Threats to tropical forests in the 21st century

But first: Why do we care?

1a. Habitat destruction: effects

1b. Habitat destruction: causes

1c. Habitat destruction for timber harvest: Gunung Palung, Kalimantan, Indonesia

- In the 1960s, logging companies legally hired local villagers to work as laborers cutting and removing trees. Most logging was illegal in the region by 1990, but skilled workers were plentiful, so logging continued under the official radar, which meant no regulation for environmental health or labor rights.
- Villagers cut trees to sell wood to foreign wood-buyers, and also for personal use in home-building and for fuel.
- 40% of villagers in the region now claim revenues from logging as their primary income source.
- Gunung Palung National Park is now the most frequently accessed source of timber in West Kalimantan, since all areas around it have been burned 3+ times in 20 years.

1d. Habitat destruction for plantation development

- Plantations are generally monocrops of species with value in the developed world; most of the crop is exported.
- Plantation crops include tropical hardwoods (mahogany, teak, ebony), rubber, oil palm, chocolate, and fruit (especially bananas).
- Like all monocrops, plantations are highly susceptible to pests and diseases. So pesticides, herbicides, and fertilizers are often used, which have long-term effects on soil and water.

1e. Habitat destruction for cattle

- Forests are burned and/or cut to make cattle pasture, often leaving adjacent forest intact, but enabling cattle access.
- Cattle cause erosion, increase siltation and pollute waterways, and do physical damage wherever they step, so habitat adjacent to cattle pasture is at risk.
- If the world were willing to eat other meat, annual yields on tropical land could increase, and ecological effects might be diminished. Some possibilities include converting cattle pasture to iguana or capybara farms, or to turtle ponds.

1f. Habitat destruction for development

- Rise in population density leads to increases in cutting and burning forest for farmland, villages, and for household wood.
- Pressure from all of these sources of habitat destruction shunts animals into ever smaller pieces of useable habitat, which makes them easier targets for hunters

2. Origins of agriculture

Farming is approximately 10,000 years old, and its invention brought about huge changes in human culture, including slowing of migration and the development of permanent settlements, increases in trade and other aspects of economy, and changes in both life style (from nomadic to sedentary) and gender roles (more sedentary --> higher reproductive rate --> women more tied to home and hearth --> decrease in women's roles in economic, religious, and other culturally important realms).

2a. Swidden (aka shifting cultivation, or slash and burn. *Tavy* in Madagascar.)

- ***What is it?*** An agricultural system in which patches of forest are cleared, then burned, and not cultivated continuously, such that periods of fallow are longer than the periods during which a plot is cultivated.
- Regeneration of the forest canopy is integral. To achieve this, the tree stumps are usually left in place while clearing, and crops are planted between them ; this prevents the soil from being packed down, aerates the ground and allows water to circulate between the roots of the trees that have been felled.
- Susceptibility of crops to invasion by pests: Low
- Long-term sustainability on a given piece of land: Low, but at low human population density this is not problematic.

Swidden: costs & benefits

- ***Ecological benefits:*** High. Forest is almost constantly in a state of regrowth; no piece of land is kept in an early successional stage for long, so diversity is almost as high as in surrounding forest.
- ***Economic benefits***: No input of agrochemicals or other technology required; in a system with an abundance of labor but little money to input, this is important.
- ***Ecological costs:*** Slight: small pieces of forest are cut, but quickly allowed to regrow.
- ***Economic costs:*** No capital investment means no capital return—swidden agriculture works for sustenance, not for profit.

2b: "Traditional" (aka rustic)

- ***What is it?*** Crop plants are grown in combination with other native plants that provide some of the ecological services required for good growing conditions: e.g. shade-tolerant species are grown under canopy trees, or Nitrogen-using species are grown with legumes, which fix Nitrogen. "Traditional" agricultural regimes
- often, though not always, use the swidden model of burning small fields in succession, and letting past fields lay fallow to regrow.
- Susceptibility of crops to invasion by pests: Low
- Long-term sustainability on a given piece of land: High.

Traditional: costs & benefits

- Ecological benefits
- Economic benefits
- Ecological costs
- Economic costs

2c. Polycultural (aka Intermediate, or Intercropping)

- ***What is it?*** Halfway between "traditional" farming, and big-business monocropping, lies polycultural farming. This is typically a highly managed, but ecologically sustainable system. Plants of various habits (canopy, understory, vine) or ecological needs (legumes with grains) are planted together, all or most of which have economic or caloric value. Native communities of animals are often maintained—e.g. songbirds and insects stick around, so pest management can be ecological and passive rather than pharmaceutical and active.
- Susceptibility of crops to invasion by pests: Low to moderate.
- Long-term sustainability on a given piece of land: Moderate to high (depends on what is planted, and how good the soil is).

Polycultural: costs & benefits

- Ecological benefits
- Economic benefits
- Ecological costs
- Economic costs

2d. Monocropping

- ***What is it?*** Single species are grown in regular rows, in full-sun, with, in most cases, regular application of agrochemicals to keep out pests, pathogens, and competitors. This is the model most familiar to Americans.
- Susceptibility of crops to invasion by pests: High.
- Long-term sustainability on a given piece of land: Low.

Monocropping: costs & benefits

- Ecological benefits
- Economic benefits
- Ecological costs
- Economic costs

2e. Gov't-decreed agriculture in Borneo

Until the mid-1990s, central Kalimantan was a swamp forest that had been undisturbed for thousands of years. What is peat?

2e. Why former peat swamps don't make good rice paddies (Source: Aldhous, P. 2004. Borneo is burning. Nature 432(7014): 144-146.)

3a. Habitat fragmentation: general effects

3a. Habitat fragmentation: What are some *specific* edge effects?

3a. Effects of habitat fragmentation from the Amazon

- Most small terrestrial mammals won't cross 80-meter swaths of pasture between forest fragments (although habitat generalists, like some possums, will).
- Carrion and dung beetles in 1 and 10 ha fragments isolated by more than 350 m for 2 or more years, are represented by fewer species, sparser populations, and smaller individuals than in nearby continuous forest. Decrease in density of these beetles is correlated with decrease in decomposition rate of dung and carrion.
- Deep-forest euglossine (stingless) bee species will not cross a clearing of 100-meters, thus isolating bees in such fragments, and the orchids that they pollinate as well.

3a. A diversion: Why do bees matter?

- The presence of forest-bee species in coffee plantations within 1 km of forest fragments increases coffee yield by 20%, and improves coffee quality by reducing the frequency of small, misshapen seeds by 27%.
- On one Costa Rican farm, during 2000-2003, these "pollination services" from adjacent forest fragments increased the value of the annual crop by $62,000, or 7%.
- Cutting those fragments and turning them over to cattle grazing would yield only $24,000 / year. (Source: Ricketts *et al*. 2004. Economic value of tropical forest to coffee production. *PNAS*, **101,** 12579-12582.)

3a. Habitat fragmentation: more effects from the Amazon

- Small mammals have ***greater*** species richness, individual abundance, and total biomass in small fragments than in continuous forest.
- Vertical distribution of mammals changes in fragments: greater biomass of mammals are in the trees in continuous forest, but on the ground in fragments.
- Same pattern holds for insect abundance and foliage density: in continuous forest, insects and leaves are denser in the canopy, in fragments, insects and leaves are more abundant in the understory.

3b. Habitat fragmentation: causes

3c. Some of the conservation issues that are raised by our understanding of fragmentation include:

4a. Harvest for food: bushmeat
- Example: Chimps in Africa
  - ◊ Hunters have guns, chimps don't, and they're social and deeply bonded to one another, so will stay to protect individuals that are hurt or killed--thus, whole families are easily killed in short order.
  - ◊ Up to 10 tons of African bushmeat pass through Heathrow customs to be eaten by Brits every day.
- Additional inobvious problems: Orphans often result from the hunting of families, which produces the opportunity for selling into the pet trade.

4b. Harvest for pet trade
- Why? Western desire for the exotic
- Example: parrots all over the world.
  - ◊ 1/3 of world's 300 parrot species are currently threatened with extinction due to collection for pet trade, in combination with habitat loss (from Worldwatch Institute, Winged Messengers: The Decline of Birds)
  - ◊ In neotropical parrots, poaching of nests is a significantly greater cause of mortality than natural causes (Wright *et al*. 2001. *Nest Poaching in Neotropical Parrots*. Conservation Biology. 15:710-720.)
- Additional inobvious problems: Money rarely ends up in hands of local (indigenous) people, so local economies are not helped. The Western pet industry makes the profits.

5a. Invasive species: What are they?
- Official U.S. definitions from Executive Order 13112 signed by President Clinton on February 3, 1999 are:
  Invasive species: an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.
  Alien species: with respect to a particular ecosystem, any species, including its seeds, eggs, spores, or other biological material capable of propagating that species, that is not native to that ecosystem.
- Several terms are often used interchangeably, including invasive, introduced, alien, and exotic species.

5b. What makes species and ecosystems invasible
- The tropics don't experience massive invasions from the temperate zone (specialists being better competitors than generalists), but tropical species can invade other tropical habitats.
- Species new to an area, without their usual suite of predators, competitors, and parasites, may outcompete native species that are still living their normal lives.

5b. The Evolution of Increased Competitive Ability hypothesis

- ***Hypothesis***: Introduced species will evolve to outcompete natives in their new homes.
- ***Predictions*** for the EICA include: organisms will lose defenses no longer necessary in their new environment, and shunt those resources to increased competitive ability. Put another way: there is a trade-off between growth and defense , and the organisms are moving along the trade-off line.
- For plants, this could mean larger size, faster growth, or greater reproductive capacity.
- There is some ***evidence*** for the EICA from Chinese tallow trees (introduced individuals show faster growth and less investment in phytochemicals that deter herbivory).

6. Ecotourism (or, humans as invasive species)

- Ecotourists visit pristine or nominally intact forests and potentially change the ecosystem.
- Benefits of tropical ecotourism are touted as bringing revenues from rich industrialized countries to financially poor, biologically rich countries.
- If the ecotour companies are not based in the vacation destinations, though, local economies are not helped, and destruction of local habitats matters little to the industry.

6. Ecotourism: keep the money local

- Local (rather than foreign) investment up front
- Local inception of ecotourist operations. If foreign-originated, locals should be involved.
- Local resource base
- Local management
- Local employees
- Invest some of the profits generated by ecotourism back in the ecosystems that are being affected by tourism.
- Strict regulations for environmental compliance

7. Non-anthropogenic disturbances

On December 26, 2004, a 9.0 earthquake off of Sumatra caused massive tsunamis across South Asia, even reaching as far as Africa. What property of water allowed the waves to travel across the Indian Ocean and still be big enough to do damage?

http://www.washingtonpost.com/wp-srv/world/daily/graphics/tsunami_122804.html

> Massive numbers of people have been displaced by this natural disaster, and will go to the forests for food and wood. Also, already financially strapped governments and NGOs (non-governmental organizations) will have fewer resources, and less incentive, to focus on conservation.

8. Global climate change: Several parameters have been identified as both drivers of environmental change, and effects of other drivers. Some of these include:

One driver of environmental change: Temperature

- Global land temperatures have increased by 0.6° C in the last century.
- Over the past 20 years, there has been a 0.26±0.05 ° C increase in air temps over tropical forests worldwide.
- **Causes**: Production of greenhouse gases from combustion of fossil fuels. Deforestation.

Effect of Temperature on Rate of Photosynthesis
- [Chlorophyll] & [carotenoids] increase as T increases, which ***increase*** C gains.
- Photorespiration increases with higher T, which ***decreases*** photosynthesis, and ∴C gains.
- Two other photosynthetic process ***increase*** C gains as well, but what will net effect be?
- Empirical research to date is conflicting, but there is some evidence that photosynthesis rates decrease with higher T.

Effect of Temperature on Rate of Respiration
- Short term experiments show exponential increases in respiration with rising temperature.
- But: short-term experiments may not be a fair gauge of the effect. Organisms are likely to evolve more efficient respiration to respond to increased T.
- Some evidence suggests that increases in [CO2] will reduce respiration, but many researchers doubt this finding.

Effect of Temperature on Rate of Ontogeny (development)
- Higher T increases the rate of ontogeny in a variety of species. Tropical trees have not been studied, but if the same trend holds for them, this would increase stem turnover rates and overall growth, as trees would reach maturity and senesce earlier.
- Empirical studies that attempt to correlate growth rate of tropical trees with temperature have shown positive, negative, and no correlations. The jury is still out.

Effect of Temperature on Rate of Soil Nutrient Availability
- High T increases soil organic C decomposition rates, which may enhance soil nutrient mineralization rates, leading to ***greater*** nutrient availability, especially for N.
- But: N may not be limiting to mature trees in most tropical forests. If so, increased N availability will not increase the rate of plant growth.
- Increase in T may also increase available P, Mg, Ca or K, and where that element is limiting, plant growth may ***increase***.
- Extra mineral inputs may lead to soil acidification, depletion of base cations, and mobilization of Aluminum ions; net effect: ***decrease*** in soil nutrient availability and plant growth rates.

Source for all material on global change: Lewis *et al*. 2004. Fingerprinting the impacts of global change on tropical forests. *Philosophical Transactions of the Royal Society of London Series B-Biological Sciences*, **359,** 437-462.

Effect of Temperature on Rate of *(your parameter here)*
- Even when there is empirical evidence of global change (e.g. global temperatures are rising), that does not mean that there is consensus, or even sufficient data yet, on what the effect of that change will be.
- When you look at all the known changes that are occurring as a result of human activities, it is clear that forests are at risk. But the particular responses to these changes are, in many cases, yet unclear.