Biomass burning as a driver for reducing greenhouse gas emissions and regional air pollution

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Habitat Loss to 1990

Source: Millennium Ecosystem Assessment
CO$_2$ Emissions from Land Use Change

Fate of Anthropogenic CO$_2$ Emissions (2000-2008)

1.4 PgC y$^{-1}$

7.7 PgC y$^{-1}$ +

4.1 PgC y$^{-1}$

45%

3.0 PgC y$^{-1}$

29%

2.3 PgC y$^{-1}$

26%

Le Quéré et al. 2009, Nature-geoscience; Canadell et al. 2007, PNAS, updated
Global biomass burning
Regional Emissions from LUC&F

- South & S.E. Asia: 25% Deforestation, 41% C Flux
- Tropical Africa: 35% Deforestation, 17% C Flux
- S. & Central America: 40% Deforestation, 43% C Flux
Forest clearing and forest cover in the humid tropical forest biome, 2000–2005

Forest loss in Brazil accounts for 48% of total biome clearing, nearly four times that of the next highest country, Indonesia, which accounts for 13%.

Hansen M. C. et.al. PNAS 2008
Land use change was responsible for estimated net emissions of 1.5 PgC per year over the last 15 years. This is 12% of total emissions in 2008, down from 20% in the 1990’s.
Fuel consumption (g C per m² of area burned) averaged over 1997–2009.

Guido van der Werf, 2010
Cumulative annual carbon emissions from different fire types and their coefficient of variation (CV) (1997–2009)

Right now: \( \approx 1.6 \text{ Pg C/year} \)

Guido van der Werf, 2010
Relative contributions from different regions of \( \text{CO}_2, \text{CO} \) and \( \text{CH}_4 \) biomass burning emissions (1997-2009)

Guido van der Werf, 2010
Decreasing fire emissions from deforestation

Global Fire Emissions Dataset (vs2)

van der Werf et al. 2006, Atmospheric Chemistry and Physics, updated
Current pyrogeography on Earth, illustrated by (A) net primary productivity (NPP, g C m\(^{-2}\) year\(^{-1}\)) from 2001 to 2006, and (B) annual average number of fires observed by satellite.
Global Deforestation Fires: Responsible for 19% of global radiative forcing

Estimated contribution of fire associated with deforestation to changes in radiative forcing compared to 1750, assuming a steady state for other fire emissions.

Bowman et al., Science, 2009
Global $CO_2$ budget for 1990-2000 (blue) and 2000-2008 (red) (GTG per year). Emissions from fossil-fuel and land-use change are based on economic and deforestation statistics. Atmospheric $CO_2$ growth is measured directly. The land and ocean $CO_2$ sinks are estimated using observations for 1990-2000 (Denman et al. IPCC 2007). For 2000-2008, the ocean $CO_2$ sink is estimated using an average of several models, while the land $CO_2$ sink is estimated from the balance of the other terms.
Biomass Burning is THE major driver for ozone in the Southern Hemisphere

OMI tropospheric ozone mean (in ppbv) for September 2007
Ozone and aerosols from Biomass Burning

Time series of tropospheric ozone mean VMR (in ppbv) and AI averaged over four broad regions (indicated) in the southern tropics: (a) South America, (b) Atlantic Ocean, (c) western Africa, and (d) Indonesia.
Carbon monoxide from deforestation: A major source

CO emissions from human sources by world region for the new scenario (B2 CLE) compared to the original IPCC SRES B2 scenario (2000).

Main drivers for deforestation
As of 2008, about 17% of Amazonia was deforested.

What public policies are needed to sustain this reduction over the next decades?

How was the reduction achieved? What public policies made it? Ex: Bolsa Floresta
Mato Grosso and Pará states are responsible for aprox. 80% of deforestation.

Ana Paula Aguiar, CST, INPE, Dez 2009
Actors in getting emissions estimates

Territorial Diversity

(i) Biomass density data
(ii) Diversity of actors
(iii) Secondary vegetation dynamics
CO₂ emissions through deforestation in Amazonia

Reduction from 900 to 500 Mtons CO₂ per year from 2004 to 2008

CCST, INPE, 2010
Copenhagen Commitment: Reduction in 80% emissions from deforestation in 2015 from 2004. Same target in the Brazilian law passed in Congress.

Brazilian Greenhouse Gases Emission Inventory 2005

- Deforestation: 56%
- Energy + Transport: 12%
- Agroindustry: 5%
- Landfills: 3%

Copenhagen Commitment: Reduction in 80% emissions from deforestation in 2015 from 2004. Same target in the Brazilian law passed in Congress.
Porto Velho aerosol: PM$_{2.5}$, PM$_{10}$ and BC 2009 - 2011
Yearly deforestation over the Brazilian Amazon region (INPE, 2010) compared to MODIS daily smoke optical depth and the daily number of hot pixels from NOAA-12 and NOAA-15. The results are shown according to the hydrological year, from August 1st of the previous year to July 31st of the years shown in the graph. The vertical lines indicate August 1st, which correspond to the onset of the burning season.
Large scale aerosol distribution in Amazonia

- Severe health effects on the Amazonian population (about 20 million people)
- Climatic effects, with strong effects on cloud physics and radiation balance.
- Changes in carbon uptake and ecosystem functioning
Biomass Burning in South America
Fires and Smoke in West Africa
Aerosol surface forcing in Rondonia

Radiative forcing (W/m²)

AOT (500 nm)

Aline Procópio, GRL 2006
Amazonia - Average aerosol radiative forcing clear sky

Top: - 10 w/m²

Atmosphere: + 28 w/m²

Surface: - 38 w/m²  CO₂ forcing=-1.6 w/m²)

Conditions: surface: forest vegetation AOT (τ=0.95 at 500nm); 24 hour average 7 years (93-95, 99-02 dry season Aug-Oct)
Biomass Burning in Amazonia is critical for water vapor transport over South America.
Left – cloud top pressure (P) vs. AOD. Lower P may indicate taller convective clouds.

Right – cloud fraction vs. AOD. The upper row is for all data and the lower row is for data restricted to cloud fraction less than half.

Koren et al., Science 2008
Conceptual overview of terrestrial carbon cycle – chemistry – climate interactions

Arneth et al., BGD 2009
Aerosol effects on the Net Plant Productivity

Kulmala et al., 2004
Strong aerosol effect on forest photosynthesis diffuse radiation have a large effect on CO2 fluxes.

Amazonia Rondonia Forest site 2000-2001

- Wet Season - NEE increase: 24%
- Dry Season - NEE increase: 46%

Increase in aerosol loading
Radiative forcing due to constant year 2000 emissions grouped by sector

(a) 2020

(b) 2100

Main sectors: Energy generation, Industry and Biomass Burning

Unger N et al. PNAS 2010;
There is no easier and cheaper way to reduce greenhouse gas emissions than reducing tropical deforestation.

The side benefits are large, not just for the Amazon but for South America and the whole globe.
Thanks for the attention!!!
The Dust and Biomass Burning Experiment, W Africa, suggests that gas phase organic carbon from biomass burning may condense onto the larger surface area of mineral dust (Haywood et al., 2008).
**How the fire regimes have changed during the industrial era, from a representative cross-section of biomes from low to high latitudes**

<table>
<thead>
<tr>
<th>Biome</th>
<th>Pre-industrial fire regime</th>
<th>Post-industrial fire regime</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tropical rain forest</td>
<td>Very infrequent low intensity surface fires with negligible long-term effects on biodiversity</td>
<td>Frequent surface fires associated with forest clearance causing a switch to flammable grassland or agricultural fields</td>
</tr>
<tr>
<td>Tropical savanna</td>
<td>Frequent fires in dry season causing spatial heterogeneity in tree density</td>
<td>Reduced fire due to heavy grazing causing increased woody species recruitment</td>
</tr>
<tr>
<td>Mid-latitude desert</td>
<td>Infrequent fires following wet periods that enable fuel build-up</td>
<td>Frequent fires due to the introduction of alien flammable grasses</td>
</tr>
<tr>
<td>Mid-latitude North American seasonally dry forests</td>
<td>Frequent low intensity surface fires limiting recruitment of trees</td>
<td>Fire suppression causing high densities of juveniles and infrequent high intensity crown fires</td>
</tr>
<tr>
<td>Boreal forest</td>
<td>Infrequent high intensity crown fires causing replacement of entire forest stands</td>
<td>Increased high intensity wildfires associated with global warming causing loss of soil carbon and switch to treeless vegetation</td>
</tr>
</tbody>
</table>
Time series of aerosol optical thickness at 500 nm for Alta Floresta, MT and Ji-Paraná, Rondônia 1999-2010.
The dust-smoke interaction region (the dust is recognized by the strong backscattering signal relative to the smoke. The data was verified with MODIS image).
Applications in assessing health effects INPE – FIOCRUZ-MS

Karla Longo and Saulo Freitas, INPE
Pressure from Climate Change issues to reduce deforestation...

Estimate of quantitative evolution of control variables for seven planetary boundaries from preindustrial levels to the present

Beyond the boundary. The inner green shading represents the proposed safe operating space for nine planetary systems. The red wedges represent an estimate of the current position for each variable. The boundaries in three systems (rate of biodiversity loss, climate change and human interference with the nitrogen cycle), have already been exceeded.

Nature, 2009
Ecosystems and Some Services They Provide

**Ecosystems**
- **Mountain and Polar**
  - Food
  - Fiber
  - Fresh water
  - Erosion control
  - Climate regulation
  - Recreation and ecotourism
  - Aesthetic values
  - Spiritual values

- **Inland Water**
  - Rivers and other wetlands
  - Fresh water
  - Food
  - Pollution control
  - Flood regulation
  - Sediment retention and transport
  - Disease regulation
  - Nutrient cycling
  - Recreation and ecotourism

- **Drylands**
  - Food
  - Fiber
  - Fuelwood
  - Local climate regulation
  - Cultural heritage
  - Recreation
  - Aesthetic values

- **Forest and Woodlands**
  - Food
  - Timber
  - Fresh water
  - Fuelwood
  - Flood regulation
  - Disease regulation
  - Carbon sequestration
  - Local climate regulation
  - Medicines
  - Recreation
  - Aesthetic values

- **Cultivated**
  - Food
  - Fiber
  - Fresh water
  - Dyes
  - Timber
  - Pest regulation
  - Biofuels
  - Medicines

- **Coastal**
  - Food
  - Fiber
  - Timber
  - Fuel
  - Climate regulation
  - Waste processing
  - Nutrient cycling
  - Storm and wave protection

- **Urban**
  - Parks and gardens
  - Air quality regulation
  - Water regulation
  - Local climate regulation
  - Cultural heritage
  - Recreation
  - Education

- **Marine**
  - Food
  - Climate regulation
  - Nutrient cycling
  - Recreation

- **Island**
  - Food
  - Fresh water

Source: Millennium Ecosystem Assessment
Impact of land change in Brazil’s emissions
Aerosol optical depth from 1999 to 2009 for 10 sites in Amazonia
Anthropogenic burning was reduced substantially in Brazil in year 2008 compared to previous years including 2007. The OMI/MLS measurements show sizeable decreases 15 – 20% in ozone in Brazil during 2008 compared to 2007 which we attribute to this reduction in biomass burning.