LUC4C Deliverable Fact Sheet

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Key findings from an Update to the Global Carbon Budget.

LUC4C co-ordinated the land ecosystem component of the annual Global Carbon Project budget update 2015. Key land carbon cycle outcomes were:

- Emissions from deforestation and other land-use change were estimated at 1.1 GtC in 2014, with large uncertainty.

CO_2 partition among the atmosphere, ocean and land

- The land sink exhibited one of the largest sink of the past 60 years removing 4.1 [3.2 to 5.0] GtC, comparable to the extraordinary sink in 2011 during La Nina episode. Consequently, the atmospheric CO_2 accumulation was below average.

Cumulative Emissions

- Cumulative emissions since year 1870 to 2015 are 555 [500 to 610] GtC including emissions from fossil fuels, industry, and land use change
- Global emissions need to decrease to near zero to stop the rise in atmospheric CO_2 and achieve climate stabilisation (at any level). This implies that there is a fixed cumulative carbon quota available to keep global average temperature below a desired stabilisation level.
- The remaining carbon quota to stay under 2°C (66% probability) has shrunk to 235 [140 to 305] GtC, corresponding to about 15-30 years at current emissions level when accounting for the uncertainty (total cumulative budget as in IPCC Synthesis Report).

Land-use change: assessing the net climate forcing, and options for climate change mitigation and adaptation

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The Challenge

The land and oceans absorb approximately one half of the anthropogenic CO_2 emissions. Therefore these natural sinks already mitigate anthropogenic climate change. How will the sinks develop in the future? To answer this question it is essential to understand the development of the natural sinks through time, their attribution to processes and regions.

The response of land ecosystems to year-to-year variability in climate due to El Niño and La Niñas is very large, and in fact some of the largest uncertainties in the global carbon cycle are associated with the land response to climate variability and change, and the land-use and land cover change flux. Reducing uncertainty in the latter is a key challenge for LUC4C.

Our Approach

Each year the Global Carbon Project makes a comprehensive update of the annual global carbon budget, and its components, including emissions from fossil fuel burning and cement production and land-use and land cover changes, and the fate of emissions, i.e. the proportion that remains in the atmosphere, and the natural land and ocean sinks. A particular focus of such an assessment is to document change and trends in emissions, CO_2 growth in the atmosphere and sinks. In addition it is important to use multiple sources of evidence, for example the land use flux can be calculated based on simple book – keeping approaches, or with land carbon cycle models using maps of changes in cropland and pasture areas as input. An advantage of the former is that it is heavily based on FAO forest inventory data, whereas the land models are able to represent environmental changes on biomass, and thus differential effects of deforestation through time.

The natural land sink can be estimated in two ways, as a residual from the other carbon cycle components, and using land carbon cycle models driven by observed climate and atmospheric composition. Closing the carbon cycle, whereby the estimated residual sink estimate matches that from land carbon cycle models, gives confidence that the community has a sufficient high level understanding of the global carbon cycle and is a key challenge.

As mentioned the land plays a role in CO_2 emissions to the atmosphere, through Land-use and land cover changes emissions, and in sequestering anthropogenic emissions. Within LUC4C we co-ordinate a synthesis of simulation results from a suite of 10 land carbon cycle models (4 from LUC4C groups). The models are run over the period 1901-2014 using observed climate, atmospheric composition, and gridded fields of land-use and land-cover changes using a common experimental protocol and approach to ensure comparability and consistency. LUC4C has pioneered the capacity building to represent land use processes in land carbon cycle models and targets structural uncertainties, i.e. to recognize and document multi approaches, then to recommend common model methodologies.

Main Findings

Terrestrial natural CO_2 Sink

The land CO_2 sink increased from 1.7 ± 0.7 GtC a^{-1} in the 1960s to 3.0 ± 0.8 GtC a^{-1} during 2005-2014, with important interannual variations of up to 2 GtC a^{-1} generally showing a decreased land sink during El Niño events, overcompensating the increase in ocean sink and accounting for the enhanced atmospheric growth rate during El Niño events. The land models also reproduce the observed mean of 3.0 ± 0.5 GtC a^{-1} for the period 2005-2014 calculated from the budget residual.

Regional land CO_2 flux attribution

In the South (south of 30 °S), the atmospheric inversions and combined land models all suggest a CO_2 sink for 2005-2014 of between 1.2 and 1.5 GtC a^{-1}. The interannual variability in the South is low because of the dominance of ocean area with low variability compared to land areas.

In the Tropics, both the atmospheric inversions and land models suggest the carbon balance in this region is close to neutral over the past decade, with fluxes for 2005-2014 ranging between –0.6 and +0.6 GtC a^{-1}. This region shows the largest variability, both on interannual and decadal time scales.

In the North (north of 30°N), the inversions and land models are not in full agreement on the magnitude of the CO_2 sink with the ensemble mean land models suggesting a total northern sink for 2005-2014 of 2.3 ± 0.4 GtC a^{-1} while the three atmospheric inversions estimate a sink of 2.5, 3.4 and 3.6 GtC a^{-1}. This analysis thus suggests that the global underestimate of land carbon cycle models originates in the North.

Net Land Use flux

CO_2 emissions from land-use change have remained constant, in our analysis at around 1.5 ± 0.5 GtC a^{-1} between 1960-1999 and 1.0 ± 0.5 GtC a^{-1} during 2000-2014. The decrease in emissions from LUC between the 1990s and 2000s is highly uncertain. It is not found in the current set of land models, which are otherwise consistent with the bookkeeping method within their respective uncertainty.

Open Issues

Closing the global carbon budget

The annual standard deviation of the CO_2 sink across the DGVMs averages to ± 0.7 GtC a^{-1} for the period 1959 to 2014. The model mean, over different decades, correlates with the budget residual with r = 0.71, compared to correlations of r = 0.52 to r = 0.71 (median of 0.62) between individual models. The standard deviation is similar to that of the five model ensembles presented in Le Quéré et al. (2009), but the correlation is improved compared to r = 0.54 obtained in the earlier study. The DGVM results suggest that the sum of our knowledge on annual CO_2 emissions and their partitioning is plausible, and provide insight on the underlying processes and regional breakdown.

However as the standard deviation across the DGVMs (e.g. ±0.9 GtC a^{-1} for year 2014) is of the same magnitude as the combined uncertainty due to the other components, the DGVMs do not provide further reduction of uncertainty on the annual terrestrial CO_2 sink compared to the residual of the budget.

Yet, DGVM results are largely independent from the residual of the budget, and it is worth noting that the residual method and ensemble mean DGVM results are consistent within their respective uncertainties. We assess a medium confidence level to the annual land CO_2 sink and its uncertainty because the estimates from the residual budget and averaged DGVMs match well within their respective uncertainties, and the estimates based on the residual budget are primarily dependent on fossil emissions and atmospheric CO_2 growth rate, both of which are well constrained.