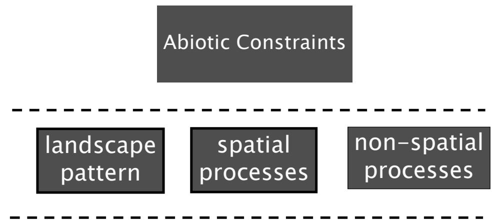
Abiotic constraints to landscape pattern and function

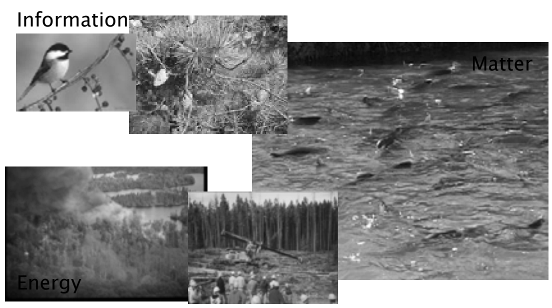
Pattern and Process



What are the components (explanation)?
- Biology
- Human activity
- Disturbance

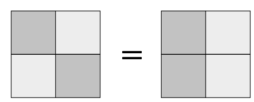
Landscape Processes

Landscape Processes are sensitive to landscape pattern because they include the lateral transfer of information, energy, or matter.

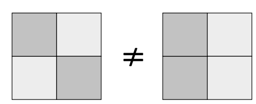


Pattern and Process

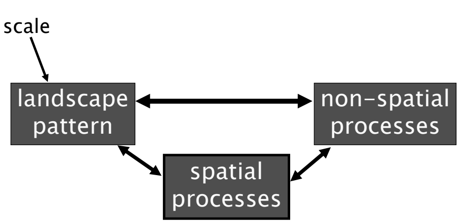
If a process is NOT a function of pattern, then it is a *non-spatial* process.



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



Pattern and Process



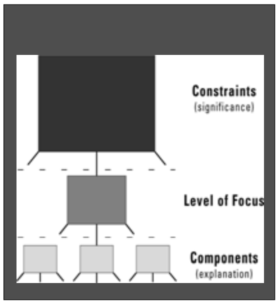
Landscape Processes

If there are no spatial processes, landscape configuration DOES NOT MATTER.

Other examples of spatial Landscape Processes?

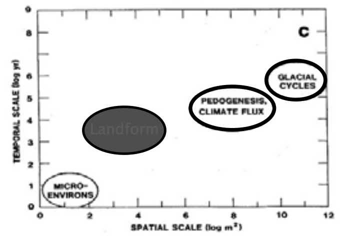
Abiotic constraints and hierarchy theory

- Level of focus constrained by higher level variables
- Lower level variables often explanatory



From Turner, Gardner, and O'Neill 2001

Abiotic constraints and hierarchy theory



From Urban et al. 1987

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**

Abiotic Constraints: Climate

Climate Definitions

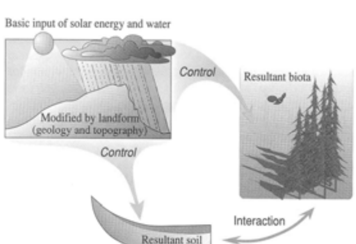
Climate Regime: composite, long-term weather patterns of a region.

Weather: Finer temporal scale changes in temperature, precip, e.g., daily fluctuations

Microclimate: Finer spatial scale differences in temperature and precip, e.g., N and S sides of hill

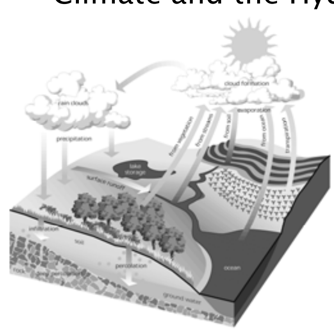
Climate controls several large scale processes:
Hydrologic cycle
Landforms and erosion cycles
Plant/animal life cycles and distributions
Fire and wind disturbance regimes

Figure 4.1. Role of climate in ecosystem differentiation.



From Bailey 1998

Climate and the Hydrologic Cycle



Actual Evapotranspiration (AET) is the quantity of water that is actually removed from a surface due to **evaporation** and **transpiration.**

Potential Evapotranspiration (AET) is the maximum water removal possible (w/o control). PET >> AET.

Climate and the Biota

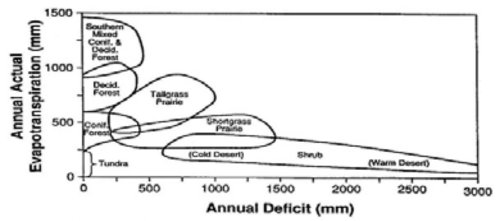
Curtis 1959: Climate and the Wisconsin tension zone

Figure 6.—Isorithms for certain climatic factors which are correlated with the tension zone. 1, average summer temperature of 67°F.; 2, average annual snowfall of 48"; 3, average evaporation during July of 5"; 4, sixty days per year with average temperature above 68°F.; 5, ninety-five days per year with 0.01" of rain or more.

Climate and the Biota

Climate can be correlated to vegetation physiognomy (plant growth form, e.g., graminoid, shrub, trees- needle-leaved evergreen, broad-leaved deciduous).

Stephenson (1990) used AET and DEFICIT (PET – AET) to predict vegetation



Climate and the Biota

Example: Neilson et al. (1983 – 1992)

- Examined large-scale regional and continental climate data spatially and temporally.
- Used weather station transects across U.S. and major biomes with characteristic composition and physiognomy.

- Result: Dominant stressors along elevational and latitudinal gradients.
- Result: Related to patch size and patch diversity.

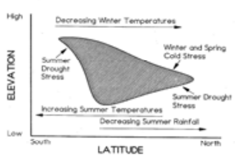
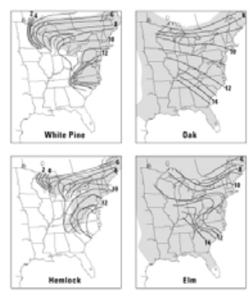


Figure 6.6. A conceptual model of the regional climatic constraints on the vertical distribution and composition of plant communities along a regional climatic gradient (Neilson and Wullstein 1983, Neilson 1987b). As the gradients converge at the apex of the wedge, the size of suitable habitat patches decreases, while their diversity increases (Figs. 6.6, 6.7).

From Neilson et al. 1992

Climate and the Biota

Long-term climate change and species distributions

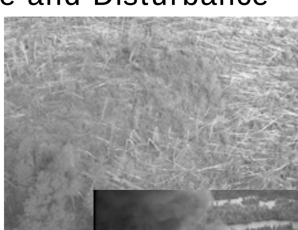


- Distributions of biota have changed due to Milankovich cycles – which appear to be related to glacial/interglacial periods.
- In response, biota may evolve and speciate, migrate, or go extinct.
- Ecotones have shifted drastically in response to long-term climate change, but species respond individualistically, not as communities.

Climate and Disturbance

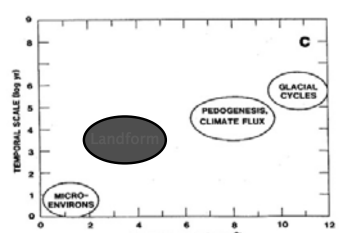
Direct:
Wind Speed
Wind Duration
Lightening Strikes
Overland flow
Flood magnitude
Flood duration

Indirect:
Fuel Quantity
Fuel Moisture



Abiotic Constraints: Landform

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



Landforms and Geomorphology

- Landforms affect water movement and concentration, and soil development differences.
- Topography and gravitational movement of water, and evapotranspiration create a toposequence or catena of soils.

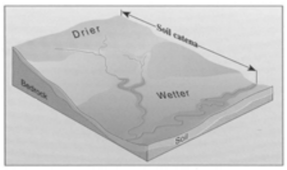


Figure 8.24. Variation is moisture creates a toposequence or catena of soil moisture regimes.

Erosion rates vary with rock type and climate: enough moisture for soil development and vegetative cover?

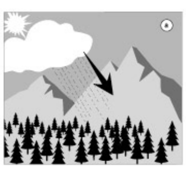
Landform and Disturbance

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

Abiotic Constraints: 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.

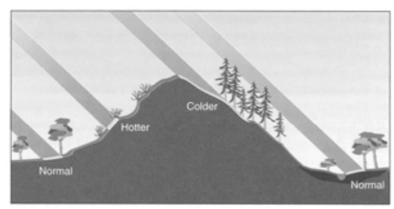


Figure 8.23. Slope and aspect affect temperature, creating topoclimates.

From Bailey 1998

Landform and Climate Interactions

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

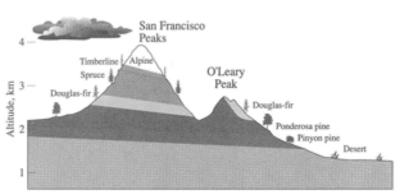


Figure 5.22. Vegetation zonation on San Francisco Peaks, Arizona, as viewed from the southeast, illustrating the effects of northern and southern exposures. From Merriam (1890).

From Bailey 1998

Landform, Climate, and Biota

Example

- Robert Whittaker (1952, 1953) sampled vegetation across a range of montane habitats, spanning elevation and aspect differences.
- Found that species responded individualistically to changing environment.
- But communities could be discerned within environmental space defined by elevational and aspect gradients.

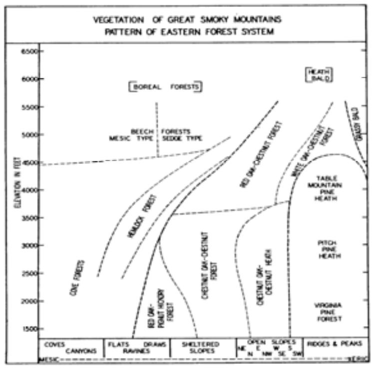


FIG. 19. (Vegetation of Great Smoky Mountains, pattern of Eastern Forest System.)

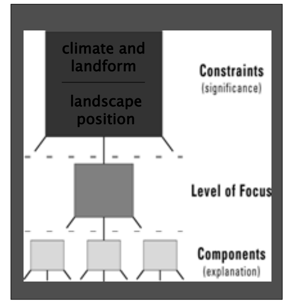
From Whittaker 1956

Abiotic Constraints: Landscape Position

An extension of landform and climate interactions

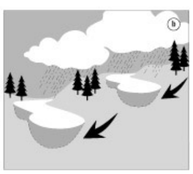
Below large scale geomorphology or landform levels.

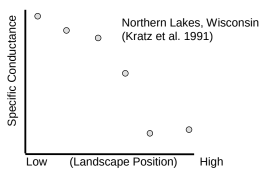
Landscape position has been shown to be important in causing pattern in many different systems, including systems with relatively little relief.



Landscape Position and Hydrology

Example:
Position of lakes in the northern Wisconsin

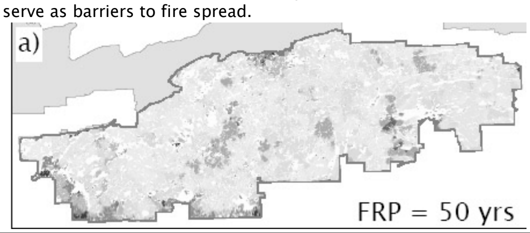




Landscape Position and Disturbance

Landforms interact with climate and increase or decrease susceptibility to disturbance.

Examples:
- Hill slopes may shelter or expose forests to windthrow.
- The greater vulnerability of ridges to fire ignition.
- Wetlands and lakes in the Boundary Waters Canoe Area that serve as barriers to fire spread.



Landscape Position 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.

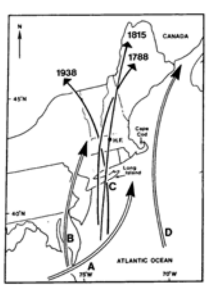
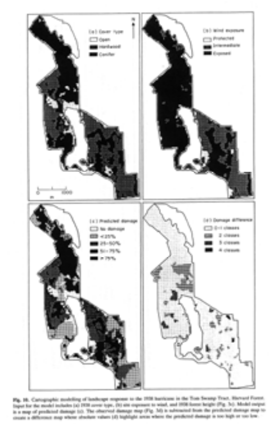


Fig. 1. North-eastern USA showing the four generalized pathways (A–D) that hurricanes follow into the region and the historical tracks of the hurricanes of 1788, 1815 and 1938 (pathway C). The location of the Harvard Forest (H.F.) is indicated by the circle. Modified from Smith (1946).

Landscape Position and Disturbance

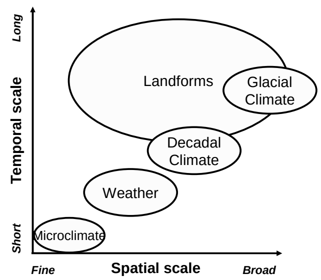
Example:
Foster and Boose (1992)
- Slope and aspect highly correlated with increasing damage.
- Tree height and species composition also significant.
- Damaged stands:
  - 3% in topographically protected sites
  - 31% intermediate
  - 66% exposed sites.



Abiotic Confounding Factors

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

- Environmental gradients are correlated and do not always change in concert. For example, temperature and precipitation may be inversely correlated in mountains.
- Physical factors all vary across scales and have their own unique variability across scales.



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.