Land-Use (& Land Cover Change), Biogeochemistry and Climate

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LCLUC and Carbon (and Climate) Dynamics

LCLUC activities impact our environment and climate

• source of atmospheric $CO_2$ and $N_2O$ (Biogeochemistry)

• changes hydrological cycle and Earth’s energy budget (Biogeophysics)
LCLUC, Terrestrial Ecosystems and Environmental Factors

- Terrestrial Ecosystems
- Climate
- N Fertilizer, Deposition
- CO₂
- Land Use Change
- Biomass Burning
- Atmospheric Chemistry
Historical LCLUC - N America & SSEA

Biome Types

- Tropical Evergreen
- Tropical Deciduous
- Temperate Evergreen
- Temperate Deciduous
- Boreal Forest
- Savanna
- Grassland
- Shrubland
- Tundra
- Desert
- Polar Desert
- Cropland
- Pastureland
- Sec. Tropical Evergreen
- Sec. Tropical Deciduous
- Sec. Temperate Evergreen
- Sec. Temperate Deciduous
- Sec. Boreal Forest

Yang, Jain et al. (2010); Meiyappan and Jain (2012)
Less primary land, more secondary land, more cropland and pastureland

Land use alters: Atmospheric CO$_2$, N & P cycles, albedo, runoff, soil water holding capacity etc.
Different Pathways of Carbon Dynamics after Deforestation

Ramnkutty et al.
LCLUC and C and N Dynamics

- Instantaneous C release
- After abandonment C stored in secondary forest (SF)
- Stored C in SF could be enhanced due to CO₂ and N fertilizations
- C accumulation in SF could be constrained due to nutrient limitation (N & P)
- N Deposition can enhanced the C accumulation
- After LCLUC soil C and N are increased for a short while, but soil C soon decreases because litter input from the deforested land is typically lower
The Impact of N Deposition and Fertilizer

Effect on C Plant uptake, N$_2$O emissions and Leaching
Carbon Emissions from Land Use Changes
Uncertainties in LU Emissions....

• Rates of land-use change
  - Deforestation, afforestation, abandonment
  - Other changes in land use

• The processes and feedbacks included in the analyses computing the flux.

• Density of carbon stocks in the areas affected by management
Various Land Use Change History

- Richard Houghton (HH)
  - Cropland, Pastureland

- HYDE
  - Cropland, Pastureland, Urban land

- SAGE
  - Cropland, Pastureland

- Hurtt et al. (GLM)
  - Wood Harvest
Comparison of Different Biome Areas (2001-2005)

Crop

Pasture

Savanna

Grass

Shrub
Comparison of Different Biome Areas (2001-2005)

Crop

Pasture

Savanna

Grass

Shrub

Arrows indicate the data set with highest area for individual biome.
ISAM Model Estimated Global Land-Use Emissions (GtC/yr)

Jain et al. (2012)
ISAM Estimated Regional Land-Use Emissions for 2000s (GtC/yr)
ISAM Estimated Land-Use Emissions for Tropics and Non-Tropics (GtC/yr)

Jain et al. (2012)
Regional Land-Use Emissions Based on HYDE Data

Jain et al. (2012)
Contribution of Wood Harvest to Regional Land-Use Emissions

Jain et al. (2012)
Contribution of Secondary Forest and N Deposition to Net C Sink
The distribution of secondary forest area regrown from:
- cropland abandonment,
- pastureland abandonment,
- wood harvest

Yang et. al. (2010, Biogeosciences)
Nitrogen Deposition

Galloway et al. (2004)

$gN/m^2$

N inputs effect C plant uptake - specially in secondary forest regions
C sink associated with the secondary forests is 0.36 GtC/yr in the 1990s
N deposition contribution is 0.13 GtC/yr

Yang et. al. (2010, Biogeosciences)
Estimated Net Exchange of C (gC/m²/yr) for the 1990s in Secondary Forests

- Positive values represent net C release to the atmosphere and negative values represent net C storage in terrestrial biosphere.

- C stocks in forests are increasing in recent years due to reforestation and afforestation.

- In some regions accumulation of C is reduced where N is a limiting nutrient or enhanced if the additional N is deposited in the forest regrowing regions.

Yang et. al. (2010, Biogeosciences)
P Cycle
Widespread P limitation in terrestrial ecosystems, especially in lowland tropical forests

natural-log transformed response ratios (RRx) in which autotroph biomass or production in the enriched treatment is divided by its value in the control treatment and then ln transformed

Elser et al., 2007
Global Distribution of P ($\text{KgP/m}^2$)

Yang et al., GBC, under revision
**N$_2$O Emissions (TgN/yr)**

- **Total Emissions**

- **Contribution of Environmental Factors and N Fertilizer**
Contribution of Land-Use Changes to \( \text{N}_2\text{O} \) Emissions in the 1990s (KgN/ha/yr)
Land-Use Management

• LCLUC would be defined broadly to include
  - human-induced changes in land cover,
  - land management
    • No tillage practices
    • fire management
    • draining of peatlands
    • fertilizer use
    • shifting cultivation
    • selective logging
Discussion