10. Feedbacks in Ecology

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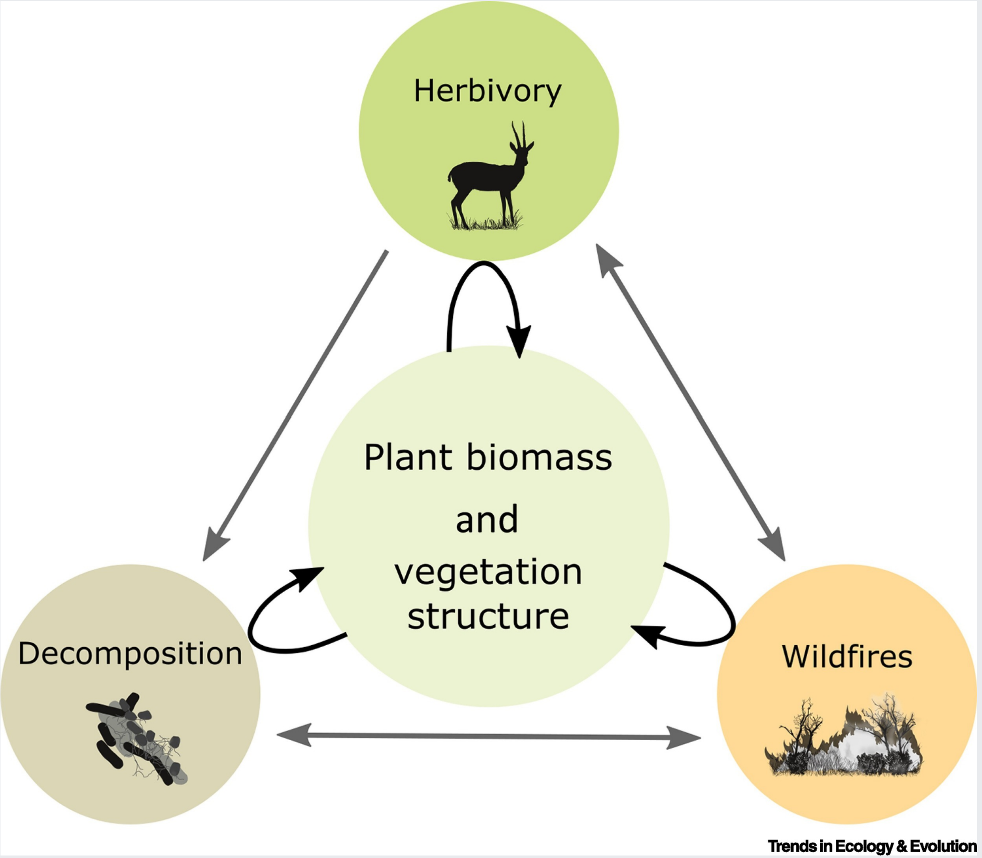
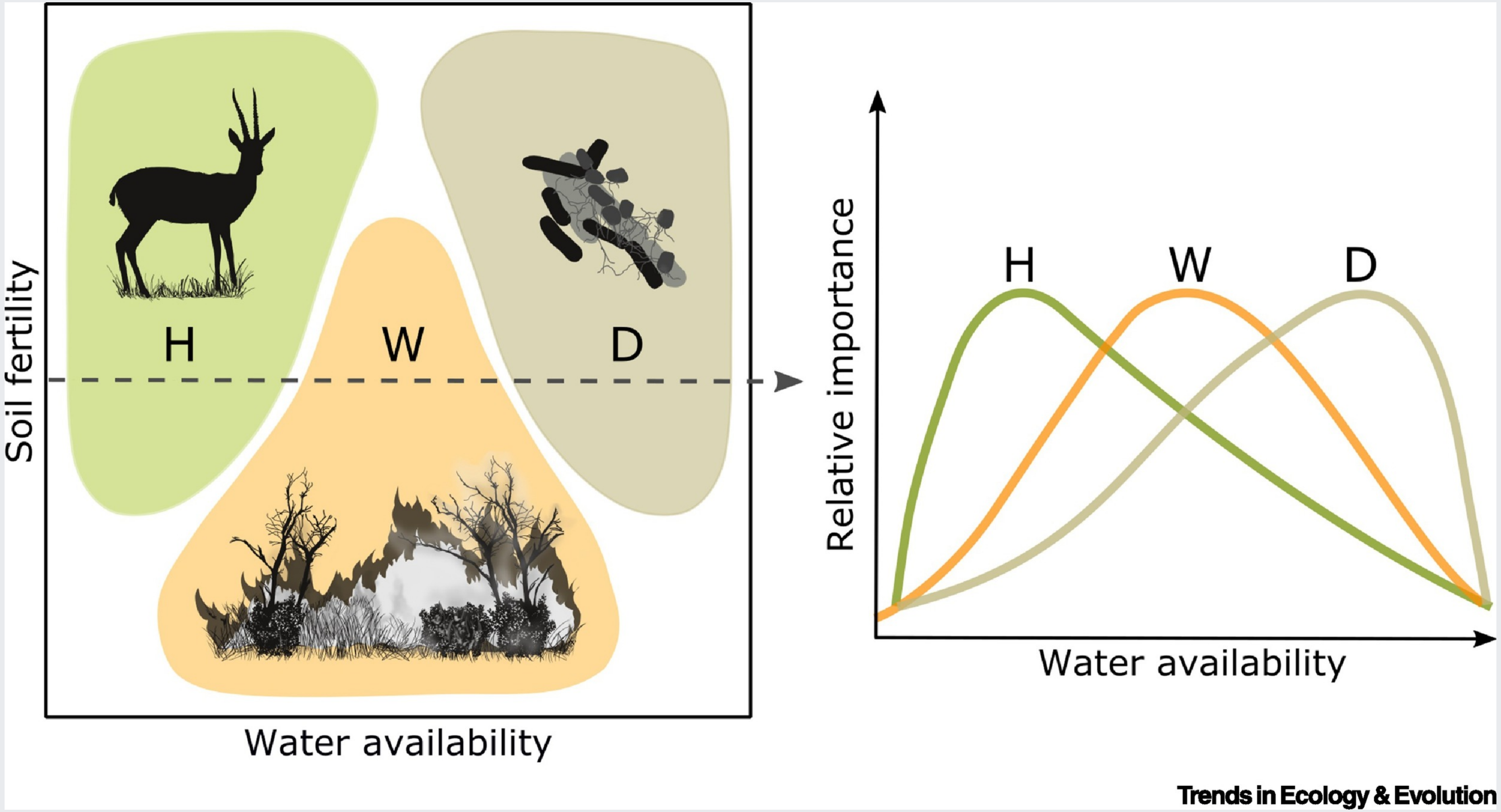
2023-02-04

The three recycling pathways



Pausas and Bond 2020. *Trends in Ecology and Evolution*

The three recycling pathways



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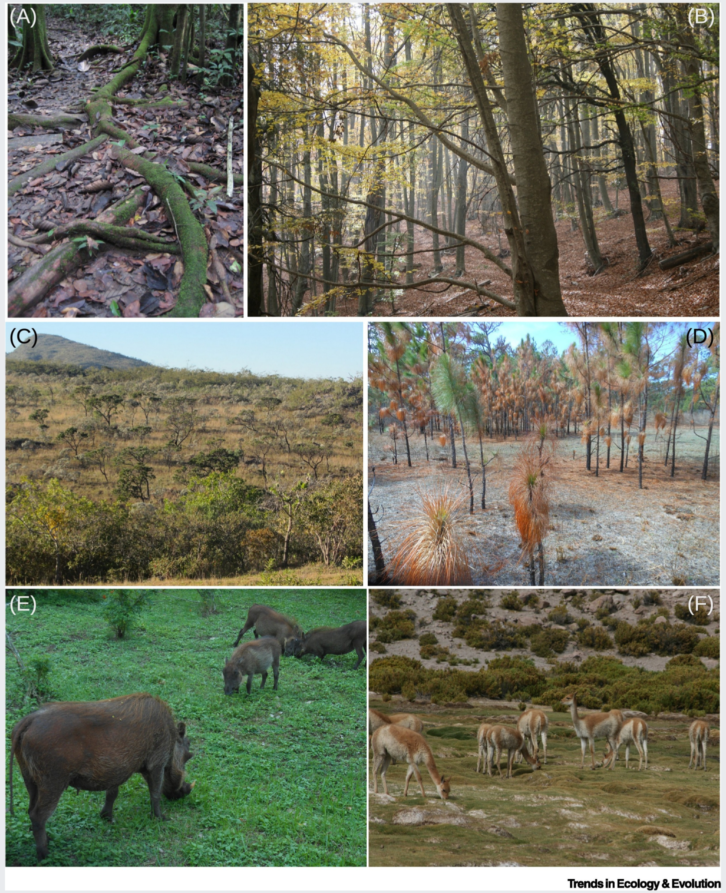
Three recycling pathways



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Microbe-driven (Top):

- Understory of a rainforest (A; Peruvian Amazon) and beech forest (B; NE Spain), with high humidity and no grasses, where litter is easily decomposed.

Fire-driven (Middle):

- South American savanna (C; Central Brazil) with flammable grasses and thick-barked trees. Frequently burned pine woodland (D; North Carolina) with a flammable grassy and litter understorey with fire-resistant pine saplings.

Herbivory-driven (Bottom):

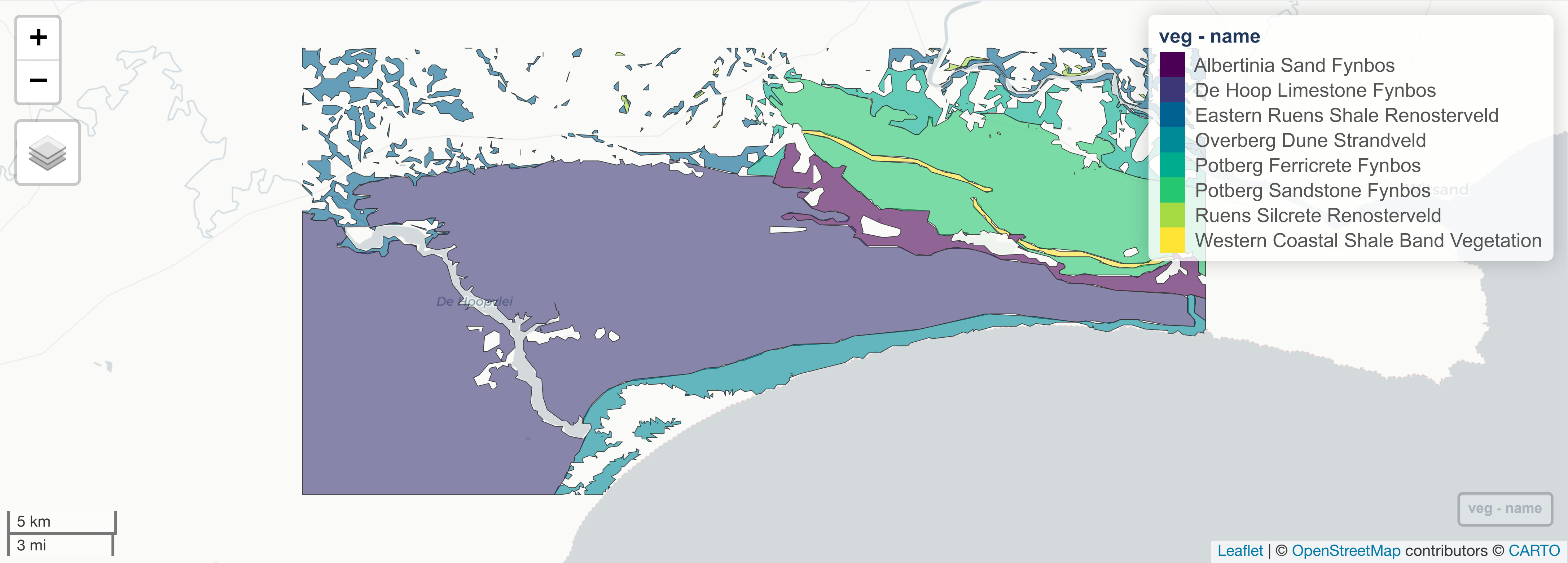
- African short-grass savanna (E; Kruger National Park, South Africa), and vicunas grazing in arid grasslands (F; Atacama, Chile).

The three recycling pathways

		Herbivory	Decomposition	Wildfire
Conditions	Climate optima	Dry, temperate	Moist	With a dry season
	Soil preferences	Nutrient rich	Moist	Nutrient poor
	Vegetation types	Open	Closed	Open
Requirements	Type of biomass	Aboveground plant	Above and belowground plant; animal	Aboveground plant
	Plant biomass consumed	Green and fleshy	Dead (litter, roots)	Dead and green
	Relevant plant attributes	Leaf quality (palatability)	Litter quality	Biomass structure, flammability
	Biomass C/N, Lignin/N	Low	Low	High
	Biomass continuity	Temporal continuity	Contact with soil	Spatial continuity
	Additional requirement	Water	Defaunation	Ignitions

Pausas and Bond 2020. *Trends in Ecology and Evolution*

What about De Hoop?



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The three recycling pathways

		Herbivory	Decomposition	Wildfire
Consequences	Vegetation feedback	Yes, palatability (grasses)	Yes, plant–soil	Yes, flammability
	For the ecosystem	Maintain open habitats	Maintain local fertility	Generate and maintain open habitats
	Plant response traits (adaptations)	Plant structural and chemical defences, trample resistance (grasses)	Decomposability	Flammability, lignotubers, seed dormancy, thick bark, etc.
Interactions	Regulated by	Predators, pathogens	Moisture, temperature, soil	Topographic barriers, ignitions, humans
	Regime factors	Density, size, gut type, sociability	Climate	Intensity, frequency, size, season
	Sensitivity to climate change	Low	Intermediate	High

Pausas and Bond 2020. *Trends in Ecology and Evolution*

The three recycling pathways - Feedbacks!

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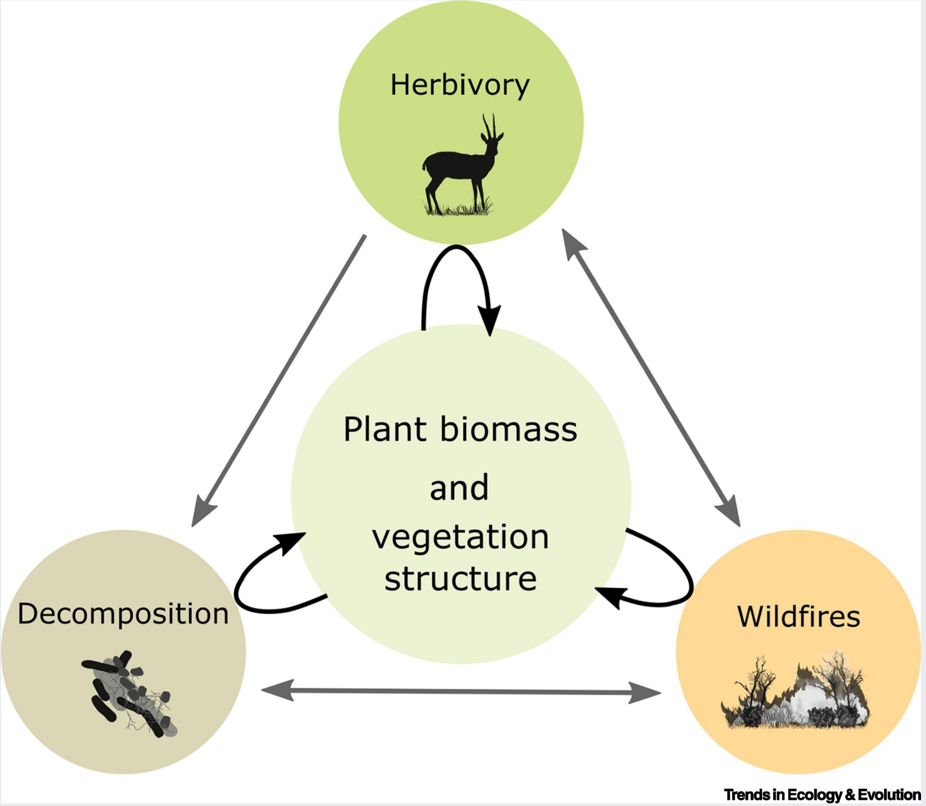
Pausas and Bond 2020. *Trends in Ecology and Evolution*

The three recycling pathways - Feedbacks!



> "***Figure 1.*** *Plant Biomass and Vegetation Structure in Terrestrial Ecosystems is Determined by Three Feedback Processes: Vertebrate Herbivory, Microbial Decomposition, and Wildfires."*

Pausas and Bond 2020. *Trends in Ecology and Evolution*

What is a feedback?

> *"the modification or control of a process or system by its results or effects"* - Oxford Dictionary

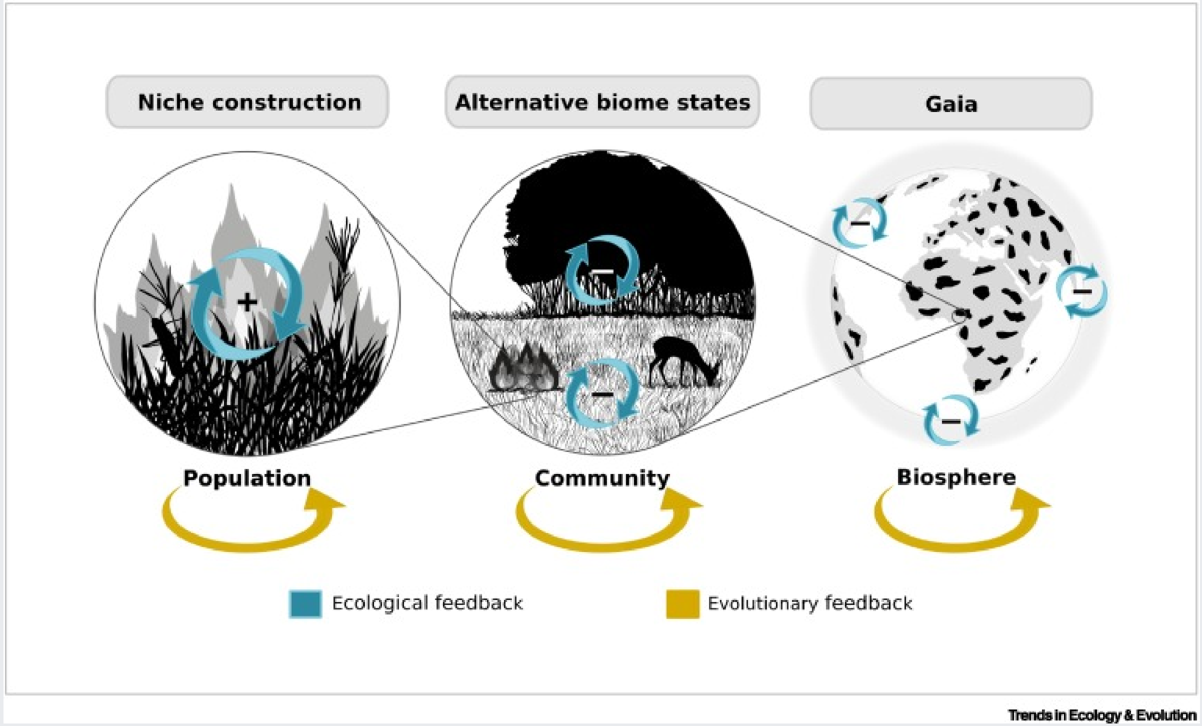
Feedbacks (in ecology) can be positive or negative:

- **Positive (amplifying) feedback:**
    - "a feedback process where a stimulus (e.g., disturbance) causes a reaction ***in the same direction*** and thus it amplifies the stimulus. Thus, it moves the system away from equilibrium; it generates instability, and when strong enough, causes state shifts. It may require an external force to initiate it."
- **Negative (stabilizing) feedback:**
    - "a feedback process where a stimulus (e.g., disturbance) causes a reaction ***in the opposite direction*** so that the state of the system is maintained. Negative feedbacks promote stability (e.g., homeostasis) and ensure the maintenance of a steady, stable state."

Definitions from Pausas and Bond 2022. *Trends in Ecology and Evolution*

What are feedbacks in ecology?

Organisms can modify their environment, and these modifications can feed back to the organism and generate emergent properties at different scales, with evolutionary consequences…



Definitions from Pausas and Bond 2022. *Trends in Ecology and Evolution*

Emergence...

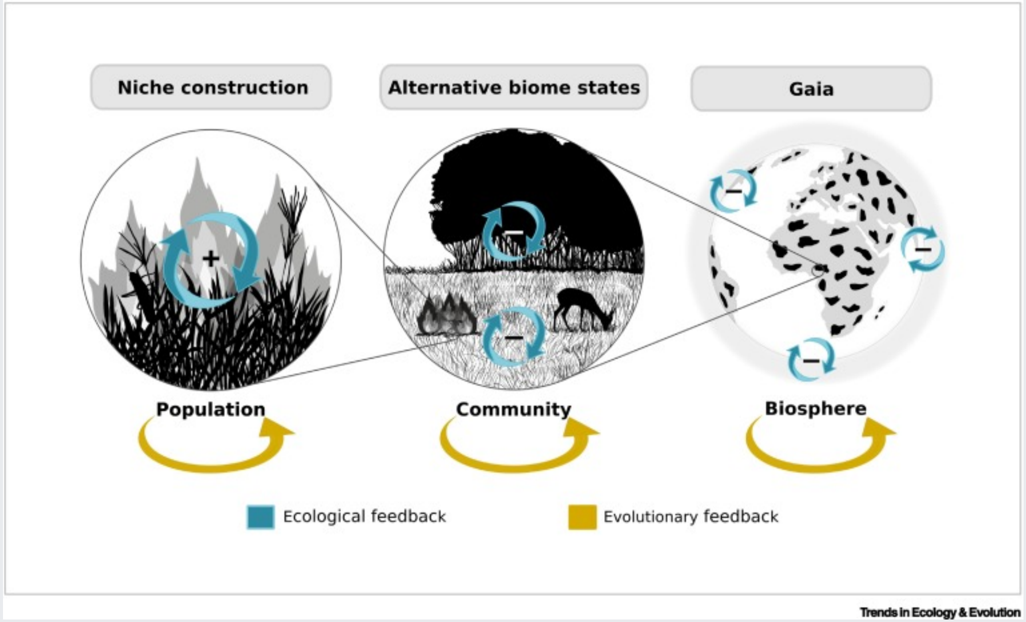
Emergent properties are properties and behaviors of a system as a whole that its parts do not have on their own - they emerge thanks to the interactions among parts.

For example, in biology, each level of organization has properties which emerge at that level.

- organisms are not just a group of organs,
- ecosystems are not just a group of species

They need to be bound together by specific interactions to emerge as such. Thus, diversity and stability of an ecosystem are emergent properties as are the life and behavior of an organism.

Emergence from feedbacks



Emergent properties…

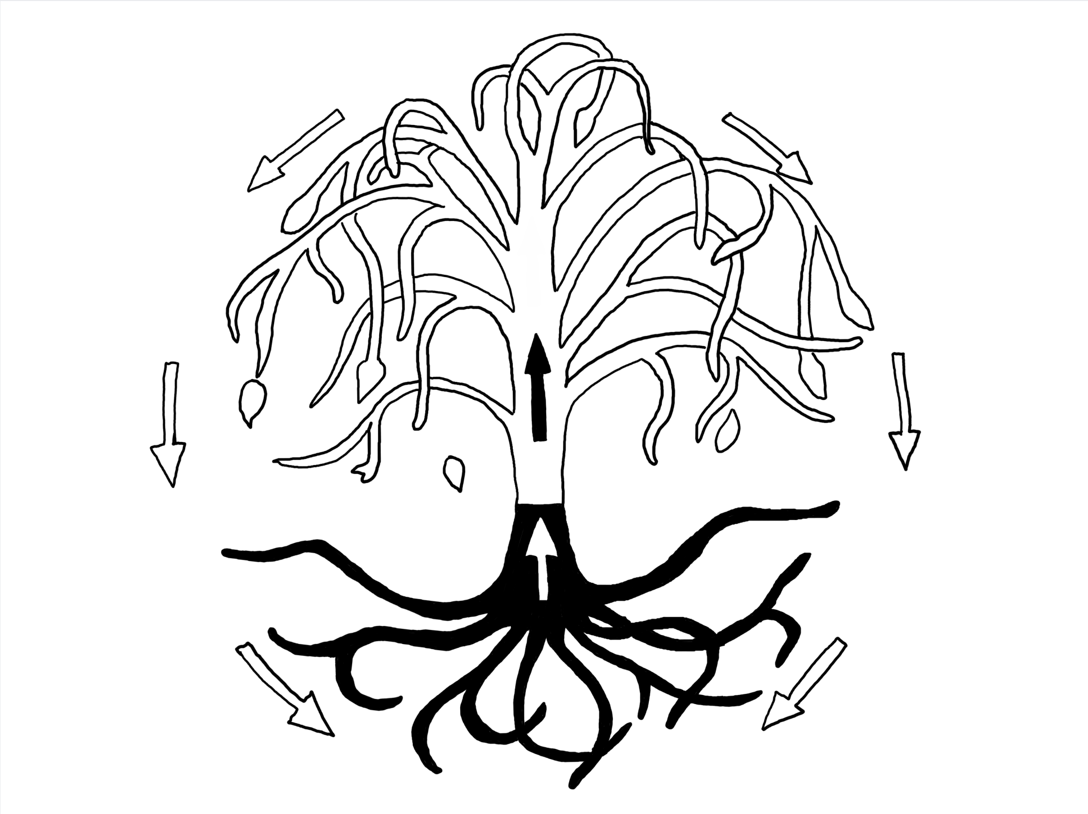
- Population/Species (niche construction)
- Community (Alternative Stable States)
- Biosphere (Gaia Hypothesis)

From Pausas and Bond 2022. *Trends in Ecology and Evolution*

Niche construction

e.g. beaver dams

Niche construction

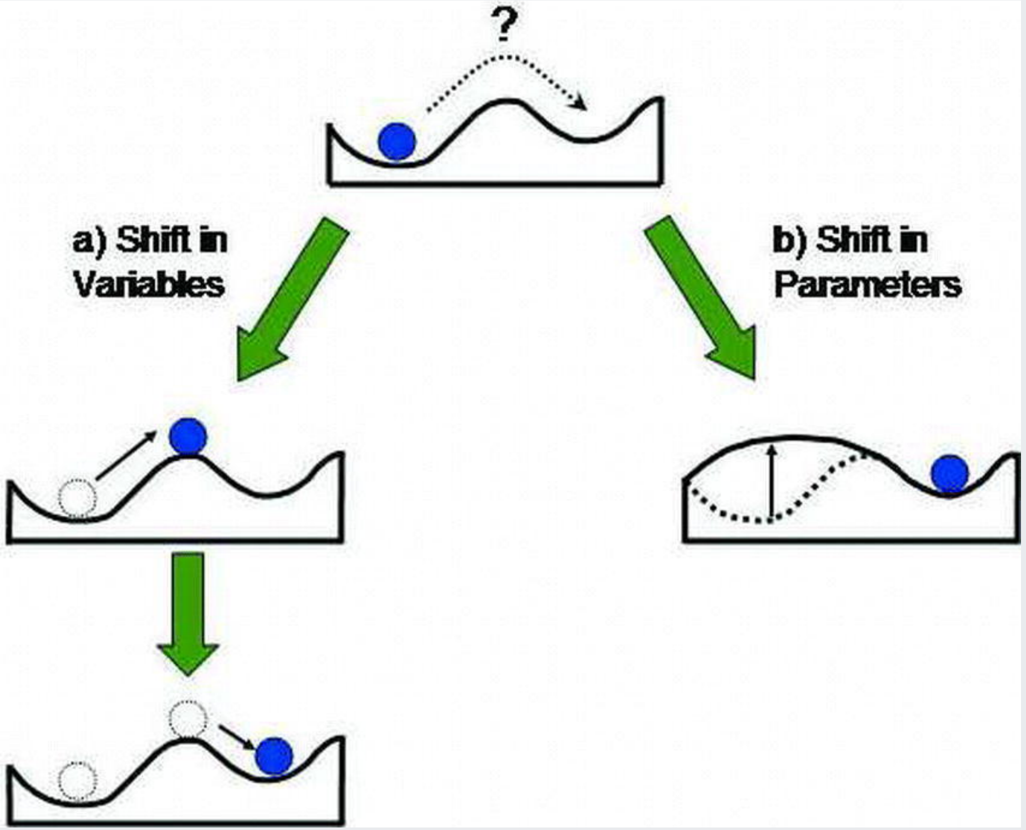


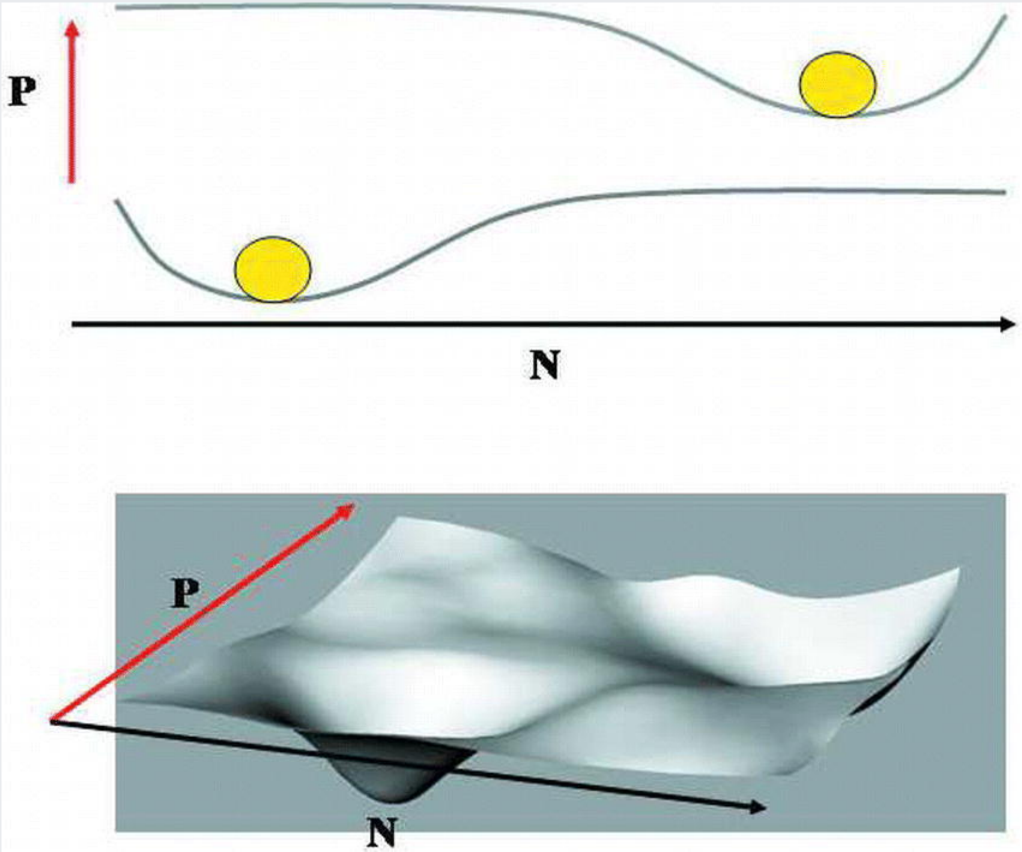
e.g. trees and plant-soil feedbacks through leaf litter etc

Niche construction

e.g. flammable plants and fire regimes

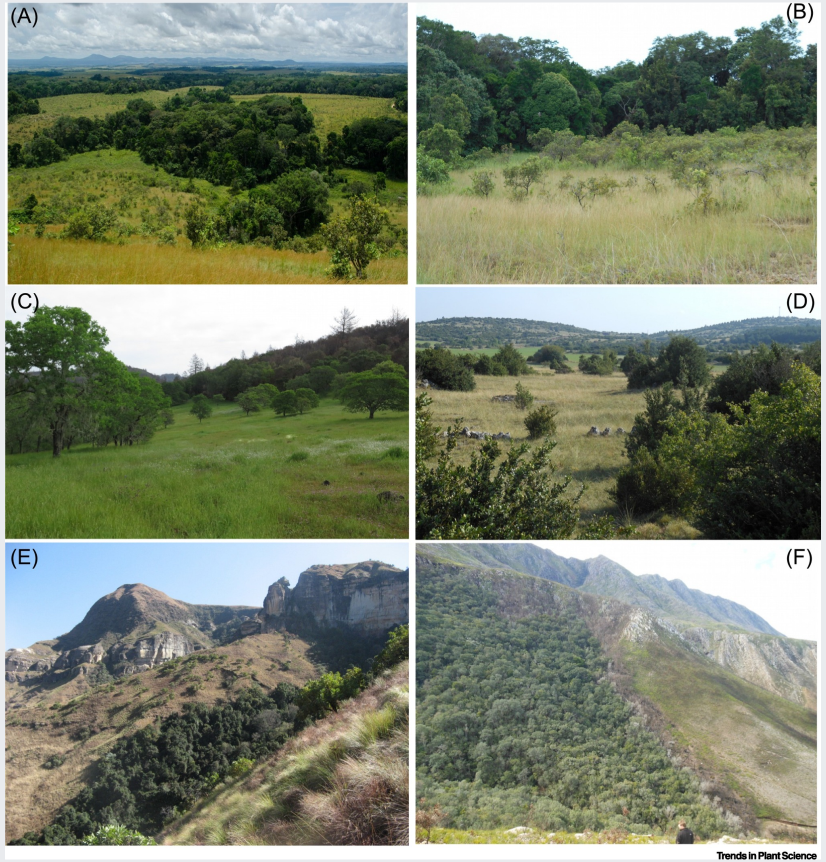
Alternative Stable States





From Beisner et al 2003. *Fronties in Ecology and Evolution*

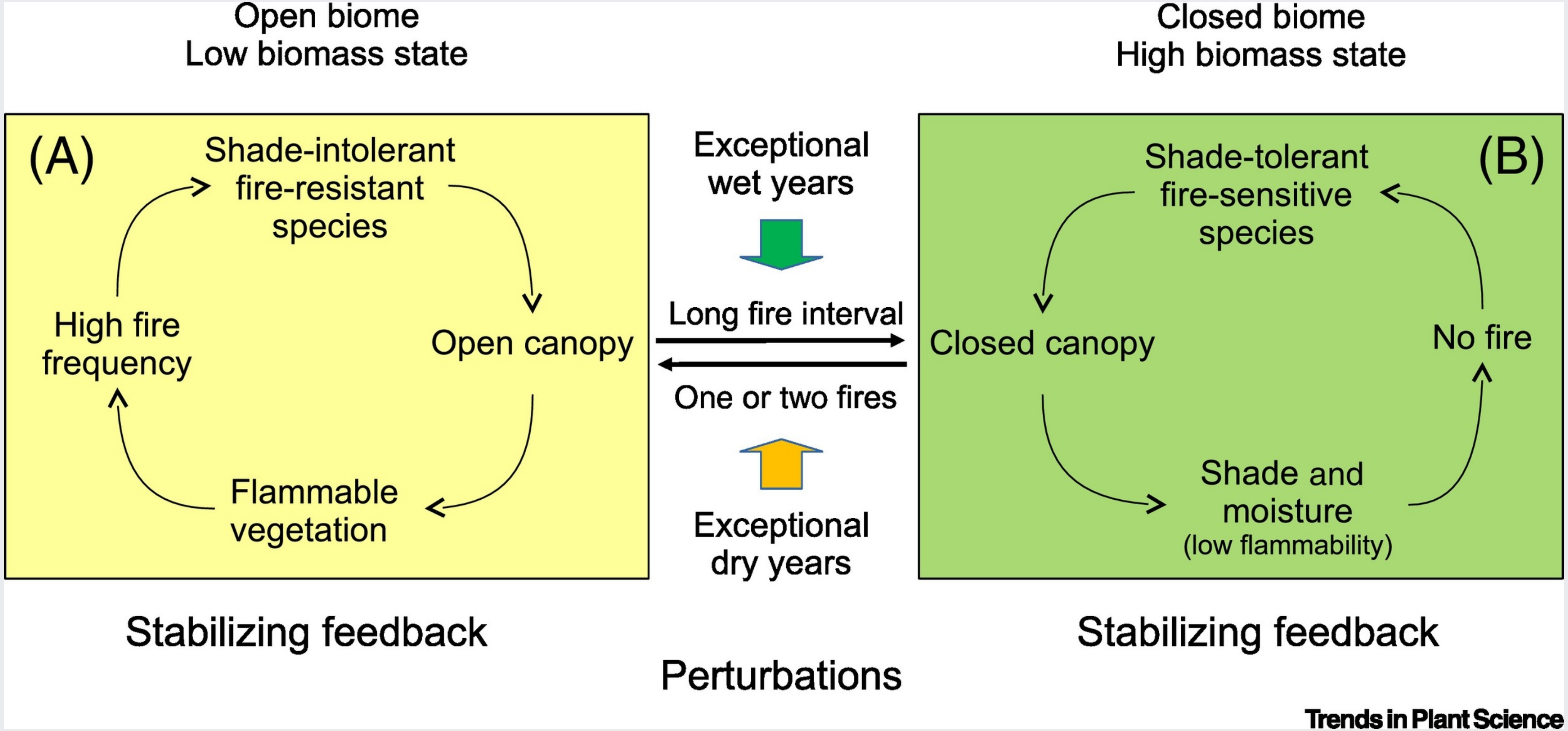
Alternative Biome States



From Pausas and Bond 2020. *Trends in Plant Science*

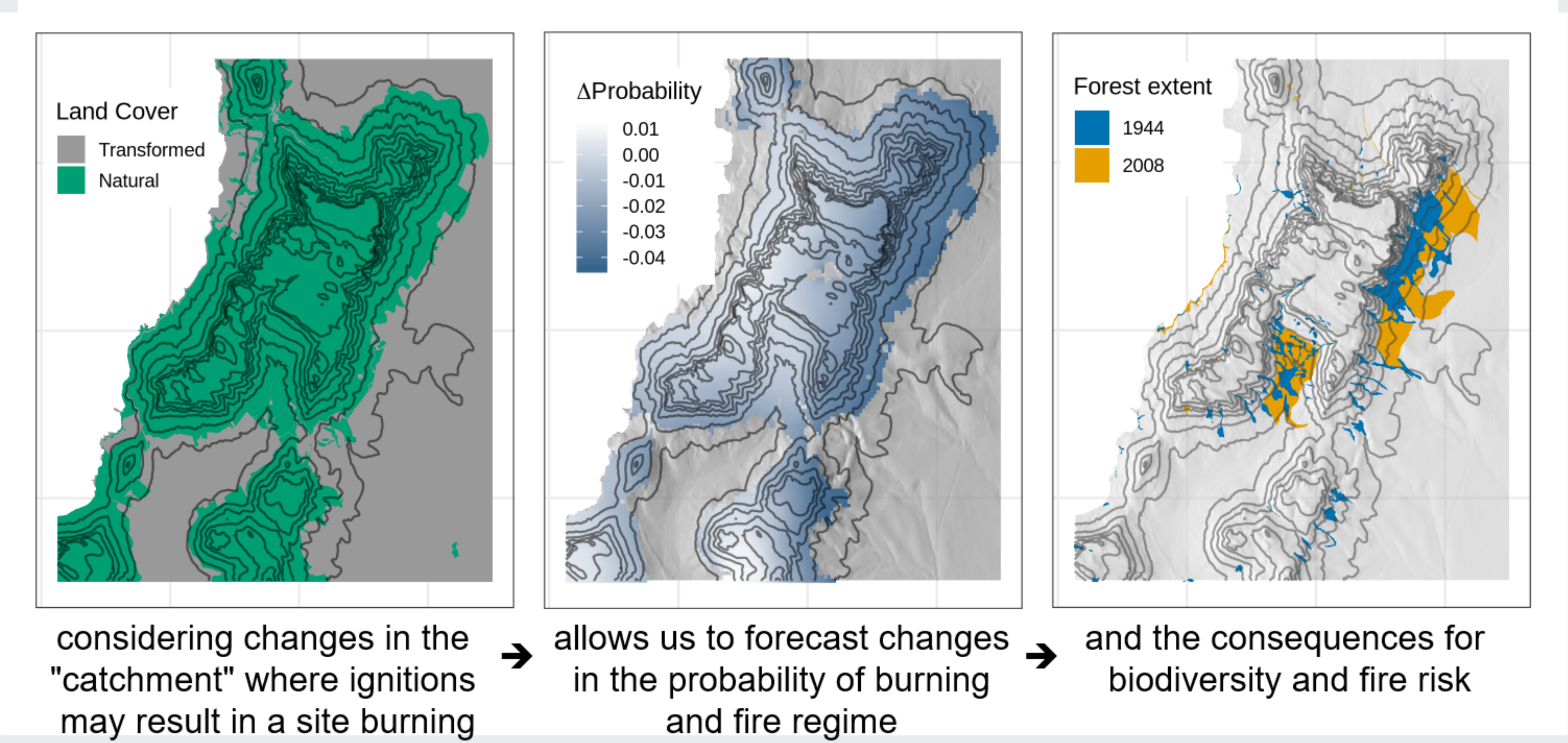
"Open" (grassland, shrubland, savanna) vs "Closed" (forest) ecosystems maintained by fire and/or herbivory

Alternative Biome States



From Pausas and Bond 2020. *Trends in Plant Science*

Alternative Biome States - altering the feedback!



Slingsby et al 2020. *Global Change Biology*

Gaia Hypothesis

"The Blue Marble" - NASA Apollo 17, 1972

- Earth as a global system with feedbacks that stabilize the planetary environment to certain states, and with state changes in geological time
- The biosphere has a major effect on the atmosphere and thus produces ecological and evolutionary feedbacks that sustain life

Gaia Hypothesis - Daisyworld model

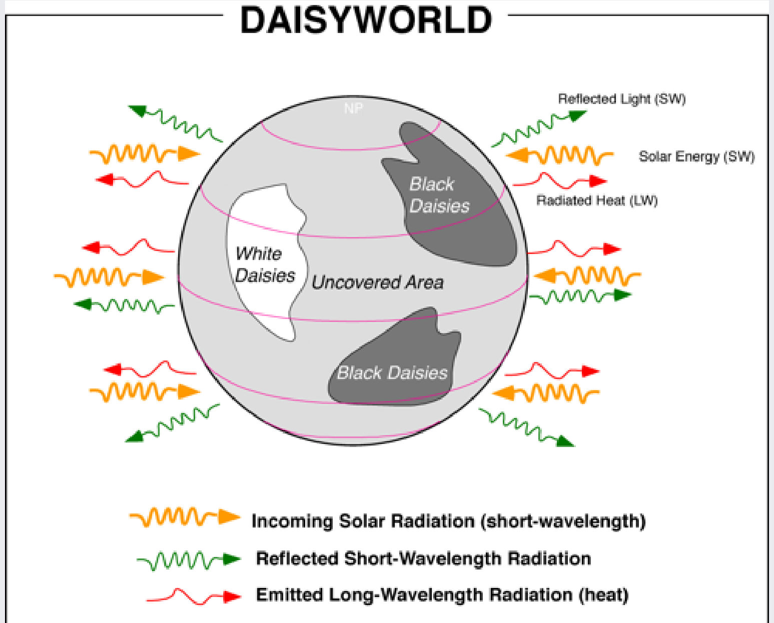
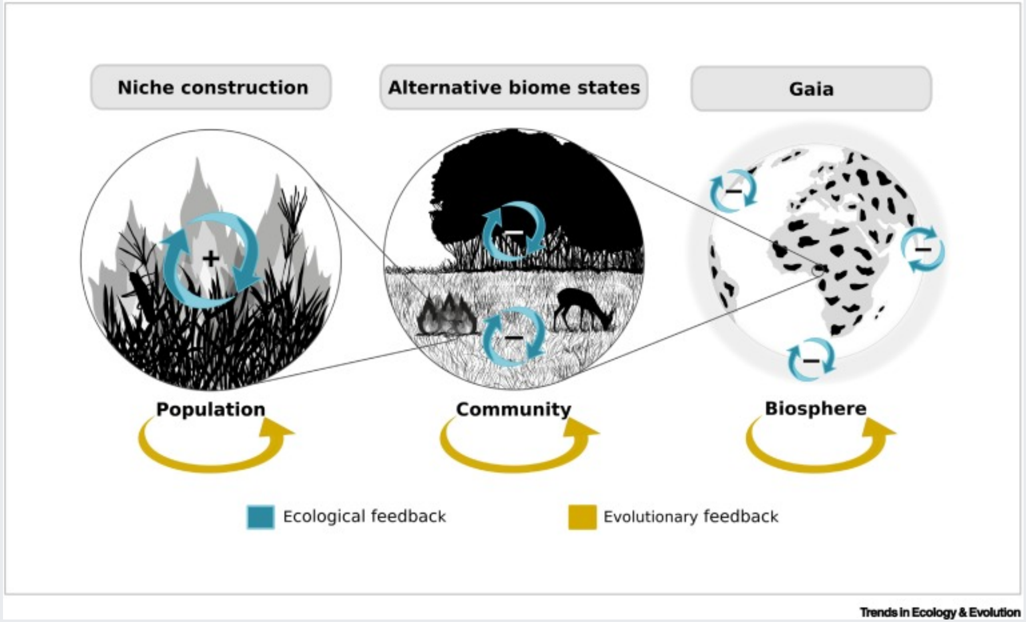


Figure 8.01 Schematic model of Daisyworld, whose surface is covered by black and white daisies and empty area. The temperature of Daisyworld is related to how much energy is received and how much is reflected; the difference is the amount of solar energy absorbed. The amount of energy reflected back to space depends on the planet's albedo (the fraction of light energy that is reflected). The albedo in turn depends on the coverage of white and black daisies. The heat radiated to space is a function of how much energy is absorbed.

- A planet with nothing but black and white daisies
- Black daisies do better under cooler climate, white daisies under warmer
- When white daisies dominate, albedo increases, cooling the planet and selecting for black daisies
- When black daisies dominate, albedo decreases, warming the planet and selecting for white daisies
- Together, these effects stabilize the planet's climate, and the co-existence of black and white daisies

Watson and Lovelock 1982, *Tellus B*

Emergence from feedbacks



Emergent properties...

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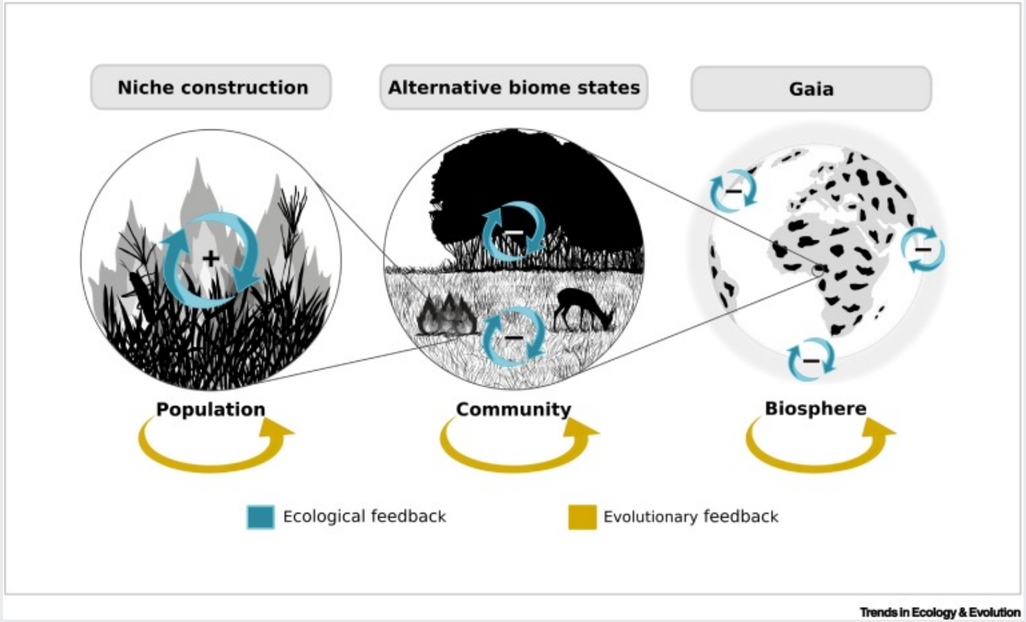
From Pausas and Bond 2022. *Trends in Ecology and Evolution*

Feedbacks across scales



Flammability…

- Population/Species (niche construction)
  - postfire gaps generate recruitment opportunities
- Community (Alternative Stable States)
  - increase in fire activity can create and maintain an open biome
- Biosphere (Gaia Hypothesis)
  - open ecosystems have greater albedo than forest, cooling the planet

From Pausas and Bond 2022. *Trends in Ecology and Evolution*

Implications of feedbacks?

Thresholds from where feedbacks can be disrupted can generate abrupt (nonlinear) changes.

- implications for local scale and global change driven by climate change, invasive species, human activities, etc.

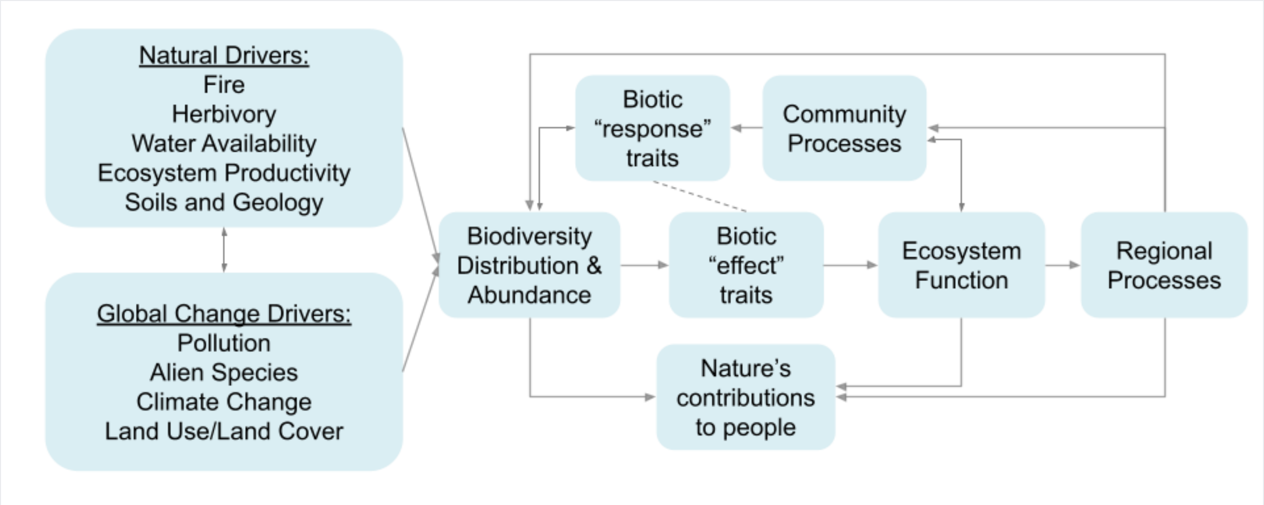
Feedbacks link across scales and a change at one scale may have big implications for other scales

- e.g. What is the effect of global tree planting? Reduced atmospheric CO2, but increased albedo and evapotranspiration?

Simple cause–effect thinking may not be adequate.

- e.g. Ideas like competition and habitat filtering applied in niche theory may not account for potential feedbacks and state shifts. How can we incorporate this?

My research focuses on four questions...



1. What determines the composition and diversity of communities and ecosystems at various scales?
2. What is the role of biodiversity in ecosystem function (and derived societal benefits)?
3. How is biodiversity changing and what are the impacts on ecosystem services?
4. How can we mitigate or adapt to changing biodiversity and ecosystem services?

Figure modified from Chapin et al. 1997, *Science*

References

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Thanks!

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