North American terrestrial CO_2 uptake largely offset by CH_4 and N_2O emissions: toward a full accounting of the greenhouse gas budget

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Objectives:

- The study seeks to estimate the overall global warming potentials (GWP) of CO_2, CH_4 and N_2O fluxes in North American terrestrial ecosystems.
- In addition, the study quantifies the relative contributions of individual environmental factors to the GWP changes from 1979-2010.
- The Dynamic Land Ecosystem Model (DLEM) was used to simultaneously quantify the magnitudes as well as spatial and temporal patterns of CO_2, CH_4, and N_2O fluxes, and to attribute GWP various environmental factors.
- The uncertainty range for contemporary GWP was quantified by synthesizing existing estimates from inventory, forward modeling and inverse modeling approaches.
- The fluxes were estimated only for the terrestrial biosphere; emissions from human activities were excluded from the estimation.
- Seven model experiments were designed to address the effects of individual and combined environmental factors on CO_2, NH_4 and N_2O dynamics.
- Seven additional baseline experiments were conducted to remove system errors.
- Model performance was widely evaluated against field observational experimental data, other modeling results, and regional inventory data.

New Science:

- The evaluation of DLEM model performance indicated that the model is able to capture the monthly/seasonal variations in CO_2, NH_4, and N_2O fluxes at a relatively high confidence level.
- The best estimate of net GWP for CO_2, CH_4 and N_2O fluxes was -0.50 $\pm$ 0.27 (mean +/- 2 SE) Pg CO_2 eq/year in North American Terrestrial ecosystems from 2001-2010.
- The emissions of CH_4 and N_20 offset about 73% $\pm$ 14% of the land CO_2 sink in the North American continent, but large differences were found across three countries.
- Offset ratios in the US were 57% $\pm$ 18%; in Canada they were 83% $\pm$ 17% and in Mexico offset ratios were 329% $\pm$ 119%.
- The GWP values in 3 extremely dry years were significantly higher than in normal years.
- During two extremely dry years (1994 and 2002) the CH_4 and H_2O emissions offset the CO_2 sink by 115% and 138%, indicating that terrestrial ecosystems in North American might act as a significant contributor to global warming in extreme drought.
- The largest influences on GWP increase was attributed to climate change and elevated tropospheric ozone concentration.
- Elevated atmospheric CO_2 concentration was the largest contributor to the reduction of GWP in North America – indicating that increased atmospheric CO_2 could directly lead

to global warming, while indirectly mitigating the warming trend via stimulating plant growth and carbon update.

- The spatial distribution pattern of the overall GWP was more consistent with that of the CO_2 fluxes than CH_4 and N_2O.
- The highest positive GWP was generally located in wetland areas (high CH_4 emission) and tropical forests of eastern Mexico (high CO_2 and H_2O emissions).
- Positive GWPs were found in Alaska, Nevada, Florida, Louisiana, and most states in Mexico, indicating these zones were potential contributors to global warming.

Significance:

- CO_2, CH_4 and N_2O contribute to more than 90% of anthropogenic climate warming.
- Both CH_4 and N_2O emissions have been predicted to greatly increase in the near future due to environmental changes over different continents.
- The sum total of CH_4 and N_2O has been estimated to contribute > ¼ of anthropogenic climate warming, playing a critical role in climate warming.
- Close linkages between these three GHGs exist, such that one gas flux could significantly affect the other two, therefore a systems approach incorporating all 3 is required to provide an accurate estimate of GWP.
- The interactive effect among multiple environmental factors on the 3 gas fluxes is significant, and should not be neglected in science or policy decisions.
- Ground and satellite observations need to be integrated with models for more accurate accounting of all 3 GHG, both for climate change science and policy decision making.
- These findings have implications for management practices. For example, nitrogen fertilization and manure applications are reported to increase carbon sequestration; such practices also may also greatly increase N_2O emission, affecting GWP.
- A comprehensive approach should be used to evaluate the consequences of such management practices on the combined GHG balance in the future.
- To reduce uncertainties, we need a better understanding of critical biogeochemical processes which control land-atmosphere GHG exchanges, interactions among multiple environmental factors, and classification and distribution of key vegetation cover types.
- A synthesis of available data from multiple sources and a framework allowing full accounting of all three GHG fluxes is urgent for global change research.

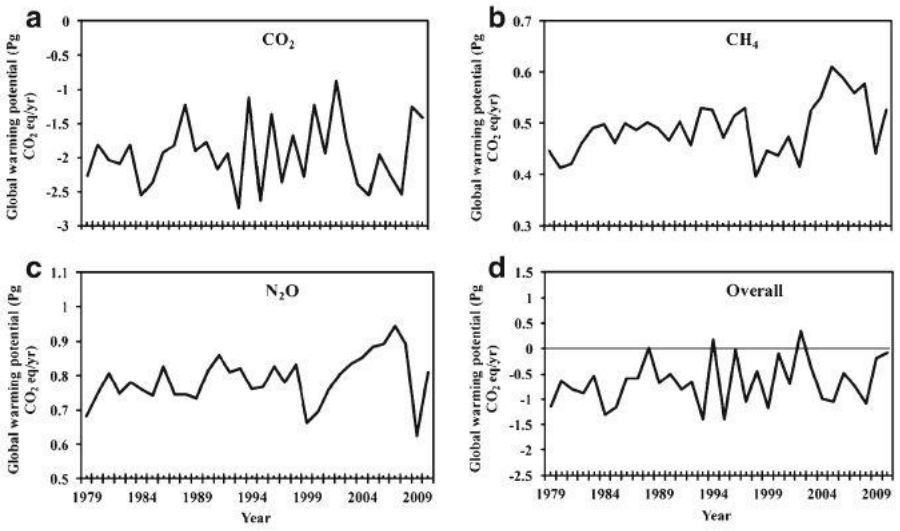

Figure 1: Interannual variations of global warming potential (Pg CO_2 eq/year) for CO_2 (a) CH4 (b) and their overall fluxes (c) during 1979-2010. Note: Positive values indicate a potential net contribution to climate warming; the data was based on our previous publications (i.e. Tian et al. 2010; Xu et al 2010, 2012).

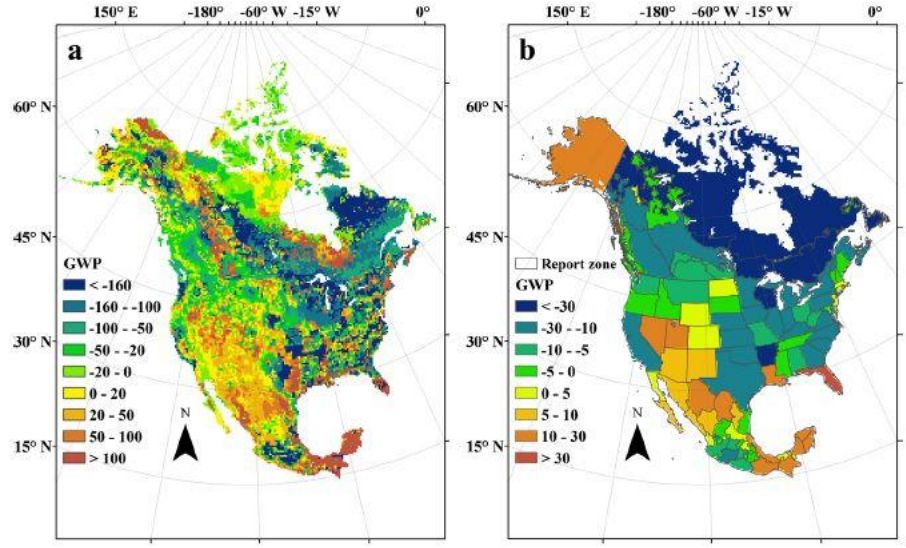

Figure 3: Spatial patterns of combined global warming potential for CO2, CH4 and N2O fluxes in North American terrestrial ecosystems curing 2001-2010 (a: pixel level, unit: g CO2 eq/m2/year; b:reporting zones (delineated as Hayes et al. 2012, unit: TgCO2 eq/year/zone)