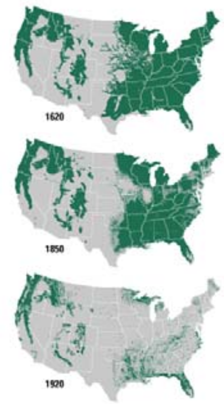
Source: Sun Valley, Idaho Fire Department

Disturbance and Landscape Dynamics

Reading assignment: T, G & O 2001. Chapter 7

Landscape pattern has changed greatly

- Changing extent of virgin old-growth in conterminous US
- How has the changing extent and pattern influenced ecological processes?



Source: T,G & O. 2001. Figure 4.7

We have previously discussed factors that make landscapes change through time

- Disturbance and stress events
- Recovery from disturbance
- Environmental conditions and species life history characteristics
- Human action, often reflecting social, economic and political values
- Chance and random events

Examples of bark beetle outbreaks

Photos: BC Ministry of Forests

What is a “disturbance”?

We know from the previous material presented that **disturbance** and subsequent **secondary succession** are major factors in determining the pattern of landscapes.

We also know that for many landscapes, periodic disturbance is necessary to maintain biomass productivity, diversity, habitat for some species, resilience, etc.

Given that- How can we define the concept or ecological term ‘disturbance’?

Defining Disturbance

A wildfire occurred in the foreground of this photo about 75 years ago. The young stand of western juniper and the big sagebrush stand have developed post-burn. The western juniper stand near the rime is much older.

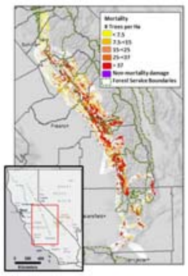
Given the dynamic nature of vegetation how can we meaningfully define what a disturbance is?

There are several approaches…

Defining Disturbance

- Drought and pine beetles have killed millions of trees in the Sierra Mountains, CA in recent years

Rare but broad scale events



- Rare but broad scale events can result in major changes to large landscapes.
- Recently, a combination of several years of extreme + insect epidemics resulted in widespread mortality of ponderosa and sugar pine trees in the southern Sierra Mountains, CA.
- More than 100 million pine trees have died, trees of all size classes are affected. Many were 100's of years old.
- Such rare events are difficult to predict in landscape modeling given their low probability and the brief temporal scale of our data.

Disturbance versus Stress

Disturbance and Stress

- Disturbance: "A relatively discrete event along time that modifies landscapes, ecosystems, community, and population structure and changes the substrate, the physical environment and the availability of resources" (Pickett and White 1985 as quoted by Farina (1998, p.51)).
- Stresses are less discrete, and include drought, herbivory, etc.
- Disturbances vary by type, scale, frequency, intensity, spatial pattern, predictability (the inverse of variability), etc.

Disturbance and Stress

- Disturbance is part of natural ecosystems (Pickett 1980)
- Disturbances change resource availability, alters environmental conditions, and favors one species over another
- Disturbance does not depend on a presumption of stability (Levins and Lewontin 1985)
- A portion of the heterogeneity in the landscape at any one time is caused by disturbance (Bormann and Likens 1981)
- Land management involves contending with and using disturbance

If there was no disturbance, would we have heterogeneity?

Approaches to Defining Disturbance

- **Results in composition change-** consider any factor that results in "significant" change in composition to be a disturbance

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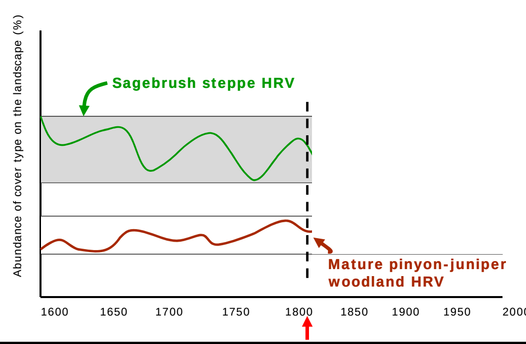
Again, this leaves us with the problem of defining what is a “significant” change.

Both composition change and process change based approaches are **scale dependent**.

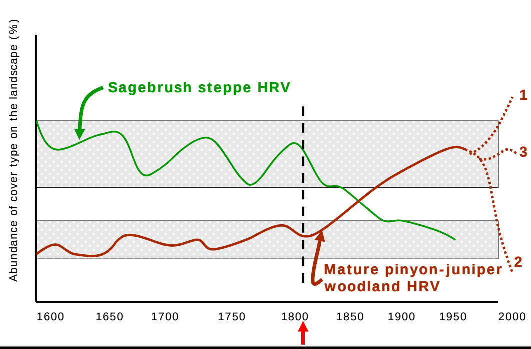
Approaches to Defining Disturbance

- Results in composition change- consider any factor that results in “significant” change in composition to be a disturbance
- Results in ecosystem functional change- consider any factor that results in “significant” change in function to be a disturbance
- **Historical Range of Variability (HRV)-** an event occurring outside of the normal range for a system

Historical Range of Variability (HRV)



Historical Range of Variability (HRV)



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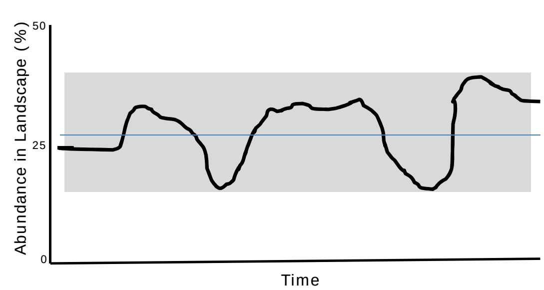

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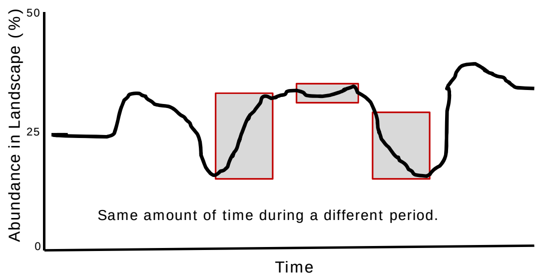
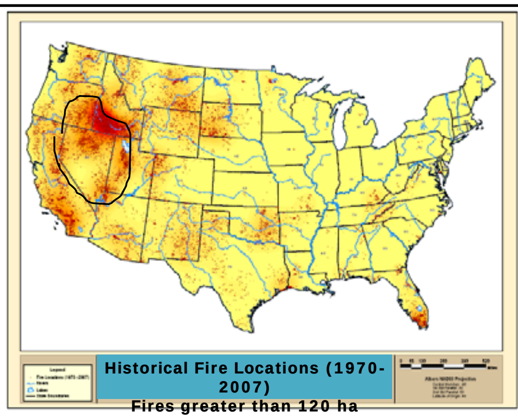
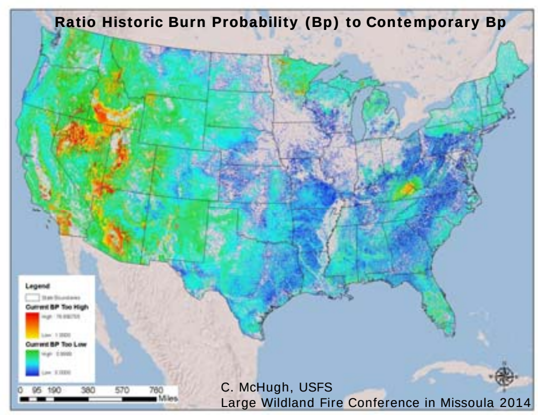


What can HRV tell you?

- A context in which to evaluate processes, especially disturbances.
- A means to interpret causes of current conditions. [Why aren't things the way they used to be? What has caused the change?]
- A means to link community, landscape and regional history.
- A reference point from which to evaluate ecosystem change. [What are things going to be like in the future?]
- A help in identifying conflicts in policy.
  Ex: fire restoration conflicts with air quality concerns
- A mechanism by which to communicate the concept of ecosystem dynamics to others.
  – Ecosystems are not static!

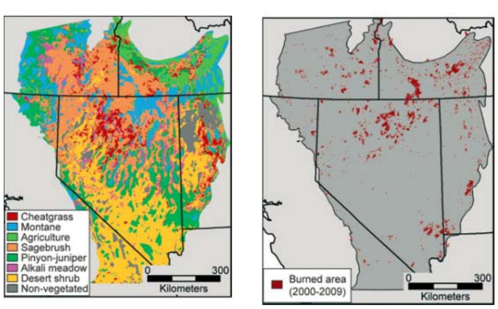


Source: USDI BLM Boise District



C. McHugh, USFS
Large Wildland Fire Conference in Missoula 2014

Great Basin Landcover



Bradley & Mustard 2008; Balch et al. 2013

Shrub Steppe Historical Mean Fire Return Intervals

Vegetation type	MFRI (years)
Mountain big sagebrush/Idaho fescue	11
	12-15
	12
	12-25
	13
	13-15
	20
	150-300 * HFR
Wyoming big sagebrush/ Bluebunch wheatgrass or Thurber's needlegrass	50-100 (Estimated)
	100
	170-350 * HFR

Now these two MFRI averages have switched.

Fires in the more mesic shrub steppe have become less common, and fires in the more arid shrub steppe have become more common

* Historical Fire Rotation method used

Adapted from Miller and others

Wyoming big sagebrush/Bluebunch wheatgrass

Wyoming big sagebrush/bluebunch wheatgrass southern I
2 years post-burn

Approaches to Defining Disturbance

- **Biomass mortality**- the loss of living biomass used as baseline

Approaches to Defining Disturbance

- **Biomass mortality**- the loss of living biomass used as baseline

Disturbance is any process or condition that is external to the natural history of the living organisms that results in <u>sudden mortality of biomass on a time scale that is shorter by orders of magnitude than the rate of biomass accumulation</u> (Huston 1994).

Approaches to Defining Disturbance

- **Biomass mortality**- the loss of living biomass used as baseline
- **Resource availability**- a sudden increase in the available resources

Approaches to Defining Disturbance

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- **Resource availability**- a sudden increase in the available resources

From a plant population perspective, a disturbance can be defined as a sudden change in the resource base in a habitat that is expressed as a readily detectable change in population response. The terms “sudden change” and “detectable response” cannot be precisely quantified (Bazzaz 1983, 1996).

Approaches to Defining Disturbance

- **Biomass mortality**- the loss of living biomass used as baseline
- **Resource availability**- a sudden increase in the available resources
- **Human value assessment**- use the value of the resources to humans as baseline

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- **Human value assessment**- use the value of the resources to humans as baseline

An event is a disturbance if it detracts from the value we place on an area.

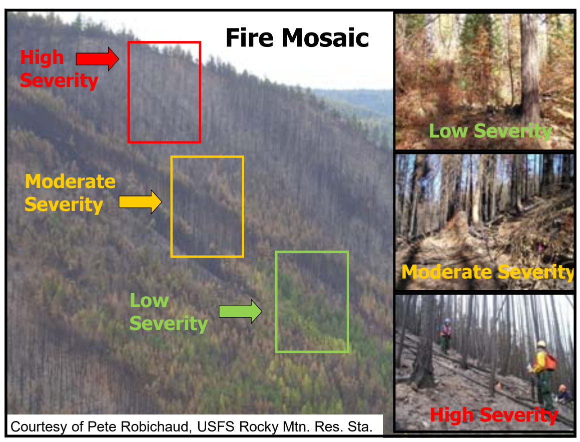
Disturbance regimes

What is meant by the term “disturbance regime”?

Disturbance regimes terminology

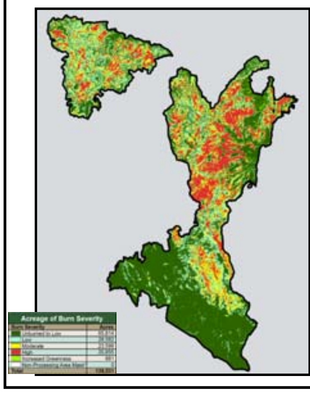
Frequency	Mean or median number of events occurring at an average point/time period
Intensity	Physical energy of the event/area/time (e.g., heat released/area/time period, wind speed for storms)
Residuals	Organisms or propagules that survive the disturbance event
Return interval	Mean or median time between disturbances, the inverse of frequency
Rotation period	Mean time needed to disturb an area equivalent to the study area
Severity	Effect of the disturbance on organisms, community or ecosystem

Source: T,G & O 2001, Table 7.1



Courtesy of Pete Robichaud, USFS Rocky Mtn. Res. Sta.

Burn severity Index (dNBR)



Difference normalized burn ratio

Difference between pre-and post fire satellite images

Uses Landsat NIR and SWIR bands

Available online at mtbs.gov

Correlates with mortality in the upper canopy

Disturbance regimes terminology

Frequency	Mean or median number of events occurring at an average point/time period
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Severity	Effect of the disturbance on organisms, community or ecosystem
Size	Area disturbed, can be expressed as "mean area"

Source: T,G & O 2001, Table 7.1

Disturbance regimes terminology

Continuity	The uniformity of severity of the disturbance across the entire affected area
Synergistic effects	The effects of an earlier disturbance on the response to another disturbance, it may be of the same or different type of disturbance

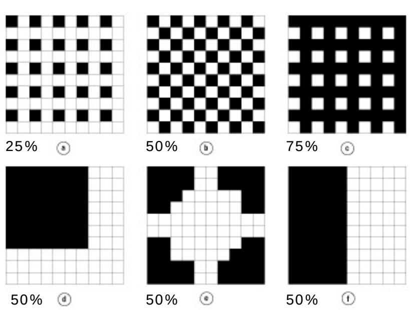
What are some examples of synergistic effects?

Why is landscape pattern important?

Landscape mosaic created by the 1988 Yellowstone Fires

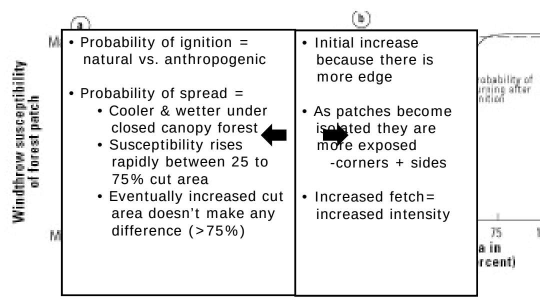
Source: T,G & O 2001, Figure 7.8

Franklin and Forman (1987) modeled different patterns of forest clear-cutting



Source: T,G & O 2001, Figure 7.3

Franklin and Forman (1987) modeled different patterns of forest clear-cutting

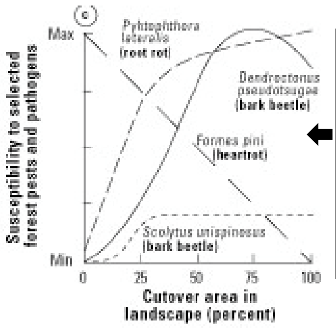


- Probability of ignition = natural vs. anthropogenic
- Probability of spread =
  - Cooler & wetter under closed canopy forest
  - Susceptibility rises rapidly between 25 to 75% cut area
  - Eventually increased cut area doesn't make any difference (>75%)

- Initial increase because there is more edge
- As patches become isolated they are more exposed -corners + sides
- Increased fetch= increased intensity

Source: T,G & O 2001, Figure 7.3

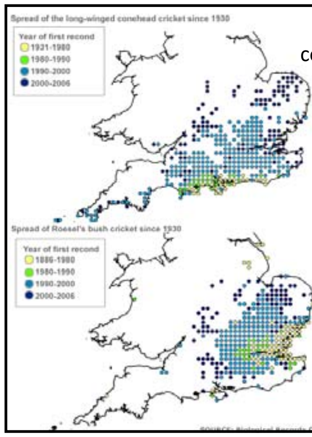
Franklin and Forman (1987) modeled the response of different patterns of forest clear-cutting



- Responses of pests and pathogens are highly variable
- Freshly felled trees > bark beetle outbreak
- Root rot increased through human spread of fungus

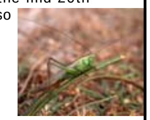
Source: T, G & O 2001, Figure 7.3

Spread of long-winged conehead and Roesel's cricket

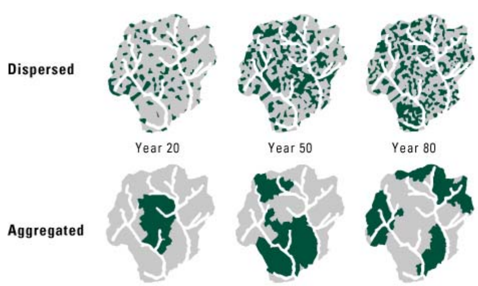


Evidence is showing that a once rare species of bush cricket, the long-winged conehead, new to Britain in the 1940s and still confined to the South Coast in the 1980s, can now be found more than 150 miles to the north, responding to the milder climate in Britain.

Another species, the Roesel's bush cricket, which was confined to the Thames and Solent estuaries until the mid 20th century, has also spread across central Britain in the last two decades.


Long-winged conehead

What landscape pattern is best?



Source: T,G & O 2001, Figure 7.12, redrawn from Wallin et al. 1994.

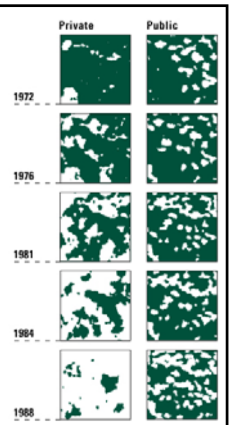
Ecological and physical processes affected by landscape pattern

- Movement and persistence of organisms
- Movement of disturbance
- Cycling and/or movement of energy and nutrients
- Micro-climate
- Rates and patterns of succession
- Habitat suitability (organisms often need 2 or more types of habitat in close proximity)
- Edges act as filters/amplifiers for transfer of organisms, nutrients, energy, disturbance etc
- Human use

Source: Turner 1989

Landscape pattern

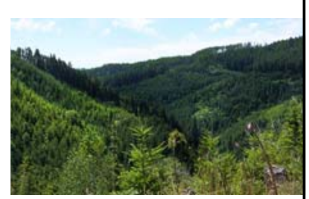
- Spies et al. (1994) contrasted the pattern and extent of coniferous forest (in green) through time on adjacent private and public lands in western Oregon.



Source: T, G & O 2001. Figure 5.3 redrawn from Spies et al. 1994.

Fragmentation

- Breaking up of a habitat or cover type into smaller, disconnected parcels (Turner et al. 2001)
- Changes in patch distribution, size and characteristics
  - Fewer patches → less total area of habitat
  - Smaller patches
    - Less interior habitat
    - More edge habitat
  - Increasing isolation of residual habitat patches



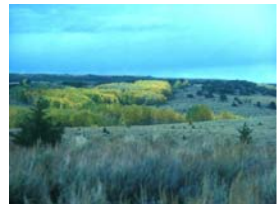
Concepts of Landscape Equilibrium

Western Chubut Province, southern Argentina

What do landscape ecologists mean when they refer to "equilibrium"?

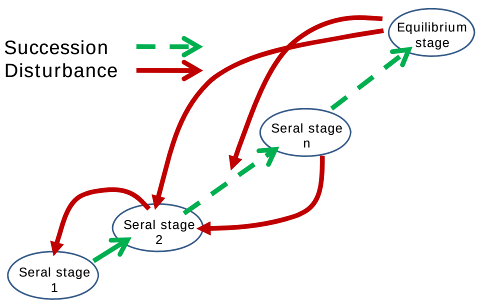
Stability and equilibrium

- Much of our ecological theory and practice depends on the existence (at least theoretically) of a single, stable equilibrium
- Steady-state mosaic
- Multiple or Non-equilibrium models
  - Multiple stable states
  - Catastrophe
  - Chaos



Source: Turner et al. 1993

Patch Level Equilibrium Model



Equilibrium?

- Many types of natural vegetation are far less stable then they appear to be
- Small or transient environmental changes can cause large and long-lasting vegetation changes
- Every point in time is special
- Because of vegetation instability, it may be impossible to define THE natural vegetation or THE natural disturbance regime in many areas

Source: Sprugel 1991

Review: What is landscape composition?

- One of the most simple descriptions of a landscape
- Absolute (area) or Relative Abundance (percentage) of different patch types.
- Patch type may be defined in terms of:
  - land-use type (forest, agricultural, urban)
  - cover type with varying levels of thematic resolution, e.g.
    - Low resolution: coniferous forest, deciduous forest, shrubland
    - Medium resolution- overstory species: ponderosa pine, Douglas-fir, lodgepole pine
    - High resolution- cover type/structural stage: sapling, pole, mature, old growth (over-mature)

Shifting steady-state mosaic

Many ecologists have assumed that, even if a stable composition (PNC) can occur, the vegetation on a site rarely develops to this successional stage. Disturbance and environmental variation prevent this from happening.

However, some have suggested that equilibrium may occur at a broader scale such as at the watershed or landscape scale. They have referred to this as a "shifting steady state mosaic" or "dynamic equilibrium".

Landscape composed of western juniper woodland, Wyoming big sagebrush steppe and riparian vegetation, Owyhee River Canyon, eastern Oregon

Shifting steady-state mosaic

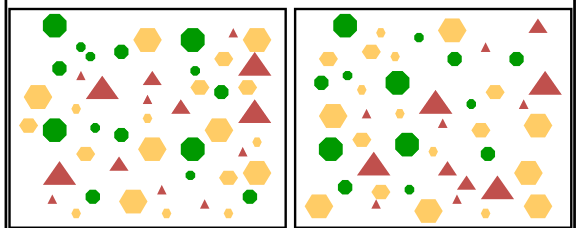
A shifting steady state mosaic model has two important components that determine the characteristics of the equilibrium state:

- the temporal component
- the spatial component

What is similar and what is different in these images?

Community: Shifting steady-state mosaic

When a community's composition is stable, the distribution of species within it continually change through time due to mortality and recruitment of individual plants but the composition remains fairly constant.

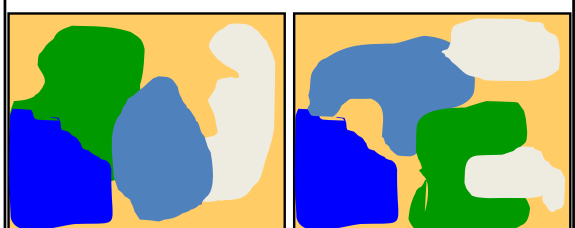


Time period 1 Time period 2

NOTE: Color indicates different species, size indicates age class.

Landscape: Shifting steady-state mosaic

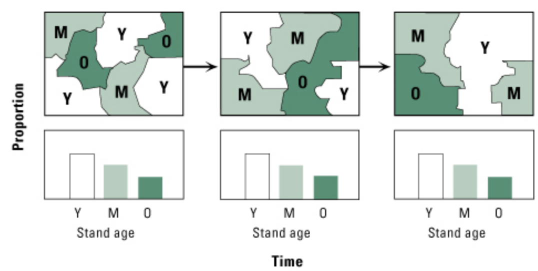
We can think of the abundance of communities (area) within a landscape in the same way when considering the shifting steady state mosaic. The locations of the communities change over time but the abundance remains fairly constant.



Time period 1 Time period 2

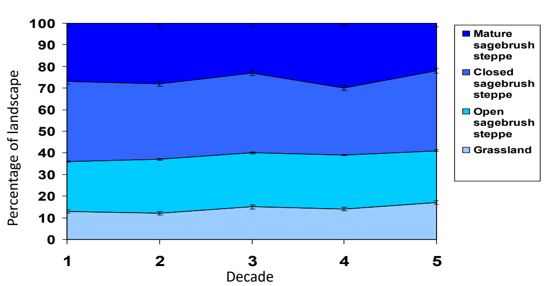
NOTE: Color indicates different communities within the landscape.

Landscape: Shifting Steady-State Concept



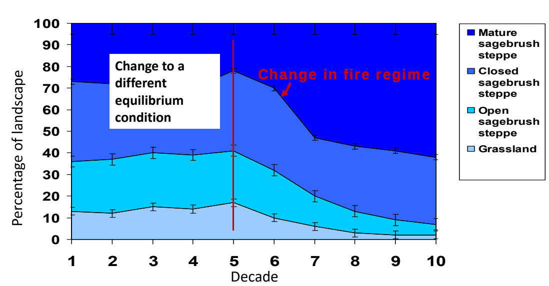
Source: T, G & O 2001. Figure 7.14

Landscape: Shifting steady-state mosaic



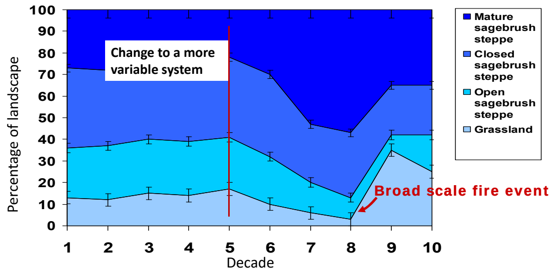
Percent of landscape in four successional stages.

Landscape: Shifting steady-state mosaic



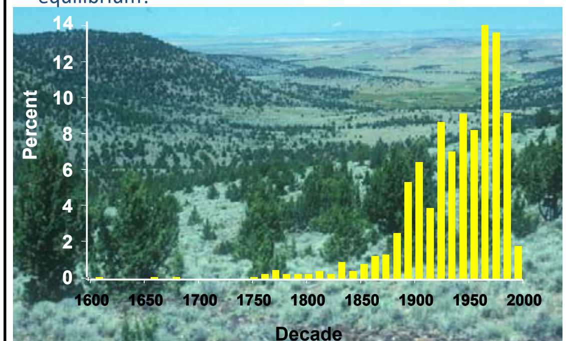
Percent of landscape in four successional stages.

Landscape: Shifting steady-state mosaic

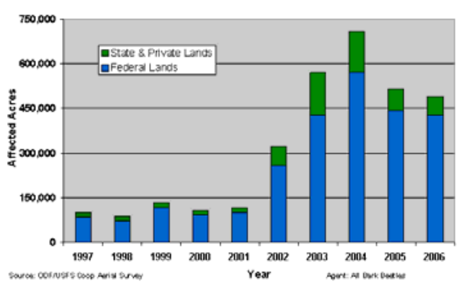


Percent of landscape in four successional stages.

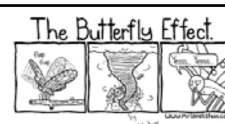
Decade of establishment of western juniper trees in the northwestern Great Basin. Looking for a new equilibrium?



Spread of bark beetles in Oregon forests



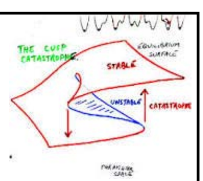
Chaos theory



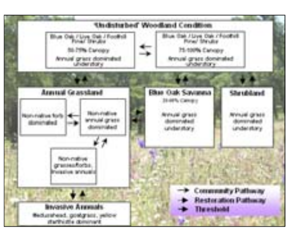
Lorenz 1972. *Predictability: Does the Flap of a Butterfly's Wings in Brazil set off a Tornado in Texas?*

- Chaos commonly refers to "a state of disorder"
- Originated in the prediction of weather systems
- Studies the behavior of dynamic systems that are highly sensitive to initial condition
- A small change in initial condition results in a wide variety of outcomes
- Chaos systems are predictable for a while, then become unpredictable
- Uncertainty in a forecast increases exponentially with elapsed time. Doubling the forecast time more than squares the uncertainty in the forecast.

Catastrophe theory

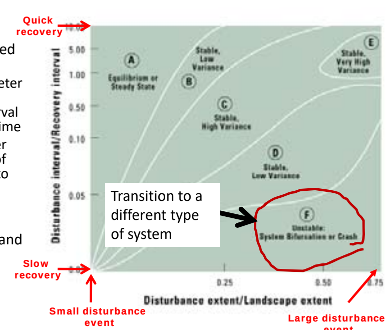


- Sudden large shifts resulting from small changes
- At a certain point the stable system becomes unstable, but can jump back to the stable system
- Example: the unpredictable magnitude and timing of a landslide
- Example: Thresholds in state-and-transition models



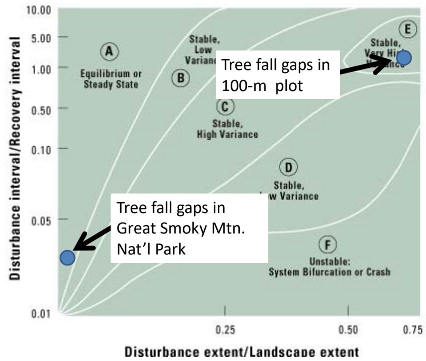
Landscape Equilibrium

- Turner et al. (1993) theorized that equilibrium depended on two parameters
  - **Temporal** parameter (T): ratio of disturbance interval to the recovery time
  - **Spatial** parameter (S): ratio of size of the disturbance to the size of the landscape
- At what values of S and T does equilibrium occur?

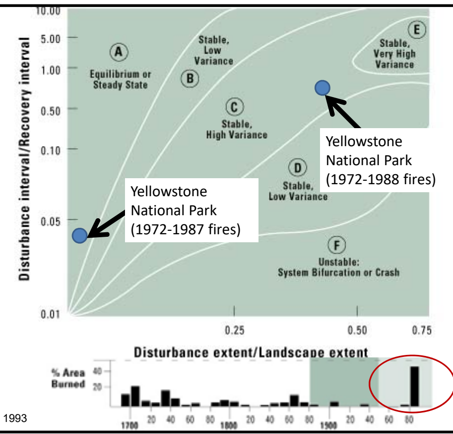


Source: T,G & O 2001, Figure 11.6 Redrawn from Turner et al 1993

Landscape Equilibrium



Source: Turner et al 1993



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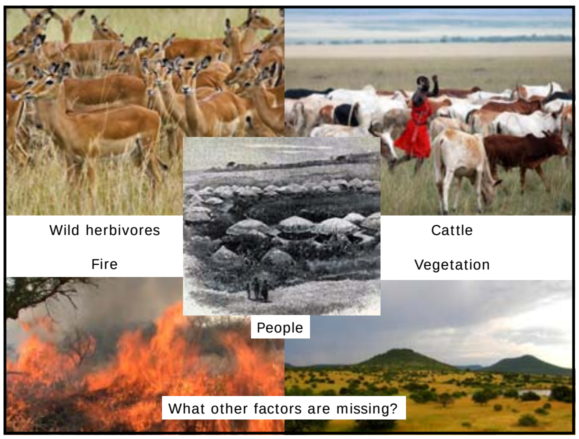

Landscape Equilibrium: Does it really exist?

Rinderpest: A highly infectious viral disease of cattle, buffalo, antelope, giraffe, and many other ungulates. An outbreak in the 1890s killed 80 to 90% of all cattle and devastated many wildlife populations in southern Africa, as well as in the Horn of Africa.

Landscape Equilibrium: Does it really exist?

Key Points

- From an ecological perspective pattern matters.
- Landscapes change as a function of environmental conditions, disturbance, succession, and human-caused factors.
- Equilibrium conditions, such as steady-state mosaic, depend upon the scale. Often equilibrium exists only at one spatial or temporal scale, and it may not exist at any scale. Multiple stable states or chaos may be more likely.
- Disturbances greatly affect the structure, composition, and function of landscapes.
- There are as many ecological implications for the lack of disturbance at the landscape scale as there are for the presence of disturbance .