RAINFOREST DYNAMICS I:

Growth, reproduction & turnover

Learning Objectives:

1. Identify factors that determine the carbon balance in a forest ecosystem
2. Define phenology and explain why it varies among species
3. Describe gap-phase regeneration
4. Describe the difference between pioneer and late-successional species
5. Explain how gap dynamics and the "shifting mosaic" theory account for high diversity in rain forests

Tropical forests that are seasonally flooded by whitewater rivers are called:

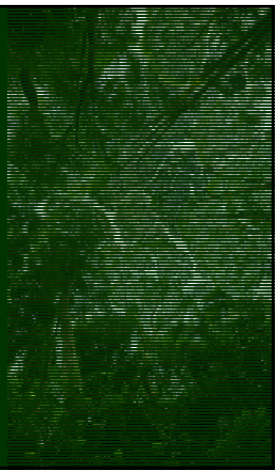
- terra firme
- várzea
- igapó

RAINFOREST DYNAMICS

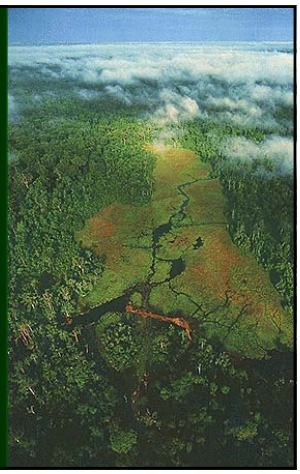
Definition of Dynamics:

"the forces or properties that stimulate growth, development, or change within a system or process."

….maintain structure and biodiversity!



RAINFOREST DYNAMICS



Growth

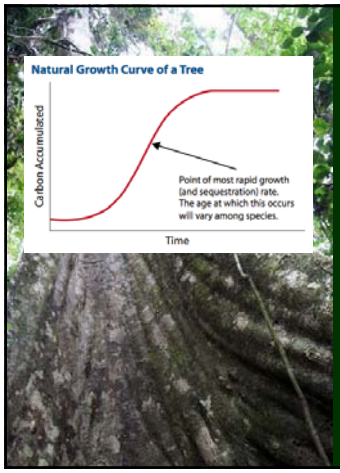
Phenology

Gap – dynamics

Succession

Nutrient Cycling

Carbon cycling



GROWTH

Rainforests have:

- highest NPP
- highest biomass (170 Mg / ha)
- longevity

How old are rainforest trees?

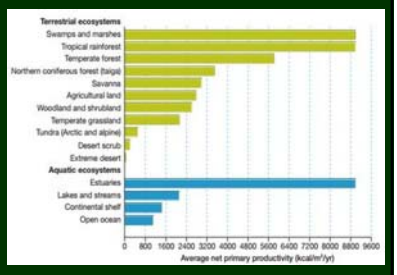
- Radio carbon dating
  - 370-800 years
- Extrapolation from long-term studies
  - but nonlinear growth rate
  - problem of suppressed seedlings

Leaf scars on palm

GROWTH & the Carbon Cycle

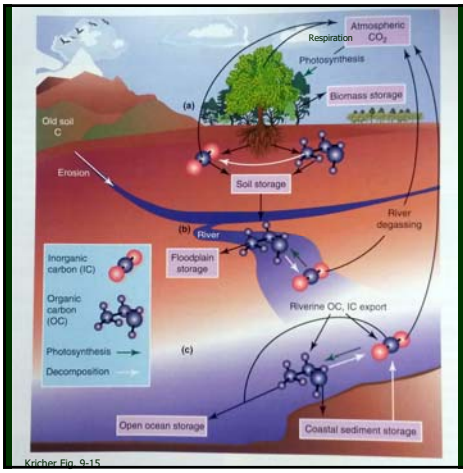
NPP = GPP - R_{plants}

- seasonality
  - temperature
  - moisture
  - sunlight
- nutrient availability
  - N, P, K
  - micronutrients
- stress / disturbance
- [CO_2]
  - we'll get to this



NPP of various ecosystems

Leibig's Law of the Minimum ??



Carbon balance is not just about the trees

Net Ecosystem Productivity:

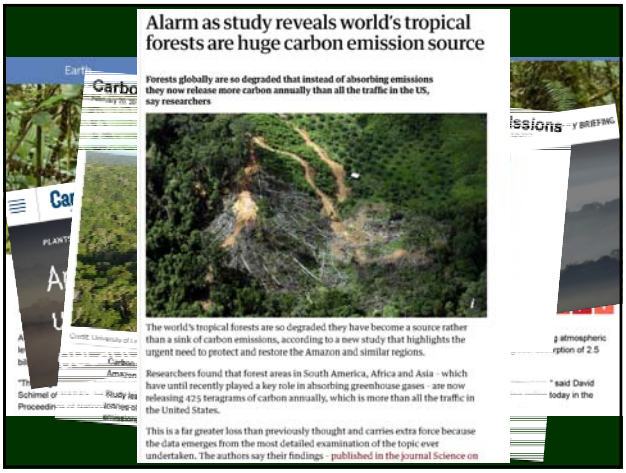
whole ecosystem carbon flux

$NEP = GPP - R_p - R_a - R_d$

ARE RAINFORESTS C SINKS OR SOURCES?

WHAT WILL HAPPEN WITH CONTINUED CLIMATE CHANGE?

(See Kricher pp 74-79



Alarm as study reveals world's tropical forests are huge carbon emission source

Forests globally are so degraded that instead of absorbing emissions they now release more carbon annually than all the traffic in the US, say researchers

The world's tropical forests are so degraded they have become a source rather than a sink of carbon emissions, according to a new study that highlights the urgent need to protect and restore the Amazon and similar regions.

Researchers found that forest areas in South America, Africa and Asia - which have until recently played a key role in absorbing greenhouse gases - are now releasing 425 teragrams of carbon annually, which is more than all the traffic in the United States.

This is a far greater loss than previously thought and carries extra force because the data emerges from the most detailed examination of the topic ever undertaken. The authors say their findings - published in the journal Science on

PHENOLOGY

THE TIMING OF GROWTH AND REPRODUCTION

Varies with climate and by species

LEAF PRODUCTION

1) Annual "leaf flush"
2) Continuous production
   - leaf life-span ≈ 3-15 months

FLOWER & FRUIT PRODUCTION

1) Subannually (55% of spp.)
2) Annually (29%)
   Flowering peak in dry season
   Fruiting peak in rainy season
3) Irregular (9%) – (e.g., masting)
4) Year-round (7%)

Delayed Greening: Young leaves of *Brownea* start out red

PHENOLOGY

TO FLOWER OR NOT TO FLOWER…

Why delay reproduction?

Synchronous reproduction = individuals flower at the same time → greater floral display

vs

Asynchronous reproduction = individuals flower at different times → attract attention

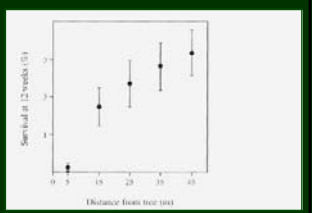
Asynchronous flowering avoids interspecific competition for pollinators

FOREST TURNOVER

Turnover = the rate at which plants die and are replaced
- depends on successional status

Mortality in mature forest

Seeds - >90% (darn beetles!)



Seedling survival with distance from fruiting adults

Seedlings and saplings
- large numbers die
- depends on growth rate, density

Adult trees
- mortality = 1.5% - 2.0% per year

Bruchid beetles emerging from infested seeds

Size Class Distributions

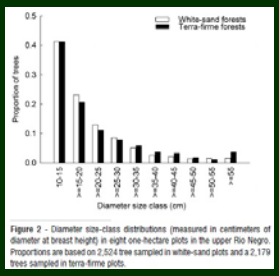
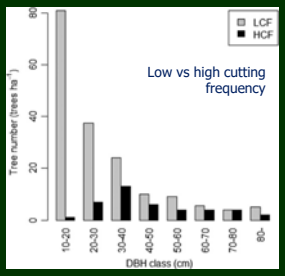


Figure 2 - Diameter size-class distributions (measured in centimeters of diameter at breast height) in eight one-hectare plots in the upper Rio Negro. Proportions are based on 2,524 tree sampled in white-sand plots and a 2,179 trees sampled in terra-firme plots.



Low vs high cutting frequency

Diameter at Breast Height (DBH) = 1.3 m

Indicate recruitment rates, management impacts, future structure

FOREST TURNOVER

How tree die and are replaced

What causes adult tree mortality?

Natural disturbance

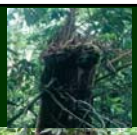
- **windthrow** = #1 cause for adult trees
- hurricanes
- fire
- disease
- flood
- landslides
- volcanoes

Humans!

Photo by S. K. Croft.

Death by hurricane (above) and volcano (left)

GAP DYNAMICS



Death of a tree creates a gap in the forest

Gap creation:

- windthrow
  - snap off
  - uproot
- die standing

GAP SIZE & FREQUENCY

TREEFALL GAPS

Size depends on:

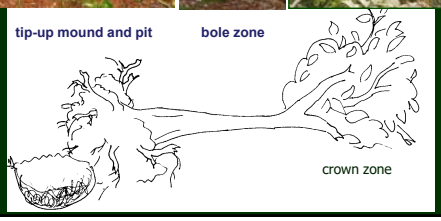
- cause of death
- size of tree
- vines / lianas

Frequency

- Malaysia = 250 - 375 years
- Costa Rica = 118 +/- 27 years

GAP-PHASE REGENERATION

TREEFALL GAP ANATOMY



GAP-PHASE REGENERATION

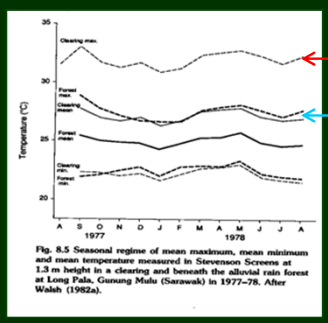


Fig. 8.5 Seasonal regime of mean maximum, mean minimum and mean temperature measured in Stevenson Screens at 1.3 m height in a clearing and beneath the alluvial rain forest at Long Pala, Gunung Mulu (Sarawak) in 1977–78. After Walsh (1982a).

Sudden increase in plant growth

Gap max.

Forest max.

Environmental Changes

- increased P.A.R.
- increased temperature
- decreased humidity
- input of nutrients

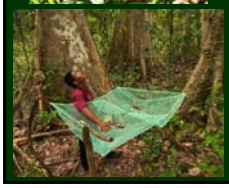
Temperature regimes in clearings versus under closed canopy.

GAP-PHASE REGENERATION

A successional process

SOURCES OF REGENERATION

1. **infill growth**
2. **seed rain**
3. **seed bank**
4. **'seedling' bank**
5. **coppice**



seed traps are used to measure seed rain

coppice

RECALL: SUCCESSION

SECONDARY SUCCESSION

starts after disturbance to existing vegetation

PIONEER SPECIES

"Early Successional species"

"disturbance-adapted species"

- light-demanding
- seed bank (photoblastic)
- seed rain

increasing shade
increasing biomass
increasing diversity

LATE-SUCCESSIONAL SPECIES

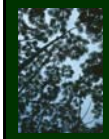
"Climax species"

"shade-tolerant species"

- shade-tolerant
- seed rain
- suppressed seedlings

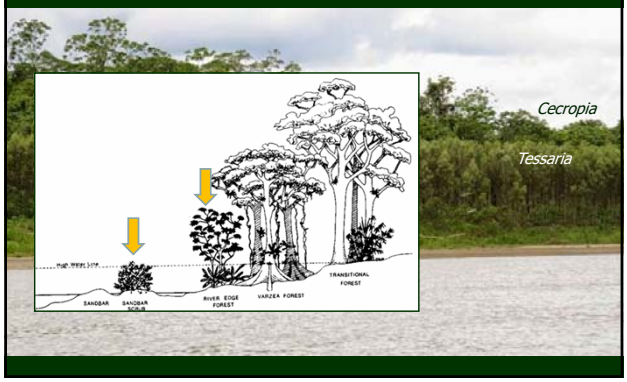
An even-aged stand of *Cecropia* pioneers recolonizes the edge of a clearing. Mature forest can be seen in the background.

SUCCESSION

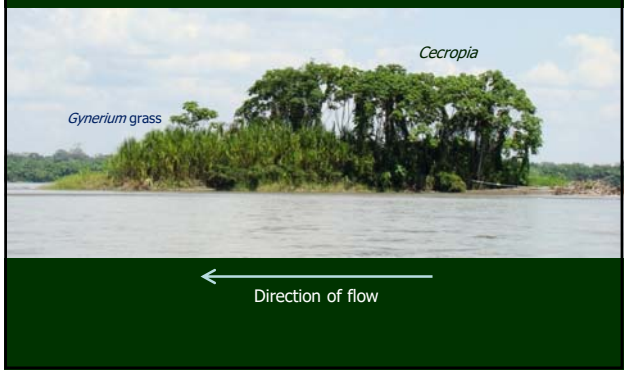


PIONEERS	LATE-SUCCESSIONAL
fast-growing	slow-growing
light-demanding	shade-tolerant
photoblastic germination	need imbibition or scarification
short-lived	long-lived
light wood	heavy wood
many small seeds	few large seeds
wind or bird dispersed	bird or mammal dispersed
form seed bank (dormancy)	no seed dormancy
few secondary compounds	protected by 2° compounds

FLOOD DISTURBANCE & RIVEREDGE VEGETATION



FLOOD DISTURBANCE & DYNAMIC RIVER ISLANDS



DISTURBANCE & DIVERSITY

Gaps
- contribute to horizontal complexity
  - **phasic complexity**

Aubreville (1938) **"Shifting Mosaic Theory"**
- combination of species that are dominant in a given area is not constant in space or time.

Dynamic equilibrium model (vs. climax community)
- structure of forest as a whole is stable, but the individuals that make it up at any point in time or space changes

Recall **Intermediate Disturbance Hypothesis!**