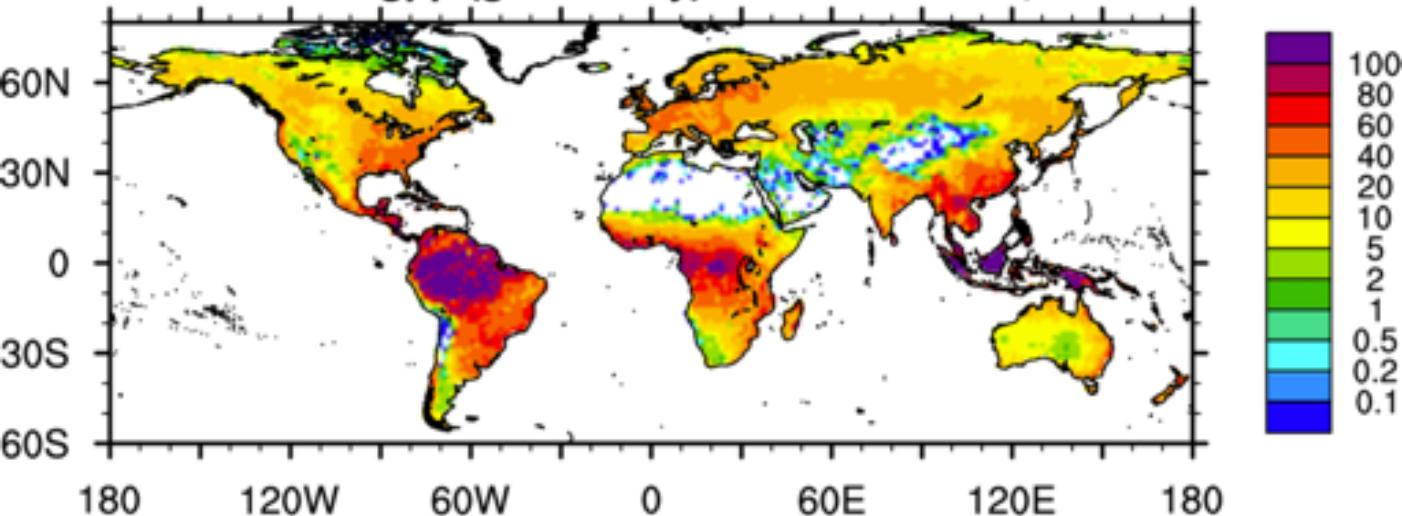


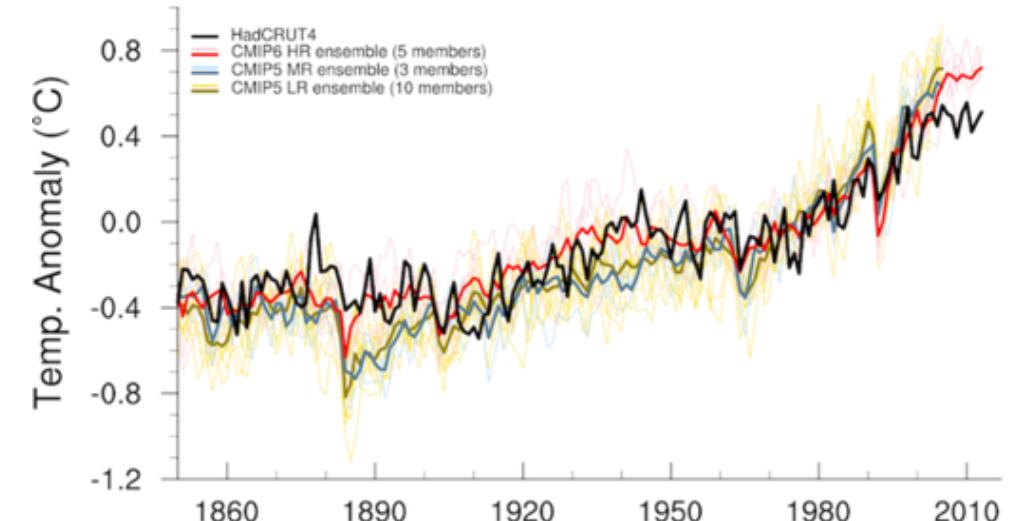
# Space and Time

October 29, 2019

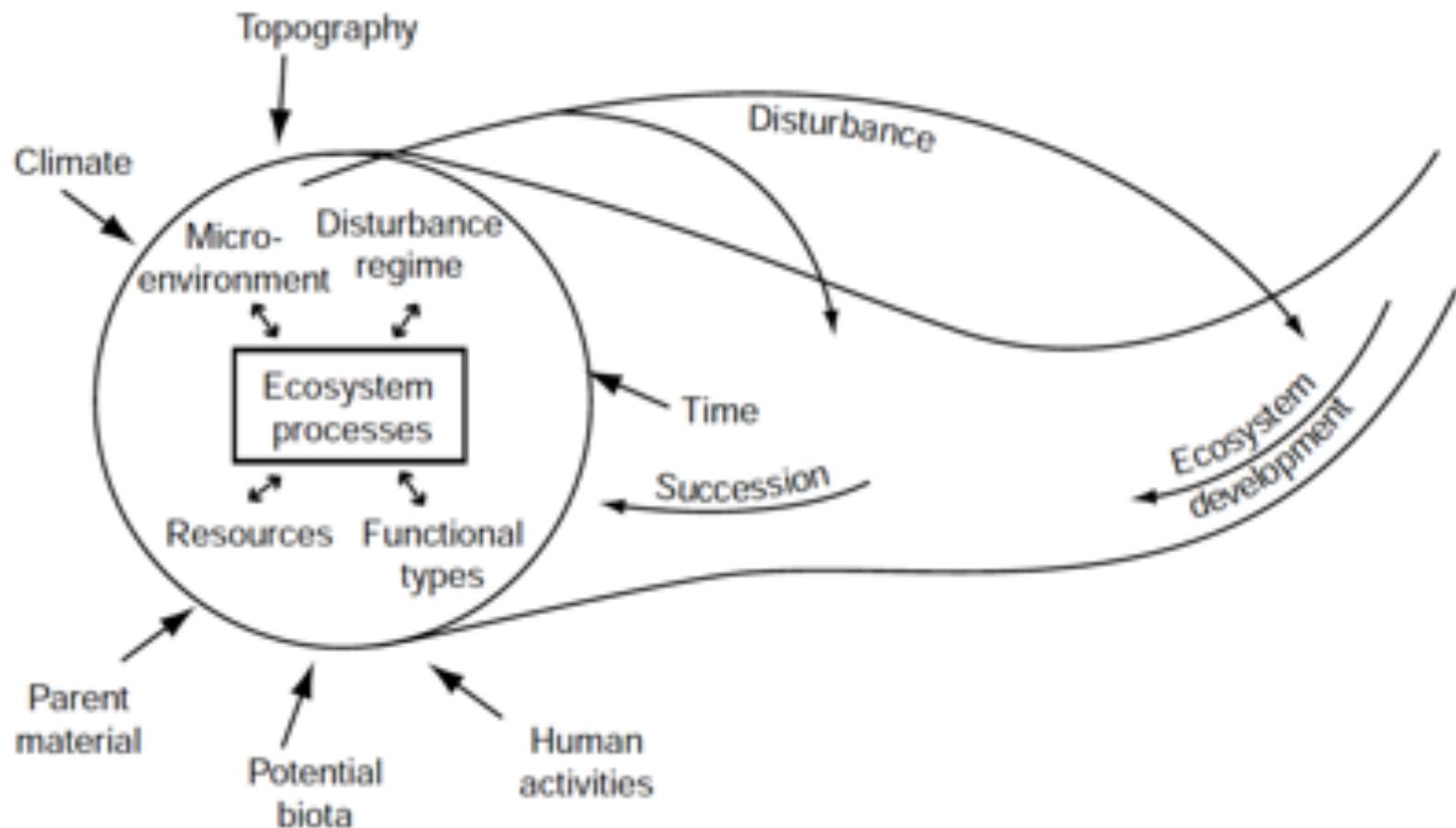
Annual Mean of gpp (gC/m<sup>2</sup>/day): FLUXNET-MTE, 1982-2005



Global Mean Surface Temperature Anomalies  
from 1961-1990 average

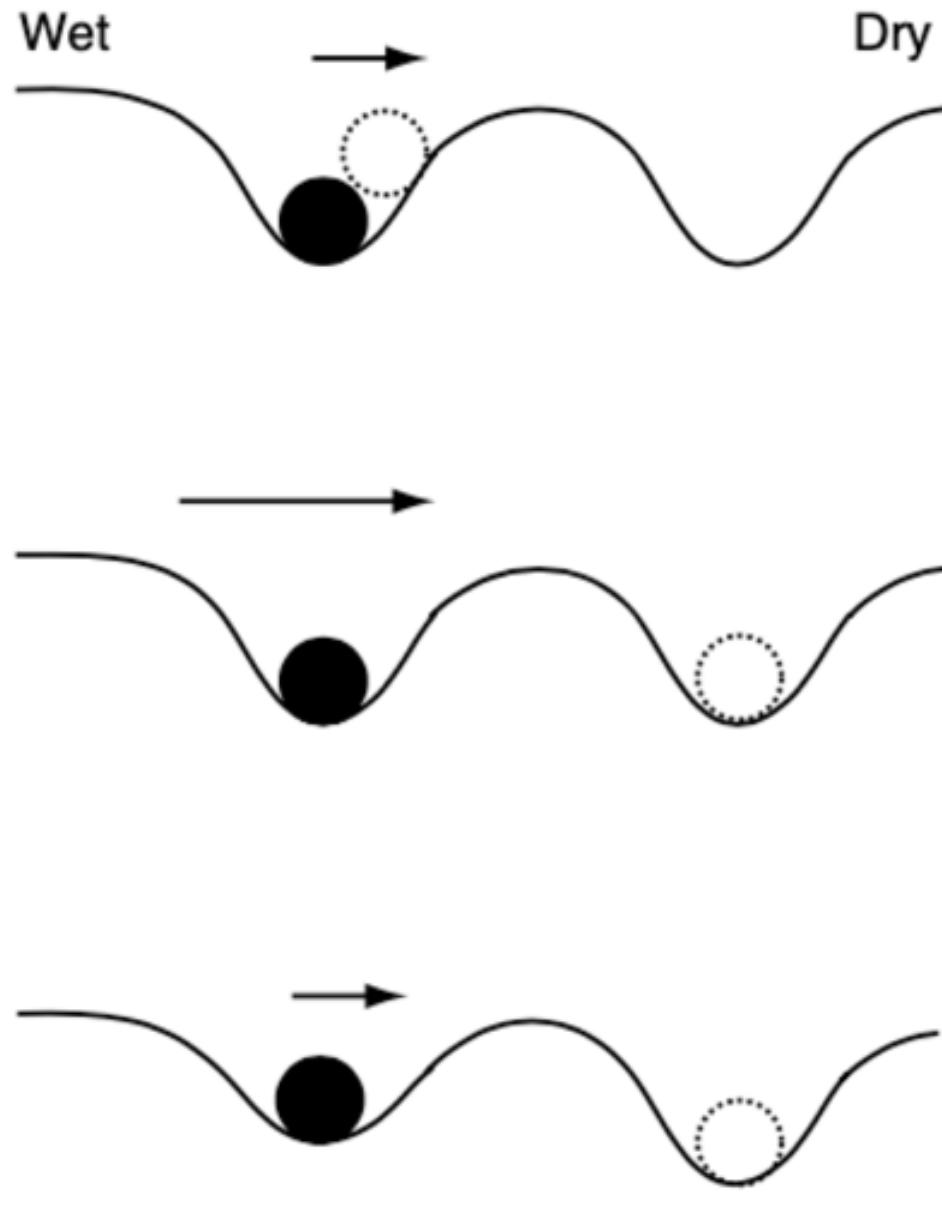


What drives changes in  
ecosystem processes over space  
and time?



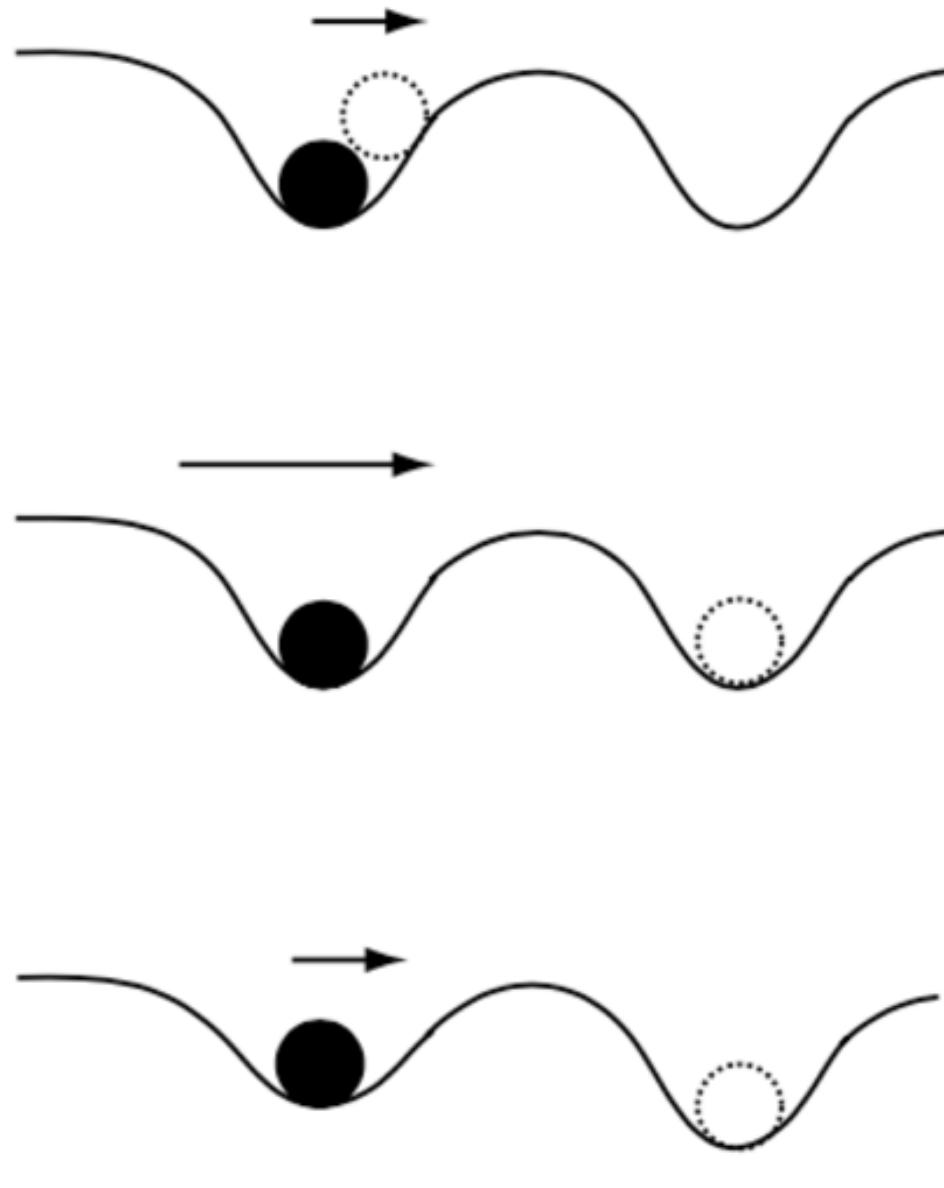
In your book, but modified from Chapin et al. (2006)

# Temporal dynamics: Resilience



Depth of cup defines resilience  
of ecosystem

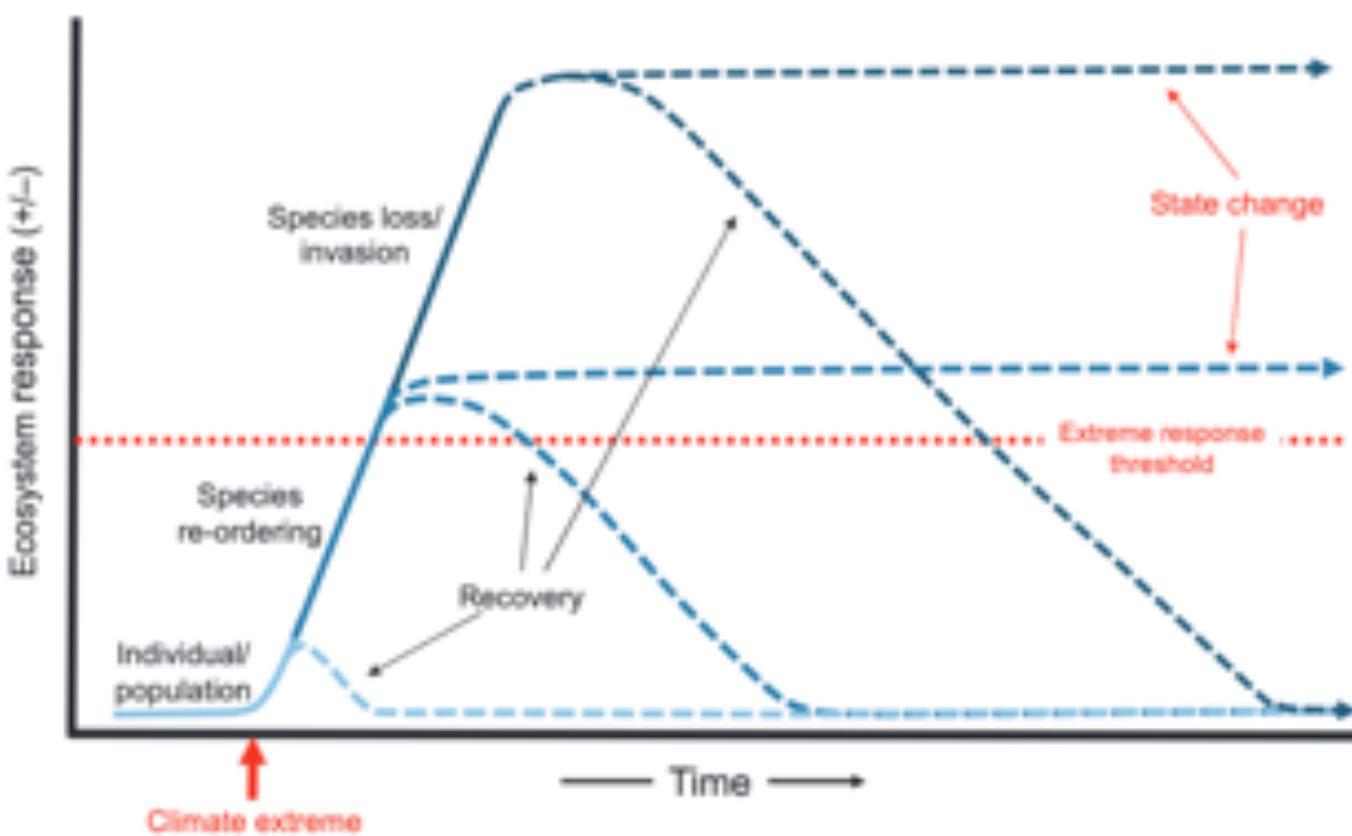
Length of arrow defines the  
strength of disturbance



Resilient, weak disturbance

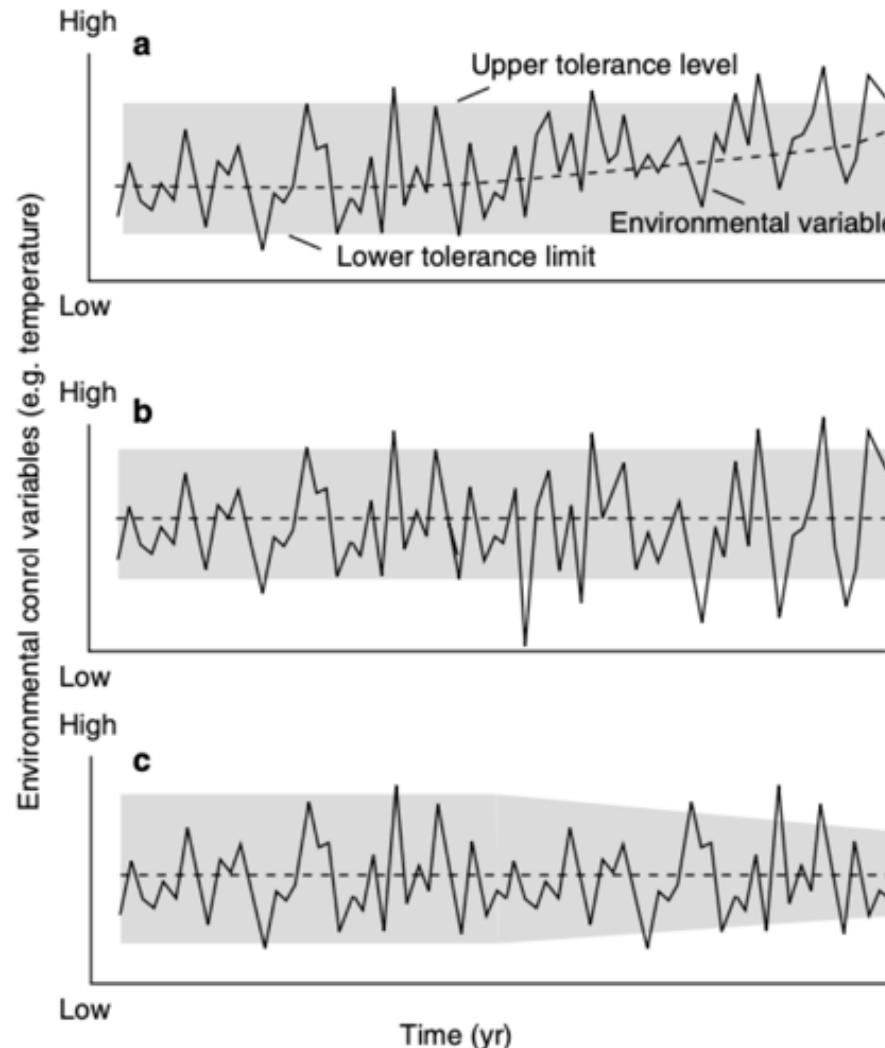
Resilient, strong disturbance

Not resilient, weak disturbance



**Fig. 2.** A mechanistic framework for assessing responses to climate extremes. A period of climate extremity that primarily affects individual-level responses (physiology, growth, fitness) of particular organisms or populations will have a smaller effect (positive or negative) on ecosystem processes (i.e. productivity, nutrient cycling) than one that results in large shifts in species abundances (species re-ordering), or in local extinction of species or invasion by others. An 'extreme climatic event' is an episode or occurrence in which a period of statistical climate extremity alters ecosystem structure and/or function outside the bounds of what is considered typical or normal variability, as a consequence of crossing an extreme response threshold (dotted red line) in which individual-level effects cascade to higher hierarchical levels to result in significant changes in community structure and large ecosystem impacts. These alterations may be characterized by prolonged recovery and/or hysteresis, or may even lead to persistent state changes.

# Range of resilience defines response

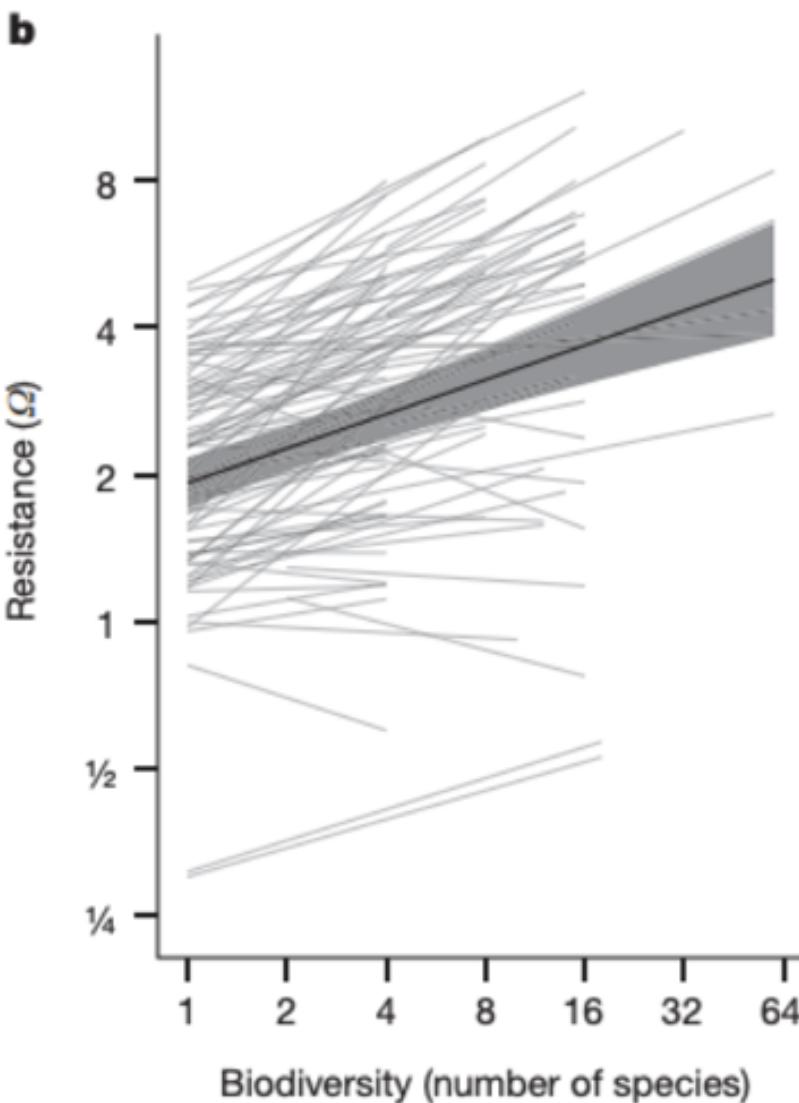


Directional shift in env. = more time outside range

More variable env. = more time outside range

Change in range = more time outside range

# Ecological community defines response



# Temporal dynamics: History

It is important to understand the natural trajectory of a system to fully understand impact of a change

It is important to understand the natural trajectory  
of a system to fully understand impact of a change

# Journal of Applied Ecology

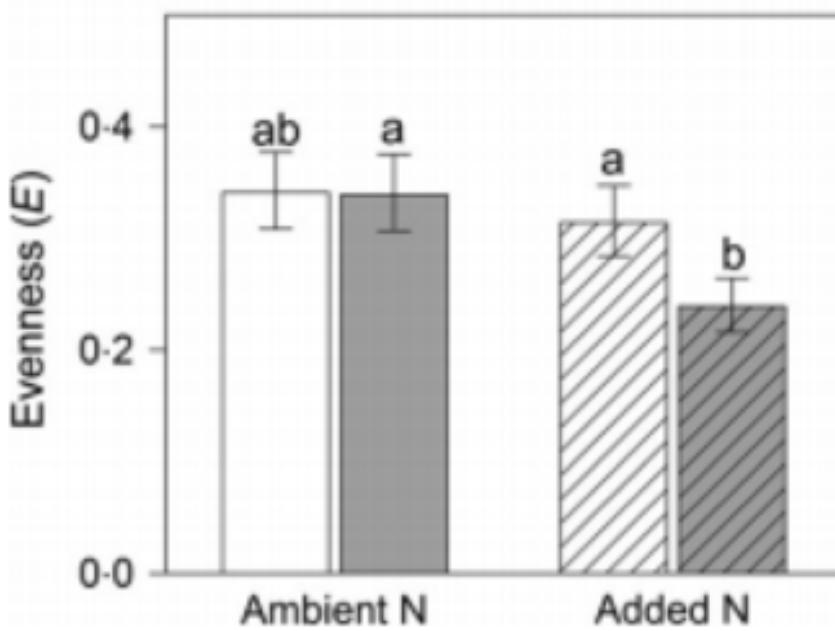
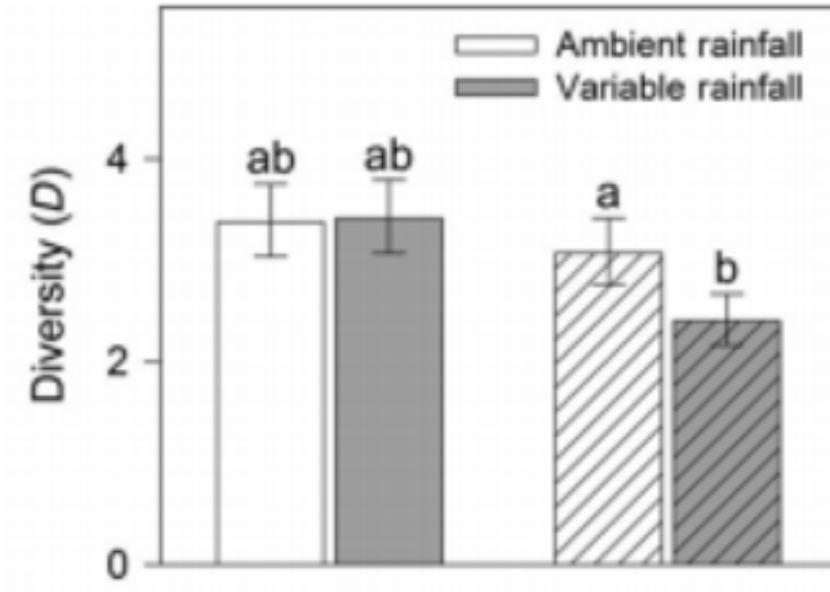


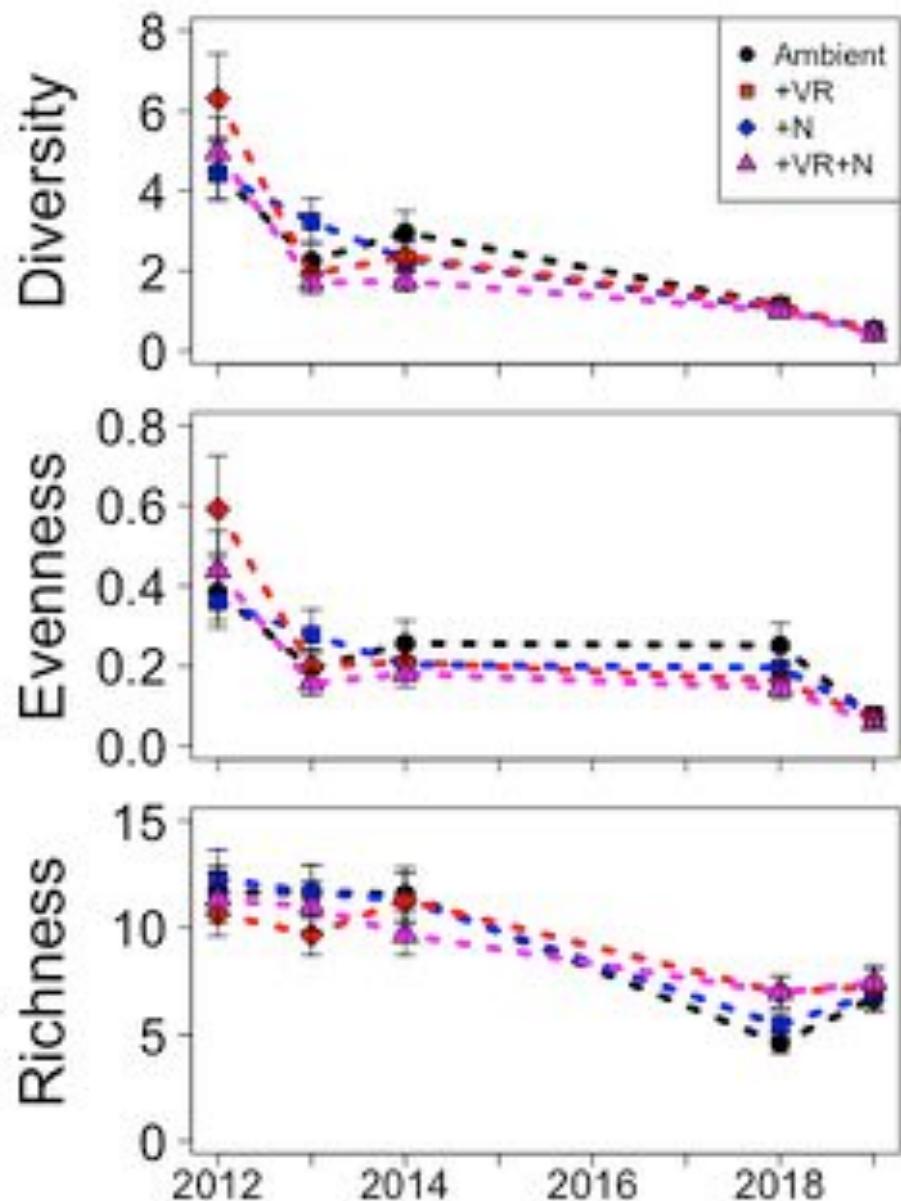
*Journal of Applied Ecology* 2016, 53, 579–586

doi: 10.1111/1365-2664.12593

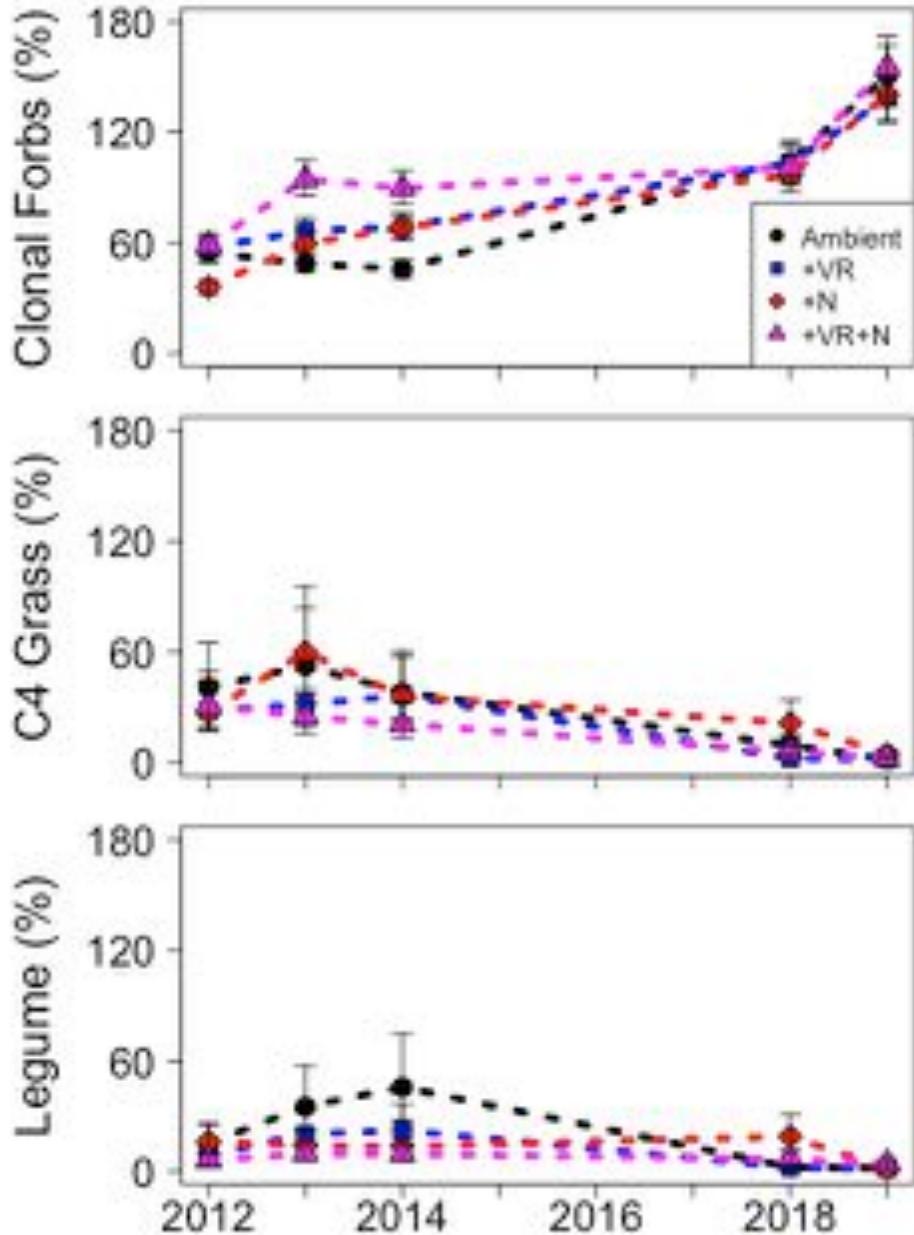
## Rainfall variability and nitrogen addition synergistically reduce plant diversity in a restored tallgrass prairie

Nicholas G. Smith<sup>1,2\*†</sup>, Michael J. Schuster<sup>3†</sup> and Jeffrey S. Dukes<sup>1,2,3</sup>





Treatments initially decreased diversity, but whole system was headed in that direction



Treatments initially decreased diversity, but whole system was headed in that direction

## PRIMARY RESEARCH ARTICLE

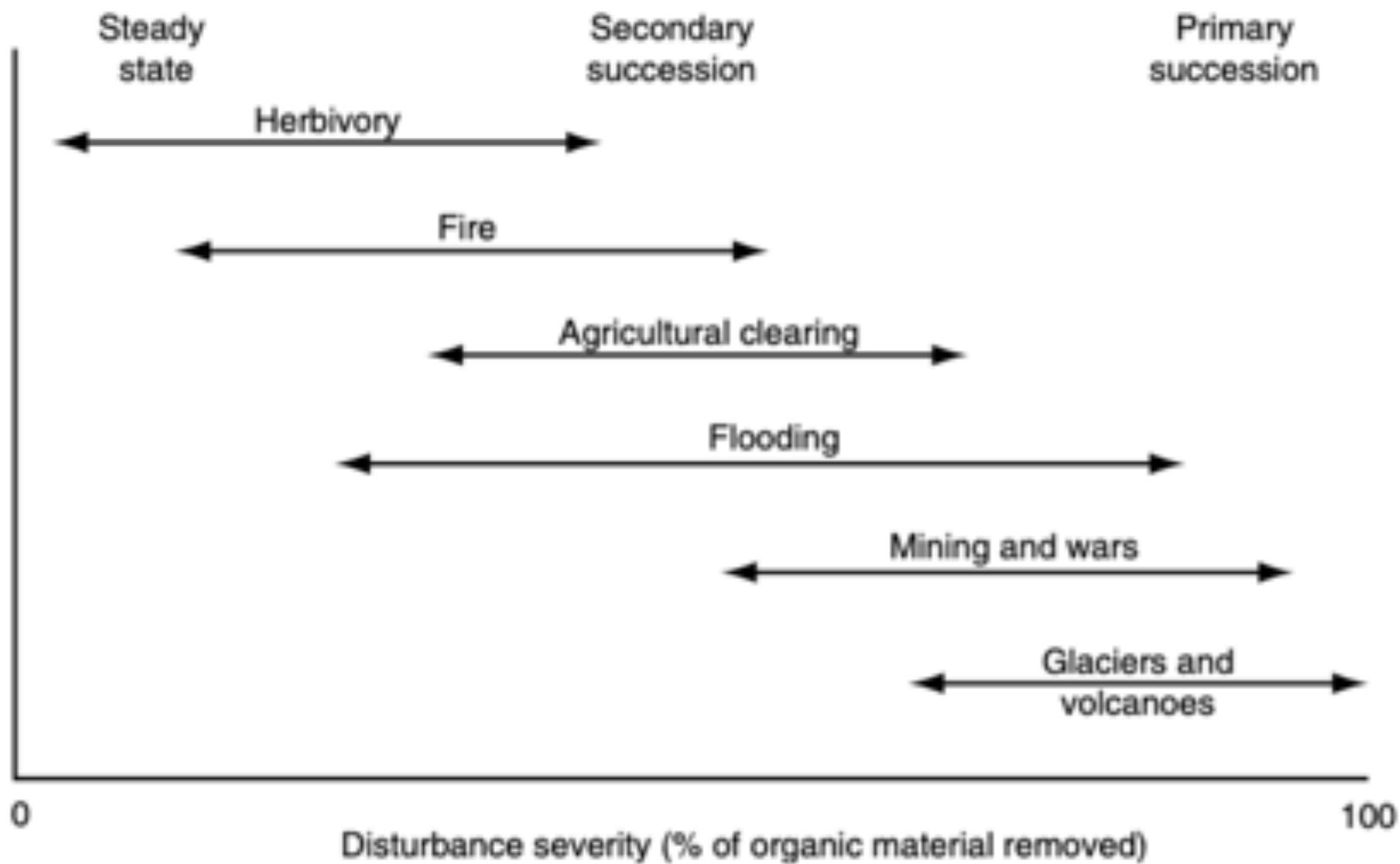
# Ambient changes exceed treatment effects on plant species abundance in global change experiments

J. Adam Langley<sup>1</sup>  | Samantha K. Chapman<sup>1</sup> | Kimberly J. La Pierre<sup>2,\*</sup>  | Meghan Avolio<sup>3,\*</sup> | William D. Bowman<sup>4</sup> | David S. Johnson<sup>5</sup> | Forest Isbell<sup>6</sup> | Kevin R. Wilcox<sup>7</sup>  | Bryan L. Foster<sup>8</sup> | Mark J. Hovenden<sup>9</sup>  | Alan K. Knapp<sup>10</sup> | Sally E. Koerner<sup>11</sup> | Christopher J. Lortie<sup>12</sup> | James P. Megonigal<sup>2</sup> | Paul C. D. Newton<sup>13</sup>  | Peter B. Reich<sup>14,15</sup> | Melinda D. Smith<sup>10</sup> | Kenwyn B. Suttle<sup>16</sup> | David Tilman<sup>6</sup>

# Temporal dynamics: Disturbance

A photograph of a forest fire. The sky is filled with thick, billowing smoke and fire. In the foreground, several tall evergreen trees stand silhouetted against the intense orange and yellow flames. The fire appears to be moving through the forest, with bright spots of light and smoke visible.

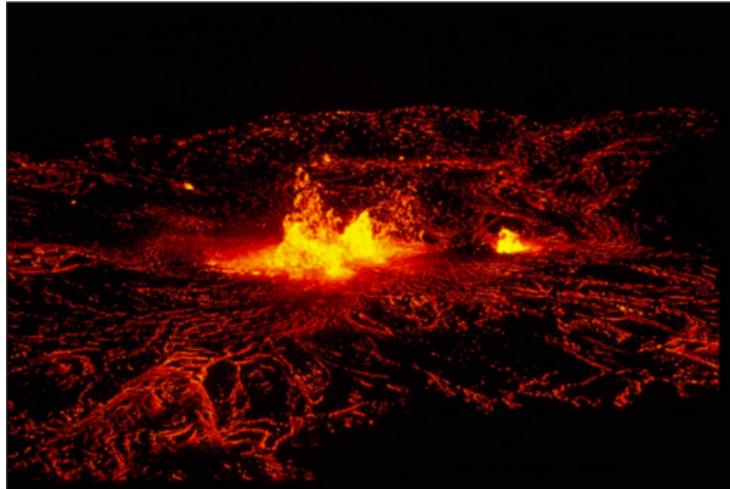
Is disturbance bad  
for ecosystems?



**Fig. 12.7** Spectrum of disturbance severity associated with major types of disturbance, ranging from normal steady-state functioning of ecosystems to primary succession

# Types of succession

- Primary
  - All organic matter is removed
  - Very little starting material
  - E.g., volcano, glacier
- Secondary
  - Some organic matter remains
  - Some starting material
  - Happening all the time
  - E.g., fire, herbivory



# An ecosystem's disturbance regime

- Type of disturbance
  - What happens?
- Severity of disturbance
  - How much change does it cause?
- Frequency of disturbance
  - How often does it happen?

# Global change is impacting disturbance regimes

## October heat wave breaks records, closes schools

The scorching heat is expected to continue Wednesday with temperatures from the South to the Mid-Atlantic forecast to be 10 to 20 degrees above average.

NBC (10/02/19)

## California wildfires trigger statewide emergency and force nearly 200,000 people to evacuate

The Kincade fire in Sonoma County and the Tick fire in Los Angeles County had burned about 35,000 acres.

NBC (10/27/19)

AP/CBS

## 2011 was Texas' driest year on record

JANUARY 7, 2012 / 9:34 AM / AP

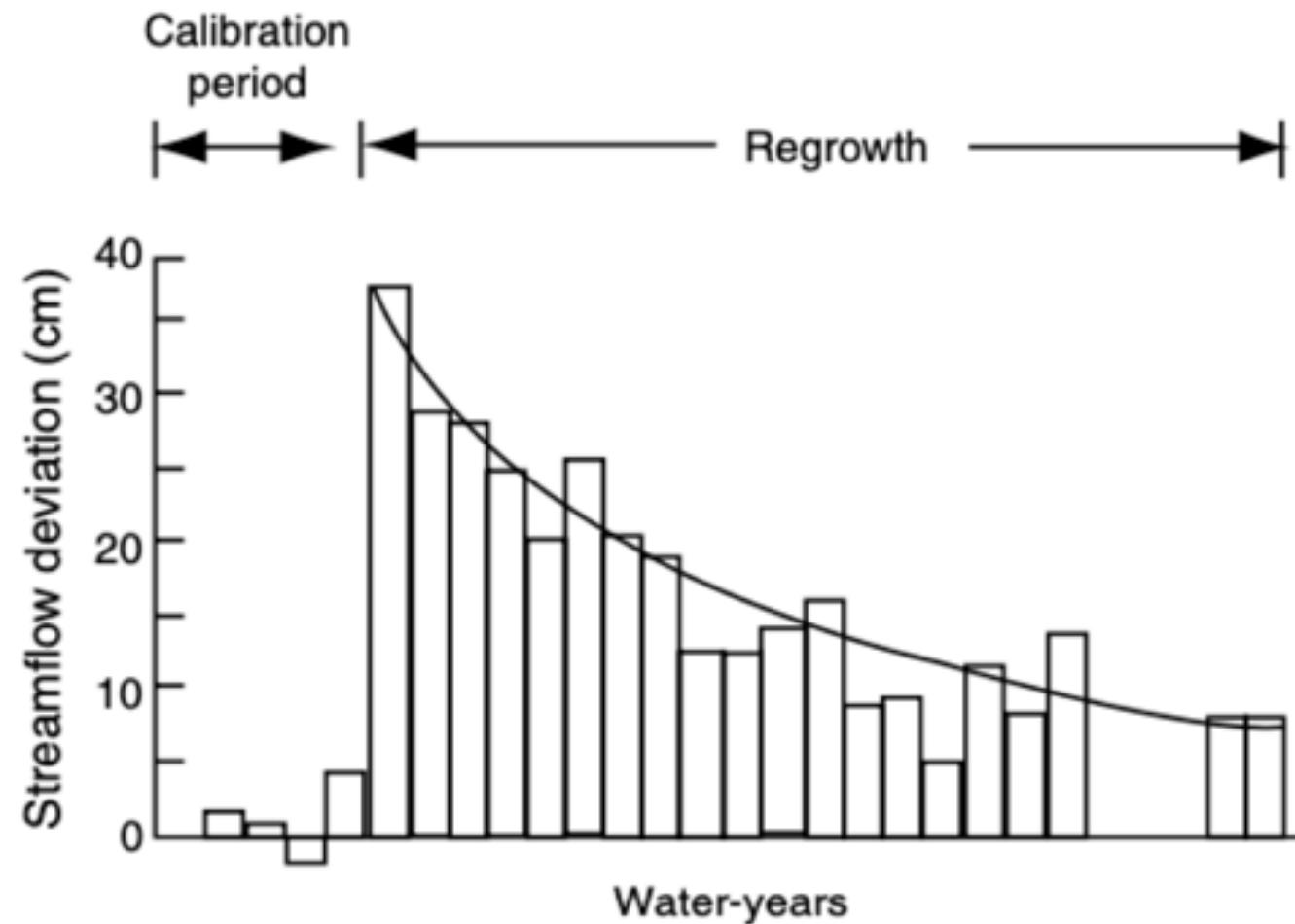


## Puerto Rico battered by Hurricane Maria: 'Devastation - it's everywhere'

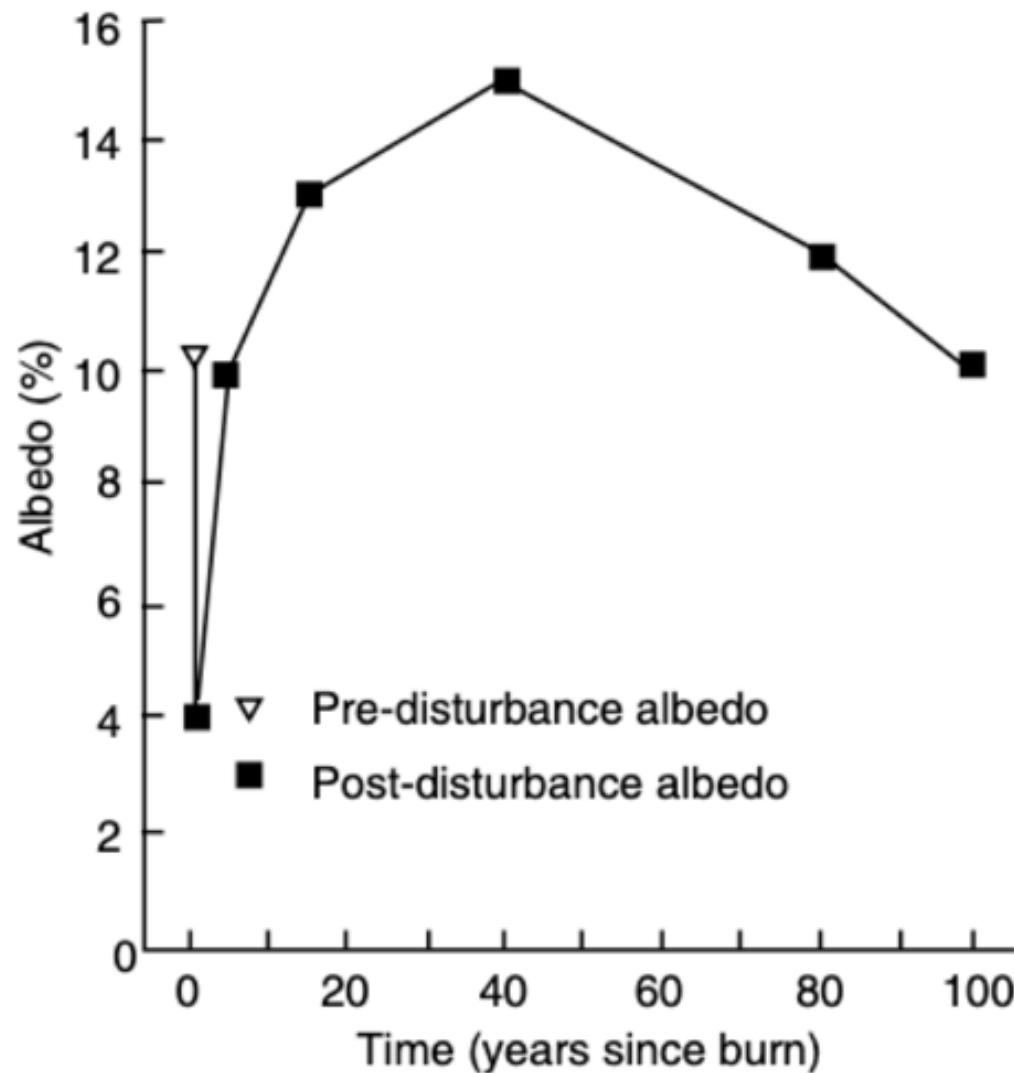
- Worst storm to hit Puerto Rico in 80 years felled trees and smashed buildings
- Governor's spokesman describes scene of 'total devastation'

Guardian (09/21/17)

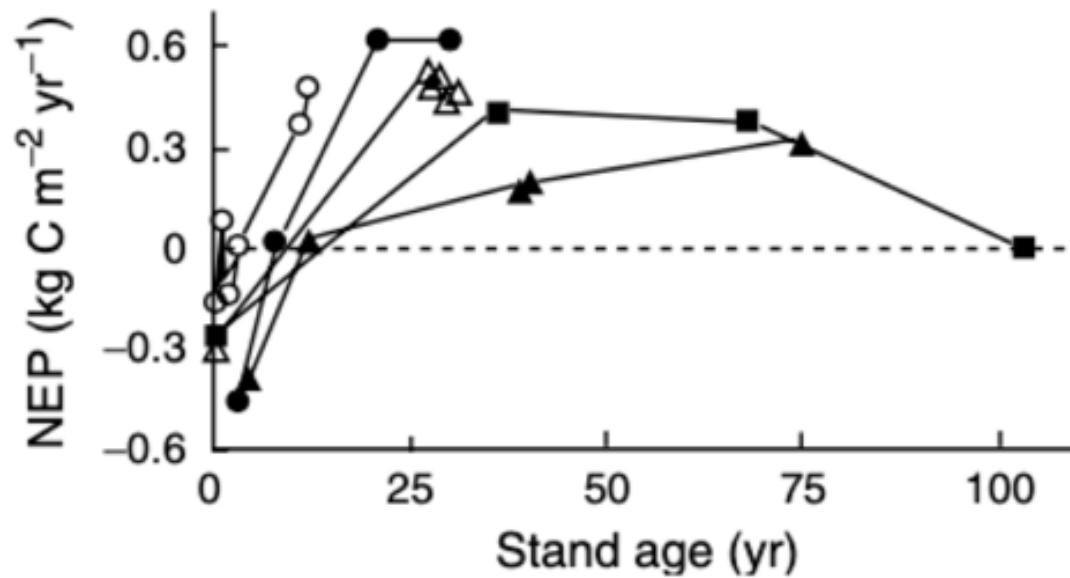
# Ecosystem impacts of disturbance - water



# Ecosystem impacts of disturbance - energy

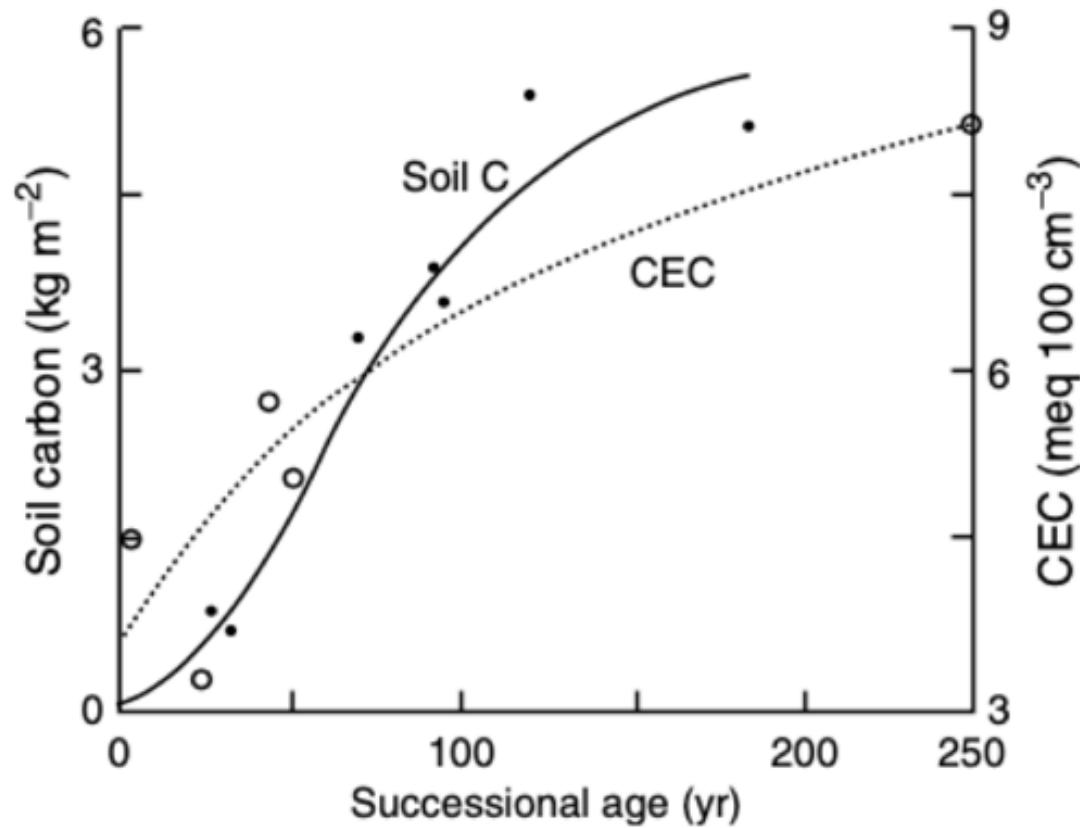


# Ecosystem impacts of disturbance - carbon



**Fig. 12.17** Successional changes in NEP of European forests measured by CO<sub>2</sub> exchange. *Black circles*, *Picea sitkensis*; *white triangles*, *Pinus pinaster*; *gray squares*, *Pinus sylvestris*; *black triangles*, *Pinus sylvestris*; *white circles*, *Quercus cerris*. Redrawn from Magnani et al. (2007)

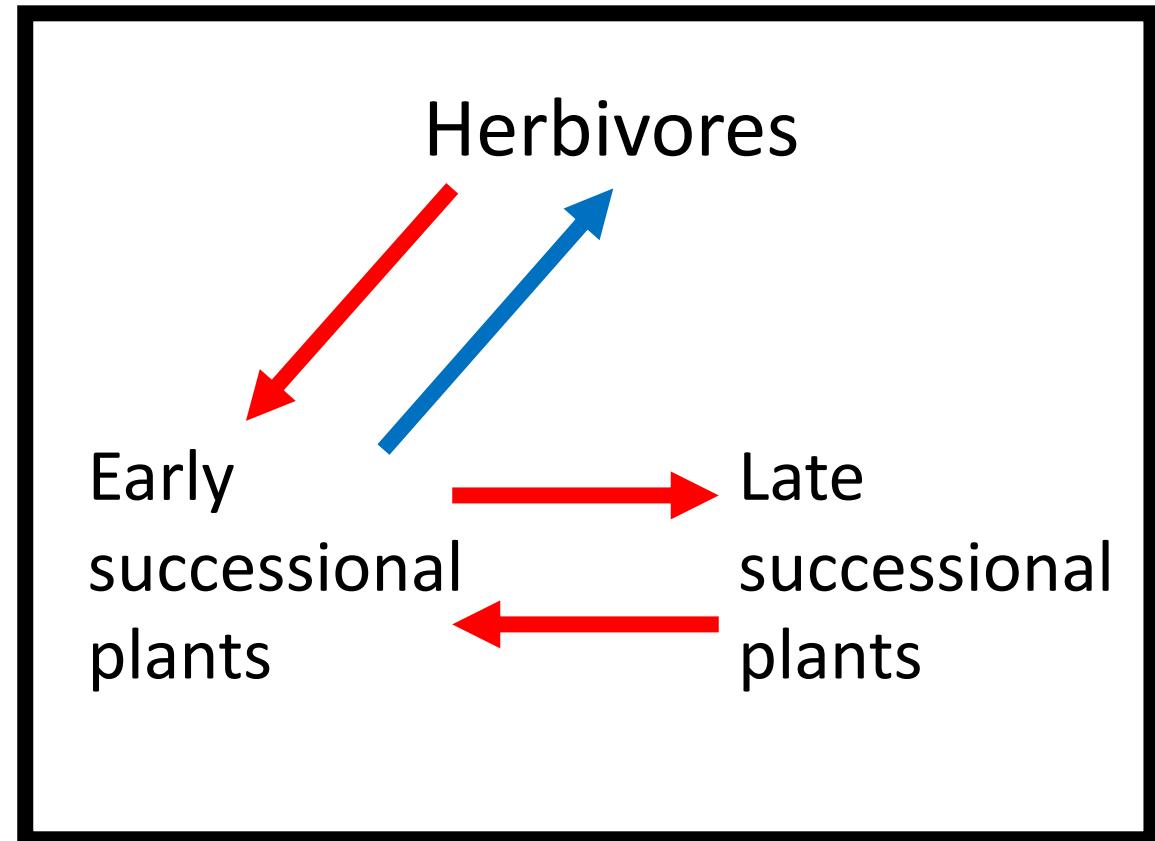
# Ecosystem impacts of disturbance - soil



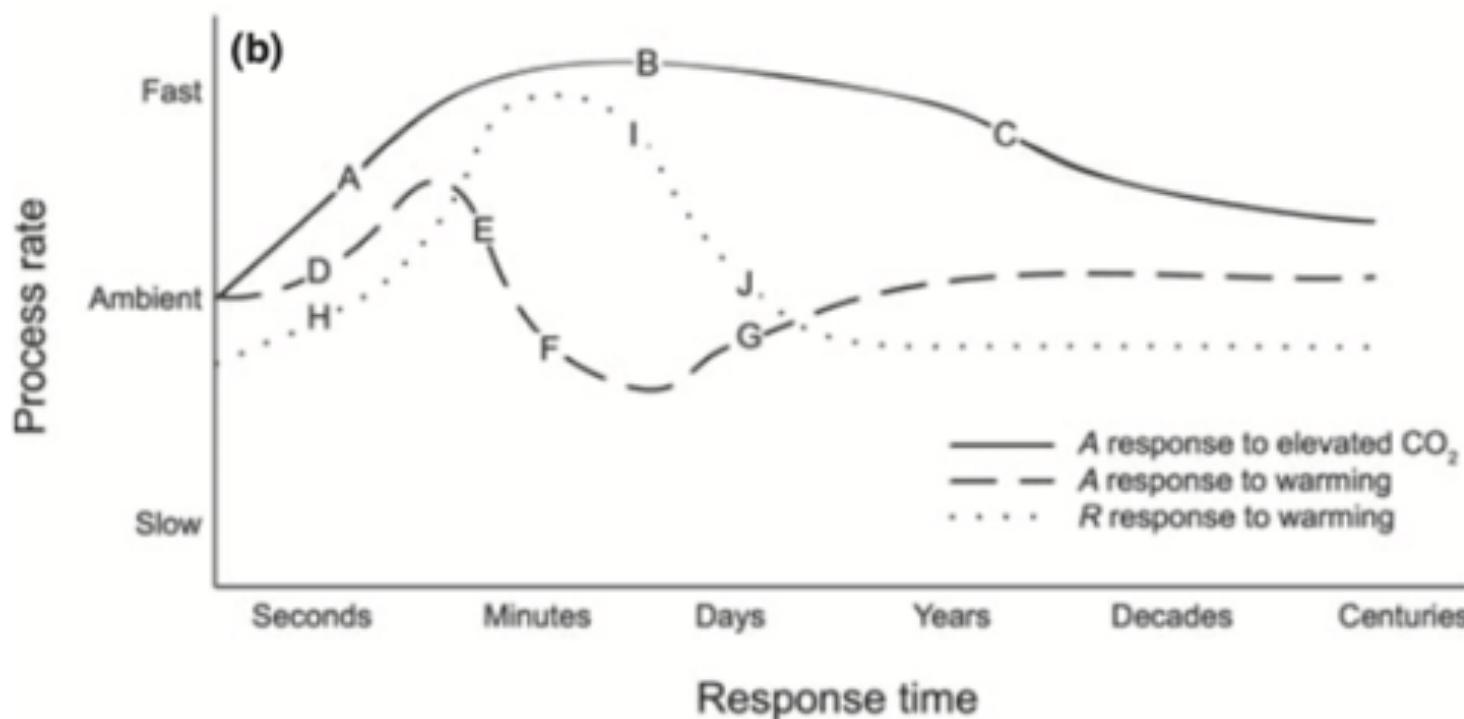
# Ecosystem impacts of disturbance - **herbivory**

# Ecosystem impacts of disturbance - **herbivory**

- Herbivory is highest during mid succession
  - Plant biomass is high
  - Plants investing in growth, not defense
- Herbivores can enhance succession
  - Might not be good for them!



Why is it important to consider  
the time scale of a study?



# Spatial dynamics: Land use and land cover change (LULCC)

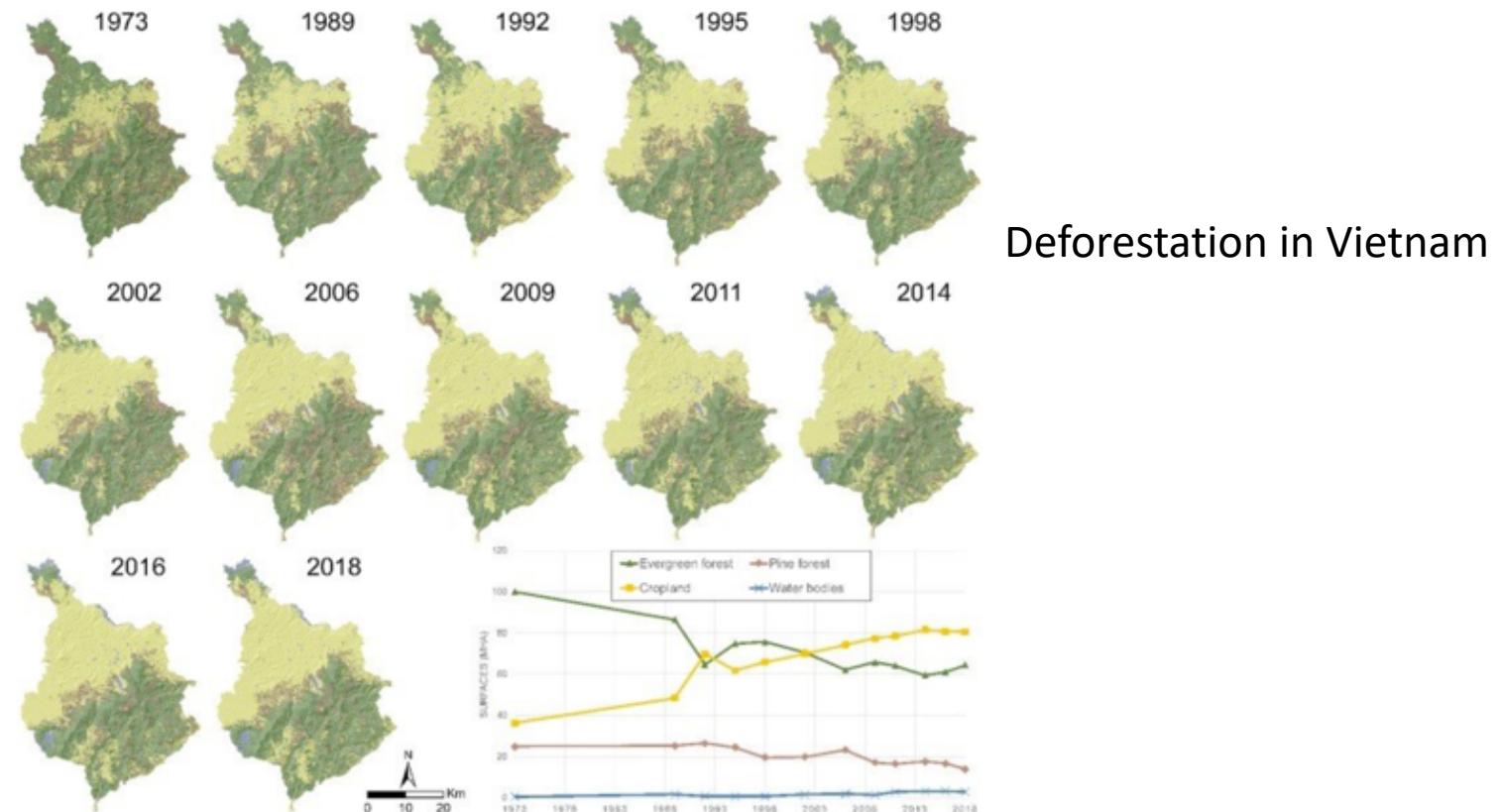
# LULCC

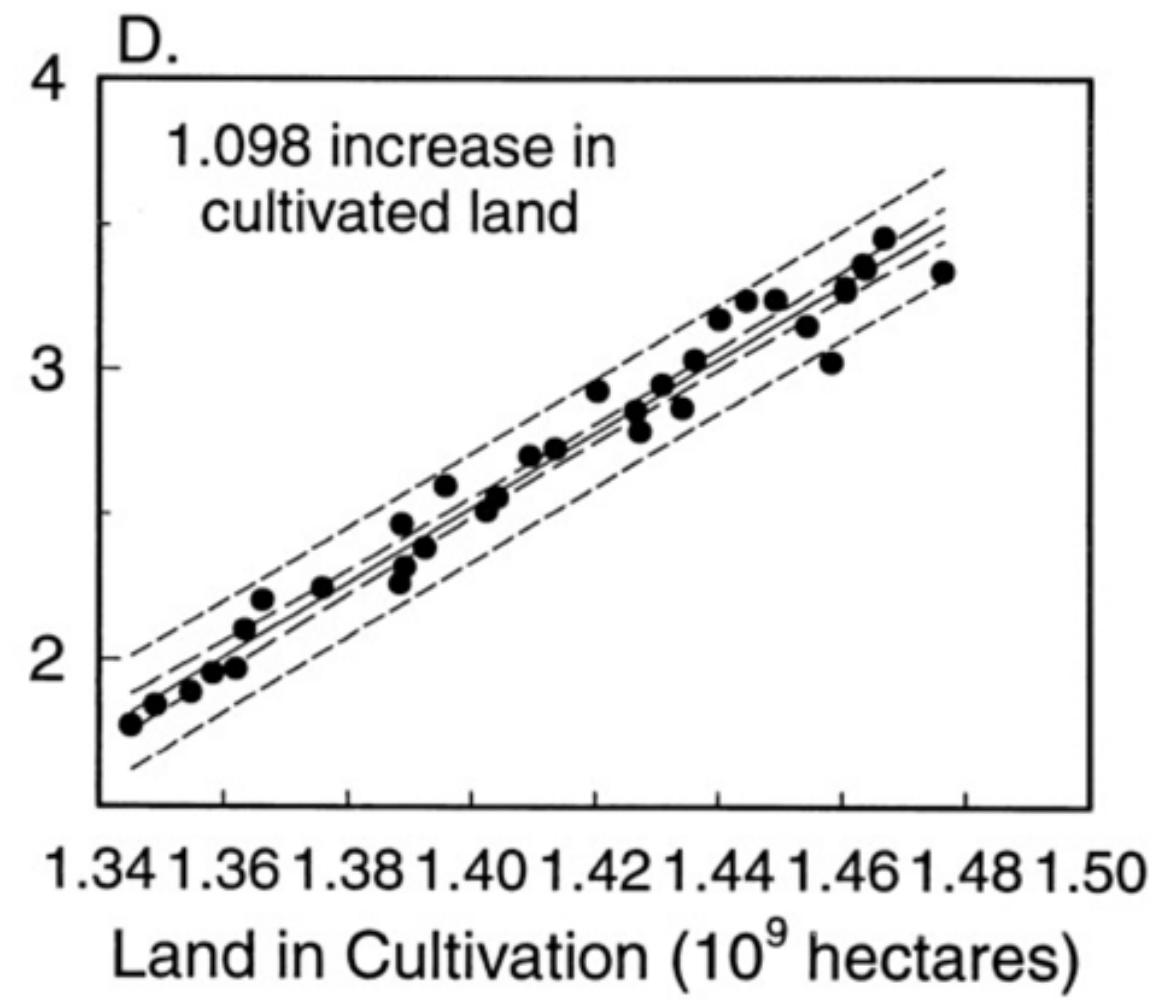
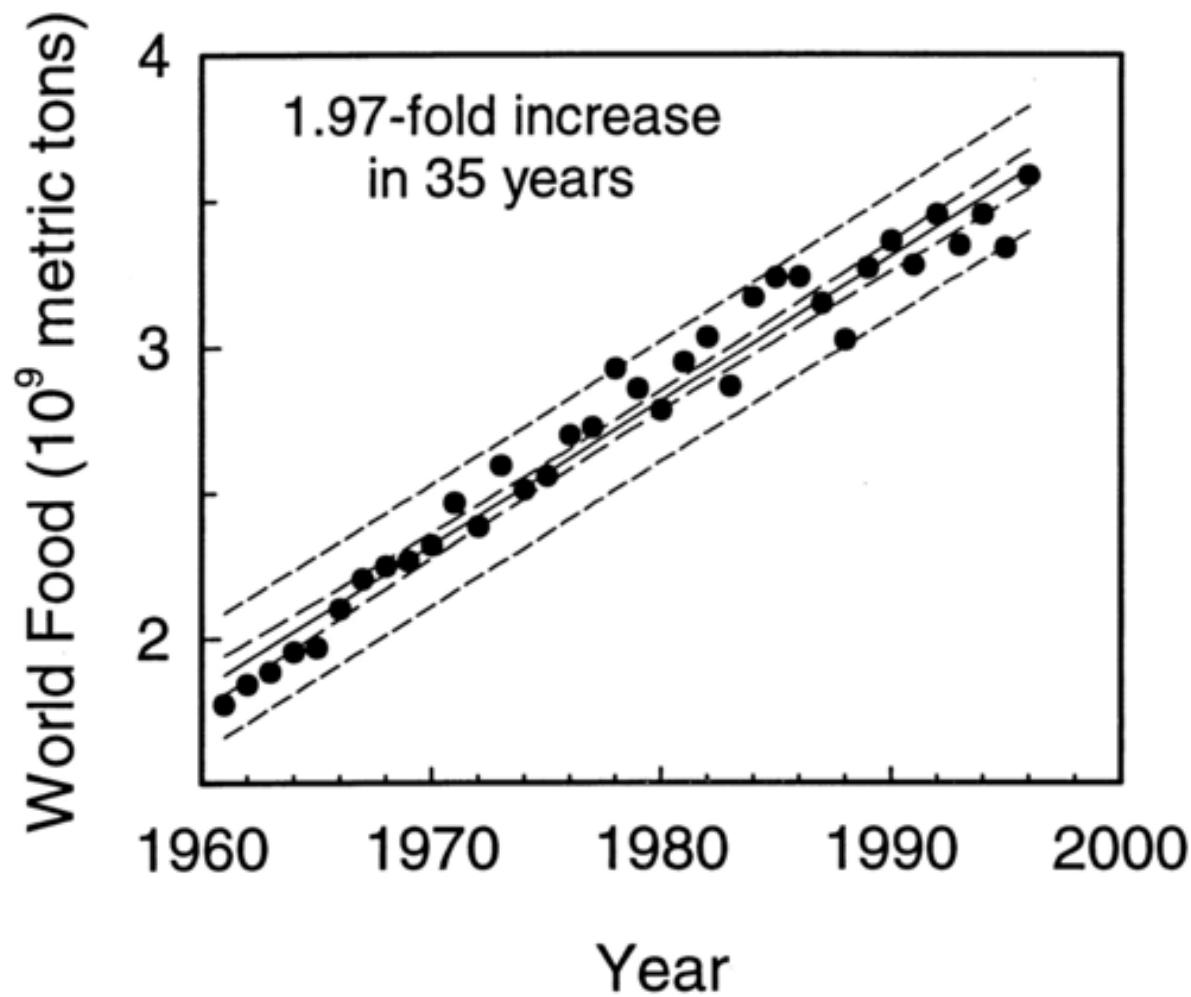
- Change from one land type to another
- Largest ongoing global change



# Extensification

- An increase in the area affected by human activities

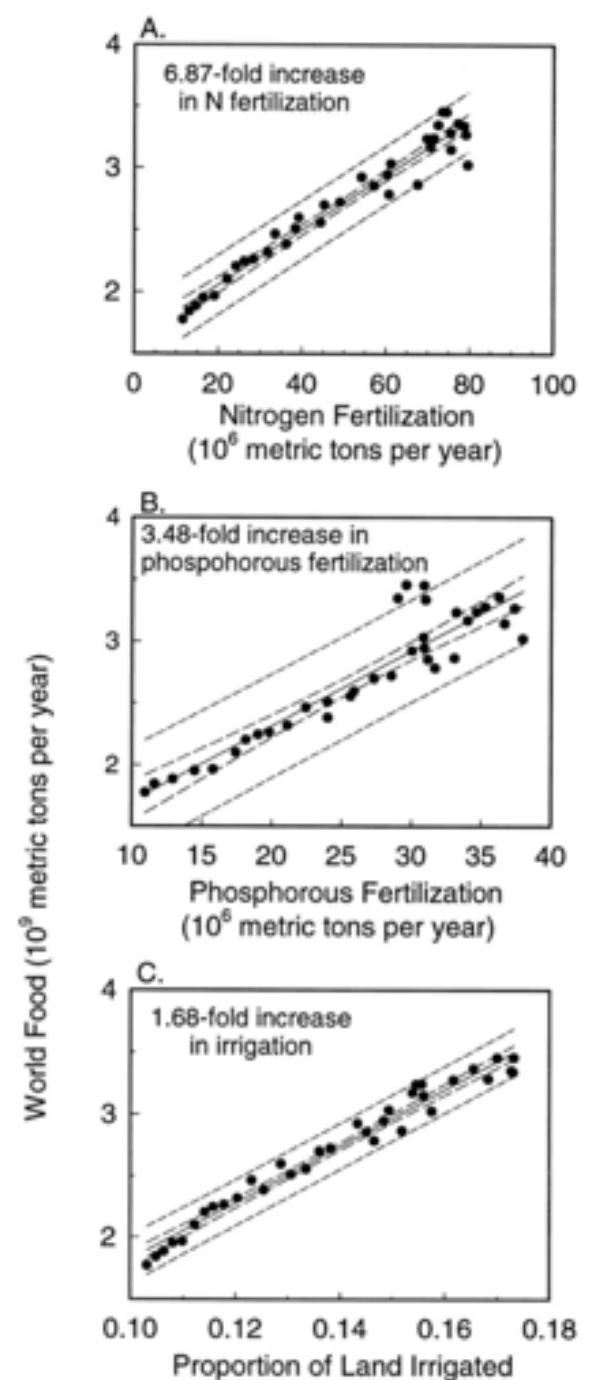




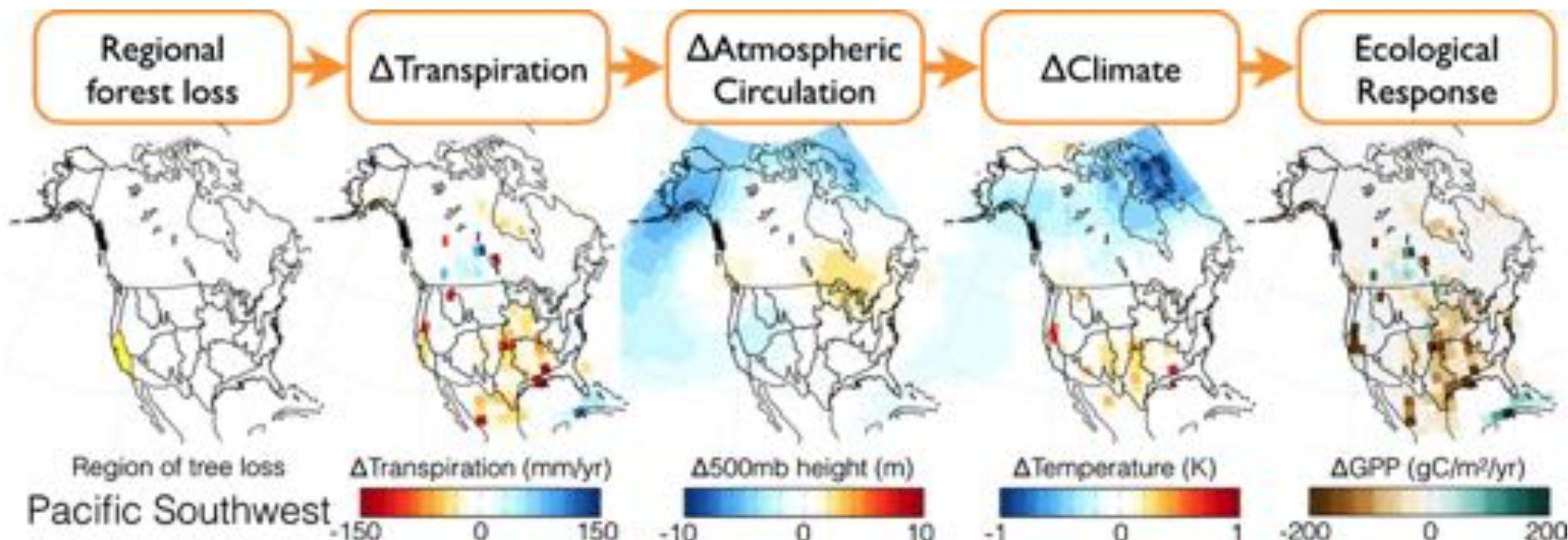
# Intensification

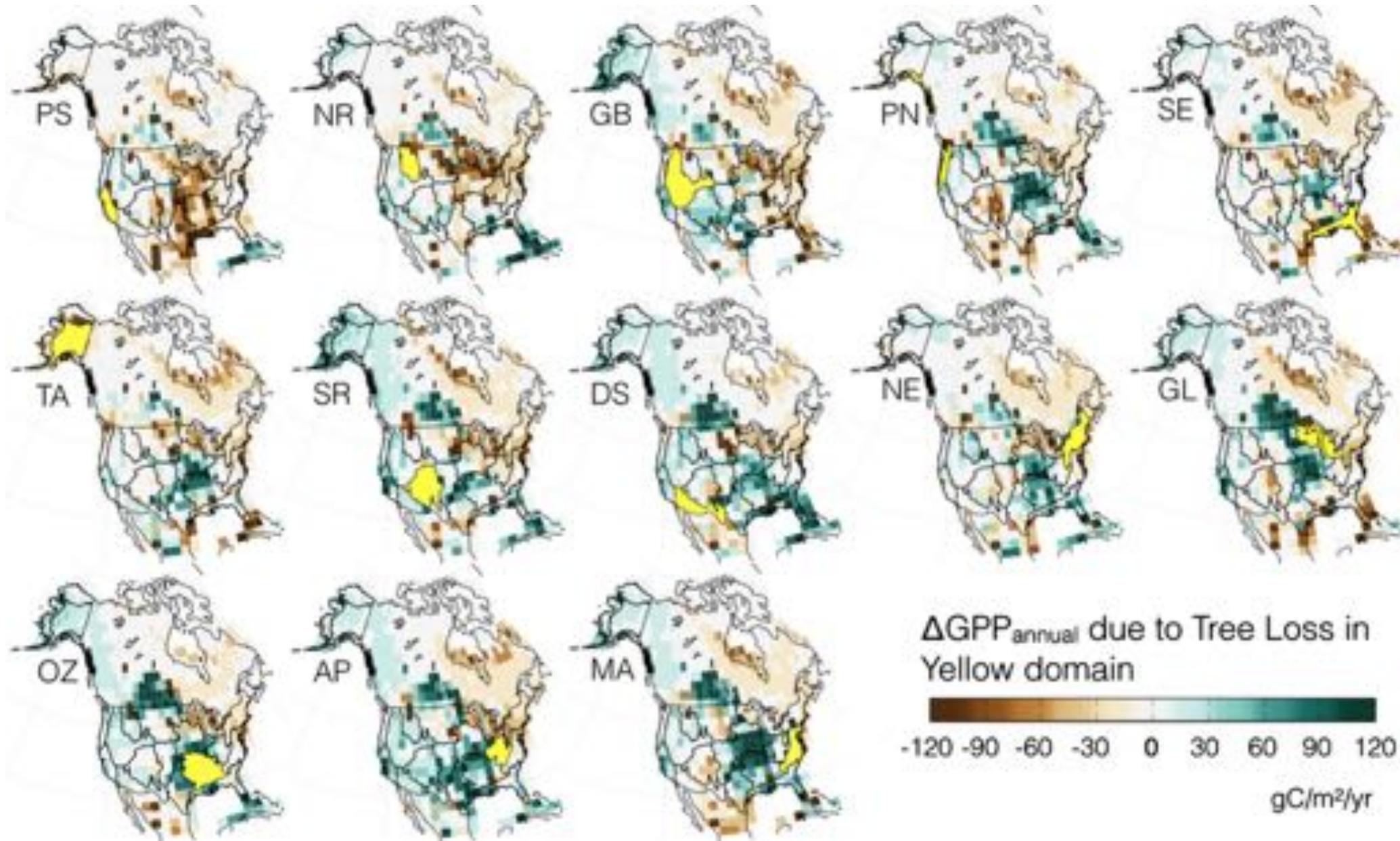
- Increase in resource use for new land use





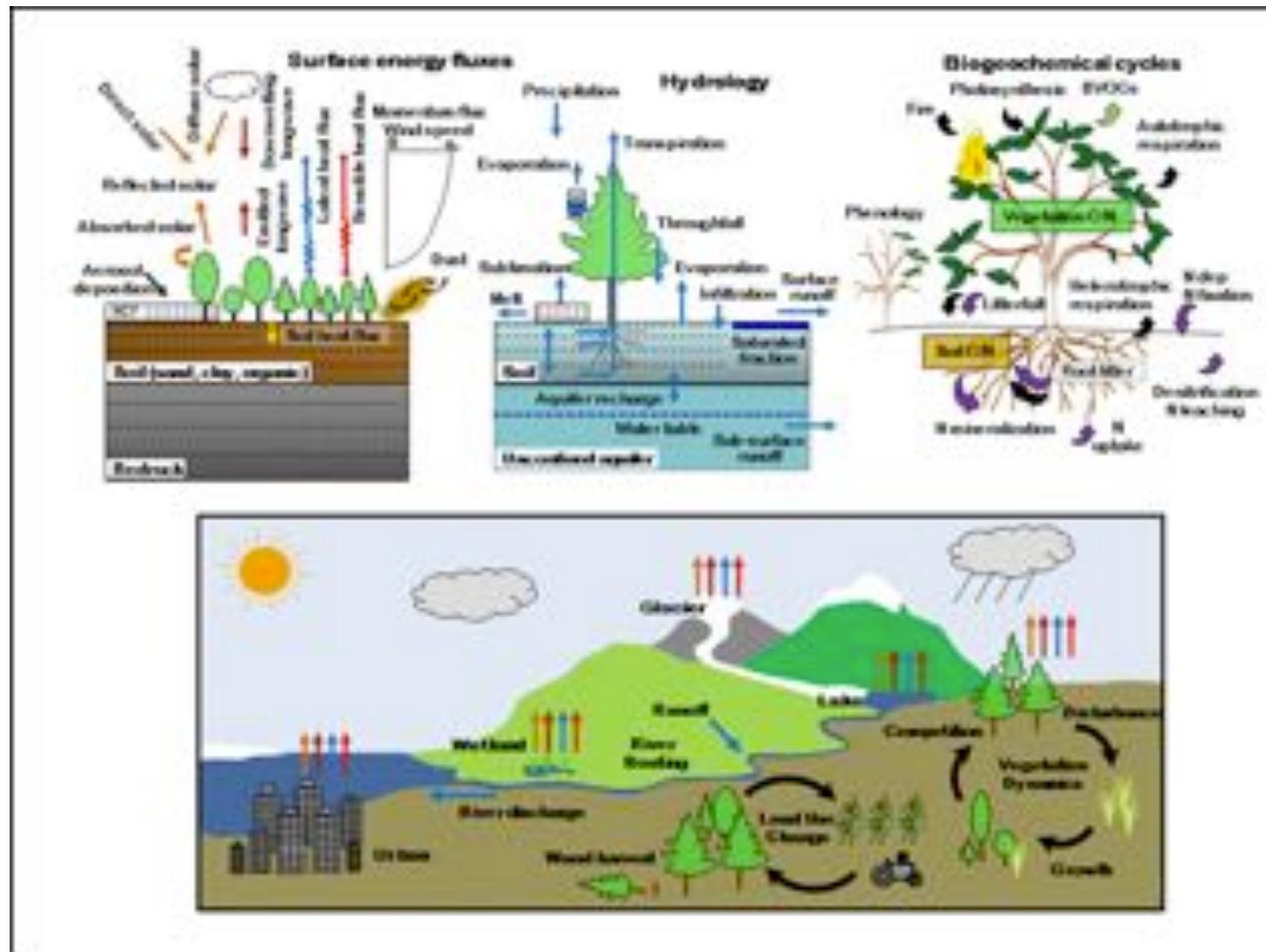
# Spatial dynamics: Eco-climatic teleconnections





How do we predict spatio-temporal changes in ecosystem processes?

# Land surface models



# Earth System Models

