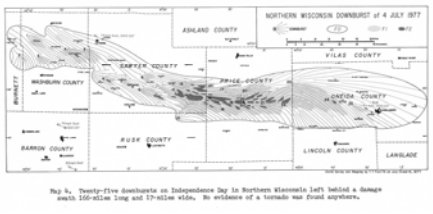
Disturbance and Equilibrium

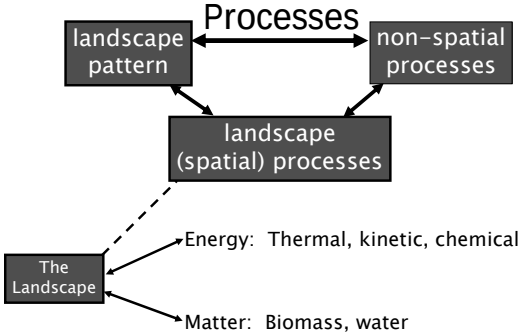
Disturbance Definition

Disturbance: Any relatively discrete event in space and time that disrupts ecosystem, community, or population structure and changes resources, substrate, or the physical environment. Disturbances typically cause a significant change in the system.

By this definition, what is NOT a disturbance?

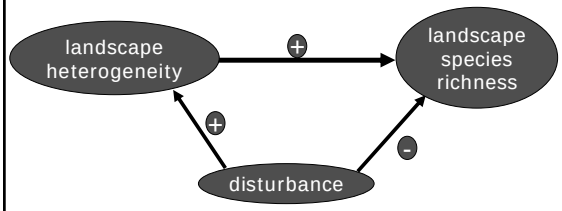


Disturbances Alter Landscape Processes



Disturbances Alter Landscape Processes

How disturbance alters species richness is complicated!



Common Disturbance Types

Disturbances are *landscape processes*: transferring energy and matter across a landscape.

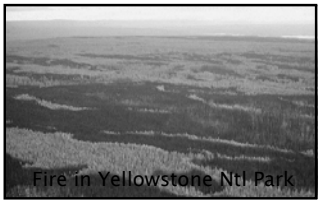
Fire
Wind
Harvesting
Insects
Flooding
Other?

What is a disturbance regimes?

Disturbance Regime:
A summary description of a repeating disturbance type *for a given landscape*, *for a given period of time*.

Disturbance regimes are typically described using empirical data and statistical summaries.

Disturbance regimes need NOT be constant over time.


Fire in Yellowstone Ntl Park

How do we describe disturbance regimes?

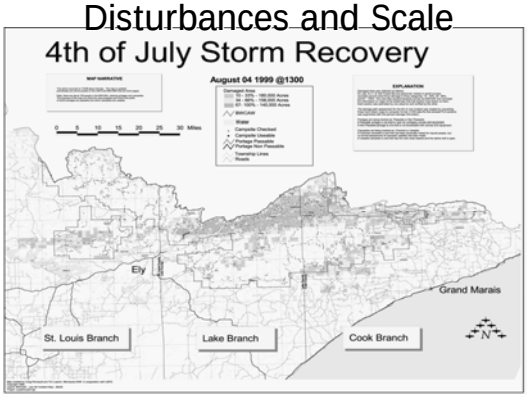
Spatial:
Mean area/size
Spatial distribution

Temporal:
Frequency
Recurrence interval
Return interval
Rotation period

Magnitude:
Intensity - energy released
Severity - mortality caused

Other:
Predictability
Feedbacks

Disturbances and Scale

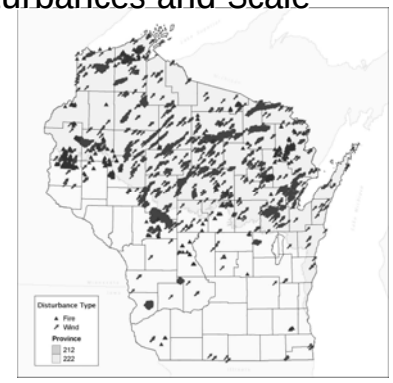


From http://www.ra.dnr.state.mn.us/bwca/maps/

Disturbances and Scale

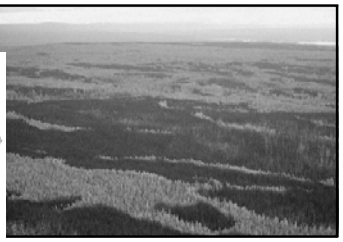
Source: General Land Office survey of WI forests, ~1860.

Lisa Schulte



Effect of Disturbances on Landscapes

Disturbances generate fine-coarse scale patch mosaic on many landscapes.



Effect of Disturbances on Landscapes

• Disturbances may perform natural functions that maintain ecosystem structure and processes.

• <u>All ecosystems</u> have a natural disturbance regime to which they are adapted.

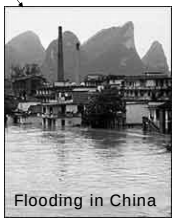
Fire-dependent forests

Effect of Exotic Disturbances on Landscapes

• Exotic disturbances may disrupt system integrity and cause permanent changes and/or the system to move to a novel (and undesirable?) state.

• Disturbances may be exotic by <u>type</u> or <u>regime</u>.

Clearcutting in Washington



Disturbance Origins

Disturbance Origins

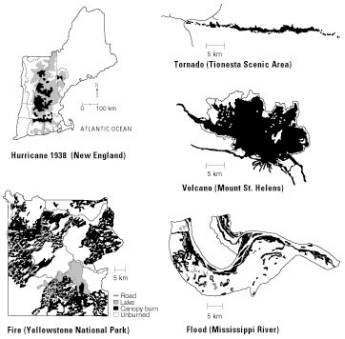
Exogenous - external to the system
but often sensitive to internal conditions

Endogenous - internal to the system
but often requires external trigger

Exogenous
Hurricane
Charley

Endogenous
Spruce beetle damage

Disturbance Caused Patterns



Very different landscape patterns may result from different disturbances.

Disturbance Interactions

Some disturbances absorb or dampen the spread of subsequent disturbances, but others magnify the spread of subsequent disturbances.
* Human often mediate disturbance interactions.

prescribed burns prevent crown fires
Also: fuel treatments

insect, wind promote crown fires

Disturbance and Landscape Interactions

At the largest scales, disturbance patterns are affected by macroclimatic patterns and by regional and local patterns of topography, soils and vegetation.

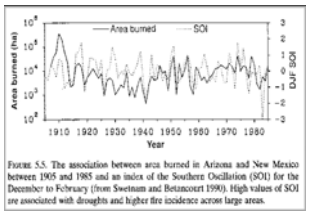
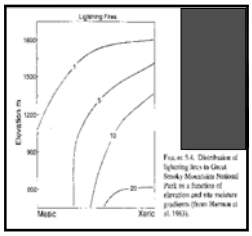


FIGURE 5.5. The association between area burned in Arizona and New Mexico between 1905 and 1985 and an index of the Southern Oscillation (SOI) for the December to February (from Swetnam and Betancourt 1990). High values of SOI are associated with droughts and higher fire incidence across large areas.

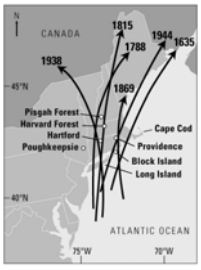


Landscape and Disturbance Interactions

At more local scales, disturbance patterns and regimes are affected by landscape position.

- Fires and gaps determined by regional and local topographic position in the Southern Appalachians (Runkle).

- Slope position and aspect controlled the susceptibility to hurricane damage in Massachusetts (Foster).



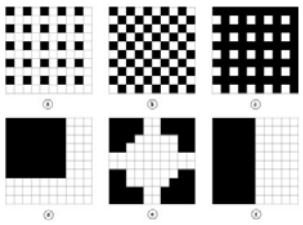
Disturbance and Landscape Interactions

Landscape pattern may affect the spread of disturbances.

- Disturbances restricted to one cover type may be slowed by heterogeneity.

- Disturbances that spread across cover types may be enhanced by heterogeneity (particularly by edges).

Cannot generalize that effect is to increase or decrease disturbance.



Franklin and Forman: Heterogeneity of forest cutting patterns affects windthrow, fire spread, pathogen spread, and insect damage.

Disturbance and Landscape Interactions

Disturbance patterns and regimes are not always affected by landscape pattern or position.

- Lack of directional disturbances and topography may limit the influence of landscape position on disturbances (Frelich and Lorimer).
- During 1988, fire weather in YNP was so severe that topography (as well as geographic barriers) had little influence on disturbance pattern.

Disturbance and Landscape Interactions: Legacies

Disturbance effects can persist for centuries.

<u>Biological Legacies</u>

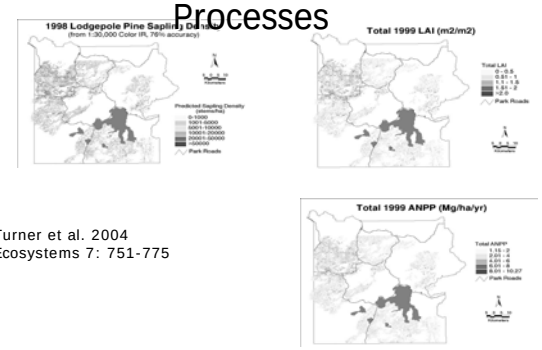
Propagules. Landscape heterogeneity typically enhances recovery via refugia for propagules (both animal and plant).

Coarse Woody Debris

Successional State. Species composition and demographics.

Mt. St. Helens
Recovery was much faster than expected due to both plant and animal legacies.

Disturbance and Landscape Interactions: Ecosystem Processes



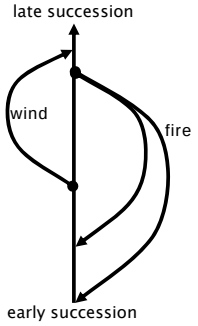
Turner et al. 2004
Ecosystems 7: 751-775

Disturbance and Landscape Interactions: Succession

Disturbance may reset succession or disturbance may advance succession!

Disturbance size and intensity are important to post-disturbance succession because they affect the availability of propagules.

The mosaic created by disturbance will influence secondary succession greatly.



Human effects on disturbance regimes

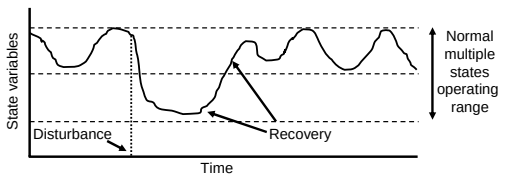
Rescaling of disturbance size, frequency, and/or intensity

Rescaling of area with barriers

Introduction of novel or unprecedented disturbances

Homogenization of natural patterns or suppression of natural processes that maintain diversity.

Disturbance and Landscape Equilibrium

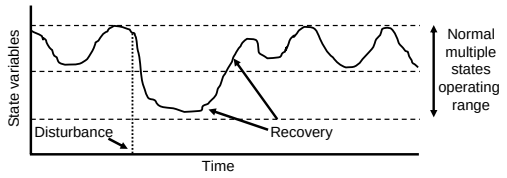


Disturbance and Landscape Equilibrium

Note: All definitions of equilibrium depend on the focal spatial/temporal scale of interest and measurement.

Regional Scale Equilibrium - Climate always changing at long time scales.

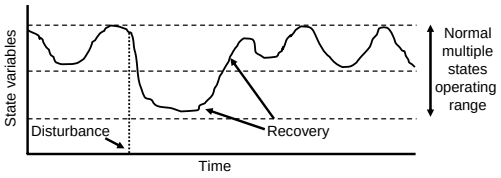
Local scale Equilibrium - More affected by shorter-term, stochastic events.



Landscape Equilibrium: Definitions

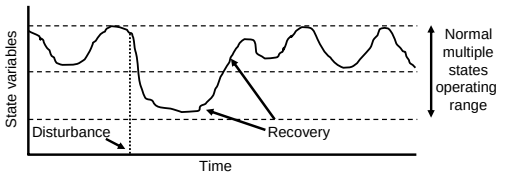
Stability: The tendency of a system to remain in a constant range of variation.

Persistence: The length of time a system remains in a defined state (or range of states).



Landscape Equilibrium: Definitions

Resistance: The ability of a system to absorb or dissipate disturbances and remain within defined bounds.
Resilience : The ability of a system to return to a state or bounds after deflection from that state.



Landscape Disturbance Dynamics: Common equilibrium patterns

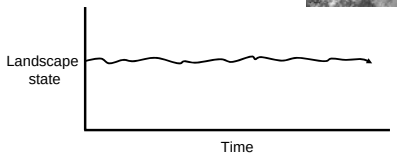
Absolute constancy: no changes through time.

Landscape Equilibrium: Types

Shifting mosaic steady-state: the landscape maintains a constant proportion in each patch type through time, as the random creation of patches by disturbance is balanced by the maturation of old patches through succession.

Typical of some eastern US forests.

Very stable over long periods of time.

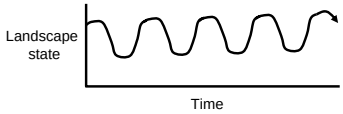


Landscape Equilibrium: Types

Stationary process: the landscape is composed of a series of processes whose distributions do not change in time or space.

Example: river flow peaks in the spring, lowest in autumn.

Very stable of long periods of time.

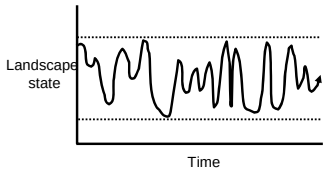


Landscape Equilibrium: Types

Bounded equilibrium: the landscape exhibits *random changes* over time in response to stochastic disturbance events, but remains within bounds.

Example: Vegetative carbon in a prairie is relatively low ('bounded') due to fire and grazing. If fire or grazing removed, it may convert to forest with high carbon.

The mean and variance are very sensitive to scale (spatial and temporal).



Disturbance and Equilibrium

Equilibrium paradigm ----------> Dynamic paradigm

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