Community Change:
disturbance and succession

Reading: Chap. 13

I. Disturbance

A. Disturbance:
   type, time, severity,
   and scale

B. Stability:
   Resistance/resilience

II. Succession

A. Primary and secondary succession

B. Changes in species composition

C. Changes C cycling

D. Changes in nutrient cycling

E. Changes in trophic interactions

F. Changes in water and
   energy balance

I. Disturbance

A. Disturbance:

CMM - "a discrete event in time and space that alters the structure of populations, communities, and ecosystems and causes changes in resource availability or the physical environment."

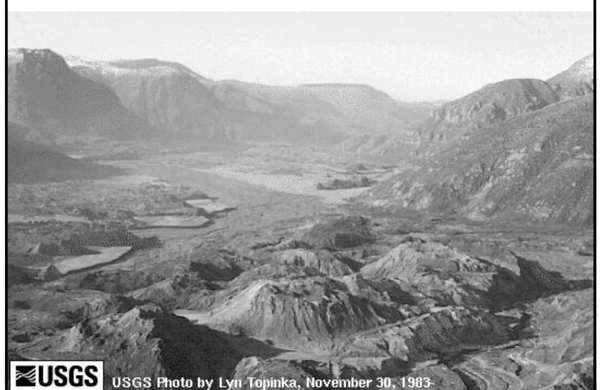
Any physical force that results in mortality of organisms or loss of biomass.

<u>Any</u> physical force?

What qualifies as “disturbance”?

http://vulcan.wr.usgs.gov/Photo/SlideSet/ljt_slideset.html

Note geologists for scale in yellow circle



What about?

- A single tree fall?
  - A log rolling against rocks in the intertidal zone?
    - A gopher mound?
      - An outbreak of gypsy moths?

I. Disturbance

A. Disturbance:

Any physical force that results in mortality of organisms or loss of biomass.

Type – what kind of disturbance event occurs

Timing: - frequency (how often)
- when, relative to other events

Severity - how much mortality/change is caused
(Intensity - how strong the force is [energy/area/time].)

Scale - how large an area it covers

How do biotic communities respond to disturbance?

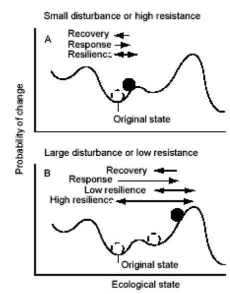
B. Stability: resistance, resilience

- Resistance: the ability of a community or ecosystem to maintain structure and/or function in the face of potential disturbance
- Resilience: the ability of a community or ecosystem to return to it's original conditions following disturbance

Draw it

What affects resistance and resilience?

Fig. 13.1



Grasslands, California

Dry forest, Hawai'i

Ohia (*Metrosideros polymorpha*)
Native trees

Non-native, easy burning, fire-tolerant grasses

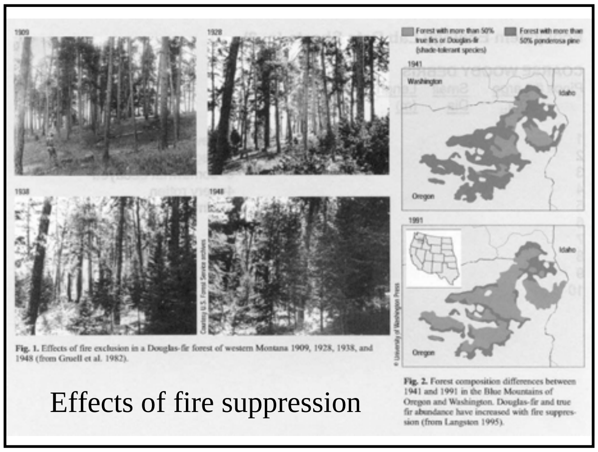


Fig. 1. Effects of fire exclusion in a Douglas-fir forest of western Montana 1909, 1928, 1938, and 1948 (from Gruell et al. 1982).

Fig. 2. Forest composition differences between 1941 and 1991 in the Blue Mountains of Oregon and Washington. Douglas-fir and true fir abundance have increased with fire suppression (from Langston 1995).

Effects of fire suppression

- The extent of resistance or resilience to a given disturbance will depend on the adaptations of the organisms affected.
- This depends on their historic exposure to that disturbance over evolutionary time.
- Humans are greatly altering disturbance cycles.

II. Succession

Directional change in ecosystem structure and functioning over time following disturbance.

Results from changes in species composition in response to biotically-driven changes in resource availability

A. Primary and Secondary Succession

- Primary succession - growth on a new mineral substrate
  - Volcanic deposition
  - Glaciation
  - Landslide
  - Sand dunes
  - River bars

A. Primary and Secondary Succession

- Secondary succession - new organisms but soil remains intact from previous community.
  - Fire
  - Clearcut
  - Insect outbreak
  - Hurricane/storm damage
  - Agriculture - old fields

Severity of disturbance

Fig. 13.4

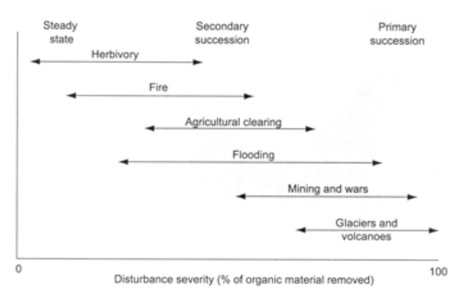
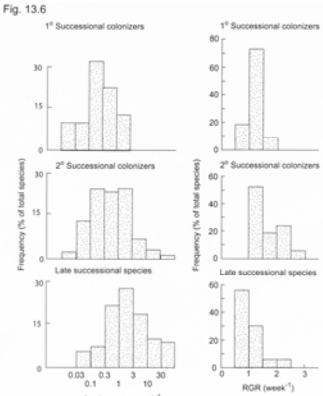


Fig. 13.6



B. Changes in species composition

1. Early and late successional species

Early and late successional species – Glacier Bay

See this site: http://glacierbay.areaparks.com/parkinfo.html?pid=8410

Early and late successional species

Table 13.1. Successional Changes in Life-History Traits after Glacial Retreat in Glacier Bay, Alaska[a].

Genus	Successional stage	Seed mass (μg seed^{-1})	Maximum height (m)	Age at first reproduction (yr)	Maximum longevity (yr)
Epilobium	Pioneer	72	0.3	1	20
Dryas	*Dryas*	97	0.1	7	50
Alnus	Alder	494	4	8	100
Picea	Spruce	2694	40	40	700

[a] Data from Chapin et al. (1994).

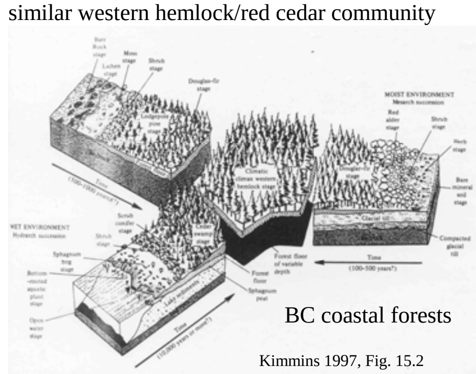
Climax communities

Early successional species: pioneer species

Late successional species: climax community

- monoclimax: one community type, determined by climate
- polyclimax: many community types depending on soils, topography, etc.

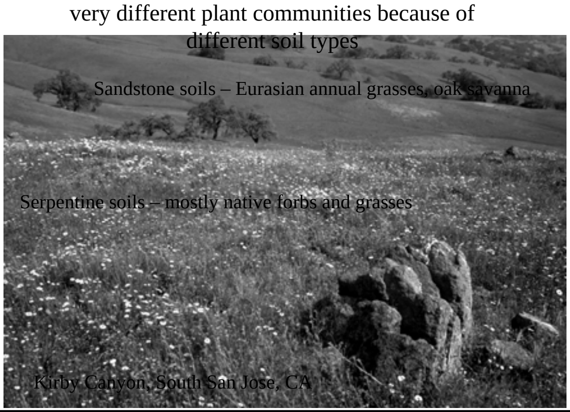
Monoclimax communities BC coastal forests – many different successional trajectories lead to similar western hemlock/red cedar community



BC coastal forests

Kimmins 1997, Fig. 15.2

Polyclimax, California grasslands: same climate, but very different plant communities because of different soil types



2. Mechanisms of succession

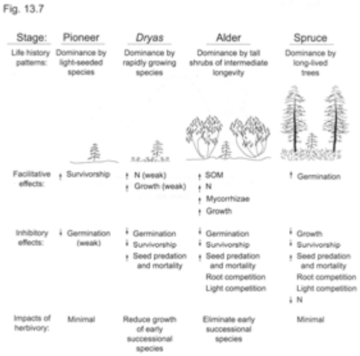
Facilitation
Inhibition
Functional traits
Herbivory

- First two influence changes in abiotic conditions and resource availability.

- All can operate simultaneously

Facilitation and inhibition can operate simultaneously.

Fig. 13.7



3. Changes in resources

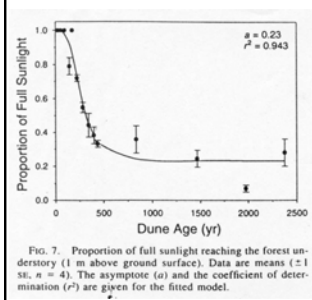
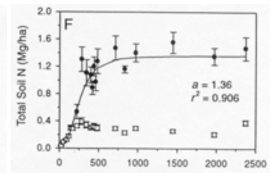


FIG. 7. Proportion of full sunlight reaching the forest understory (1 m above ground surface). Data are means (± 1 SE, n = 4). The asymptote (a) and the coefficient of determination (r^2) are given for the fitted model.

Light



Nitrogen

BIOTIC INFLUENCES:
Light availability declines and N availability increases.

Lake Michigan dunes, primary succession (Lichter 1998)

C. Changes in Carbon Cycling

1. Biomass
2. GPP, NPP
3. Het. respiration, NEP

C. Changes in Carbon Cycling

1. Biomass – increases to a maximum

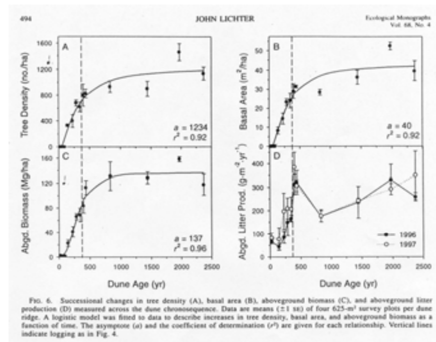


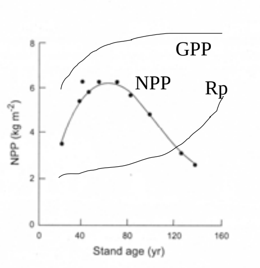
FIG. 6. Successional changes in tree density (A), basal area (B), aboveground biomass (C), and aboveground litter production (D) measured across the dune chronosequence. Data are means (± 1 SE) of four 625-m² survey plots per dune ridge. A logistic model was fitted to data to describe increases in tree density, basal area, and aboveground biomass as a function of time. The asymptote (a) and the coefficient of determination (r^2) are given for each relationship. Vertical lines indicate logging as in Fig. 4.

Lichter 1998

C. Changes in Carbon Cycling

2. NPP – typically maximum in mid-succession

Fig. 13.8



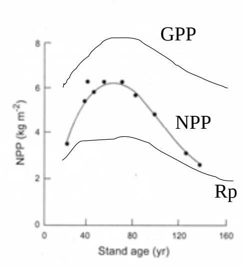
Why?

a. Increased plant resp.?

C. Changes in Carbon Cycling

2. NPP – typically maximum in mid-succession

Fig. 13.8



Why?

a. Increased plant resp.

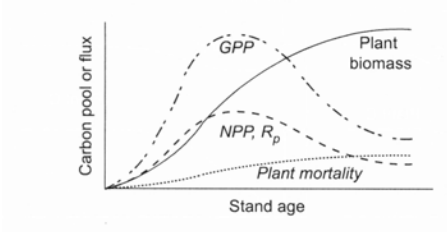
b. Hydraulic conductance

c. Soil nutrients

C. Changes in Carbon Cycling

2. GPP, NPP - summary

Fig. 13.9



C. Changes in Carbon Cycling

3. NEP – peaks in mid-succession, ~0 in late succession (GPP = R_{total})
Heterotrophic respiration – increases to a max

5. Carbon Cycle of Terrestrial Ecosystems 151

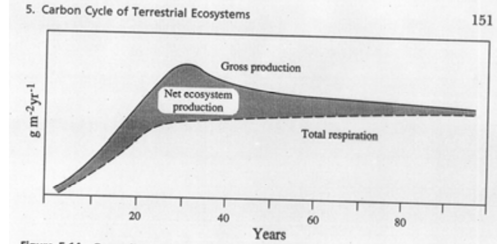
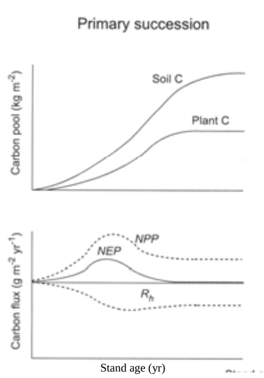


Figure 5.14 Generalized trends in primary production and respiration during ecosystem development. Modified from Odum (1969).

Schlesinger 1995

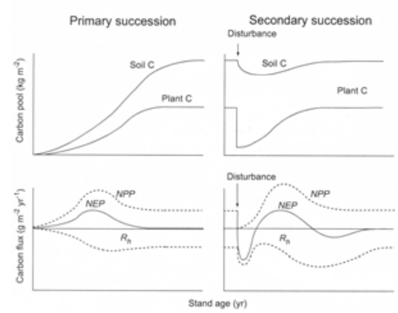
3. Heterotrophic resp. and NEP
a. Primary Succession

Fig. 13.~~10~~ 11



3. Heterotrophic respiration, NEP
b. Secondary Succession

Fig. 13.~~10~~ 11



Can we pull more CO_2 out of the atmosphere by converting old growth forests to young forests?

- GPP higher in young than old forests
- NPP higher in young than old forests
- NEP higher in young than old forests

- So, should we cut old growth forests that aren't pulling CO_2 out of the atmosphere and replace them with young tree plantations?

But, total C storage higher in old than young growth forests

Table 1. Carbon (*33*) storage in a 60-year-old *Pseudotsuga* forest and a 450-year-old *Pseudotsuga-Tsuga* forest.

Component	60-year-old forest: Mg of C per hectare	60-year-old forest: Reference	450-year-old forest: Mg of C per hectare	450-year-old forest: Reference
Foliage	5.5	(*20*)	6.2	(*16*)
			−7.0	(*40*)
Branchwood	7.0	(*20*)	26.3	(*16*)
Boles (wood and bark)	145	(*20*)	323	(*16*)
Coarse roots	29	(*34*)	71	(*16*)
Fine roots	5.6	(*35*)	5.6	(*16*)
Fine woody debris and forest floor	7.1	(*36*)	26	(*16*)
Coarse woody debris	3.8	(*37*)	97	(*25*)
	−19	(*38*)		
Soil carbon	56	(*39*)	56	(*16*)
Total*	259 to 274		611 to 612	

*Range given because of variation in estimates for foliage and coarse woody debris.

Harmon et al. 1990 Science

Where does the C go from logging?

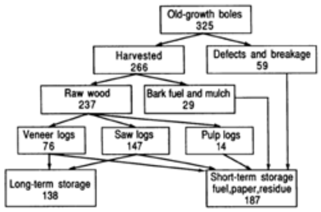


Fig. 1. Flow of C (megagrams per hectare) into long- and short-term storage components after harvest of a 1-ha old-growth forest. Data are from studies on Douglas fir and western hemlock (*14–17*). Boards and plywood are assumed to enter long-term storage (>5 years). Sawdust, scrap, and pulp are assumed to enter short-term storage.

Over half goes to fast turnover pools, then to the atmosphere.

Harmon et al. 1990 Science

~250 years for C storage to return to old growth levels

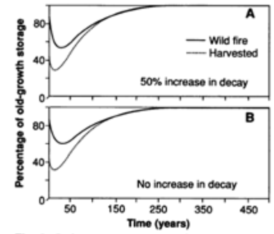


Fig. 2. Carbon storage, expressed as a percentage of old-growth storage, in a simulation of a Douglas fir and hemlock old-growth ecosystem disturbed by fire or timber harvest. The assumptions are that fire used in site preparation will remove 50% of the fine woody debris and forest floor and 25% of the coarse woody debris. The simulation was run with two scenarios: (**A**) disturbance is followed by a 50% increase in the decomposition rate, which decreases 3% annually and reaches old-growth values in 100 years; (**B**) disturbance does not affect decomposition rates.

Harmon et al. 1990 Science

Most rotations are 60-80 years

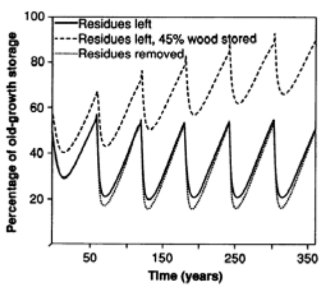


Fig. 3. Carbon storage expressed as a percentage of old-growth storage in a simulation of repeated harvests on a 60-year rotation. The assumptions are that site productivity will not change, that disturbance will initially increase decomposition rates 50%, and that fire used in site preparation will remove 50% of the fine woody debris and forest floor and 25% of the coarse woody debris. Three scenarios were examined: (i) coarse woody debris and residues such as defective boles are left on site; (ii) coarse woody debris is left but other residues are removed; and (iii) all residues are left, but 45% of harvested wood is converted to long-term storage (buildings and other structures) with a 2% annual loss.

Harmon et al. 1990 Science

D. Changes in nutrient cycling

1. Primary succession
   - Increased N availability early (inputs)
   - Open ⟶ closed
   - Decreased N availability late (litter quality)

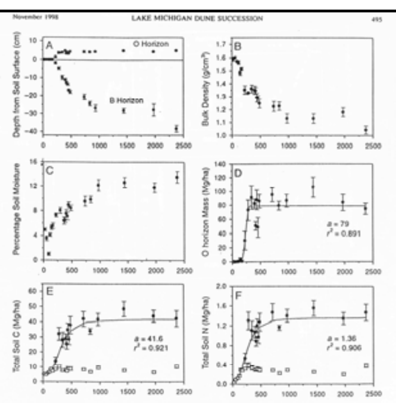


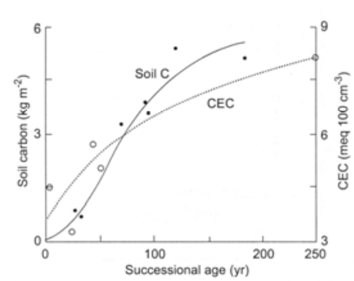
FIG. 8. Soil profile development (A) and changes in field bulk density (B), percentage moisture (C), O horizon mass (D), soil carbon (E), and soil nitrogen (F) during primary succession. Data are means (±1 se, n = 12). The asymptote (a) and coefficient of determination are given for the fitted model in D–F.

Soil properties

(Lichter 1998)

Soil properties - Glacier Bay: increased soil C leads to increased CEC

Fig. 13, ~~11~~ 10



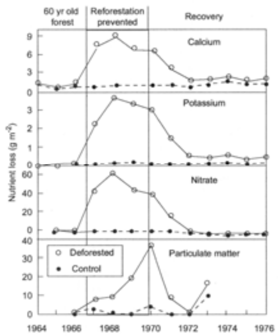
(to 45 cm depth)

D. Changes in nutrient cycling

2. Secondary succession

- Nutrient loss following disturbance removing plant biomass.
- Results from both decreased plant uptake <u>and</u> decreased microbial immobilization.

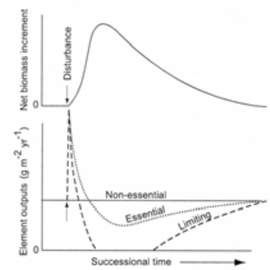
Fig. 8.8



D. Changes in nutrient cycling

2. Secondary succession: limiting nutrient (often N) controls uptake/loss of other essential elements

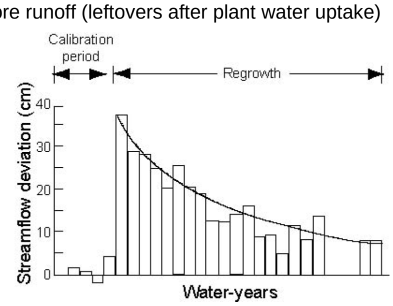
Fig. 13.12



And increased runoff:

Runoff increases after disturbance

- Less transpiration
- More runoff (leftovers after plant water uptake)



13.13

See book (pp. 298-301):

E. Changes in trophic interactions

F. Changes in water and energy balance