Threats to terrestrial ecosystems in the 21st century (1 of 2)

1. Terrestrial ecosystems at risk. As of 1997:
- 1/3 - 1/2 of the Earth's surface had been transformed by humans;
- more than half of all accessible surface fresh water was put to use by humanity; and
- about one-quarter of bird species on Earth had been driven to extinction.

Source: Vitousek et al., 1997. Human Domination of Earth's Ecosystems. Science 277 (5325): 494 - 499.

Why care about tropical forests?

2a. Habitat destruction: effects
- Tropical deforestation alters regional climate
- Can induce feedback effects by ⇑ surface temps, and ∴ influencing atmospheric [CO_2].
- Causes regional decreases in precipitation.
- Increases rate of erosion, → (leading to) increased siltation in rivers, altering river biota.
- Lower rainfall causes lower water supply, → less water in rivers and for agricultural systems, increase in air and water pollution, and higher rate of disease in cities.

2b. Habitat destruction: causes

3. 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.

3a. Swidden (aka shifting cultivation, or slash and burn): **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.

3b: "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.

3c. 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).

3d. 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.

Two examples of agriculture's effects in tropical ecosystems:
3e. Gov't-decreed agriculture in Borneo's peat swamps

3f. Brazil's tropical savannah and dry woodland (the Cerrado)

3g. Habitat destruction for plantation development

- Plantation crops include tropical hardwoods (mahogany, teak, ebony), rubber, oil palm, chocolate, and fruit (especially bananas, as above).
- Plantation agriculture is >400 years old.
- Environmental issues include: soil erosion, decline in soil fertility, pollution from agrochemicals (like all monocrops, plantations are highly susceptible to pests & diseases, so pesticides, herbicides, and fertilizers are often used), carbon sequestration, and biodiversity declines (Source: Hartemink, A. E. 2005. Plantation agriculture in the tropics - Environmental issues. *Outlook on Agriculture*, 34, 11-21).

Are "conventional" agricultural practices negatively affecting biodiversity?

Given that global food demands are predicted to more than double by 2050, how can we meet the challenge of feeding the Earth's people while simultaneously protecting wild species and habitats?

- Two competing solutions have been proposed:
  - wildlife-friendly farming (which boosts densities of wild populations on farmland but may decrease agricultural yields)
  - land sparing (which minimizes demand for farmland by increasing yield).
- These two alternatives are hotly debated in the literature now. See, for example:
  - Green *et al*., 2005. Farming and the fate of wild nature. Science 307 (5709): 550 - 555.
  - Vandermeer & Perfecto, 2005. The future of farming. Science 308 (5726): 1257 - 1258.

4. Climate change: empirical evidence

The world's climate is becoming warmer and wetter (although in places, becoming cooler and/or drier). See the Global Change Master Directory (run by NASA) at http://gcmd.gsfc.nasa.gov/ for an impressive array of databases to support this contention.

4a. Atmospheric [CO_2]:

- Past climate change on Earth has been due primarily to 4 parameters: variations in the Earth's orbital characteristics, volcanic eruptions, variations in solar output, and atmospheric [CO_2]. The first 3 are not changing (although atmospheric changes effect how much solar radiation reaches and stays at Earth's surface).
- Concentrations of CO_2 and other greenhouse gases are increasing significantly.

4b. Precipitation (& snow cover)

A recent review of empirical research on long-term trends in global precipitation patterns identifies the follow trends:

- Increased variation of precipitation everywhere (planet-wide). Variance has increased particularly in equatorial regions.
- Wet areas are becoming wetter; dry areas drier.
- Increased precipitation in high latitudes of Northern hemisphere (temperate and arctic zones). But snow cover is decreasing and glaciers are retreating (correlated to elevated temperature).
- Decreased precipitation in China, Australia, Southern Europe, & South Pacific Island states.
- 2 - 4% increase in "heavy precipitation events" (e.g. major tropical storms) over the last 50 years (correlated with increased intensity and frequency of El Niño/ENSO events).

- Source: Dore, M. 2005. Climate change and changes in global precipitation patterns: What do we know? Environment International 31(2005): 1167-1181.

4c. Phenology shifts

- Phenology: the timing of seasonal activities of species, such as flowering or breeding.
- Several datasets support the conclusion that phenologies of many plant and animal species are advancing, and that these shifts are related to climate change, especially warming.
- But not all species in a given ecosystem experience phenology shifts, thus putting inter-related species (predator - prey, flower - pollinator, etc) at risk of falling out of sync with one another. As the mechanisms of phenology for plants, insects and vertebrates differ, we can't expect all species to respond identically to climate change.
- Possible result: trophic decoupling of food web phenology ⇒ biodiversity loss.
- Source: Visser & Both. 2005. Shifts in phenology due to global climate change: the need for a yardstick. Proc. R. Soc. B (2005) 272: 2561-2569.

4d. The Third Assessment Report of the IPCC (Intergovernmental Panel on Climate Change) is reviewed in Easterling and Apps (2005; Assessing the Consequences of Climate Changes for Food and Forest Resources: A view from the IPCC. Climate Change 70: 165-189). Major findings include:

- While deforestation rates have decreased since the early 1990s, degradation with a loss of forest productivity and biomass has occurred at large spatial scales as a result of fragmentation, non-sustainable practices and infrastructure development (≈23% of all forest and agricultural lands were classified as degraded since WWII).
- At a worldwide scale, global change pressures (climate change, land-use practices and changes in atmospheric chemistry) are increasingly affecting the supply of goods and services from forests.
- The most realistic experiments to date (free air experiments in an irrigated environment) indicate that C-3 agricultural crops in particular respond favorably to gradually increasing atmospheric CO_2 concentrations (e.g., wheat yield increases by an average of 28%).
- However: extrapolation of experimental results to real world production, in which a variety of factors are likely to be limiting at some point (e.g., nutrients, temperature, water) remains problematic.
- For some crops (e.g. rice), CO_2 benefits may decline quickly as temps warm beyond optimum photosynthetic levels.
- Crop plant growth may benefit relatively more from CO_2 enrichment in drought than in wet conditions.
- It is still extremely difficult to separate the relative influences of elevated ambient CO_2 levels, climate change responses, and direct human influences (such as present and historical land-use change) on trees. One area of consensus is that any CO_2 fertilization effect will disappear in the next 100 years, due to influences from other factors.
- Any warming in the tropics will likely diminish crop yields. In contrast, temperate zone warming of up to 2 - 3 °C could be tolerated by crops, especially if coincident with ⇑ precipitation (based on modeling studies).
- In those few regions where direct human pressures on forests are low, the impacts of climate change can be more cleanly delineated. These include: changes in natural disturbance regimes, growing season length, and local climatic extremes.

How do we accurately integrate empirical data about global warming (some of which, itself, requires interpretation, as it is based on historic levels of, for instance, ozone), with predictions for future trends?

Global Change Workshop January 12, 2006

Reading: Lewis, Malhi and Phillips, 2004.
First: Review of Lewis *et al.*'s (2004) Introduction, and a summary of their evidence on temperature.

- Each of 8 groups will be assigned one of the 8 "drivers" of change identified by Lewis *et al* (excluding temp and lianas).
- Each group will review and assess the authors' evidence for this driver, and its importance, in impacting tropical forests.
- Finally, each group will present their summaries, for not more than 5 minutes (absolute max) to the whole class in the final hour of the class. Everyone in each group should be prepared to present; we will reveal the "rule" for whom will present right before the presentations.

Presentations should include:
1) Identification and definition of the driver.
2) How much it has changed in the late 20th century. Is the evidence solid? Are the data debated? Is there any reason to doubt the findings?
3) Assuming that the level of change reported is trustworthy: Is this a level of change that is likely to be ecologically meaningful? That is: is this much change of your driver likely to impact, or change, in any way, tropical forest ecosystems?
4) Given your answers to 2 and 3, what do the authors and/or your group predict regarding the impact of this change on tropical forests? (Note that some drivers, e.g. nutrient deposition, have multiple known mechanisms, and thus were used to generate multiple hypotheses in the paper. See Table 1 for summary.)
5) For tropical forests, argue how important you think this particular driver is, relative to the other eight being discussed in class today, in explaining observed changes in tropical forests in the last 30 years.

Your presentations will be best (most clear, educational, and effective at communicating complex information simply) if you skip technical or data-laden details and instead argue larger points. This is, thus, an exercise not only in collating and assessing the information in Lewis et al, but also in presentation of dense scientific data in a format that is memorable yet still accurate.

Groups:
1. Precipitation
2. Solar radiation
3. Climatic extremes
4. Atmospheric [CO_2]
5. Nutrient deposition
6. Tropospheric O_3/acid deposition
7. Hunting pressure
8. Land-use changes