

Who I am

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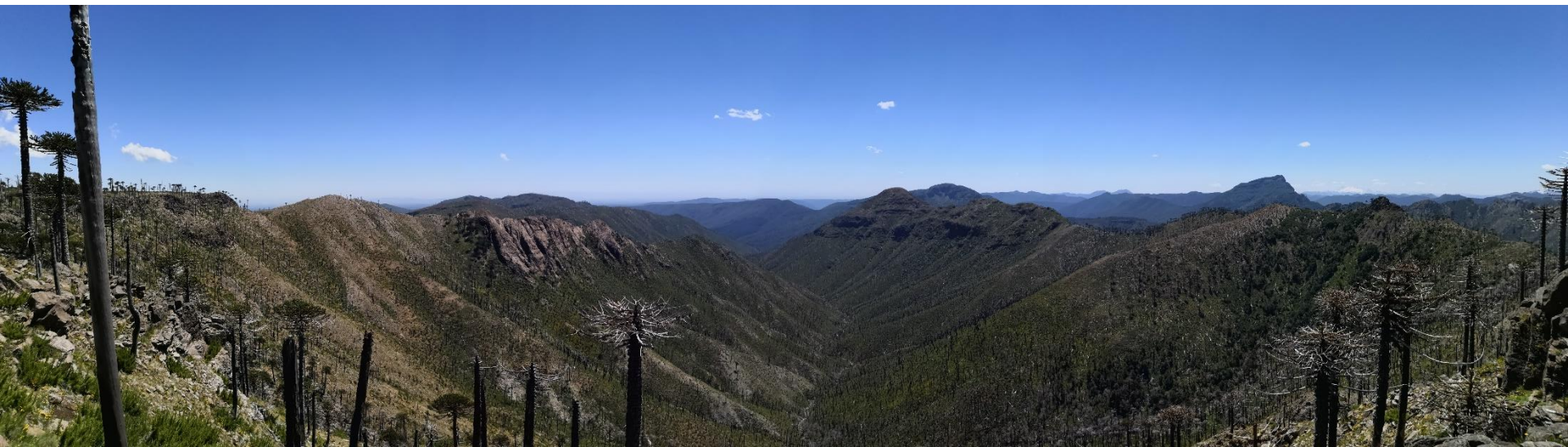
Web: <http://www.disafa.unito.it/do/docenti.pl/Show? id=mgarbari#profilo>

My research interests

- Impact of human activities on forest landscapes
 - a. Land use change (cambiamenti dell'uso del suolo) in ambito montano (Alpi, Appennini e Hymalaya)
 - b. Impatto antropico sulla struttura forestale a scala di paesaggio e di popolamento
 - c. Effetti del cambiamento climatico: innalzamento della treeline (limite degli alberi) e successione primaria in seguito al ritiro dei ghiacciai
- Natural disturbance regimes
 - a. Boschi vetusti (Alpi, Appennini, Balcani)
 - b. Dinamiche di accumulo della necromassa (legno morto) in bosco (Alpi, Appennini, Rocky Mountains)
 - c. Rinnovazione post-disturbo

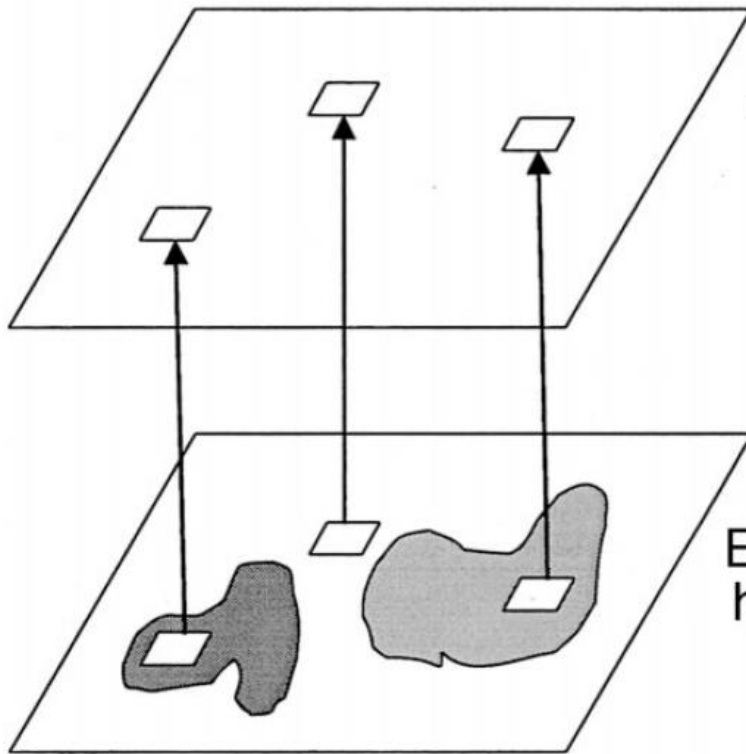
Structure of my presentation

- Landscape Ecology: an introduction
- Tools and data sources in forest landscape ecology
- Case studies: Land use legacy on forest ecosystems
- Case studies: Forest recovery after wildfire (D. Morresi)



Traditional VS Landscape Ecology

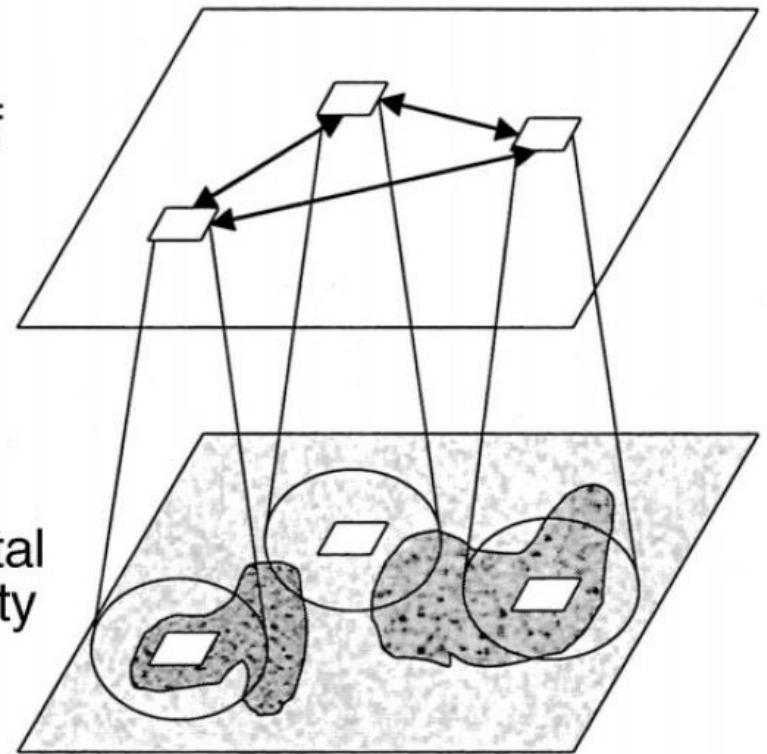
A) Ecology



Variance of
ecological
process

Environmental
heterogeneity

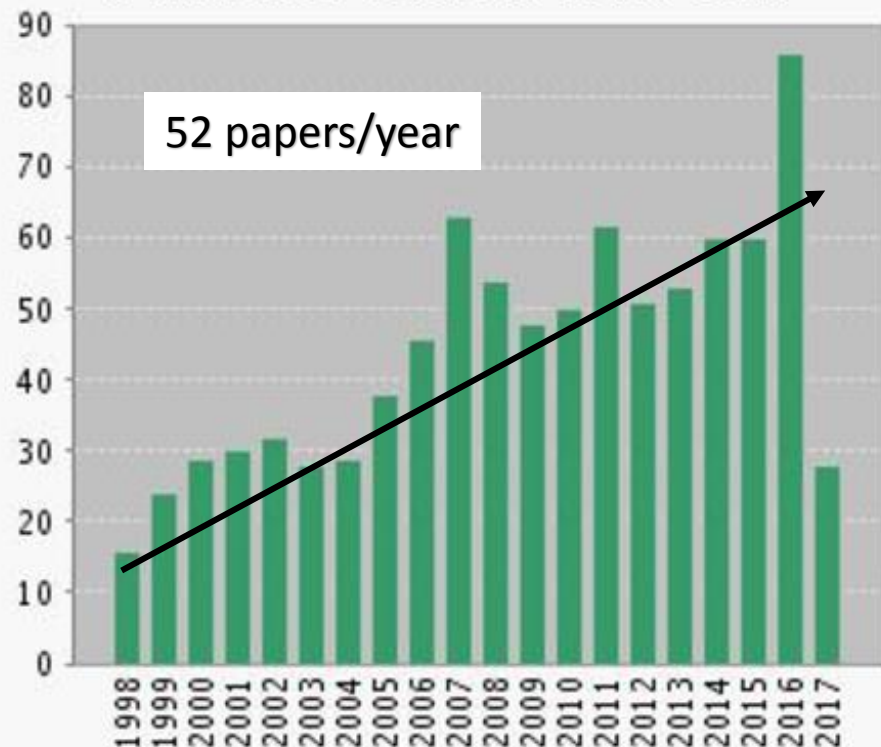
B) Landscape Ecology



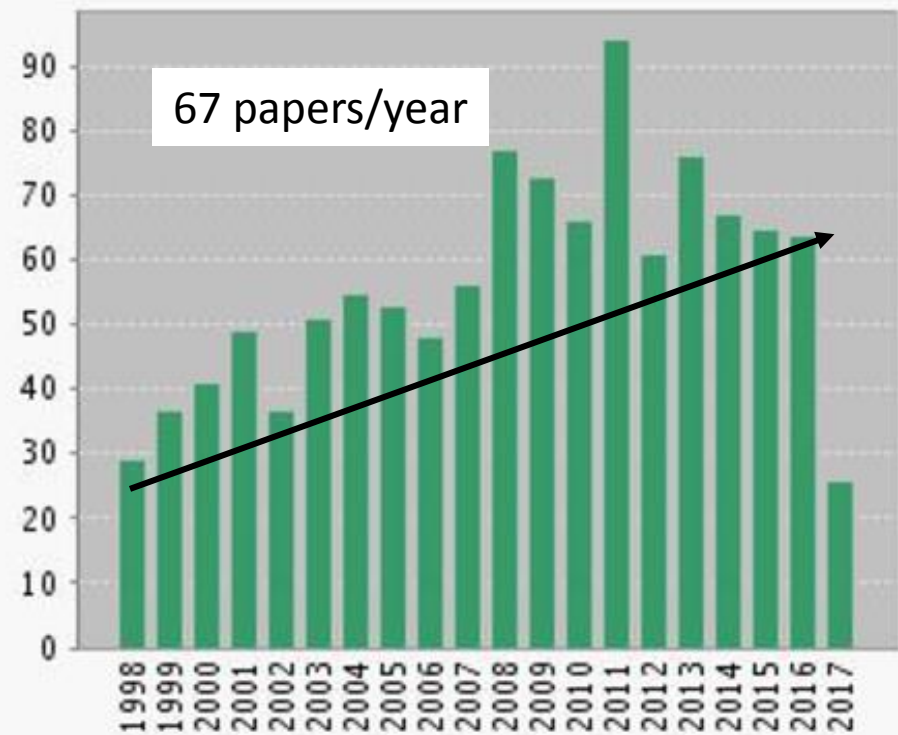
20 years of research in Forest Landscape Ecology

CONSTANT INCREASE: Forest related papers

Topic **FOREST** in the journal
LANDSCAPE ECOLOGY



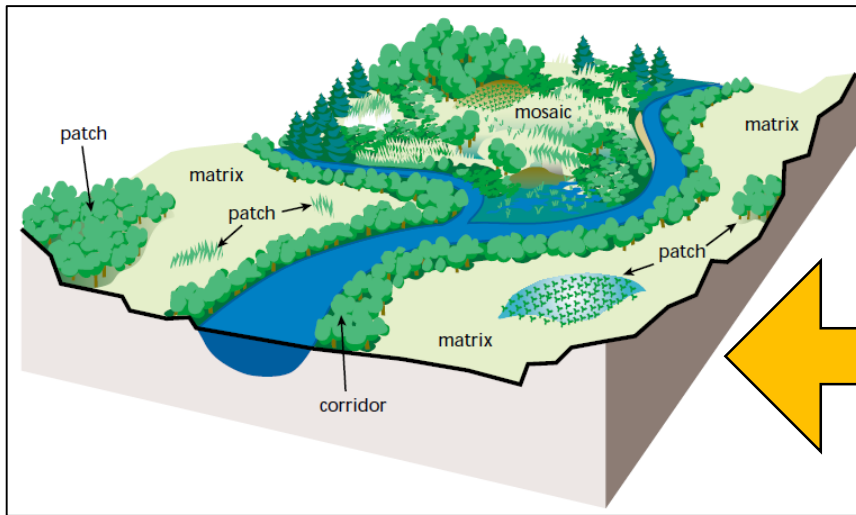
Topic **FOREST LANDSCAPE
ECOLOGY** in all *ISI journals*



Forest Landscape Ecology

Relationships between:

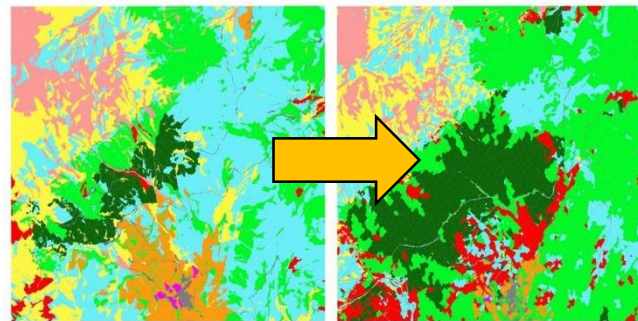
LANDSCAPE STRUCTURE



ECOLOGICAL PROCESSES



DYNAMICS



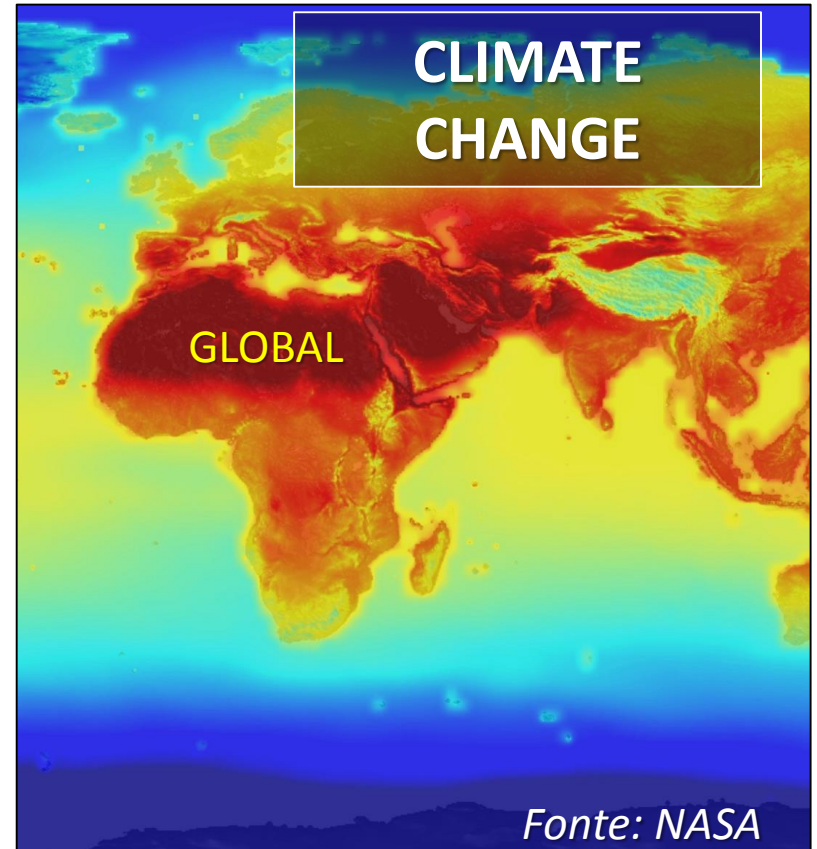
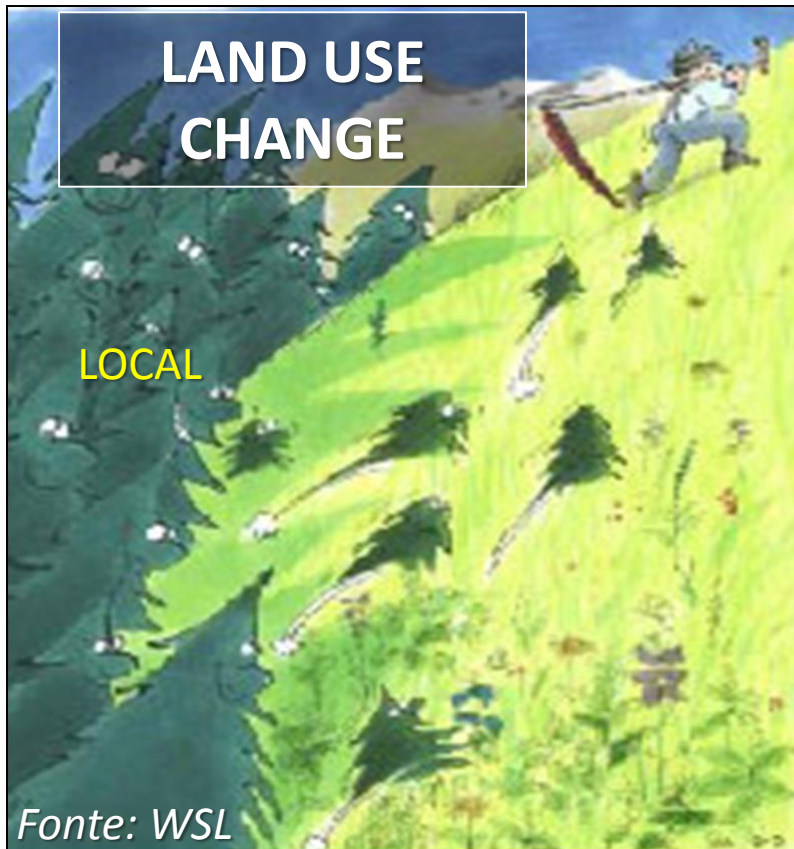
SIBILLINI NORD-EST 1954

SIBILLINI NORD-EST 2012

CHANGES

Forest dynamics

Stresses the **SPATIAL COMPONENT** of data
to study **FOREST DYNAMICS**



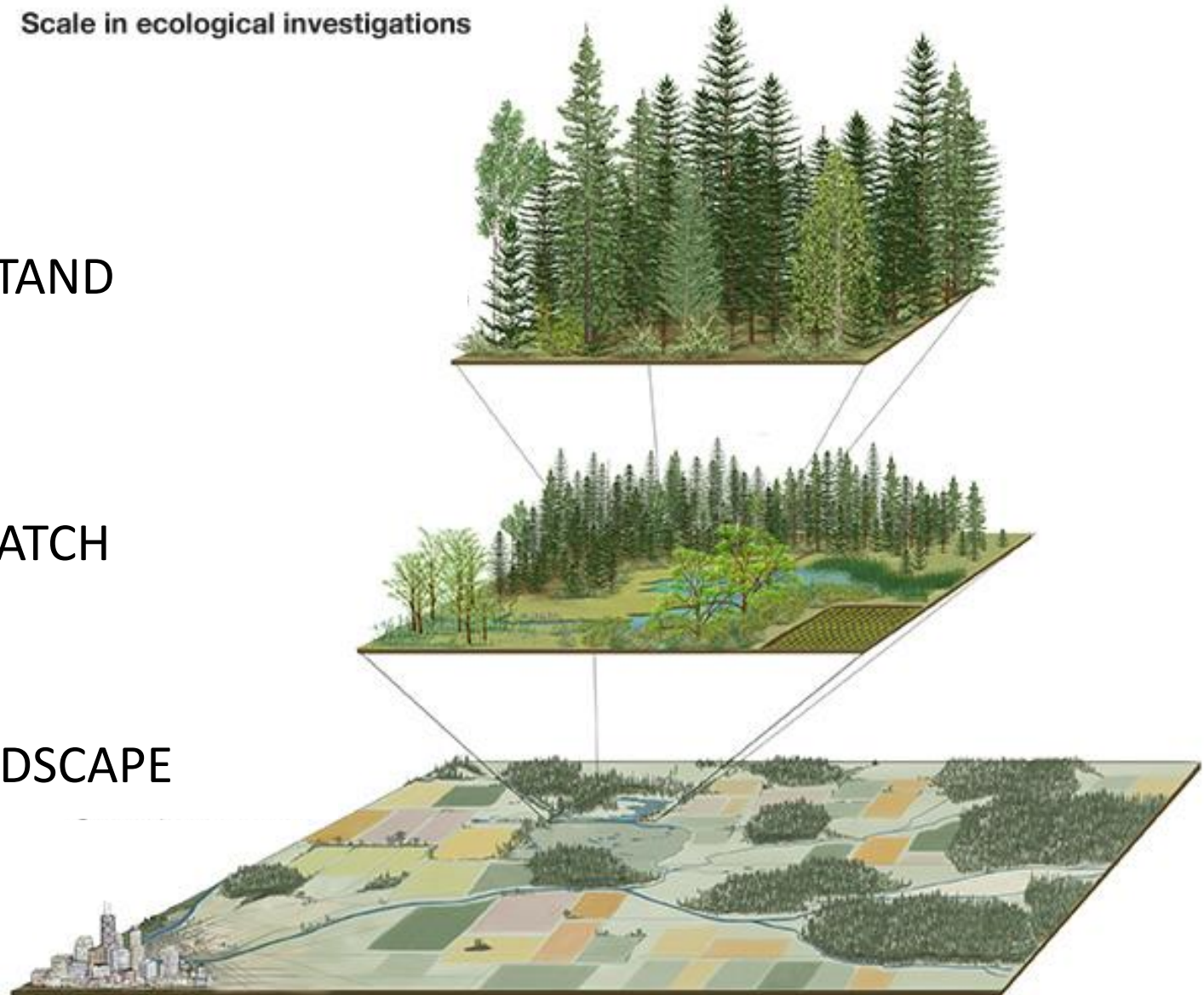
Multiscale Approach

Scale in ecological investigations

STAND

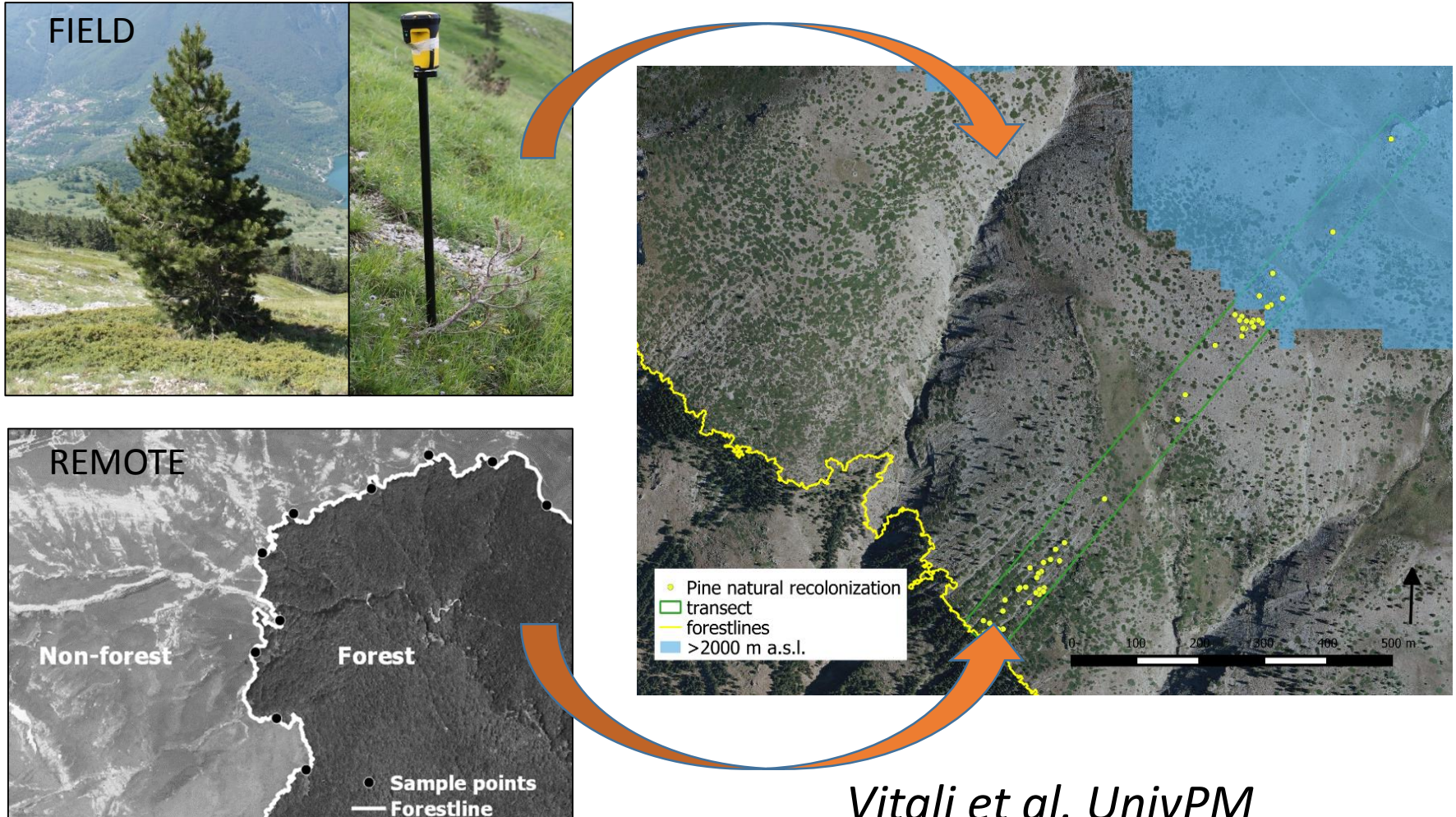
PATCH

LANDSCAPE



Multidisciplinary

RS – GIS – GPS – Field – Ecology & Society



Vitali et al. UnivPM

Landscape approach to Habitat Change post-fire

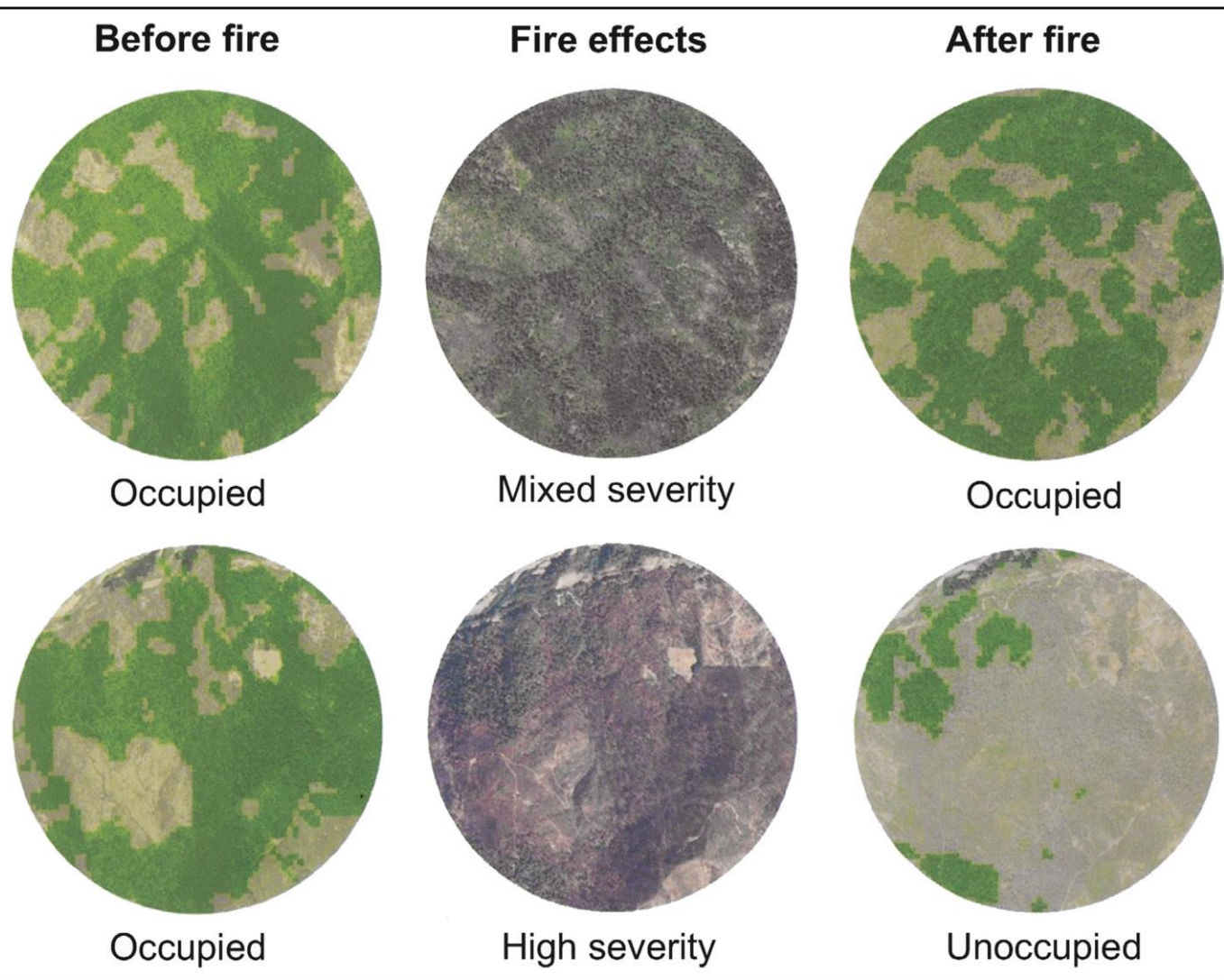


Figure 5. Aerial images of nesting and roosting (NR) forest cover (green shading) before and one year after wildfire in northwest California. The top row shows northern spotted owl (*Strix occidentalis caurina*) response to a mixed-severity fire that did not appreciably alter the pattern of NR forest cover; the territory was not abandoned. In contrast, the bottom row shows high-severity fire, which removed enough NR cover to cause territory abandonment. Occupancy data from Rockweit *et al.* (2017).

Stevens et al. 2019

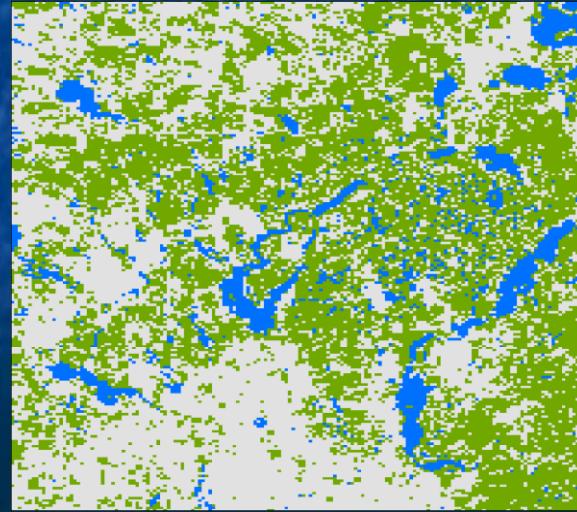
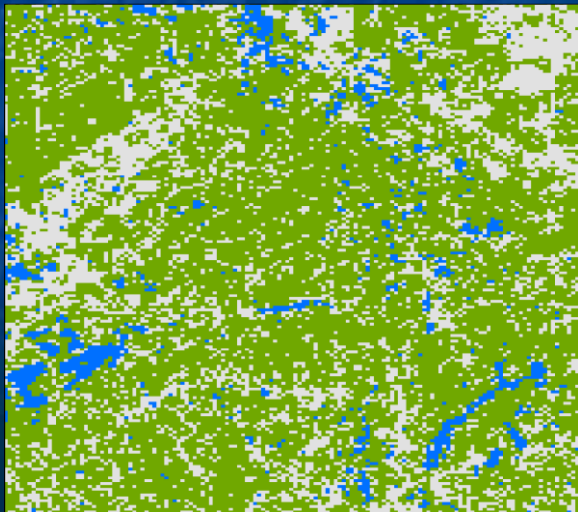
Landscape Ecology

Introduction

from David J Mladenoff

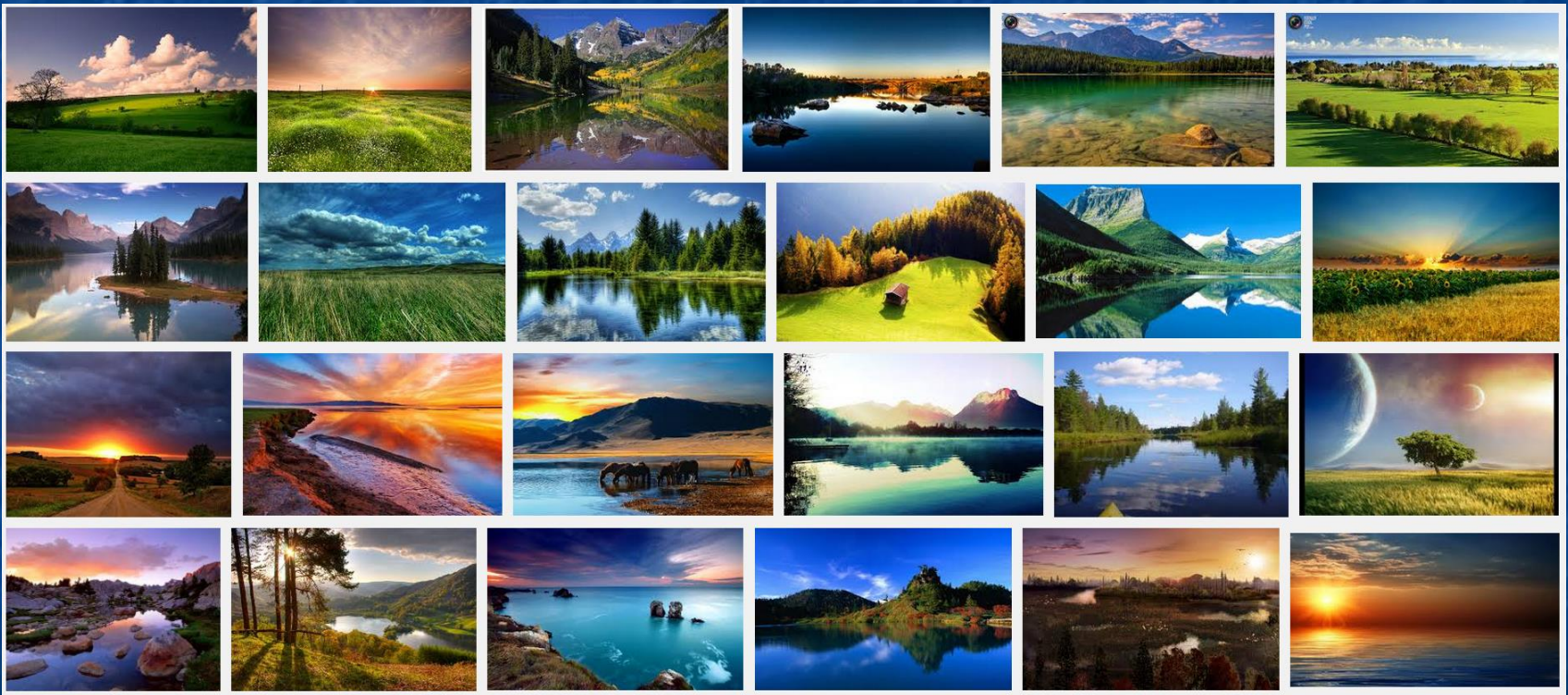
Ecology is the study of interactions among organisms and their environment

- Ecology has often assumed a non-spatial, homogeneous environment.
- The environment is extremely variable spatially.
- Interaction strength varies with distance.



Different concepts of landscape

Aesthetic landscape → gradevole o sgradevole (dipende dalle culture e dai punti di vista)



Ecco cosa troviamo su Google immagini se cerchiamo "Beautiful Landscape".

Different concepts of landscape

Geographic landscape → a portion of land dominated by a geomorphologic process.



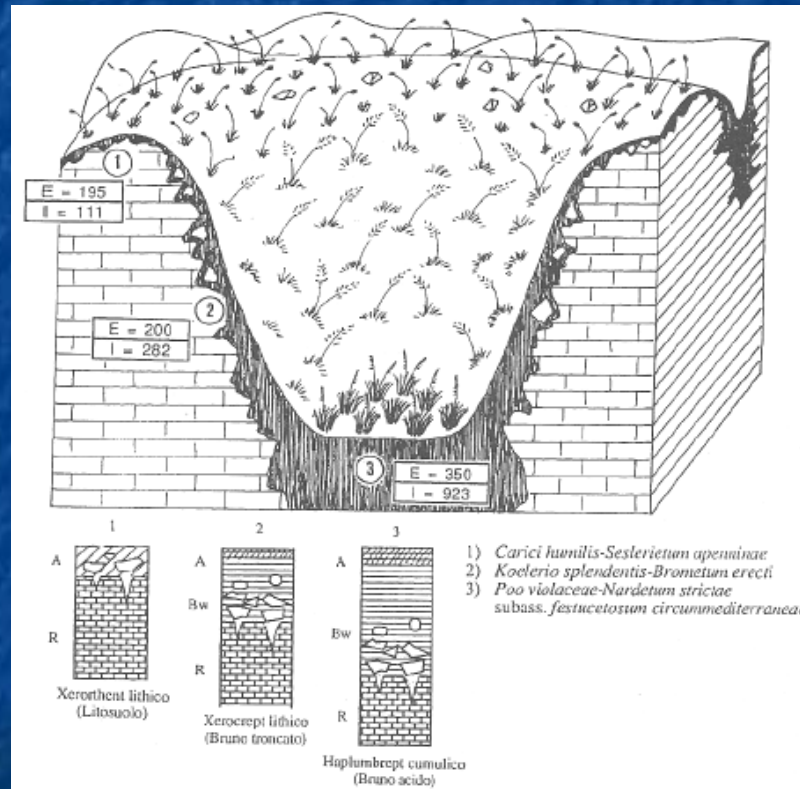
Paesaggio glaciale (<http://nsidc.org/>).



Paesaggio desertico (Joshua Tree NP, R. Hitchman).

Different concepts of landscape

Geobotanic landscape → characteristic ensemble of floristic associations.



A sinkhole vegetation association (Biondi, 1996).

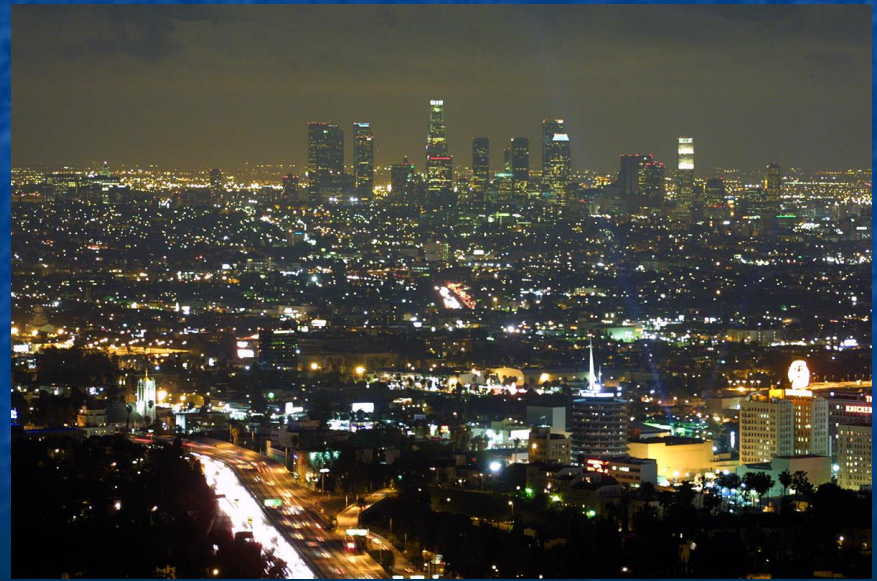
Different concepts of landscape

Anthropogenic landscape → the living geographic space used by humans (Troll, 1968).

An integration between the physical template, ecological elements and human infrastructures (Naveh, 1987).



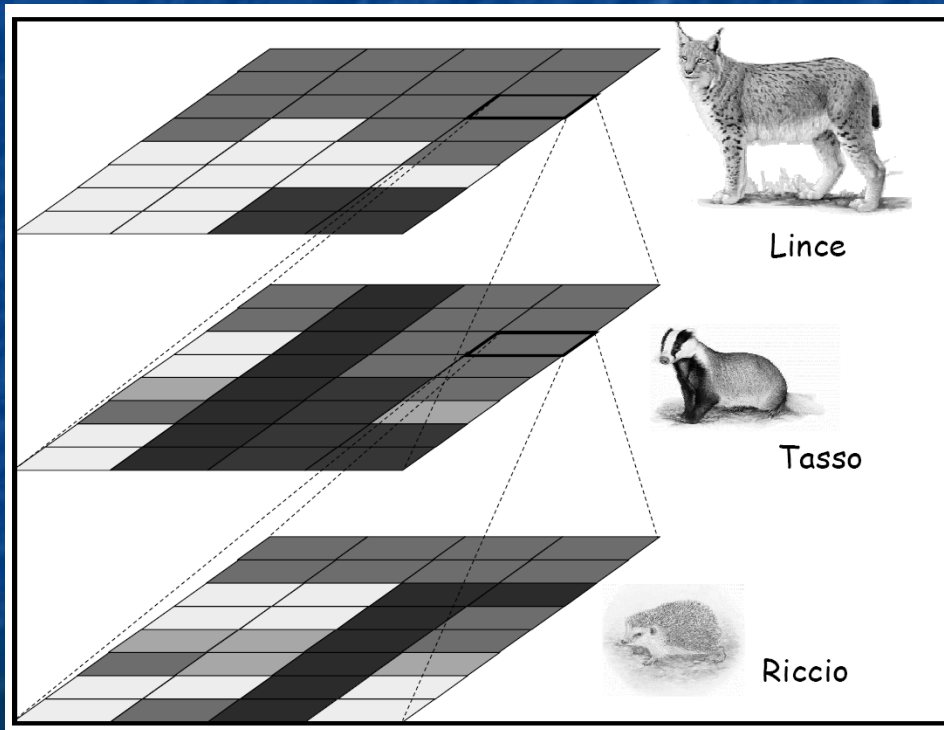
Paesaggio Agricolo.



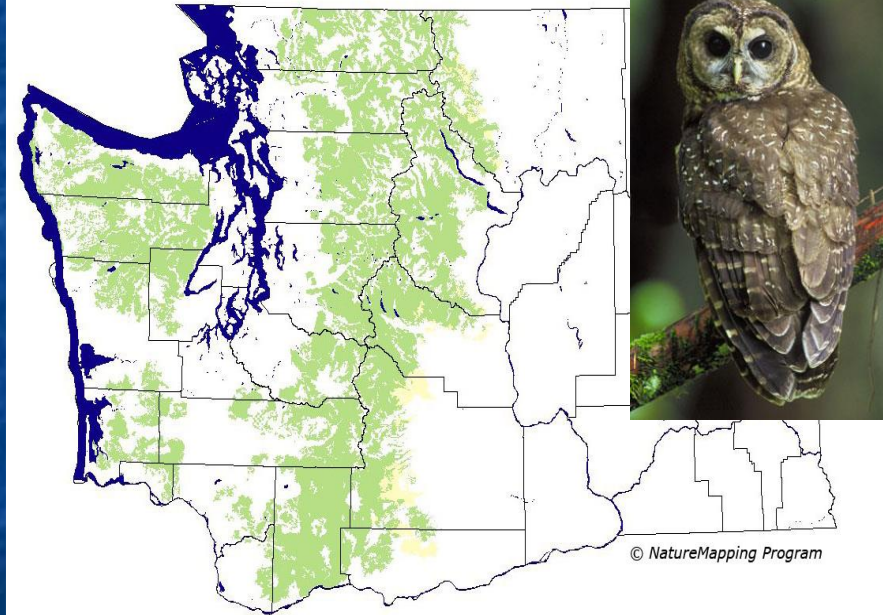
Paesaggio Urbano.

Different concepts of landscape

Ethologic landscape → the perception the species have of the environmental context. It is a matter of spatial and temporal scale.



Spotted Owl *Strix occidentalis*



Landscape is..

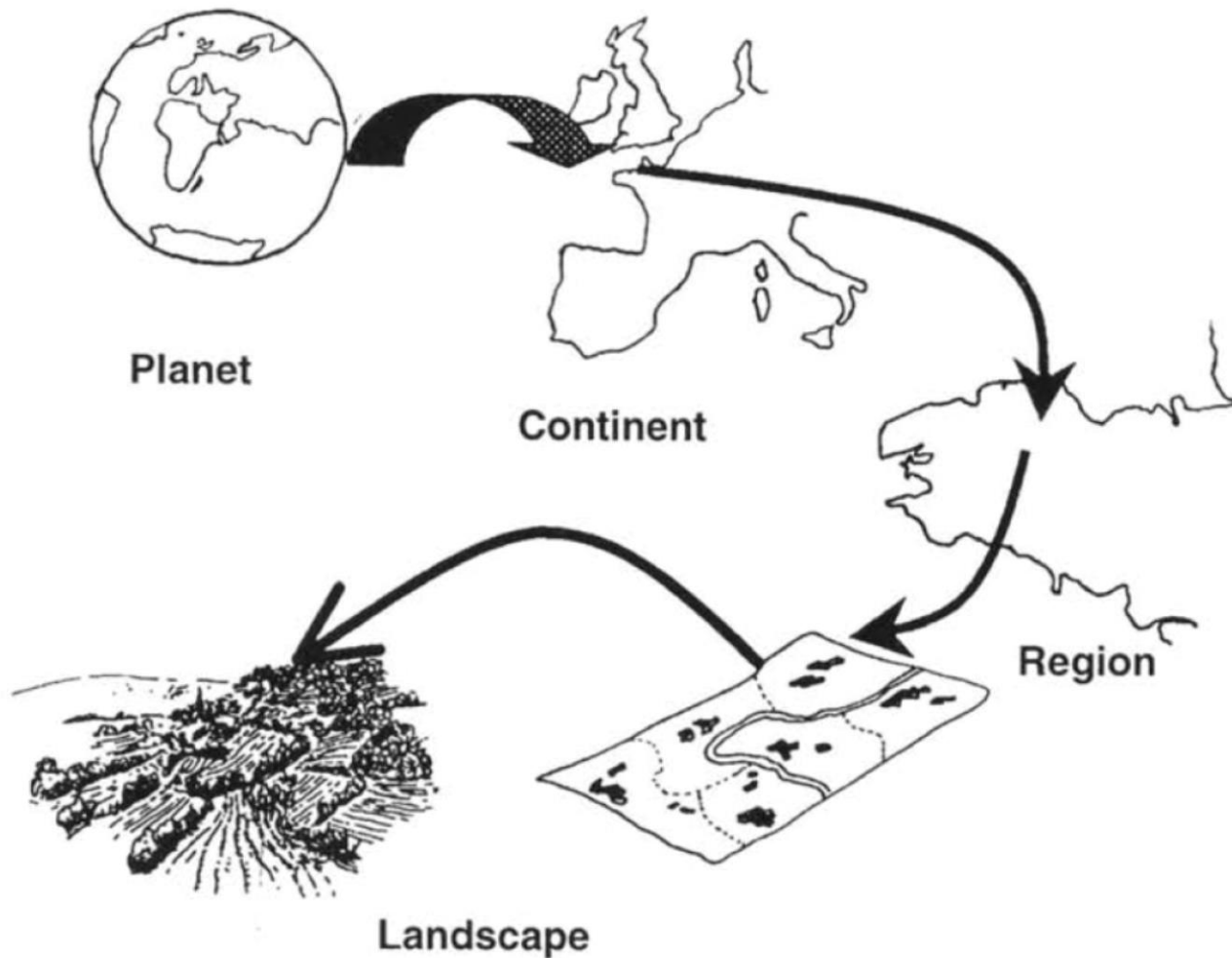
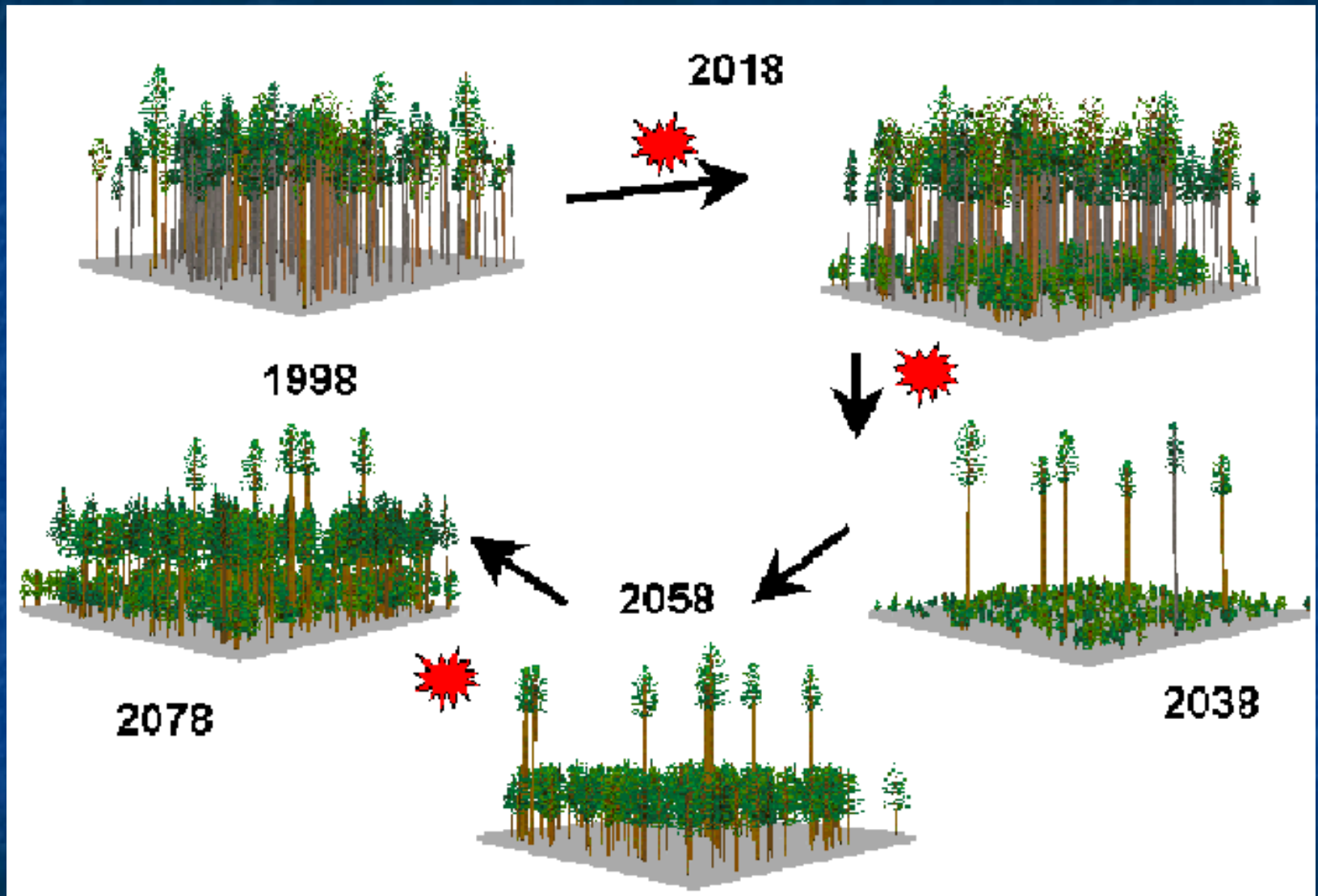
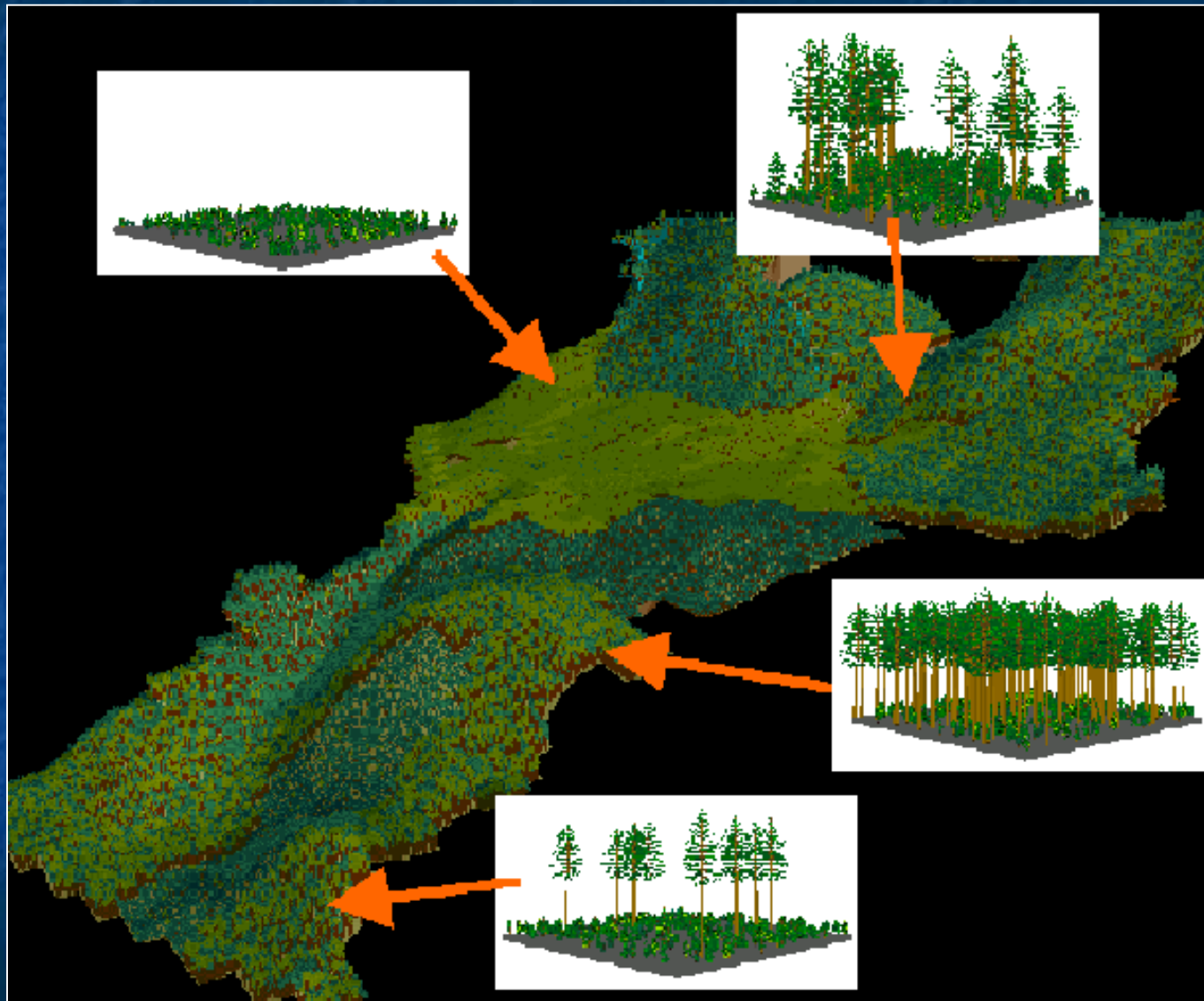


Fig. 1. The landscape as a level of organization of ecological systems, located above the ecosystem but below the region and continent (Forman, 1995)

Traditional ecology focused on omogeneous entities within a defined stratum.



Landscape Ecology focuses on landscape mosaic where spatial attributes as position, dimension, shape, dynamics and interaction between patches are all important.



Definitions

Landscape: an area that is spatially heterogeneous in at least one area of interest.

Patch: the elements that make up a landscape.

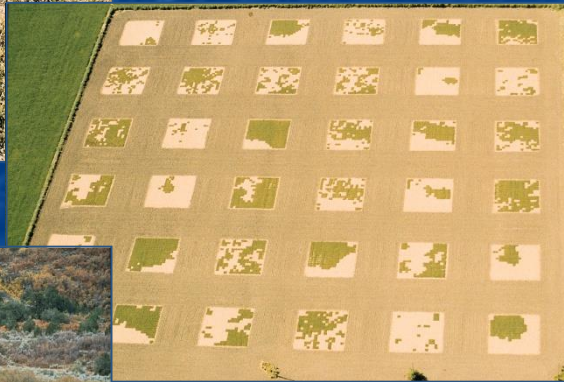
Pattern: the arrangement and composition of the patches that compose a landscape



Definitions



4m²



16m² plots



1km²



100s of km²

Landscape Structure: spatial relationships among landscape elements

Landscape Function: how the elements act and interact

Landscape Change: alteration of the structure and function of the landscape over time

Landscape Management: the management of structure and function to achieve a desired condition

Key Landscape Ecology Questions



1. What processes create landscape pattern?
2. What are the consequences?
3. How do we measure pattern? At what scale?
4. How does pattern change through time?
5. How do we predict and manage pattern?
6. How do pattern and process interact?

What else defines landscape ecology?

- Landscape ecology often (not always) focuses on broader scales than traditionally examined in ecology.
- Landscape ecology emphasizes variation in both *spatial* and *temporal* scales!



What else defines landscape ecology?

Landscape ecology often (not always) focuses on the role of humans in affecting patterns and processes.



Landscape ecology also recognizes that humans are but one agent affecting landscapes.



Landscape Ecology

Brief History

The European School



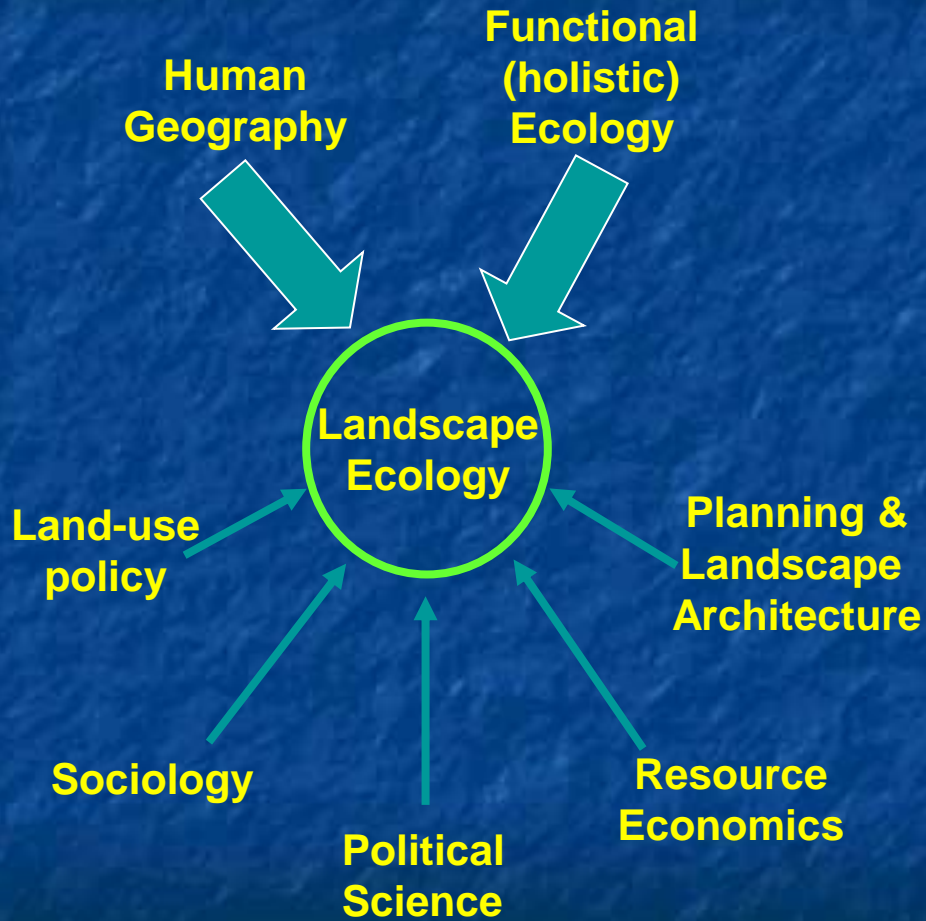
- “Original” landscape ecology
- Traced to Von Humboldt in 1807
- Russian physical geographers Berg, Solnetsev
- “Landscape ecology” coined by Troll in 1939
- Emphasizes typology, classification, nomenclature, and deals mostly with human-dominated systems
- Also the foundations of hierarchical land classification

The North American School

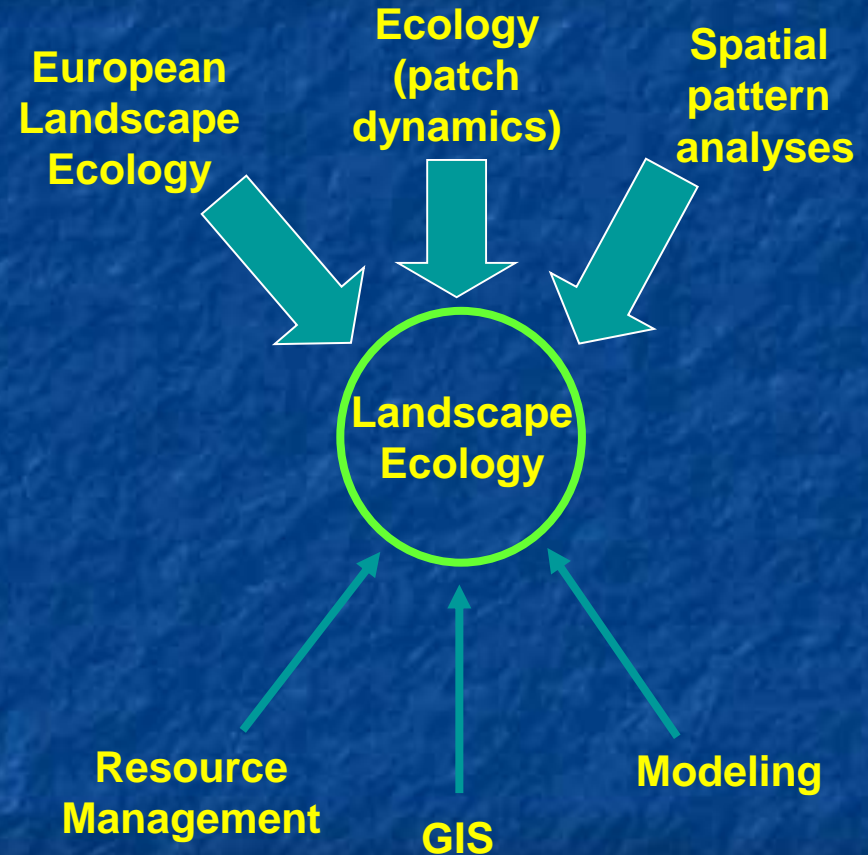


- Much younger; effectively launched at Allerton Park, IL in 1983.
- Much stronger focus on natural systems, more a branch of ecology.
- Deals more with statistics, models, technology, and theory
- Found in Biology, Ecology, Forestry, and Natural Resources Departments in the US.

European vs N American



European School



N American School

Why has Landscape Ecology emerged
as a discipline?

Why has landscape ecology emerged?

#1: Spatial scale of environmental problems has increased



Habitat Fragmentation



Fire in WUI



Invasive species



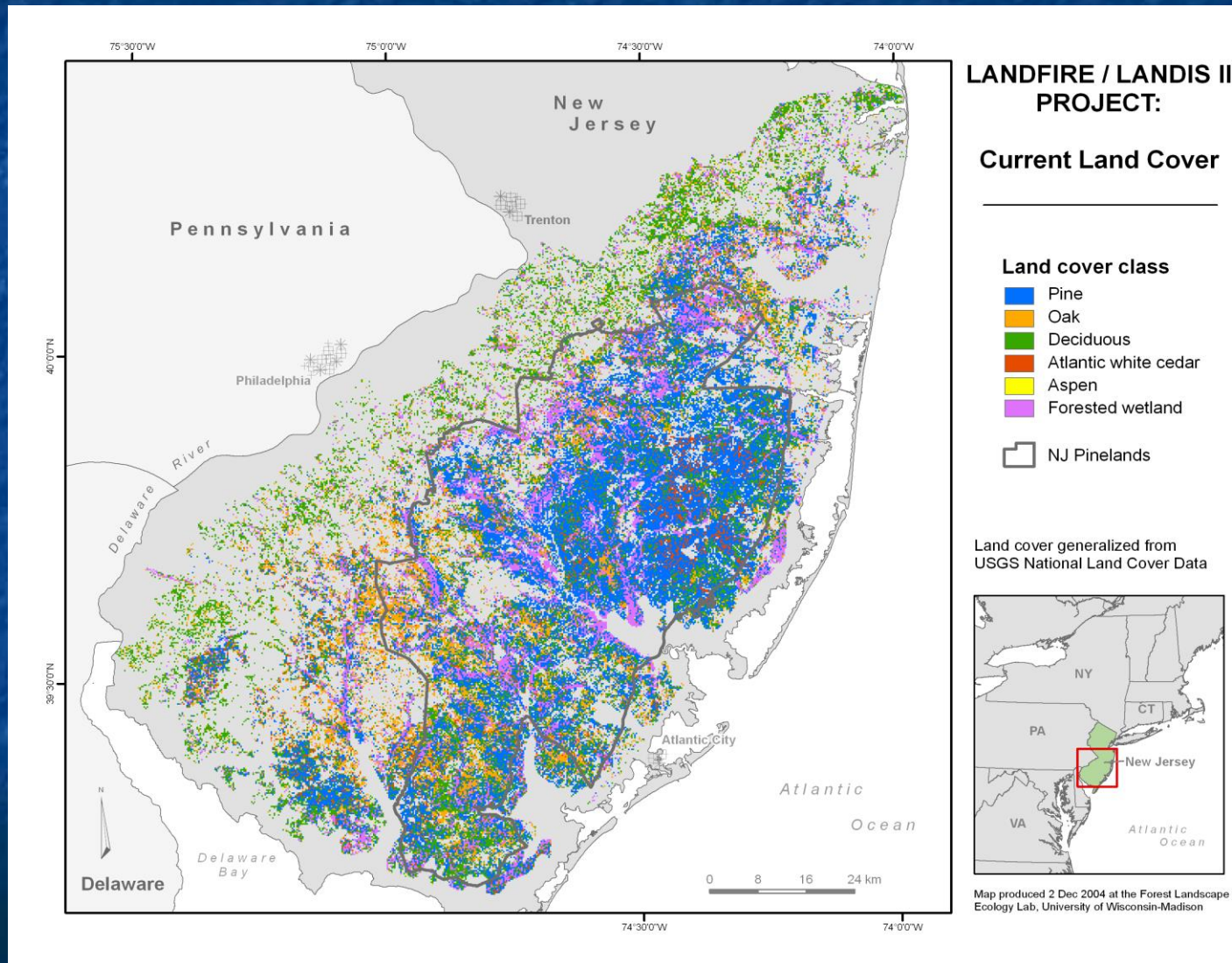
Urban sprawl



Widespread human disturbance

Why has landscape ecology emerged?

#2: A growing appreciation of spatial context

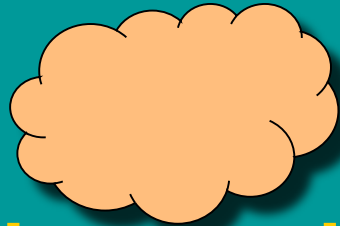


Why has landscape ecology emerged?

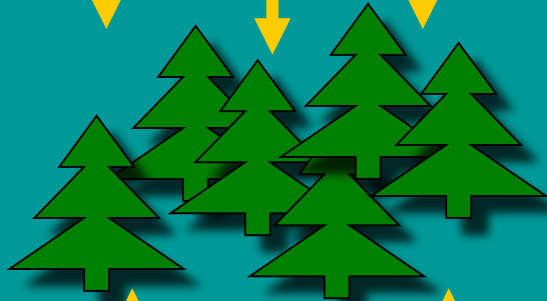
#3: Development of the necessary theories

Hierarchy Theory

Climate,
landform,
soil



Forest Stand



Tree
physiology,
establishment,
competition,
etc.



Why has landscape ecology emerged?

#4: Concepts of disturbance have changed

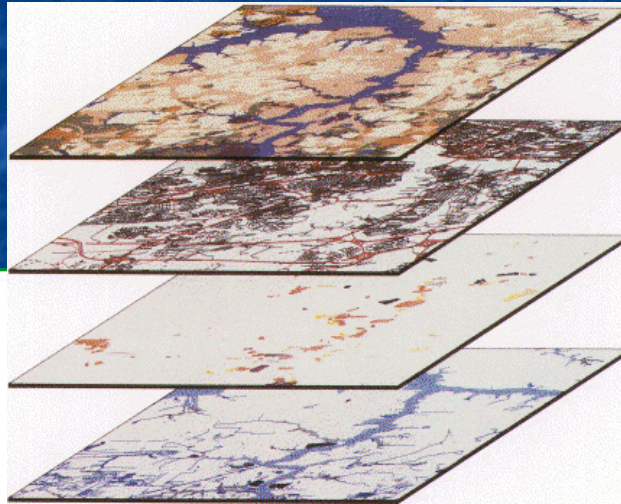
Equilibrium paradigm -----> Dynamic paradigm

- ✓ Species composition is relatively constant in a community.
- ✓ Disturbance and succession alter communities but are less important than the climax community itself.
- ✓ Ecosystems can be understood within the context of the ecosystem itself, because the ecosystem is self-contained and controlled internally
- ✓ Species composition may (or may not) reach equilibrium based on interactions between disturbance and communities.
- ✓ Disturbance is an essential part of ecosystems and ecosystem dynamics.
- ✓ Ecosystems must be understood within a larger spatial and temporal context, because ecosystems are open systems and incorporate disturbances at multiple scales

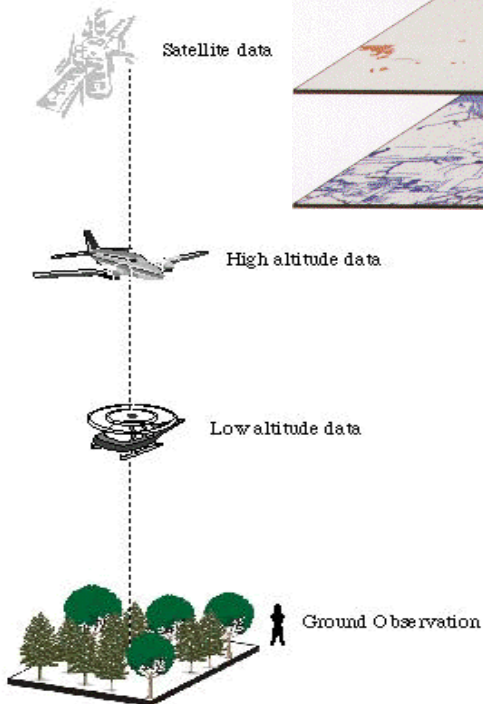
Why has landscape ecology emerged?

#5: Technological advances

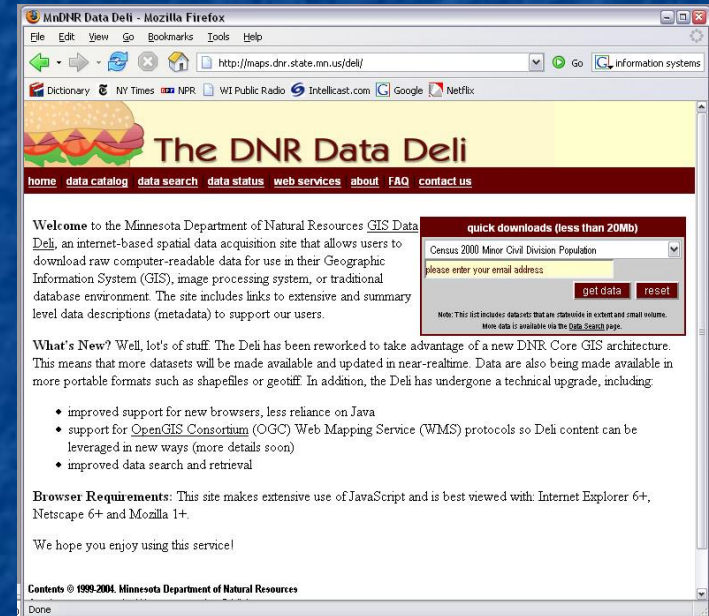
Geographic Information Systems



Remote Sensing



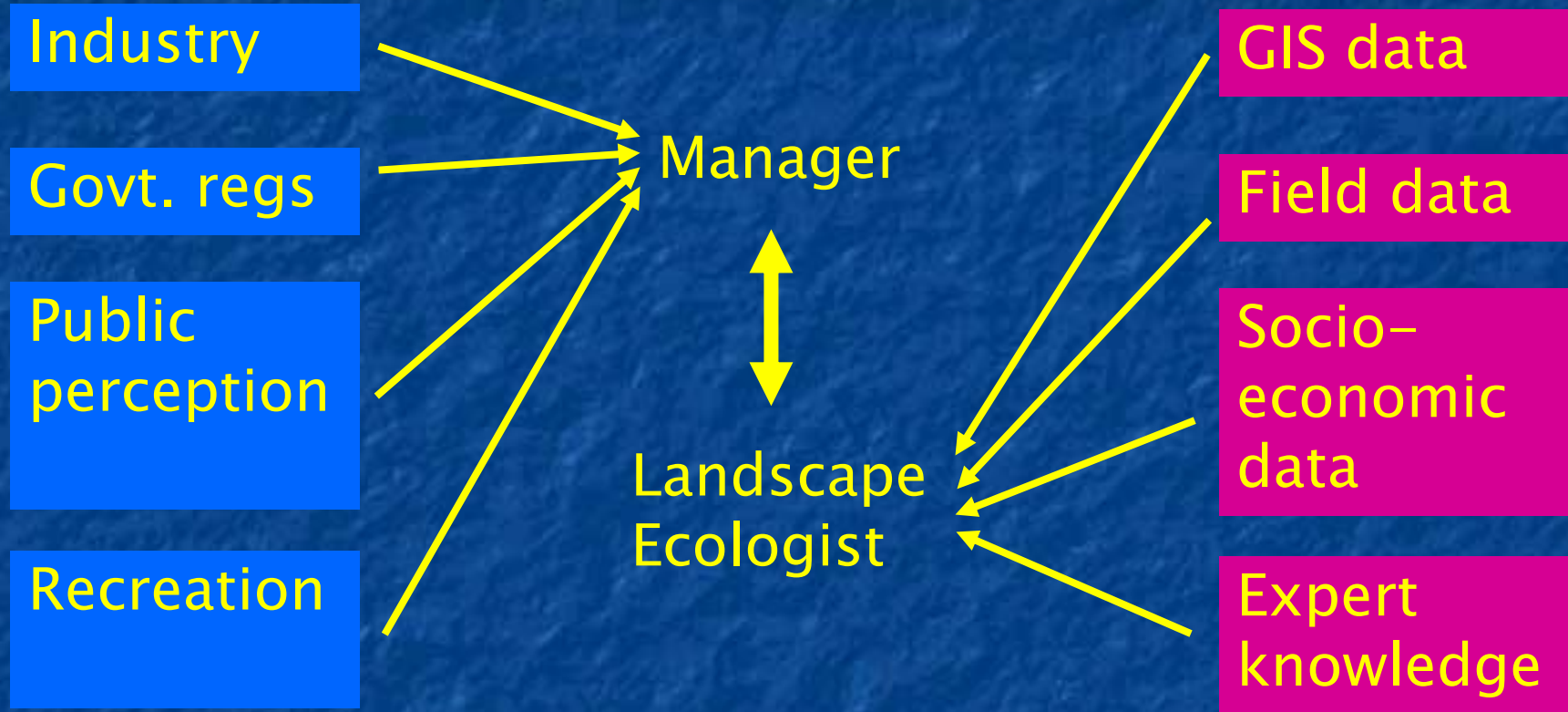
The Internet, Available Data



Models, Programming, Computing Power

Why has landscape ecology emerged?

#6: Management needs applied ecology



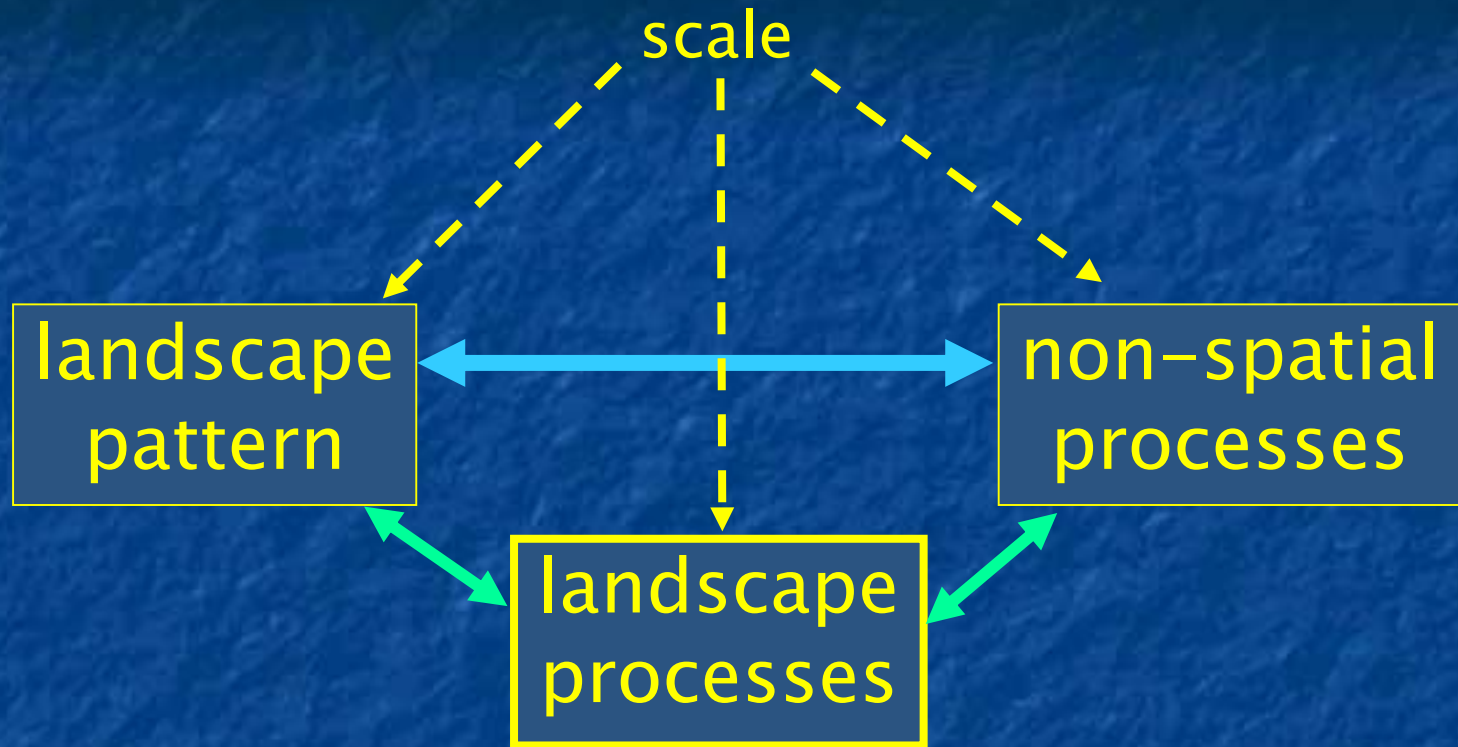
Landscape ecology 'scales up' ecological data / knowledge to a scale that is meaningful to management.

Landscape ecology: Concepts

- Scale and hierarchy theory
- Finding the correct scale for a study
- Detecting/characterizing landscape structure
- Agents of pattern: physical templates, biotic processes, disturbance
- Implications of structure to organisms, communities, and ecosystems
- Landscape dynamics – centered on landscapes as well as organisms
- Applied landscape ecology: conservation, land use, planning

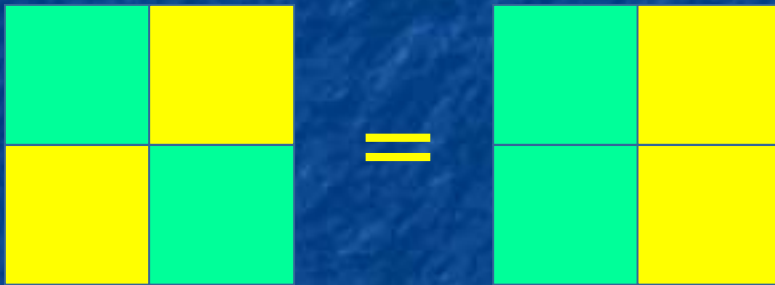


Pattern and Process



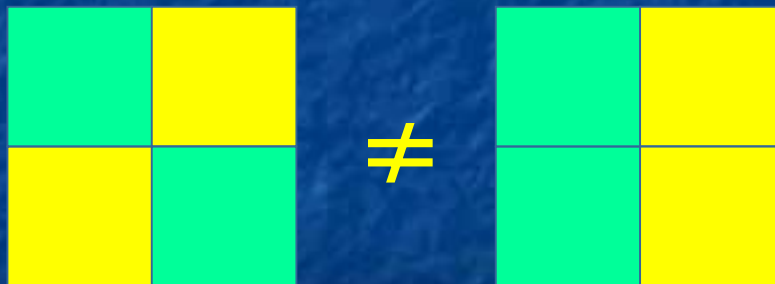
Pattern and Process

If a process is NOT a function of pattern, then it is a *non-spatial* process.



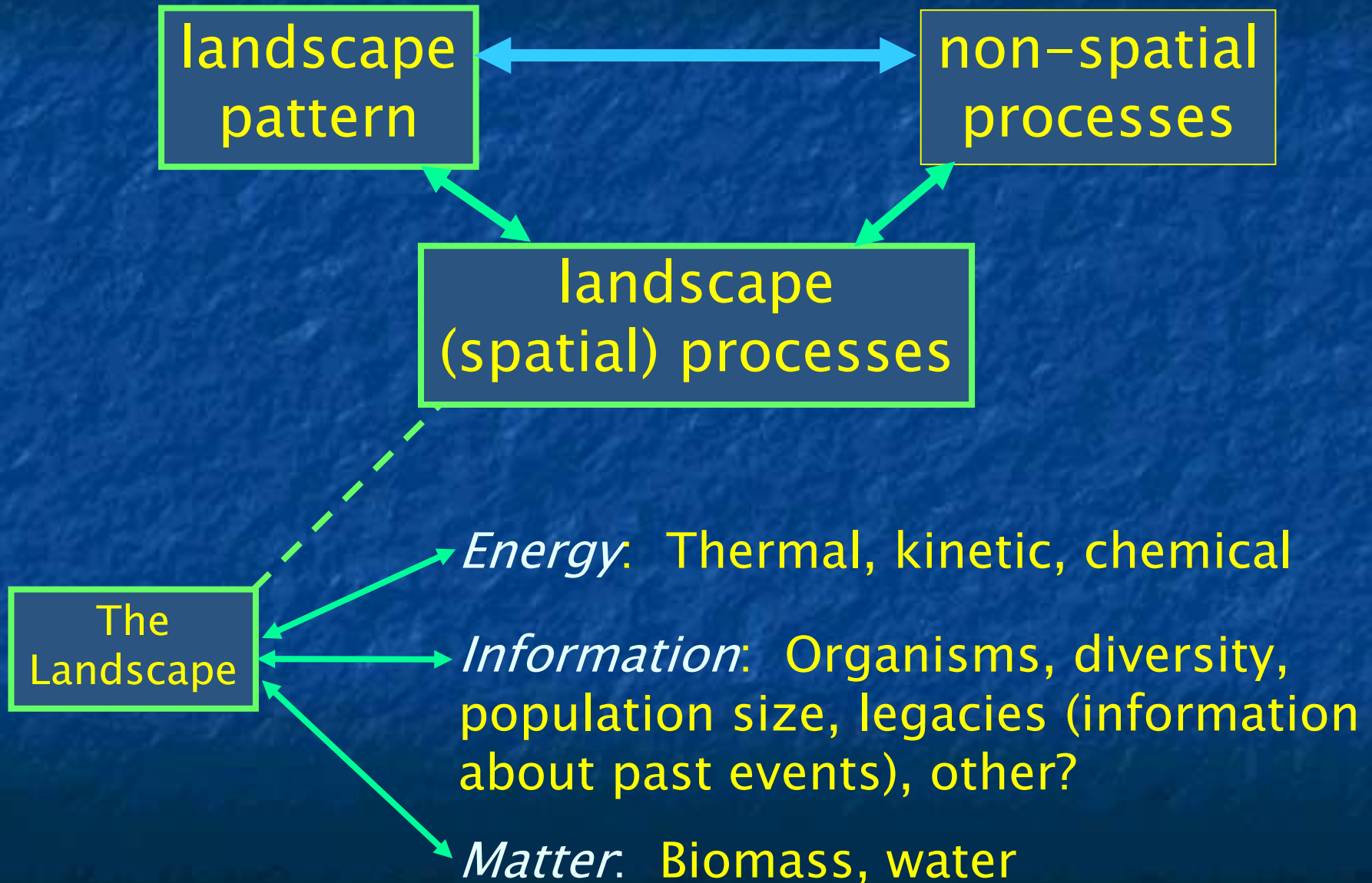
e.g. earthquakes,
tornado

If a process is a function of pattern, then it is a spatial, or *landscape process*.



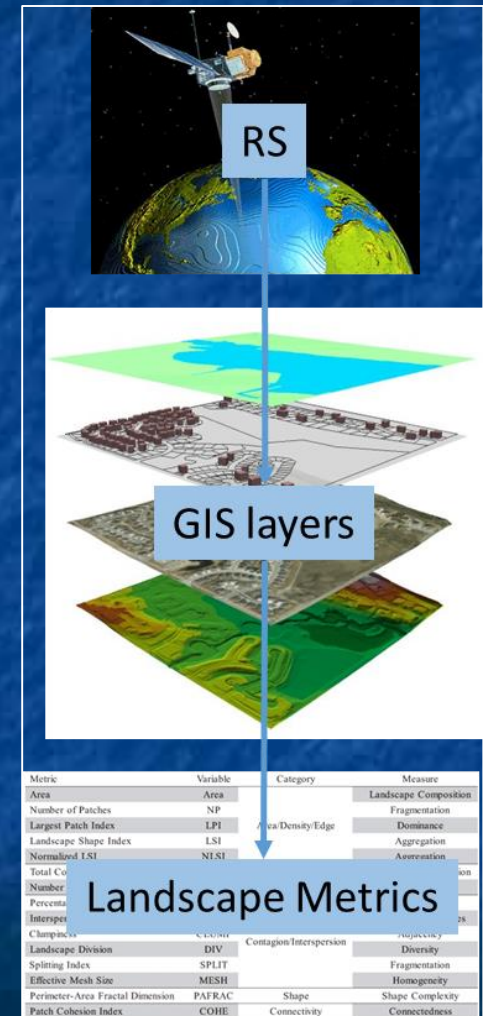
e.g. animal movement,
wildfire spread

Landscape Processes and Ecology

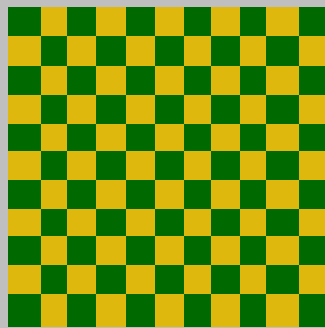


Pattern = Structure

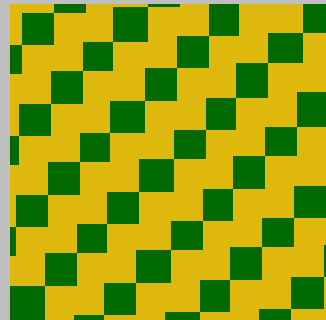
- Spatial discretization of continuous variables collected with Remote Sensing techniques.
- After image classification, we need to manage the data in a GIS and then use a statistical package (e.g. Fragstats or R) to measure the landscape and its structure (landscape metrics).



PATTERN = MOSAIC



CHECK



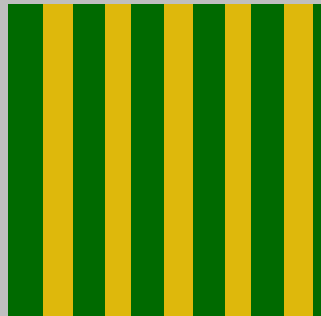
FRAGCHECK



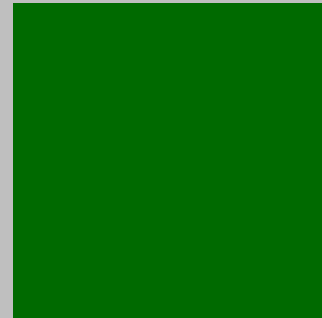
WAVES



CIRCLES



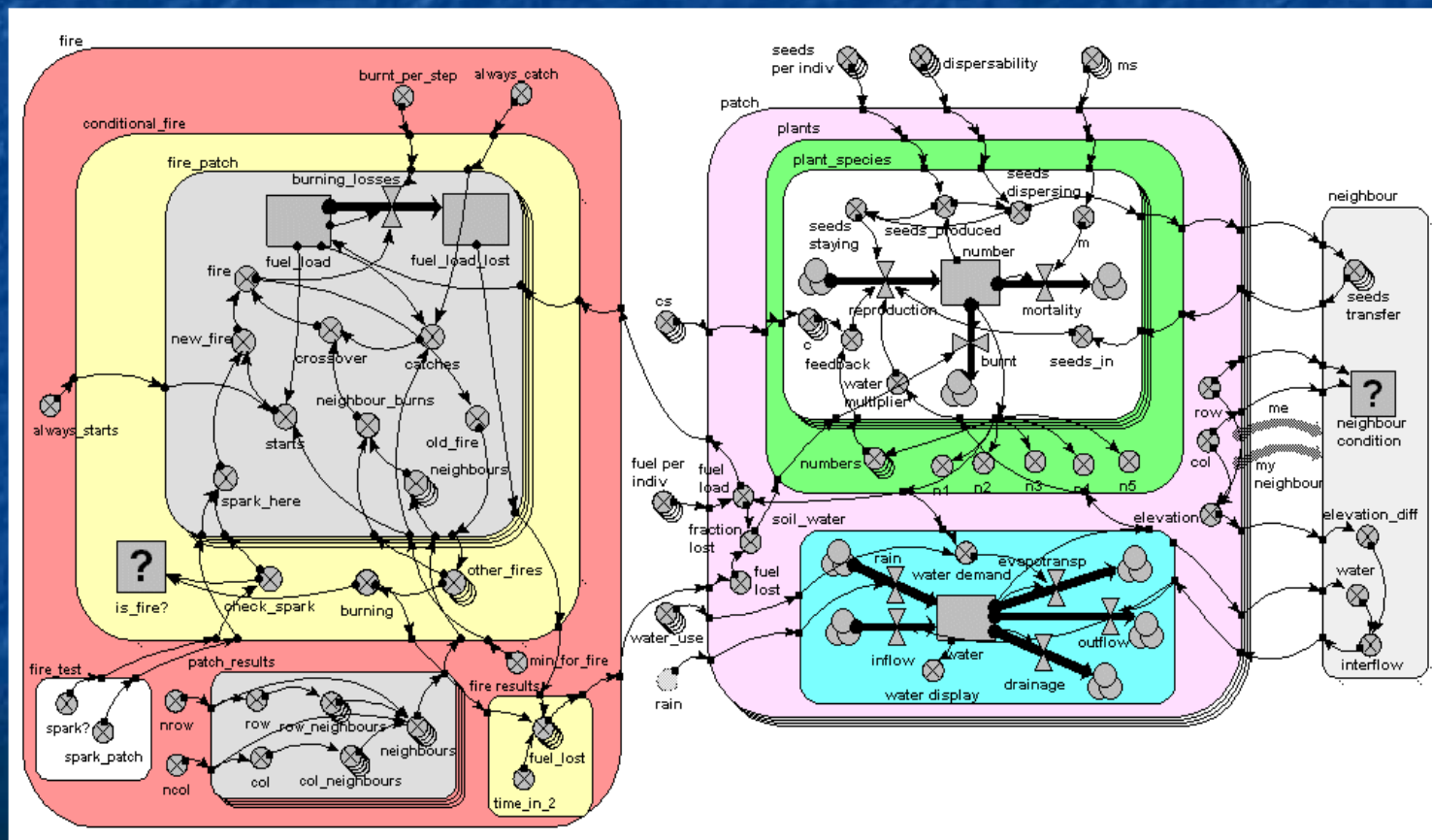
ROWS



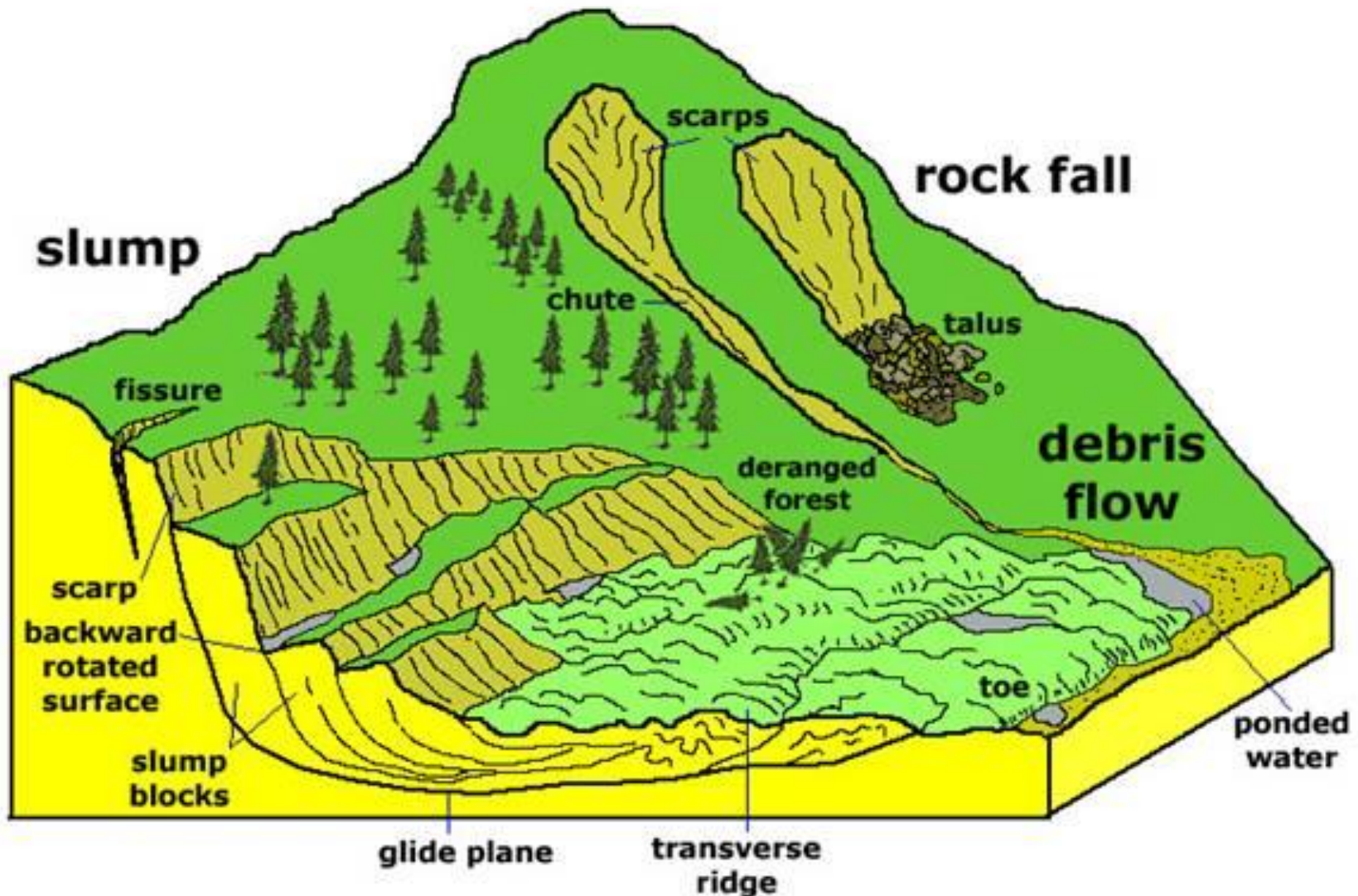
HOMO

Ecological PROCESSES

Interaction between landscape elements. Fluxes of energy, material and species between ecosystem components (e.g. nutrient cycle, animal movements..).



Physical processes



Key elements

(Forman 1989, 1995)

Patch : homogeneous area that differs from the surrounding landscape in its fundamental characteristics.

Matrix : the dominant and more connected landscape element playing the most important role in landscape function.

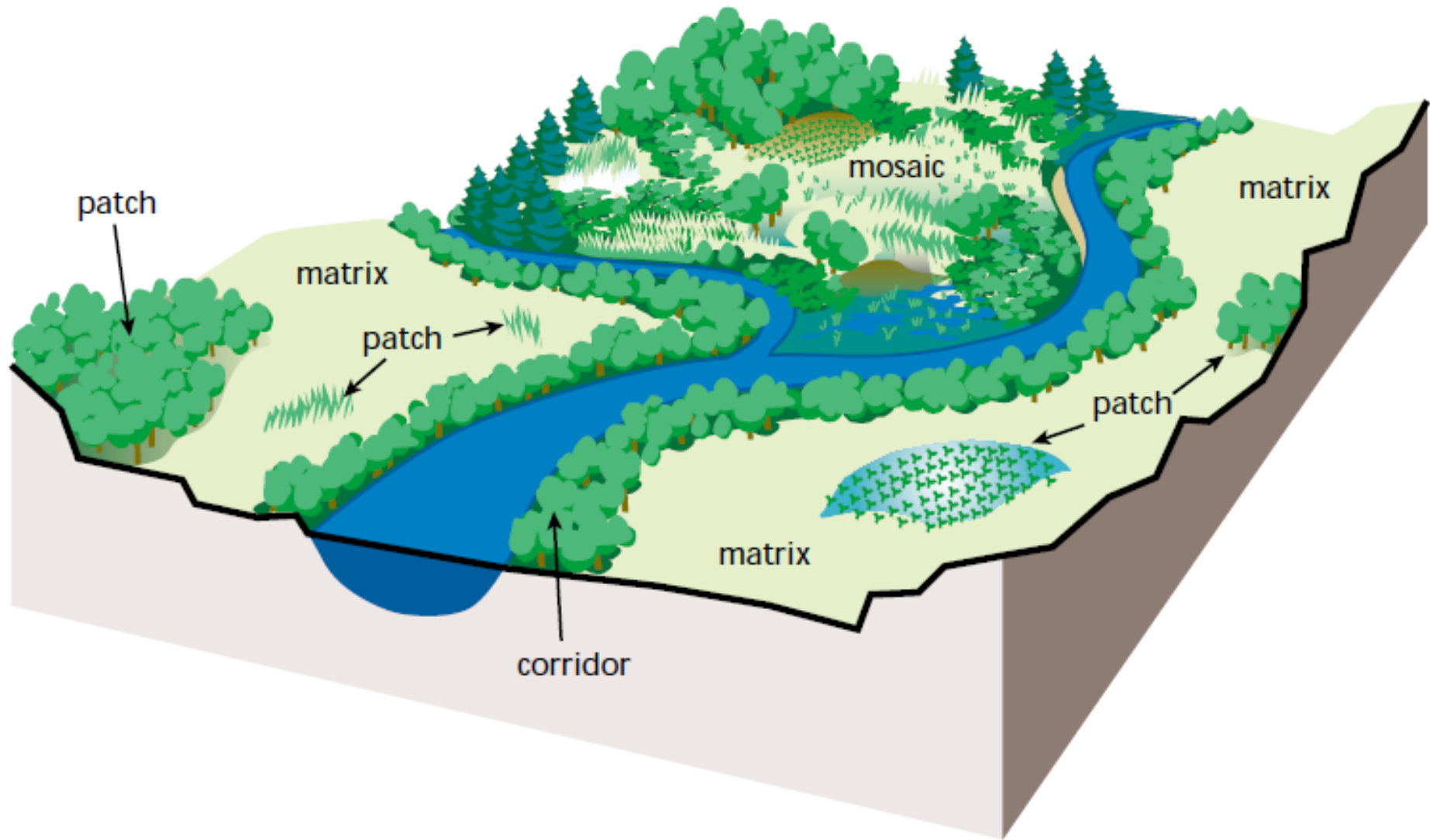
Key elements

(Forman 1989, 1995)

Corridor : narrow stripe of land connecting 2 or more patches (small core area, lots of edges)

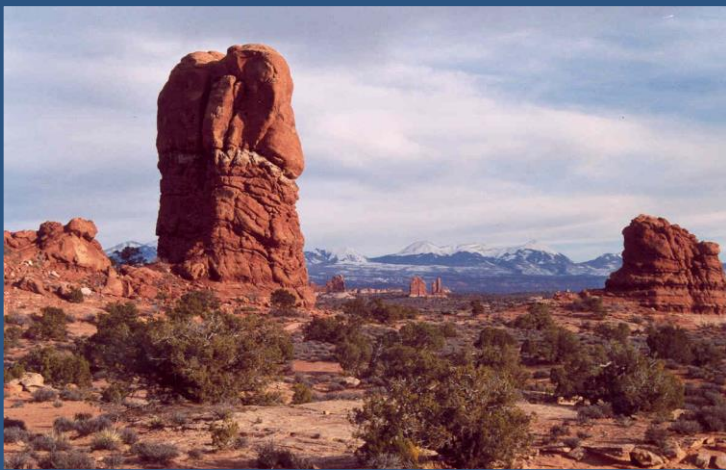
Edge : abrupt contrast between landscape elements (can also be an ecotone)

Landscape elements



Landscape mosaic (FISRWG, 1998).

Abiotic Constraints on Landscape Pattern and Function



Climate = long term or prevailing weather affecting the distribution of energy and water in a region

- **Temperature**
- **Moisture**

Landform = geomorphic features affecting physical relief and soil Development, microclimate

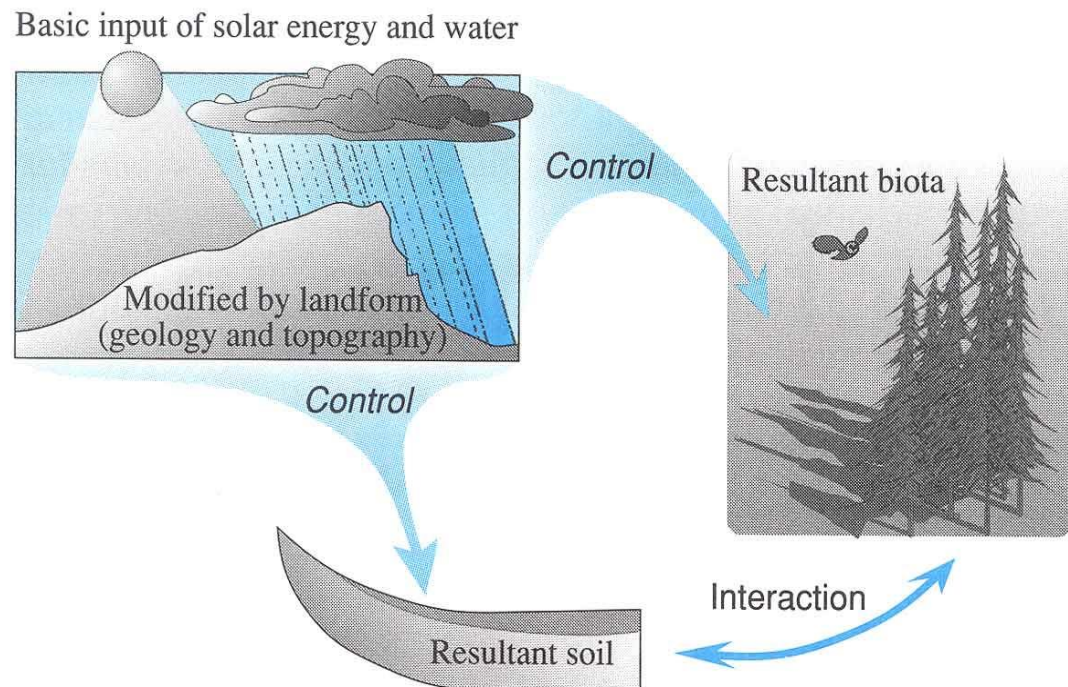


Abiotic Constraints: Climate

Climate controls several large scale processes:

- Hydrologic cycle
- Landforms and erosion cycles
- Plant/animal life cycles and distributions
- Fire and wind disturbance regimes

Figure 4.1.
Role of climate
in ecosystem differentiation.



From Bailey 1998

Abiotic Constraints: Landform

- Next level down in hierarchy of constraints.
- Modifies and is modified by climate.
- Provide the template for disturbance and biotic responses.

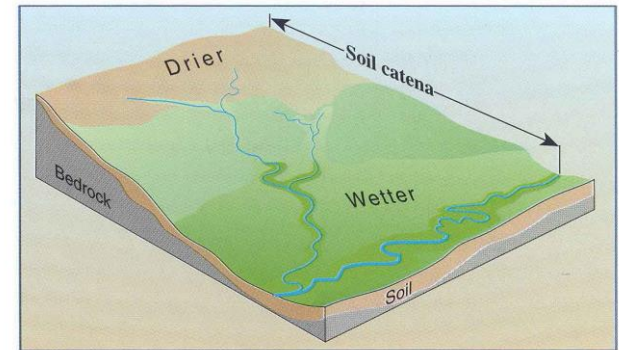
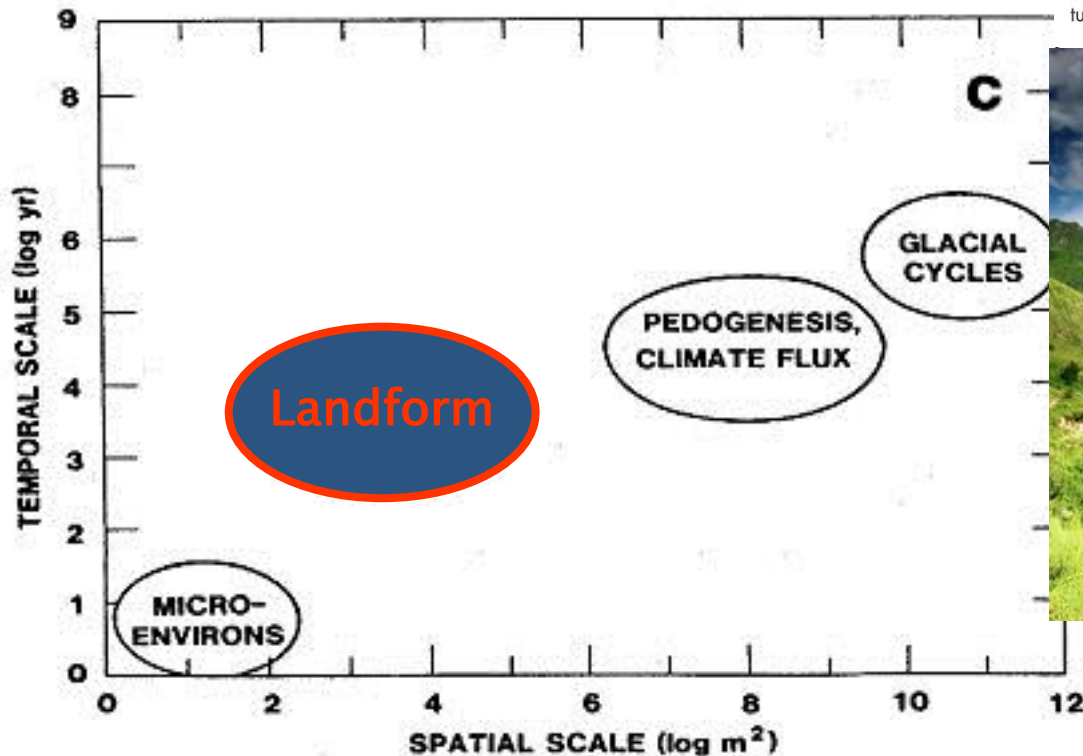


Figure 8.24. Variation in moisture creates a toposequence or catena of soil moisture regimes.



Landform and Disturbances

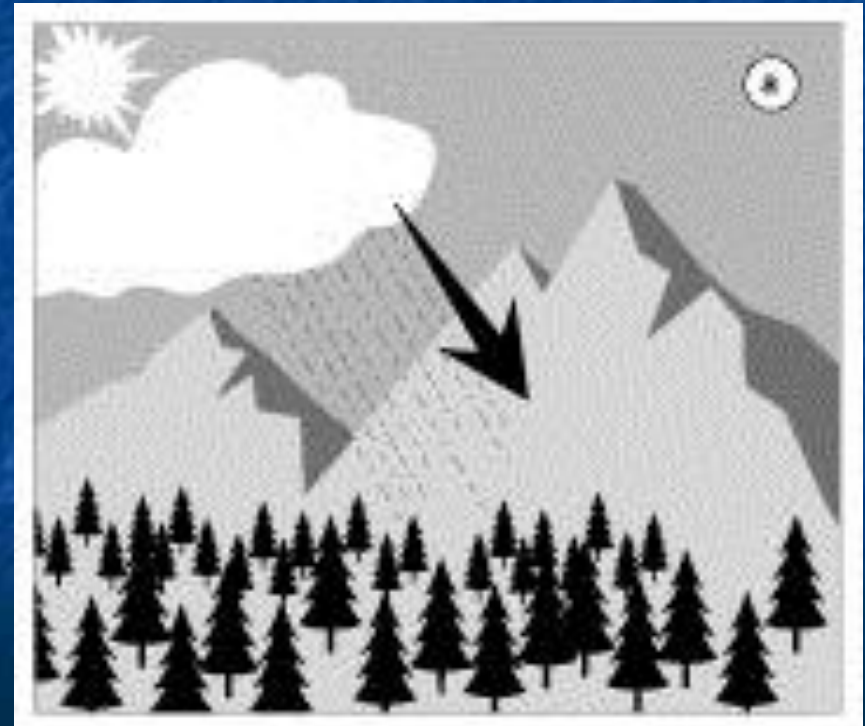
Landforms may affect the frequency and spatial characteristics of fire, wind, and grazing, as well as other natural and anthropogenic disturbances.



Landform and Climate Interactions

Landform and climate interact at all scales (continental to landscape to site).

Elevation, aspect, and surface texture interrupt air masses and influence energy input from sunlight, and precipitation and nutrient inputs.



Landform and Climate Interactions

Example: Greater insolation on south slopes causes warmer sites, greater evapotranspiration.

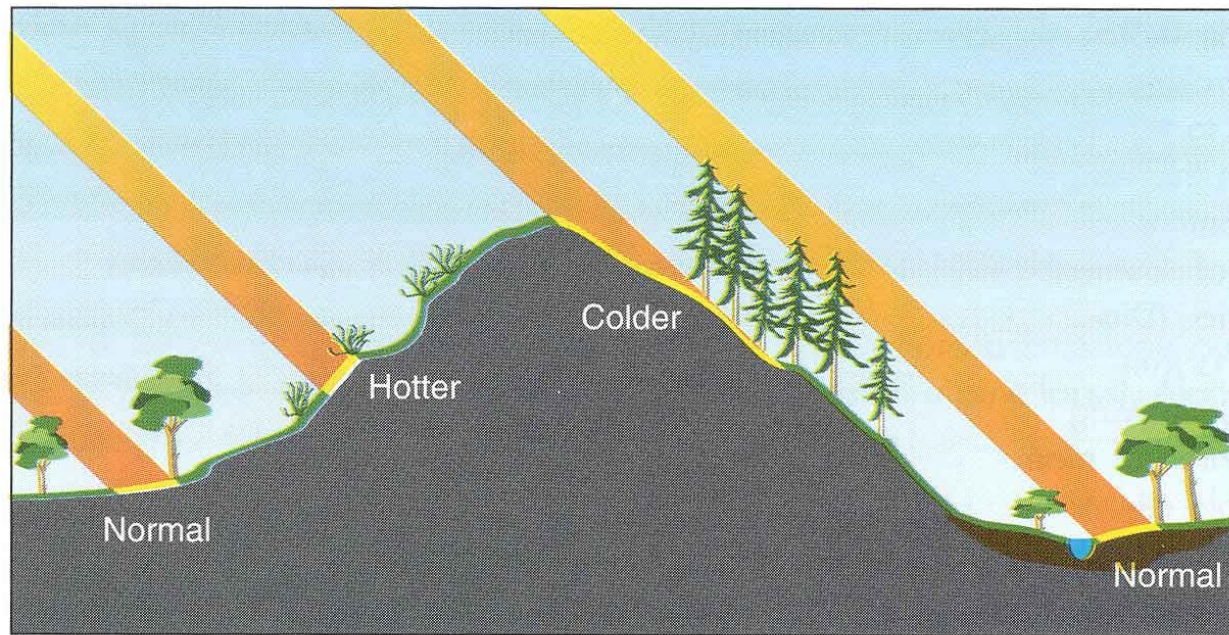


Figure 8.23. Slope and aspect affect temperature, creating topoclimates.

From Bailey 1998

Landform and Climate Interactions

Example: Elevation can cause rain shadow effect in rugged terrain.

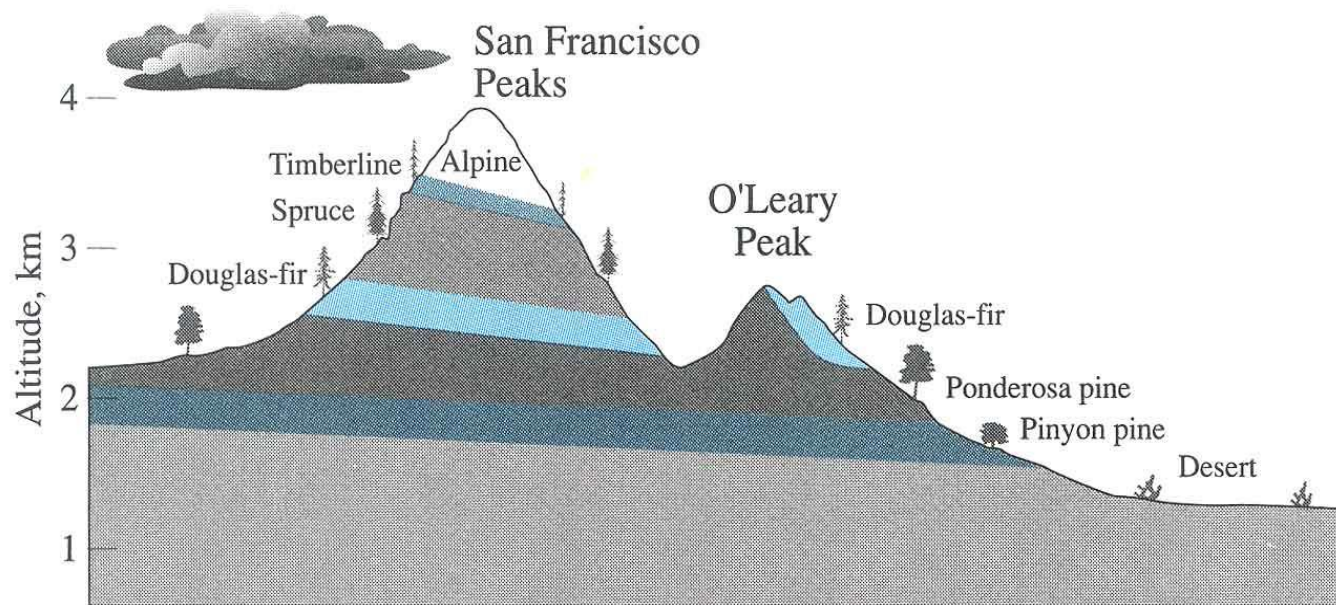


Figure 5.22. Vegetation zonation on San Francisco Peaks, Arizona, as viewed from the southeast, illustrating the effects of northern and southern exposures. From Merriam (1890).

Climate and Disturbance

Direct effects:

Wind Speed

Wind Duration

Lightening Strikes

Overland flow

Flood magnitude

Flood duration



Indirect effects:

Fuel Quantity

Fuel Moisture



Landform and Disturbance

Landform interacts with climate and will therefore create microclimatic conditions that will alter the local disturbance regime.

Example: Foster and Boose (1992)

- Studied hurricane effects in New England.
- Used GIS to correlate severe hurricane damage to forests and topography.

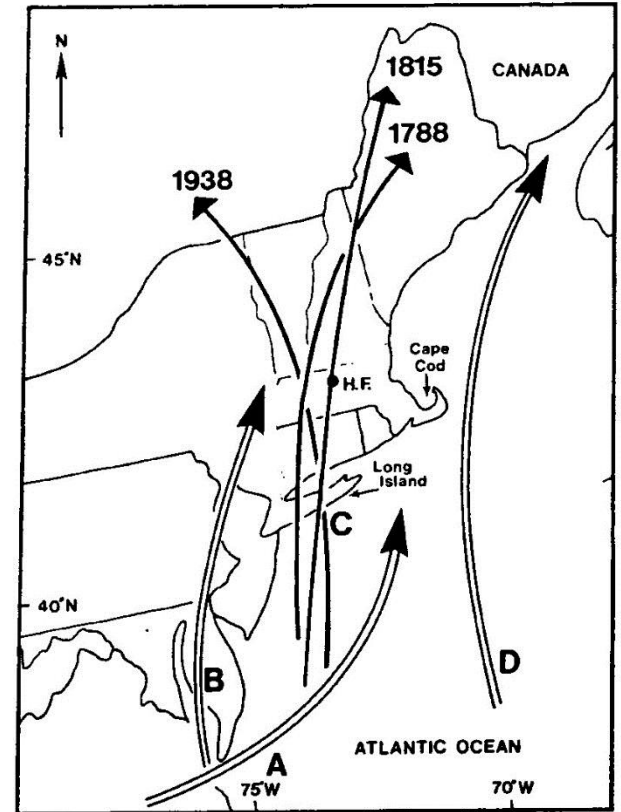


Fig. 1. North-eastern USA showing the four generalized pathways (A–D) that hurricanes follow into the region and the historical tracks of the hurricanes of 1788, 1815 and 1938 (pathway C). The location of the Harvard Forest (H.F.) is indicated by the circle. Modified from Smith (1946).

Landform and Disturbance

Example:

Foster and Boose (1992)

- Slope and aspect highly correlated with increasing damage.
- Tree height and species composition also significant.
- Damaged stands:
 - 3% in topographically protected sites
 - 31% intermediate
 - 66% exposed sites.

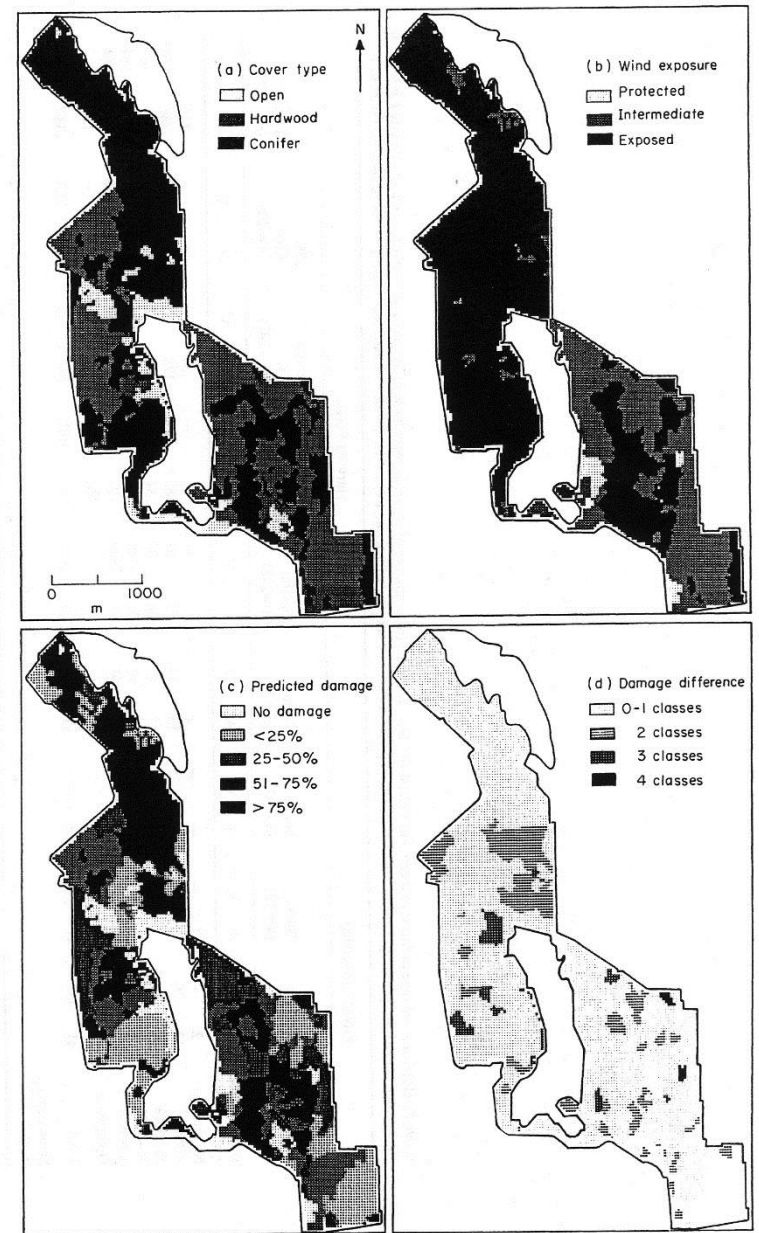


Fig. 10. Cartographic modelling of landscape response to the 1938 hurricane in the Tom Swamp Tract, Harvard Forest. Input for the model includes (a) 1938 cover type, (b) site exposure to wind, and 1938 forest height (Fig. 3c). Model output is a map of predicted damage (c). The observed damage map (Fig. 3d) is subtracted from the predicted damage map to create a difference map whose absolute values (d) highlight areas where the predicted damage is too high or too low.

Abiotic Confounding Factors

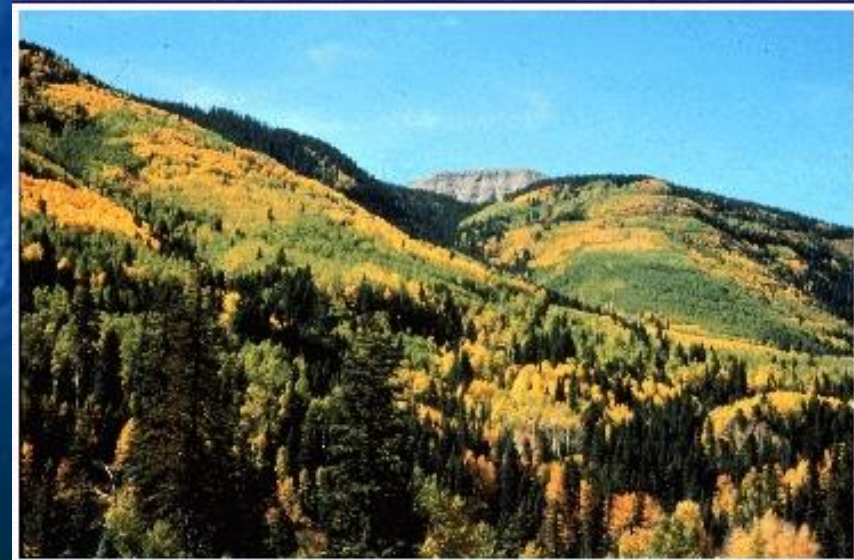
Direct inferences between the abiotic template and landscape patterns are not always obvious!

- Biotic responses to physical factors are not always predictable due to differential rates of establishment, growth, mortality.
- Interactions such as competition may confound the relationships.
- Disturbance may alter biotic composition.

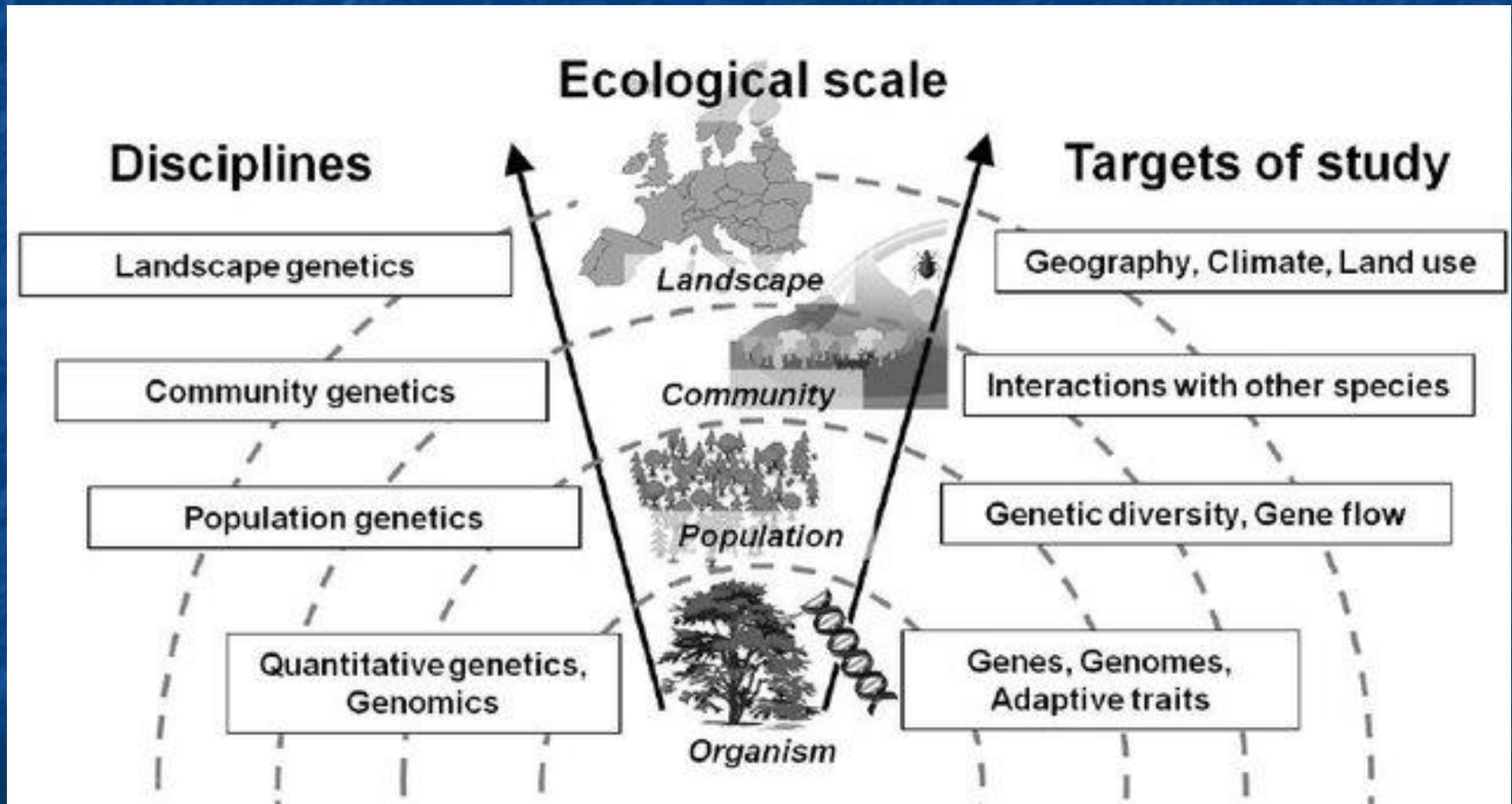
Competition



Disturbance



Scale and Hierarchy Theory



Scale

"The problem of pattern and scale is the central problem in ecology, unifying population biology and ecosystems science, and marrying basic and applied ecology. Applied challenges ... require the interfacing of phenomena that occur on very different scales of space, time, and ecological organization. Furthermore, there is no single natural scale at which ecological phenomena should be studied; systems generally show characteristic variability on a range of spatial, temporal, and organizational scales."

Simon Levin 1992

Value of Scale Theories:

- Heuristic value
- Focus measurement
- Model Parameterization
- Management – Range of Natural Variation

Temporal and Spatial Scales in Ecology

Different patterns may emerge at differing scales of investigation of almost every aspect of every ecological system.



Local scale: red pine is declining and may disappear from the Boundary Waters Wilderness Canoe Area



Landscape scale: red pine is thriving in Superior Nt'l Forest due to active management.

Spatial scale: definitions

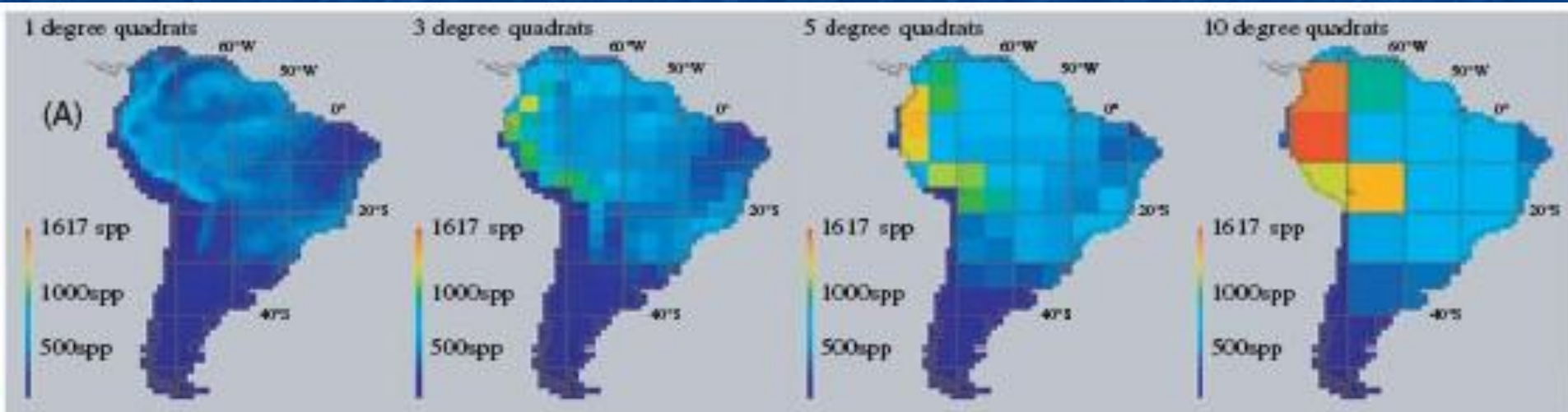


Grain = minimum resolution of the data, defined by the cell size (for raster data) or minimum polygon size (vector data).

Extent = the scope or domain of the data, defined as the size of the landscape or study area under construction.

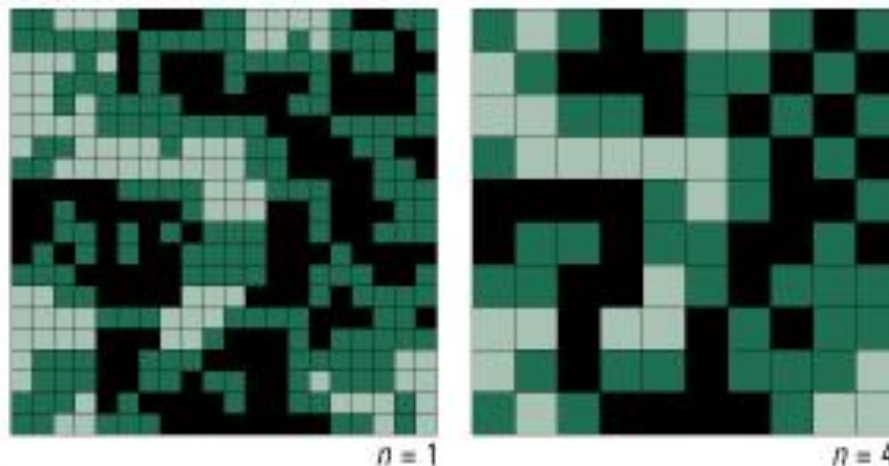
Spatial scale: Grain

Grain & Raster Data

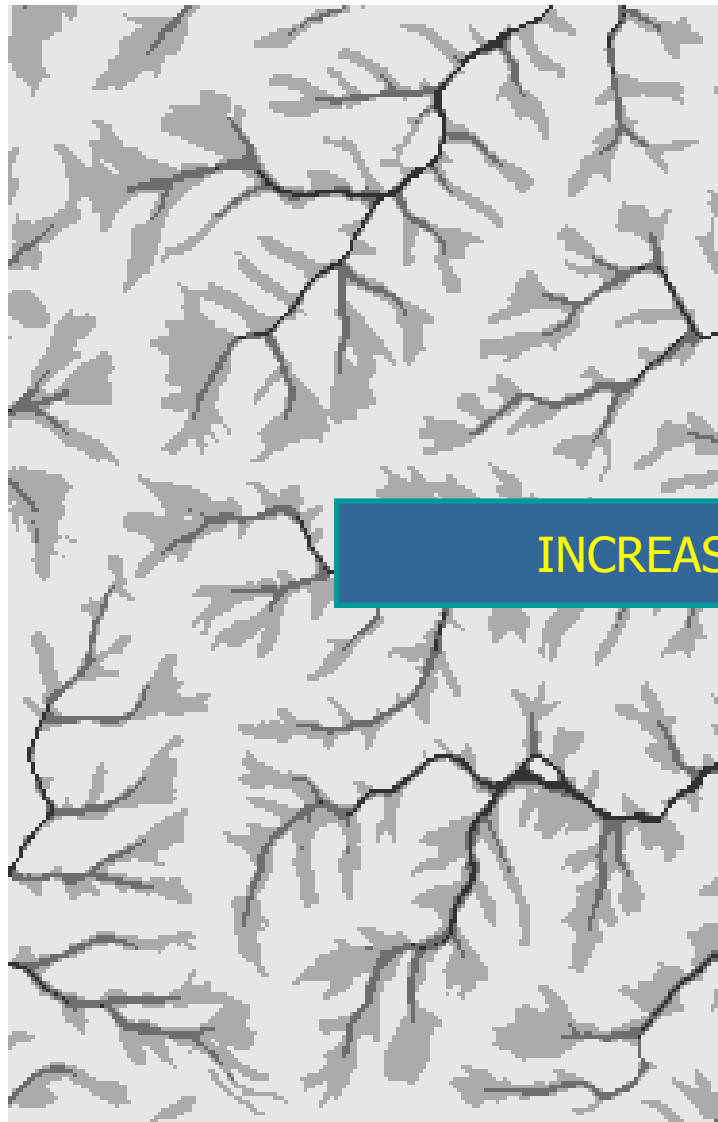


Source: Rahbek Ecology Letters 2005

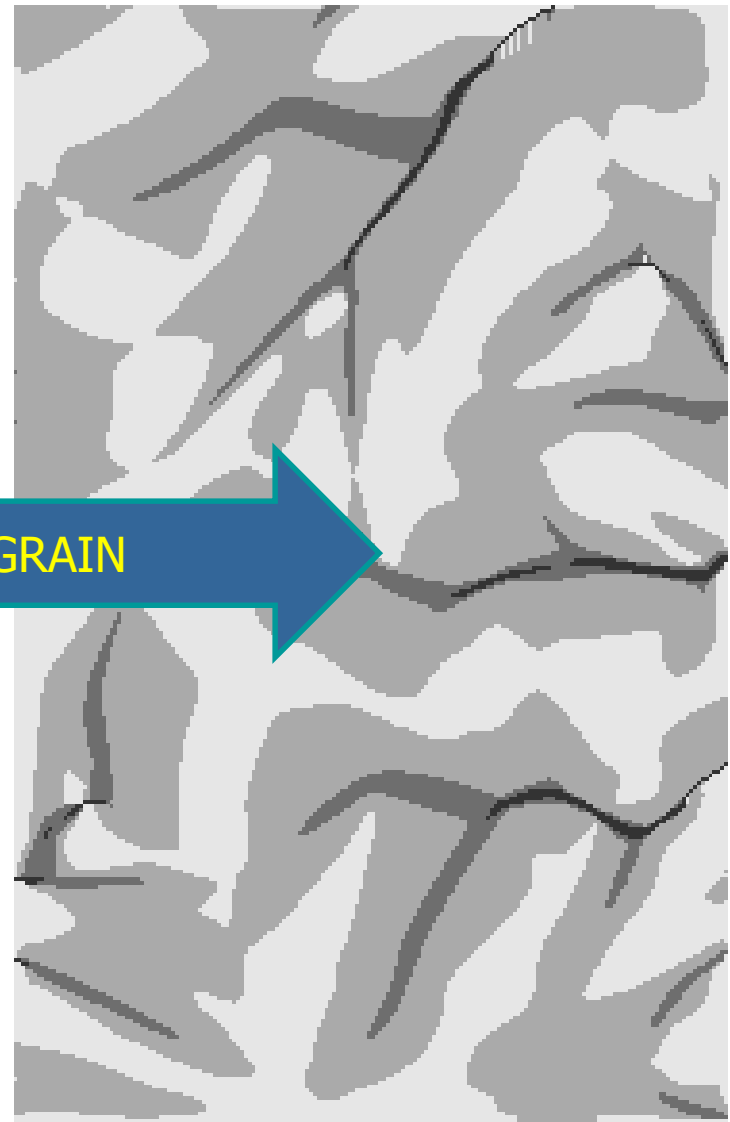
(a) Increasing Grain Size



Digital Elevation Model (DEM) with different spatial resolutions



INCREASING GRAIN



Spatial scale: Grain



Grain & Vector Data

Grain = minimum resolution of the data = minimum mapping unit.

Is Grain a relevant concept for vector data?

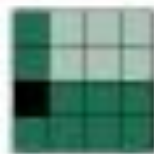
Yes, because:

a) Grain influences both polygon area and perimeter length.

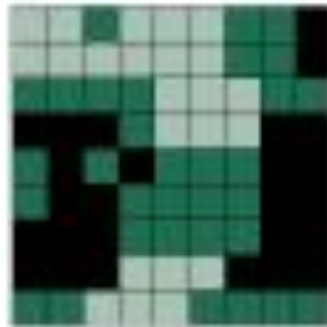
b) You must be aware of the grain when combining or using multiple data sets.

Spatial scale: Extent

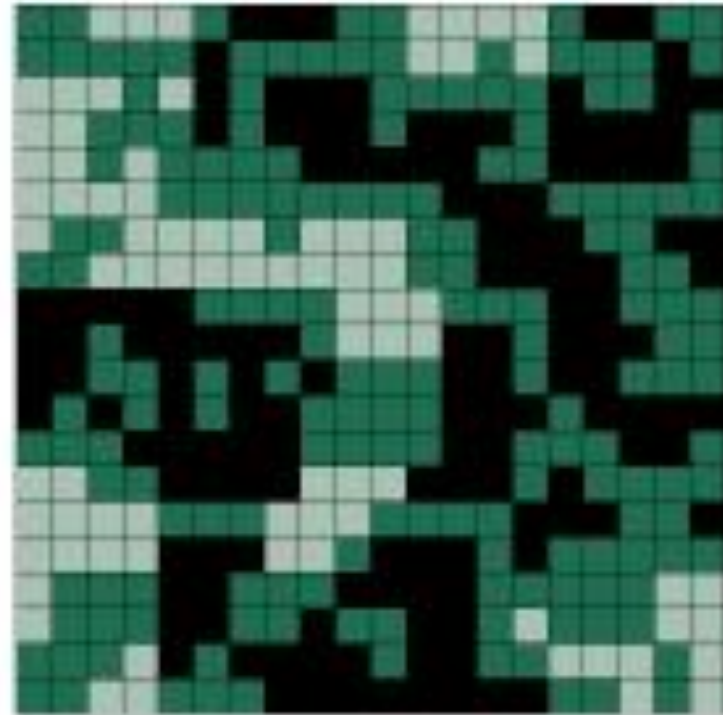
② Increasing Extent



$a = 16$



$a = 81$



$a = 400$

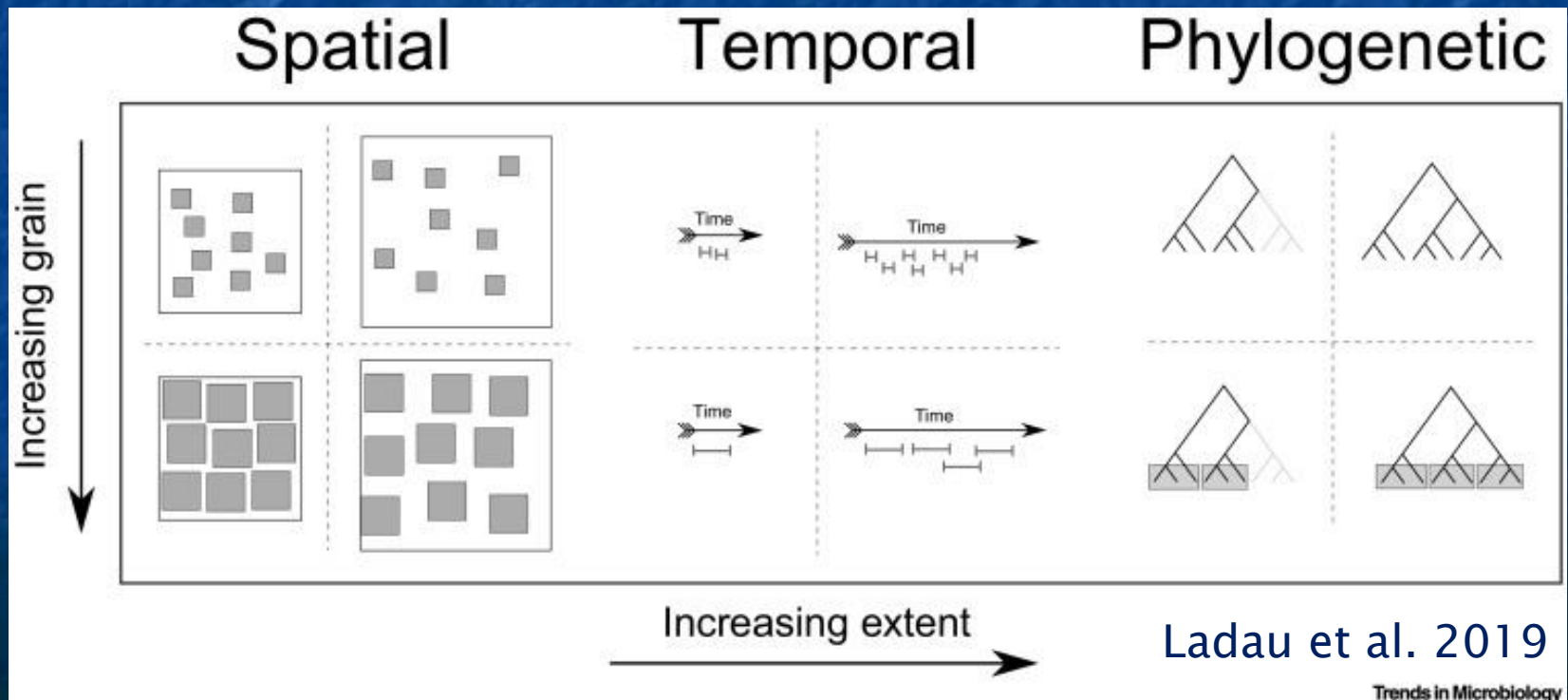
Temporal scale

Grain or resolution

Minimum resolution or frequency of temporal data (year, 10 years, 100 years).

Extent

Total temporal range of the study

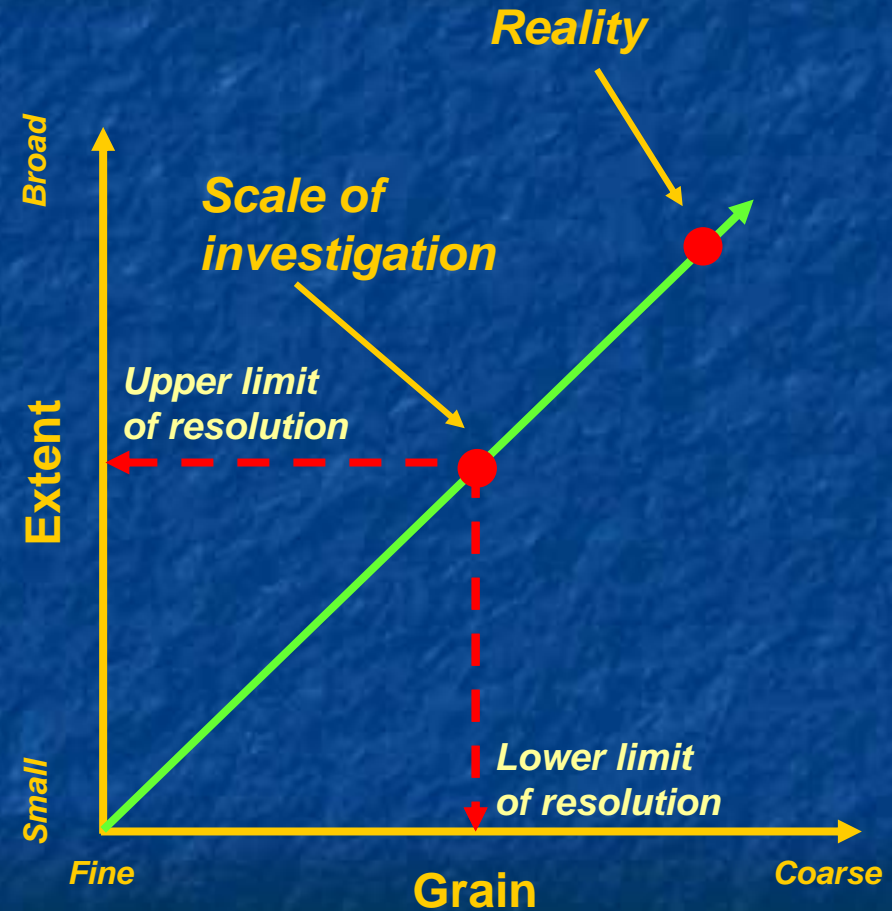


Ecological scaling: notes and rules

- Grain and extent are correlated:
As the study area increases, we generally lose resolution; high resolution usually requires a smaller study area.

The smaller the grain, generally the more information or data collected.

- The upper limit of data resolution is set by the extent
- The lower limit by the grain.



We cannot detect patterns finer than the grain or coarser than the extent.

Ecological scaling: notes and rules

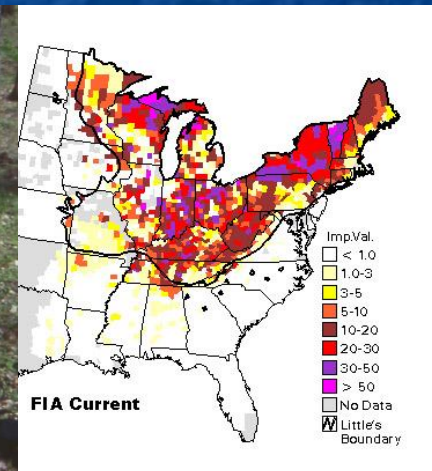


To an Organism:

- Grain is the smallest component of the environment that is relevant to the organism.
- Extent is the maximum distance at which an organism interacts with an external object.

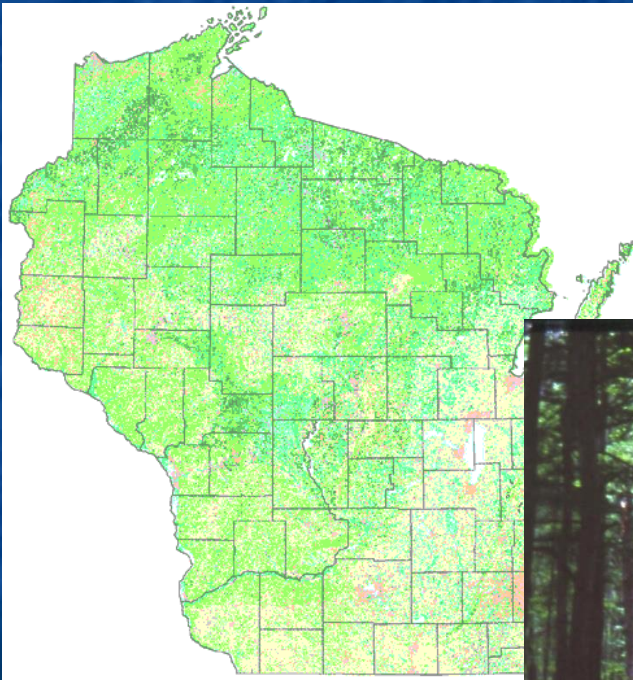
To Humans:

- Grain might be the finest unit of management or study.
- Extent is the total area under investigation or management.
- May be determined by the scale of the data or other technological limitations.



Effects of scale: Abiotic/biotic relationships

- Biological interactions may separate or reduce the relationships between the abiotic template and landscape pattern.

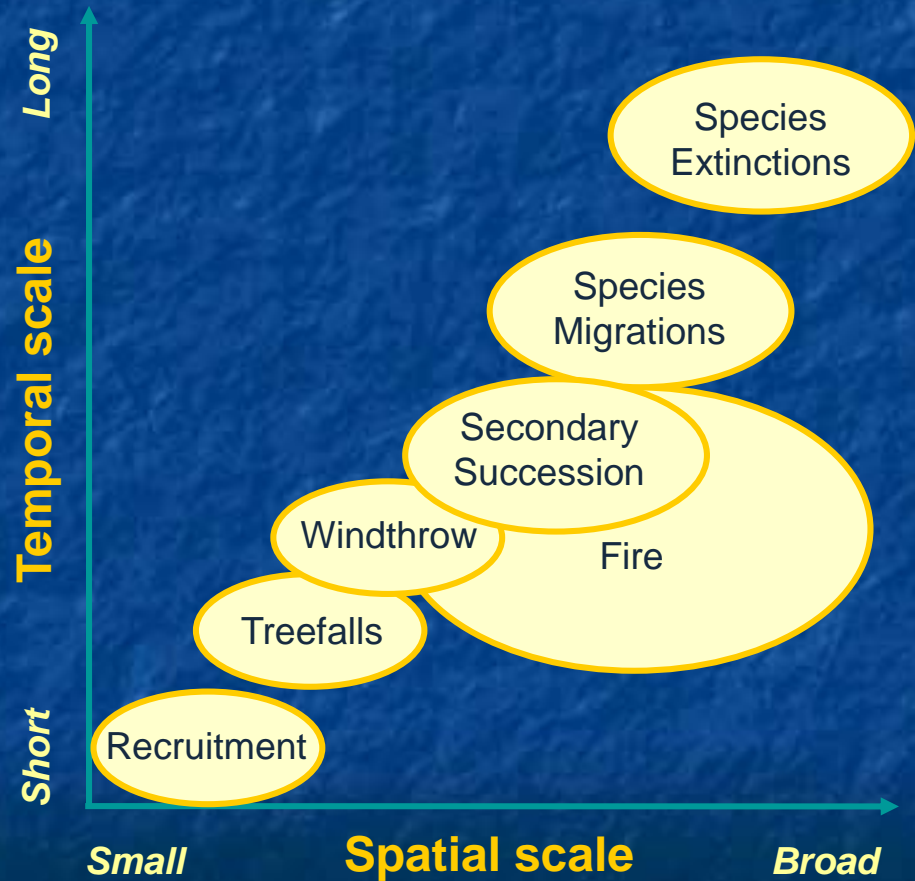


- Biota may introduce indirect effects, feedbacks, and spatial or temporal lags that are not immediately observable at larger scales.

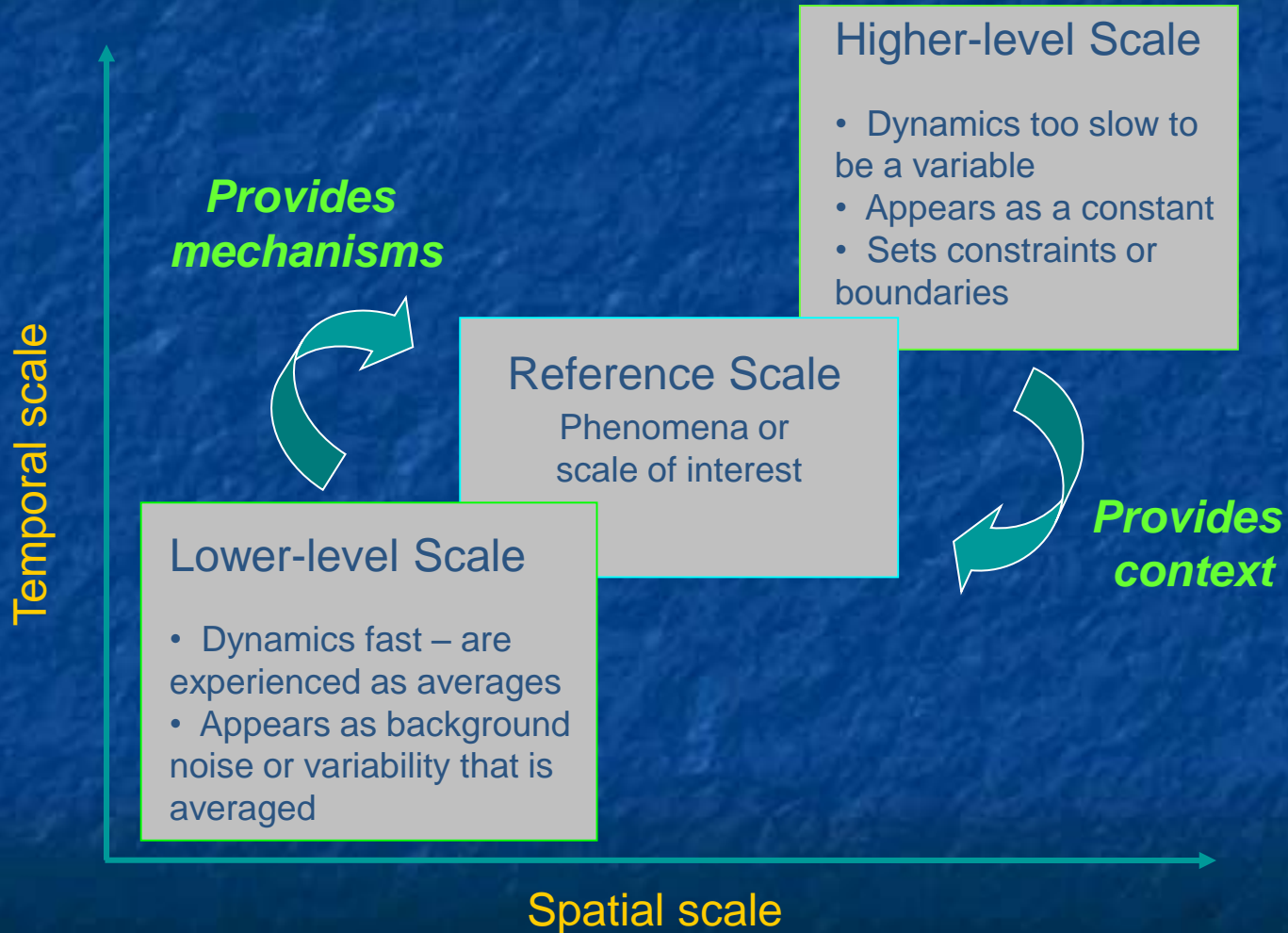


Theories of Scale: Characteristic scale

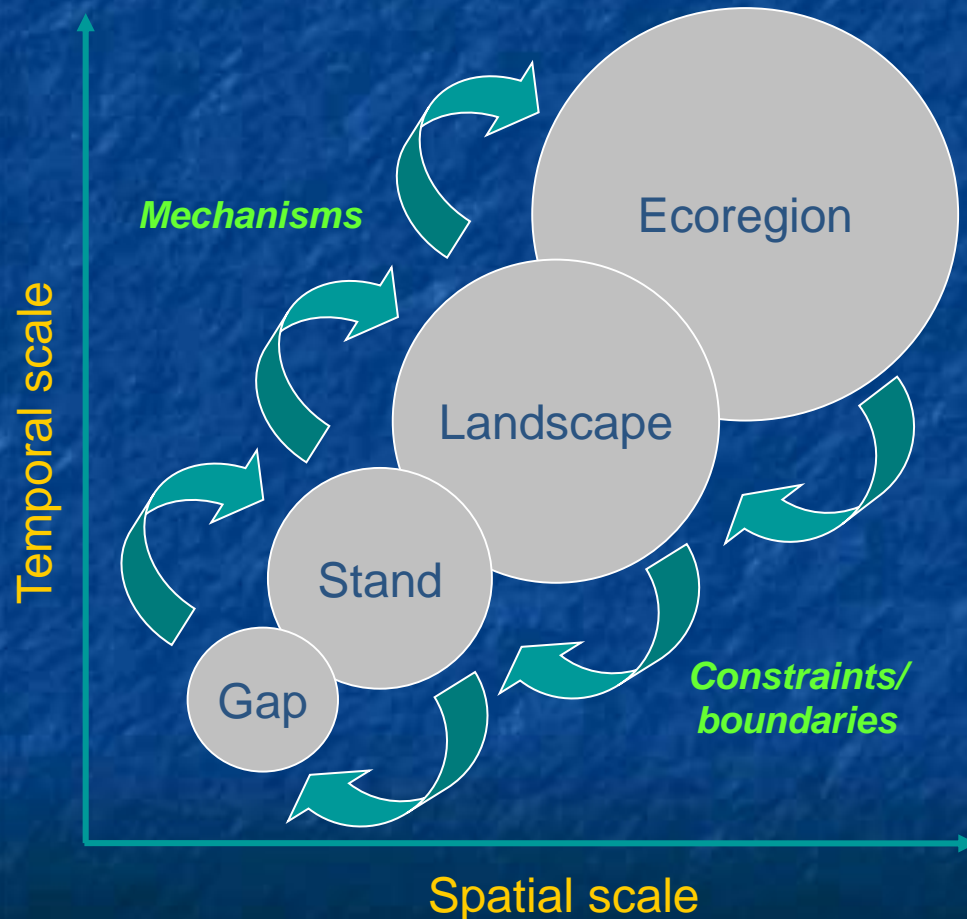
- Ecological phenomena have characteristic spatial and temporal scales, or spatiotemporal domains, and should be addressed at their characteristic scales.
- As the spatial or temporal scale changes, the phenomena of interest change.
- Short-term changes often affect small areas while long-term changes affect larger areas.



Theories of Scale: Hierarchy theory



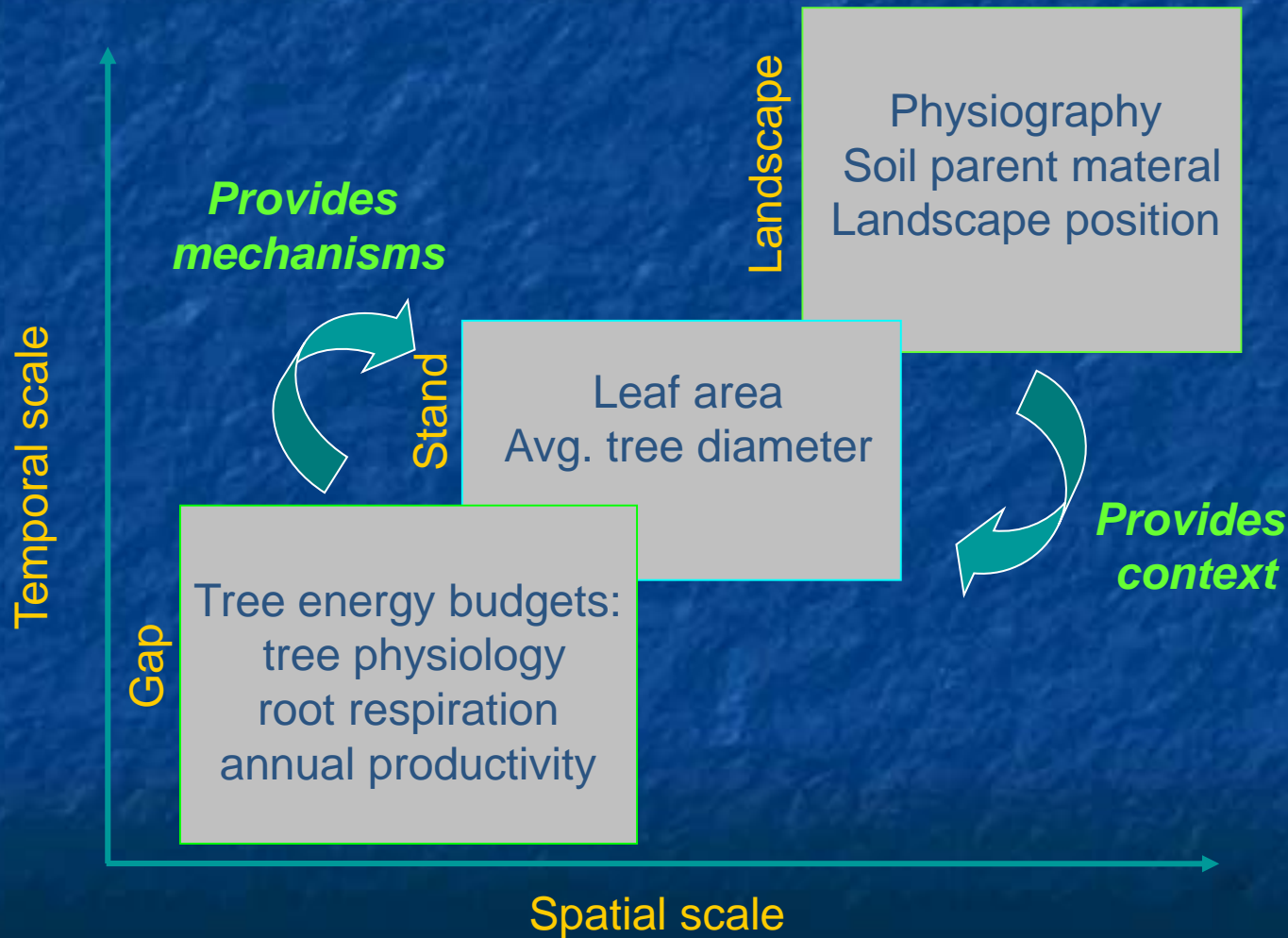
Hierarchy theory: examples



- Ecoregion: defined by climate and geology; 100,000s ha; 1,000s–10,000 yrs.
- Landscape: defined by physiographic province, changes in land use, disturbance regimes: 10,000s ha, 100–1,000 yrs.
- Stand: defined by topographic position, disturbance patches: 1–10s ha, 10–100s yrs.
- Gap: defined by the influence of a single large tree: 0.01–0.1 ha, 1–10s yrs.

Hierarchy Theory: Examples

Objective: predict the increase in biomass of a forest stand over 100 years



Hierarchy theory: examples

Objective: predict forest stand dynamics over 100 years

