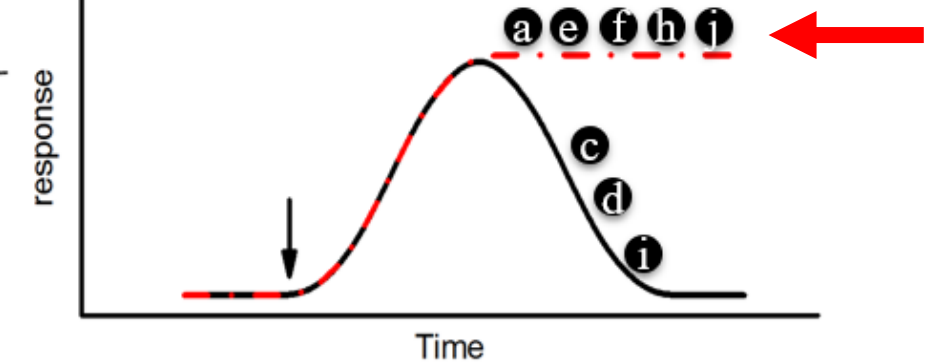
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## Response patterns

Start of the responses: Immediate vs. lagged



Duration of the responses: Transient vs. persisting





## Take home:

- ✓ Tree- and ecosystem-level **responses were pervasive** across a number of traits on long-term temporal scales
- ✓ However, after reaching a peak the magnitude of these responses either decreased or reached to a new **Dynamic Equilibrium**



A scenic view of a mountain range with a prominent snow-capped peak and a valley below. The mountains are covered in green forests, and the sky is clear blue. The text "Thank you very much!" is overlaid in yellow.

**Thank you very much!**

**Acknowledgements:**

The study is dedicated to Matthias Dobbertin, the visionary initiator of this long-term irrigation experiment, who passed away in 2012.

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