Forestry and land use impacts on land carbon storage

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• A failed attempt to estimate LU impacts globally

• Decaying carbon

• An alternative way forward, old growth forests
Traceability framework

\[
\frac{dX(t)}{dt} = BNPP(t) - \xi ACX(t)
\]

First order kinetics
Change in pool size
Influx - outflux

\[
\frac{dC}{dt} = Influx \ - \ \tau C
\]

Luo et al. 2003 GBC
Luo and Weng 2011 TREE
Luo et al. 2012
Xia et al. 2013 GBC
\[
\frac{dX(t)}{dt} = BNPP(t) - \xi ACX(t)
\]
C flow among soil C pools

Respiration flux to atmosphere when transfer carbon
Carbon flux to atmosphere due to fire (potentially lose, or wild fire)

\( f_{1\, \text{metab}} (L/N) 1 - f_{1\, \text{metab}} (L/N) \)
\( f_{2\, \text{metab}} (L/N) 1 - f_{2\, \text{metab}} (L/N) \)

Observations

"Observations"

Standard LPJ-GUESS

MODIS NPP

FLUXCOM MET GPP

FLUXCOM ANN GPP

FLUXCOM RF GPP

Tabulated data:

- Soil Metab (12)
- Soil Structure (5)
- Surface Humus (7)
- Surface Microbial (8)
- SurfMetab (9)
- SurfFWD (10)
- SurfCWD (11)
- SurfStruct (4)
- Carbon flux to atmosphere due to fire

References:

Wu et al, 2018, Scientific Reports
FLUXCOM GPP and LPJ-GUESS respiration

Estimate of NPP reduction due to land use

Scaled with land use reconstructions

And Holocene NPP reconstructions

Climate and CO₂

NPP

vegetation

Veg turnover (pool size & MRT)

faster soil C

Soil C transfer (pool size & MRT)

slower soil C

Decay (pool size & MRT)

Decay (MRT, country specific)

Harvest

Wood and crops

HWP

Scaled with land use reconstructions

8k years

Climate and CO₂

And Holocene NPP reconstructions

Estimate of NPP reduction due to land use

Scaled with land use reconstructions
- **NPP**
  Fluxcom GPP and LPJ-GUESS Ra

- **Soil C**
  WISE "equilibrium" C, excluding peat lands and permafrost

- **Veg C**
  VOD-based Liu et al 2015

- **HWP MRT**
  Calculated from Mason-Earles et al 2012

- **Wood harvest**
  Redist of FAO stats

- **Crop harvest**
  Redist of Erb et al

- **MRT veg reduction**
  Erb et al 2016

- **NPP reduction**
Optimised to match datasets on present C pools

Present day biomass following Liu et al 2015, VOD-based. (+ simulated root fractions)
Vegetation carbon

Potential Veg C

Actual Veg C

Expected trajectory after complete LU abandonment.

LU debt, difference between potential and actual Veg C
debt at 1850 increased debt, 1850-2000

Debt mainly due to deforestation
Vegetation carbon

Potential Veg C

Actual Veg C

Expected trajectory after complete LU abandonment.

LU debt, difference between potential and actual Veg C

debt at 1850
increased debt, 1850 - 2000
**Vegetation carbon**

- **Potential Veg C**
- **Actual Veg C**

Expected trajectory after complete LU abandonment.

LU debt, difference between potential and actual Veg C

debt at 1850
increased debt, 1850 - 2000

Loss of MRT
Loss of NPP
Soil carbon

Soil carbon is more complex

Even if we knew bulk soil C age (e.g. Radiocarbon) and amount, soil C response to C influx (NPP, harvest) and decomposition rates (climate etc) can not be constrained!

- Soil C dominated by slow C pool
- Soil C dominated by fast C pool
Soil carbon

Soil carbon is more complex

Even if we knew bulk soil C age (e.g. Radiocarbon) and amount, soil C response to C influx (NPP, harvest) and decomposition rates (climate etc) can not be constrained!

Soil C dominated by slow C pool

Soil C dominated by fast C pool

Identical apparent soil C age!
Identical year 2000 pool sizes!
Identical apparent MRT!
Soil carbon

Small potential for mitigation

Large potential for mitigation
We can still make a map

- Potential land uptake can not be constrained Pg C
- Perhaps it would look something like this? 800 Pg C, the model would pass global benchmarks perfectly!
Decaying carbon
Decaying carbon
Turnover rate ($\tau$) is the fraction leaving the pool over a time step, defined as $1/$turnover time.

$$\frac{dC}{dt} = \text{Influx} - \tau C$$

In steady state the carbon pool size do not change why influx = losses:

$$\frac{dC}{dt} = 0 \rightarrow \text{Influx} - \tau C = 0 \rightarrow C_{\text{steady state}} = \frac{\text{Influx}}{\bar{\tau}}$$

$$\text{turnover time} = \frac{C_{\text{pool}}}{\text{Efflux}}$$
Ecosystem decaying biomass turnover time

Turnover time = $C_{\text{pool}} / C_{\text{efflux}}$

Ahlström et al. In review
Ecosystem decaying biomass turnover time

Ahlström et al. In review
Ecosystem decaying biomass turnover time

Ahlström et al. In review
HWP decaying biomass turnover time

Timing of carbon emissions from global forest clearance

J. Mason Earle1*, Sonia Yeh2 and Kenneth E. Skog3

Land-use change, primarily from conventional agricultural expansion and deforestation, contributes to approximately 15% of global greenhouse-gas emissions1. The fate of cleared wood and subsequent carbon storage as wood products, however, has not been consistently estimated, and is largely ignored or oversimplified by most models estimating greenhouse-gas emissions from global land-use conversion2. Here, we estimate the fate of cleared wood and timing of atmospheric carbon emissions for 11 countries. We show that 30 years after forest clearance the percentage of carbon stored

Fraction HWP C remaining on land

Time since harvest (years)

Ahlström et al. In review
Anthropogenic VS natural turnover times

Ahlström et al. In review
Anthropogenic VS natural turnover times

Ahlström et al. In review
Climate models (GCMs)

Future warming in January

18 GCM average

Ahlström et al, 2012, ERL.
Anthropogenic VS natural turnover times

Wooden house: ~70 years
Paper: ~1-3 years
Bioenergy: 0-1 years
Waste to energy?
Landfills?

Ahlström et al. In review
Old growth forests

De Jong et al. In prep

Geerte De Jong
Master thesis student

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Old growth forests

Paired analysis:

Data points within the old growth forests are compared to data points in a spatial buffer around the old growth forest.

Percentiles of the annual distribution (99th to 70th)
Thank you