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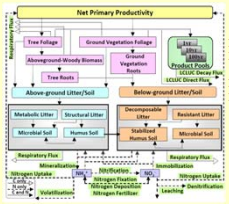
# Impacts of Future Land-Use Change on Nitrogen Leaching and Global Water Quality

Prasanth Meiyappan[1], Rahul Barman[1], Atul Jain[1], Gregory McIsaac[1], Peter Lawrence[2]
[1]University of Illinois at Urbana-Champaign, Urbana, IL 61801 [2]National Center for Atmospheric Research (NCAR), Boulder, CO 80307

## MOTIVATION AND OBJECTIVES

- Humans have more than doubled the rate at which nitrogen enters the terrestrial biosphere due to agricultural land expansion, fossil fuel burning and fertilizer application (Galloway et al., 2004)
- Water quality degradation associated with nitrogen leaching is an important environmental issue worldwide (Davis and Koop, 2006)
- To data, very few national to global scale studies exist (Dumont et al., 2005) and estimates of nitrogen leaching is still insufficient (Seitzinger et al., 2005)
- The goal of this study is to estimate the impact of future (until 2050) land-use change activities on nitrogen leaching and global water quality based on two IPCC AR5 RCP's (RCP4.5 and RCP 8.5)

## METHODS




**ISAM–NC**

- 20 biome types
- 0.5 x 0.5 degree resolution
- 30 min temporal scale
- Season-to-interannual variability (phenology)

Jain and Yang (2005, GBC)
Jain et al. (2005, GRL)
Jain et al. (2006, JGR)
Jain et al. (2009, GBC)
Jain et al. (2009, GBC)

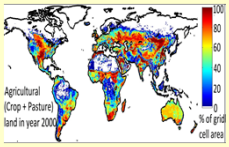
- ISAM's biogeochemistry couples C-N (Jain et al., 2009)
  - Carbon and nitrogen cycling in plants and soils
- Energy processes from Common Land Model (CoLM)
  - Canopy temperature, photosynthesis based on a two-big-leaf canopy scheme
- Hydrological processes from Community Land Model (CLM 3.5)
- N dynamics evaluated with a range of observations and conditions

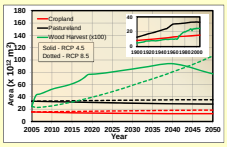
**Input Data**

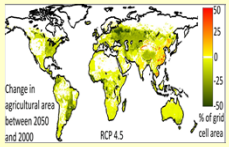
- Historical period (1700–2005) – HYDE Database ( Goldewijk et al., 2011)
- Future (2006–2050) – Land Use Harmonization database (Hurtt et al., 2009)
- $CO_2$ data – CMIP5 Recommended Values (Meinshausen et al., 2011)
- N Deposition data for Historical and Future Period (Lamarque et al. 2005)
- Climate Data – 3 hourly NCEP reanalysis data for historical period and 2001-2005 climate repeated between 2006-2010 period

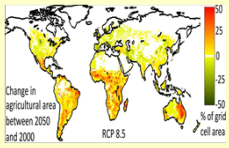
## RESULTS

### LAND-USE CHANGE

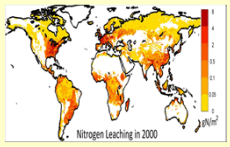


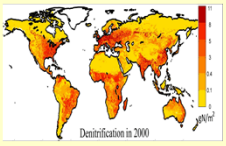



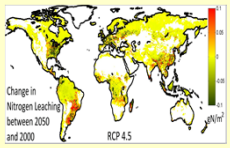



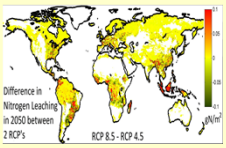




### NITROGEN LEACHING – LAND-USE EFFECT




### GLOBAL NITROGEN BUDGET

| Inputs/Outputs | 2000 - 2005 | 2045 - 2050 | |
|---|---|---|---|
| | | RCP 4.5 | RCP 8.5 |
| BNF* | 186.0 | 180.9 | 173.8 |
| N deposition ($NO_y$) | 45.7 | 37.1 | 41.7 |
| N deposition ($NH_x$) | 51.9 | 57.2 | 41.7 |
| Denitrification | 128.7 | 141.7 | 125.7 |
| Leaching | 141.3 | 121.8 | 131.3 |
| Leaching due to LUC | 62.7 | 50.3 | 56.8 |

Units in TgN $yr^{-1}$ *BNF–Biological Nitrogen Fixation

## CONCLUSIONS

- Tropical and Subtropical regions show higher leaching due to moist soil conditions
- Nitrogen leaching in temperate regions have high seasonal variability
- RCP 4.5 and RCP 8.5 shows a decrease in BNF. An decrease in agricultural activity (RCP 4.5) increases BNF, but an projected increase in wood harvest overcompensates the increase by reducing the processes that occurred in those natural landscapes, thus leading to a net decrease in BNF for RCP 4.5
- Decreasing N deposition rate has an increasing contribution of land-use change to total N leaching (Table)
- Wood harvest contributes to about 53% of total nitrogen leached due to LUC for RCP 8.5
- Nitrogen leaching is very sensitive to climate. This study employs constant climate for future. This could have substantial impact on our estimates.

## FUTURE WORK

- Include biogeophysical impacts of land-use change on nitrogen leaching
- Improve and validate model performance with observational data sets (eg. FLUXNET-MTE)
- Integrate River Transport Model (RTM) to ISAM-NC to determine nitrogen loading of rivers and validate using measurement data from several sites

## REFERENCES

- Gruber, N. and Galloway J.N., An Earth-system perspective of the global nitrogen cycle, *Nature*, 451, 293-296, 2008.
- Jain, A. K. et al., Nitrogen Attenuation of Terrestrial Carbon Cycle Response to Global Environmental Factors, *Global Biogeochemical Cycles*, 23, GB4028, 2009.