Increased Influence Of Nitrogen Limitation On Carbon Dioxide Emissions From Future Land Use And Land-use Change (LULUC)

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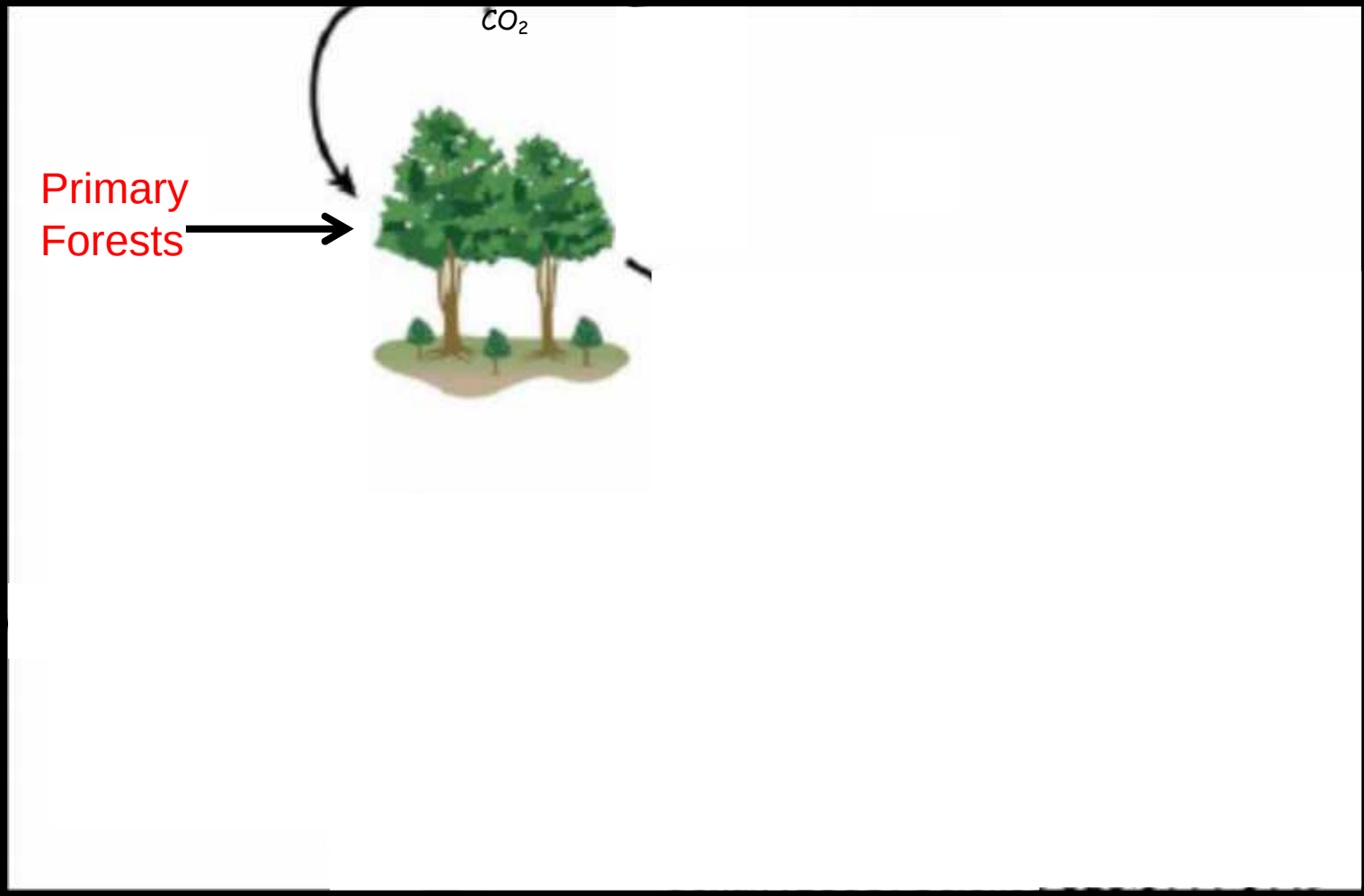
Some Basic Definitions

- "Land use (LU)" refers to management without changing the land cover, such as wood harvest and agricultural management (e.g., cropping practices and irrigation)
- "Land use change (LUC)" refers to conversion of one land cover type to another, such as clearing forest to grow crops.
- CO_2 emissions from LULUC represents the "net effect"
  - Including CO_2 sources (emissions from deforestation, logging, and other direct human activities) and
  - CO_2 sinks (as vegetation regrows following land disturbance).

LULUC and C ~~and N~~ Dynamics (ISAM-C)



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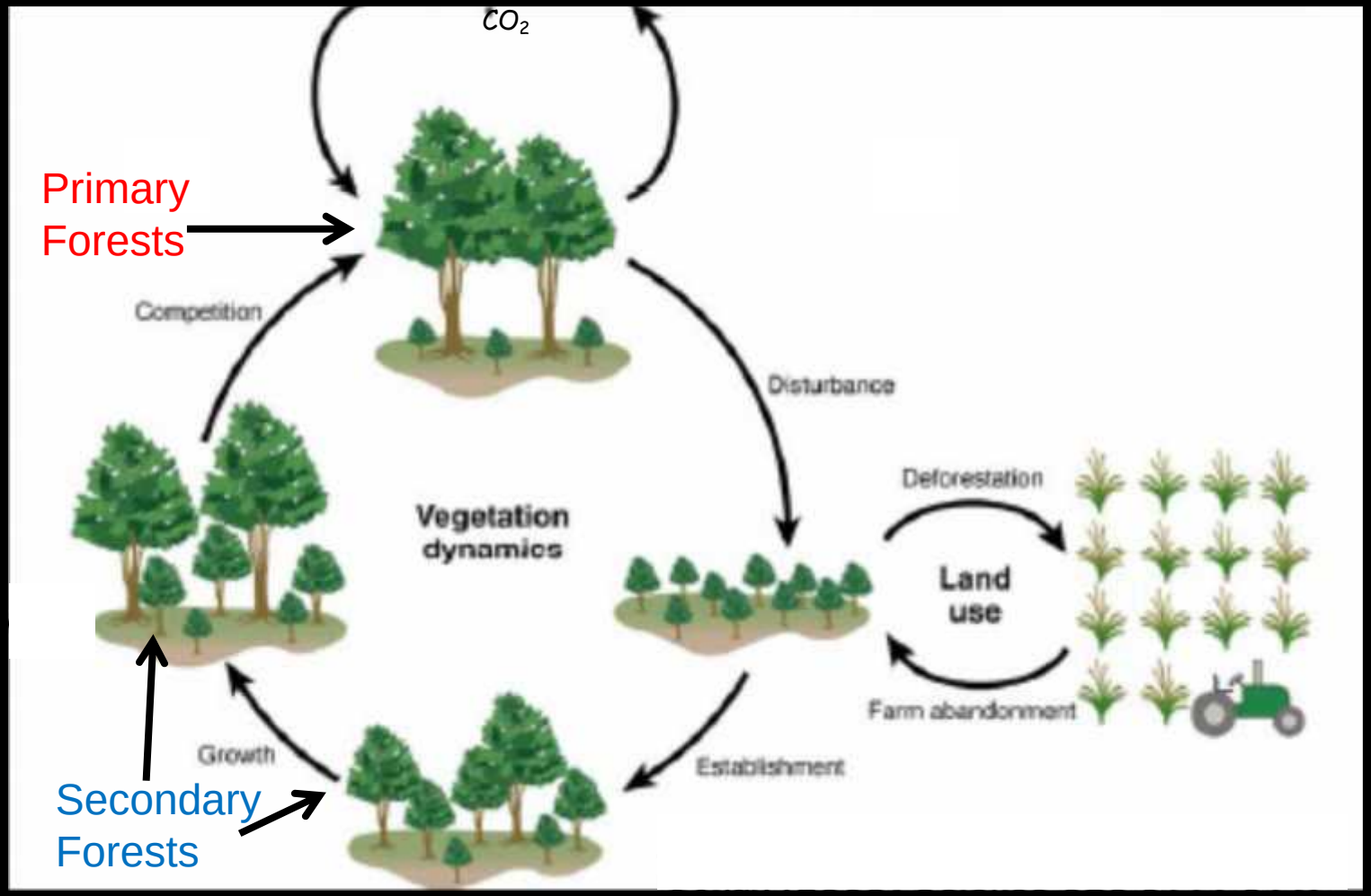

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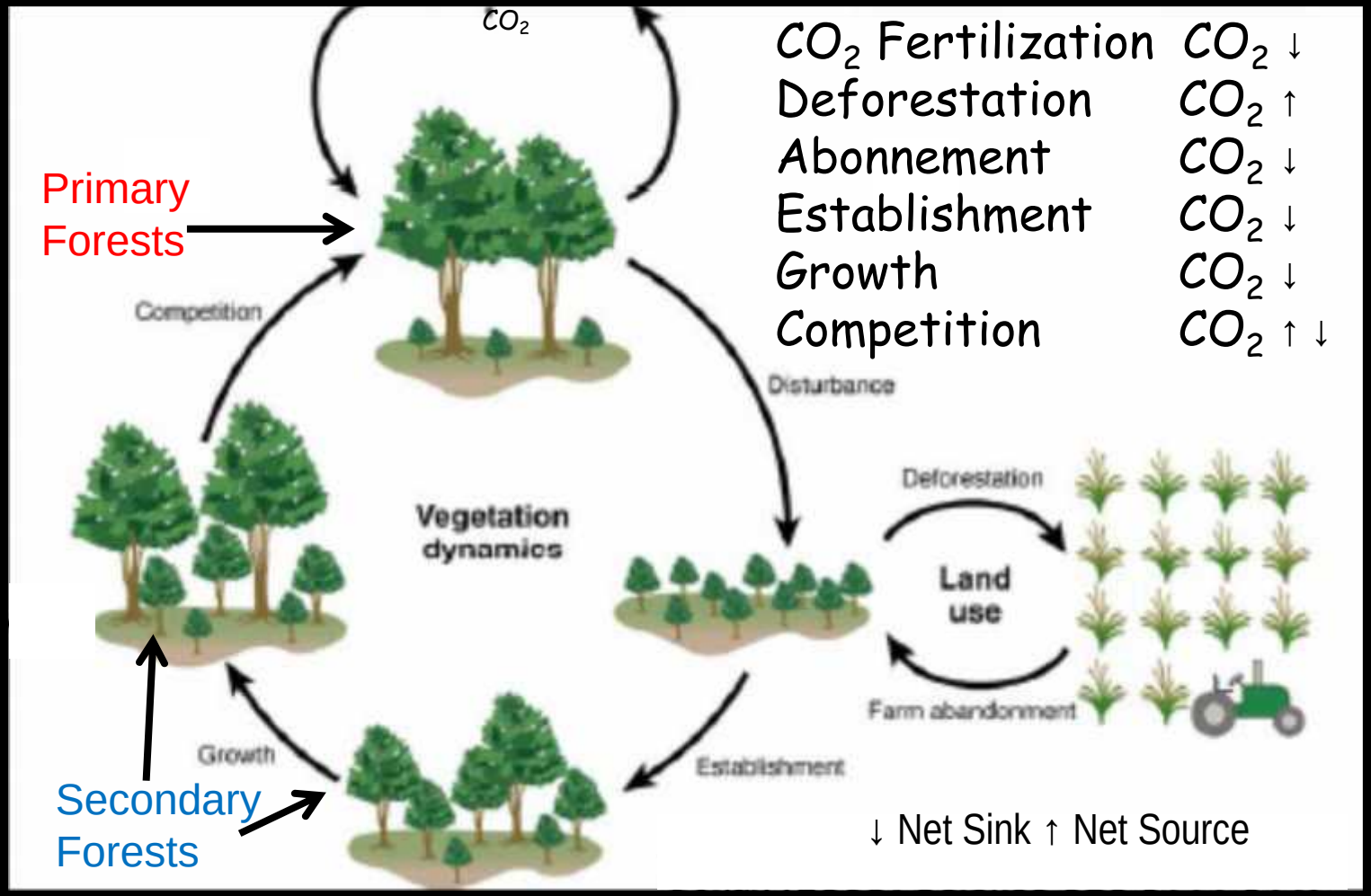
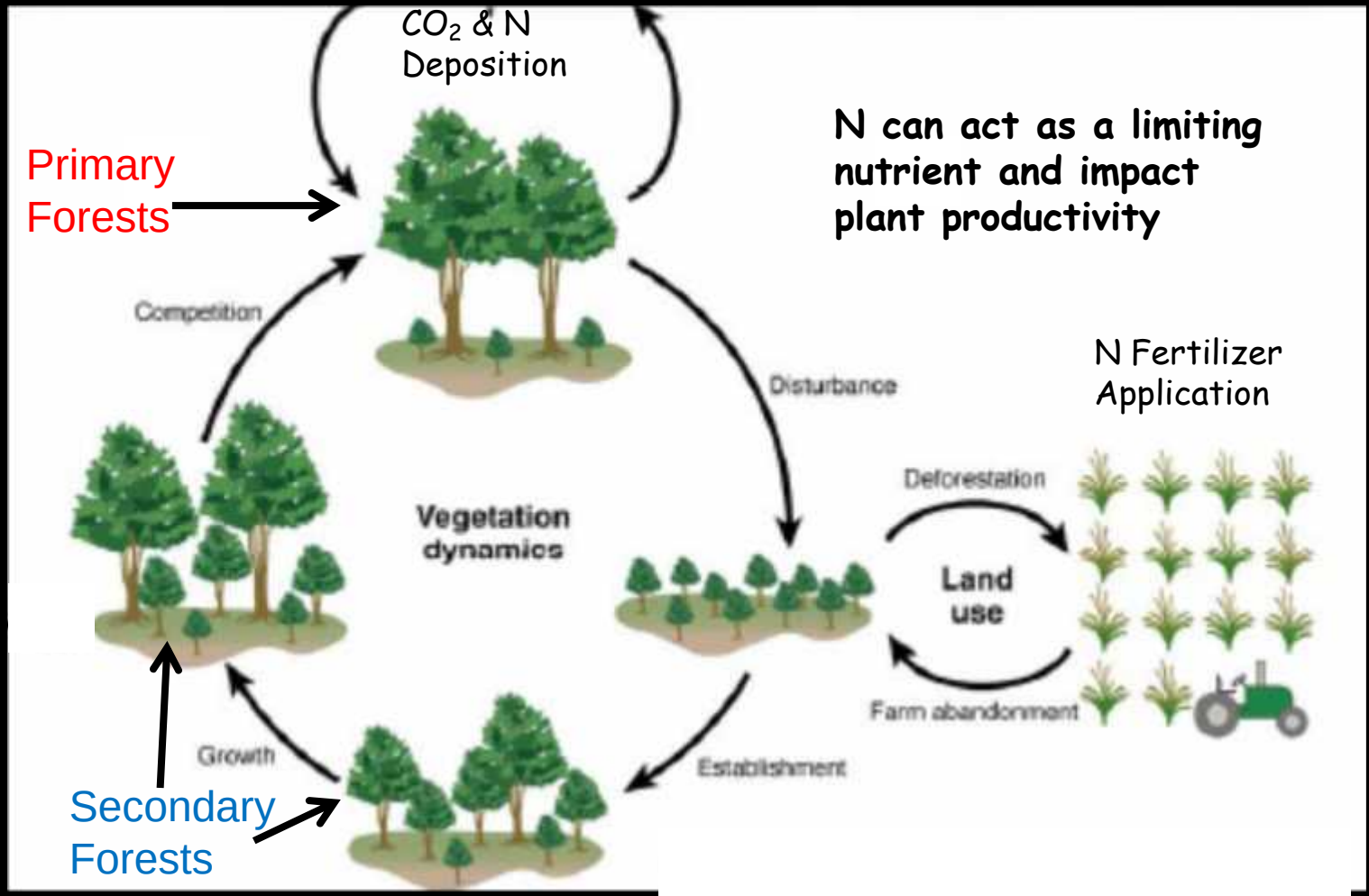


LULUC and C and N Dynamics (ISAM-NC)



Forest Management and Secondary Forest

- Historically, more secondary forests have resulted from wood harvest than from agricultural abandonment, underscoring the importance of forest management in estimating LULUC emissions
- The 21st century scenarios based CMIP5 project a 380–1080% rise in global total forest due to wood harvest compared to those of the 20th century

Objectives

- Quantify the contributions of LULUC to terrestrial carbon emissions, for the period 1800-2100
- How these contributions are impacted by the N dynamics
  - Use of ISAM land surface model with carbon and nitrogen dynamics
  - Use of three different LULUC reconstruction over the period 1800-2012
  - Use of 4 IPCC RCP for LULUC data for the 21st century data

Direct and Indirect Emissions

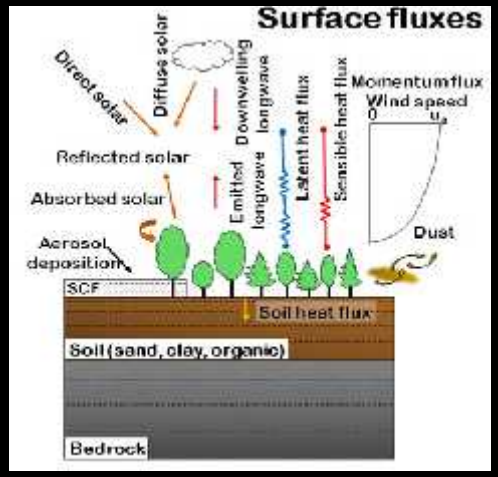
- We study the relative contribution of
  - the direct effects of human LULUC activities

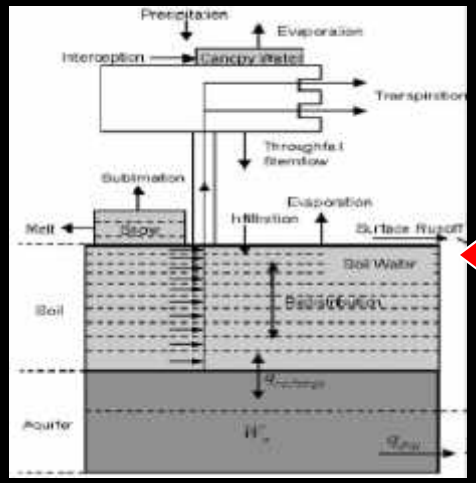
versus

  - the indirect effects of human LULUC activities via environmental changes (climate, CO_2, and nitrogen deposition) to total LULUC emissions

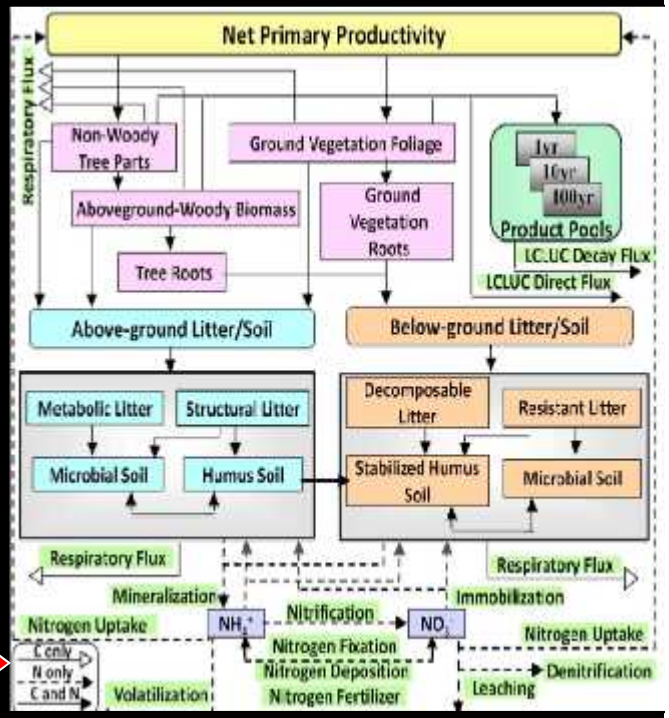
Schematic Diagram of the Current Version of ISAM

Photosynthesis, hydrology and energy components





Biogeochemistry components



Dynamic growth of Different PFTs

Phenology	• Dynamic development with accumulated heat • Dynamic response to extreme environmental condition
Carbon & Nitrogen allocation	• Adaptive response of leaf, stem, root and rhizome carbon to light, water and nutrient stresses
Vegetation structure	• Dynamic development of LAI, canopy height, and root depth with accumulated carbon biomass in leaf, stem, leaf and rhizome. • LAI response to photoperiod • Root depth and distribution response to water and nutrient stress

- Season-to-interannual variability
- 1 hourly temporal scale
- 0.5x 0.5 degree spatial resolution

LULUC Activities

- Considered four major LULUC activities:
  - cropland expansion and abandonment,
  - pastureland expansion and abandonment,
  - urbanization, and
  - regrowth due to wood harvest.

LULUC Data

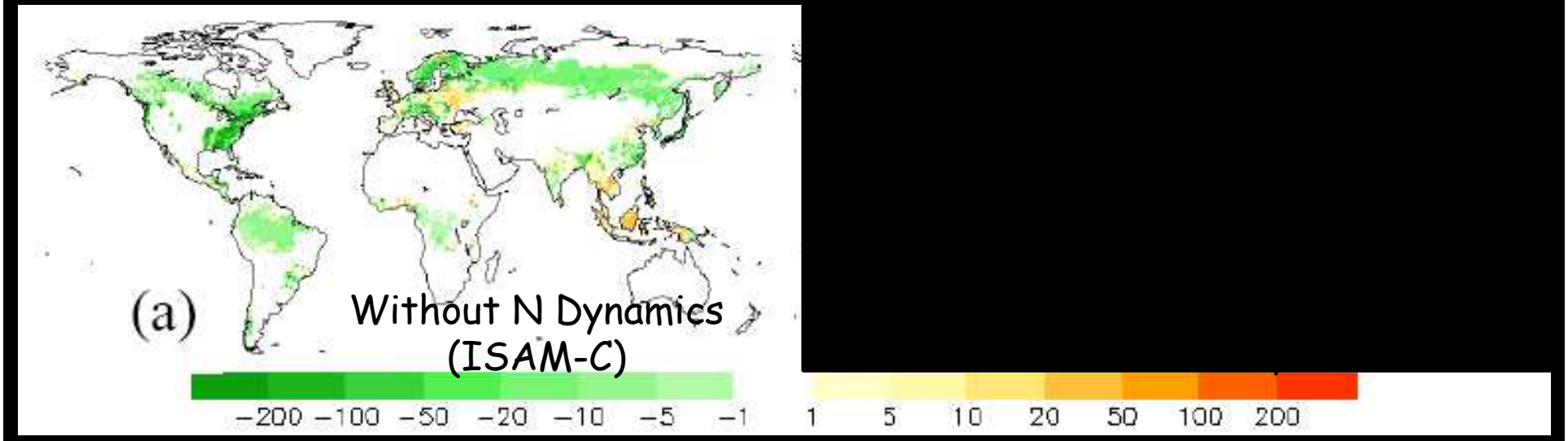
Historical Data (≤ 2005):

- Used three global historical data sets of cropland & pastureland
  - SAGE (ISAM-RF), HYDE (ISAM-HYDE), Houghton (ISAM-HH)
- A common data set for historical wood harvest and urban land
  - GLM (Hurtt et al., 2011)

Future Data (> 2005)

- The future projections for LULUC (cropland, pastureland, and wood harvest) are based on the four RCPs derived.

Estimated Net Exchange of C ($gC/m^2/yr$) for the 2000s in Secondary Forests



- **C stocks in forests are increasing in recent years due to reforestation and forest management**

Positive values represent net C release to the atmosphere and negative values represent net C storage in terrestrial biosphere

Jain et. al. (2013, GCB)

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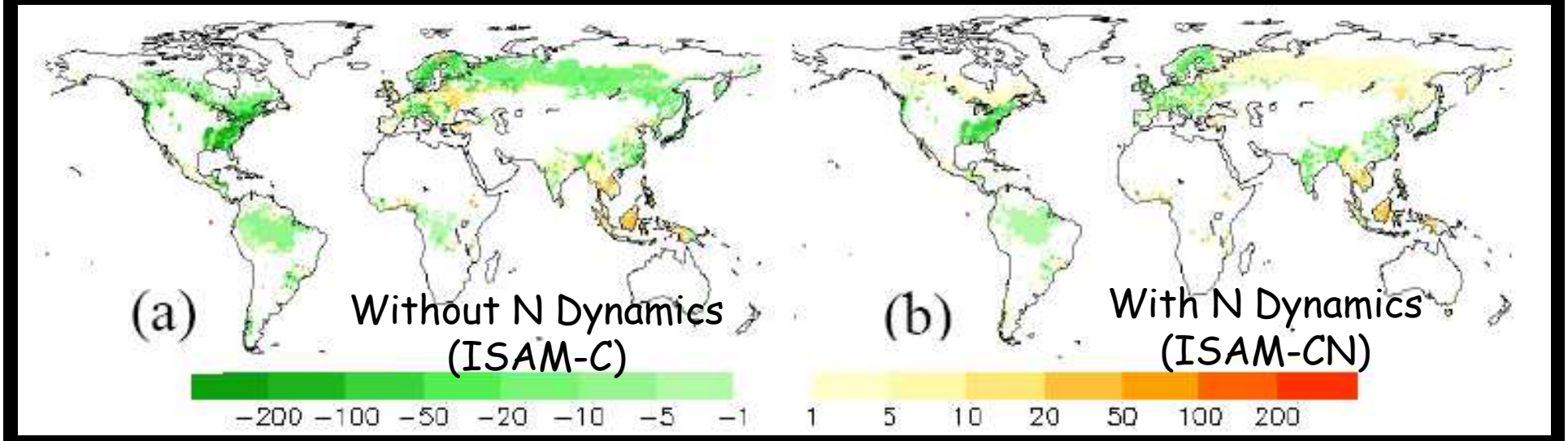
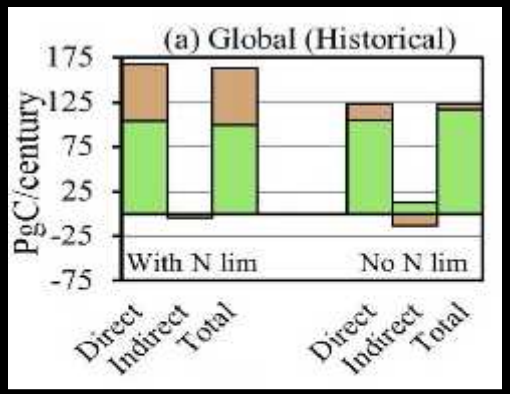


- C stocks in forests are increasing in recent years due to reforestation, abandonment and management (wood harvest)
- In some regions accumulation of C is reduced where N is a limiting nutrient or enhanced if the additional N is deposited in the forest regrowing regions

Positive values represent net C release to the atmosphere and negative values represent net C storage in terrestrial biosphere

Jain et. al. (2013, GCB)

Model Simulated LULUC Emissions (Pg/Century)



Meiyappan et. al. (2015, GBC)

LUC (green bars) and LU (brown bars)

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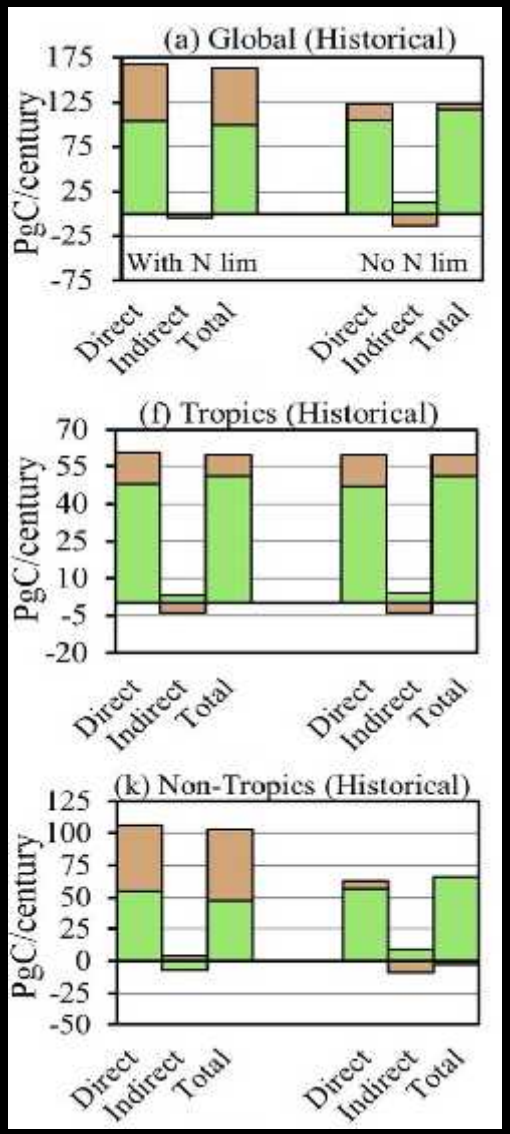

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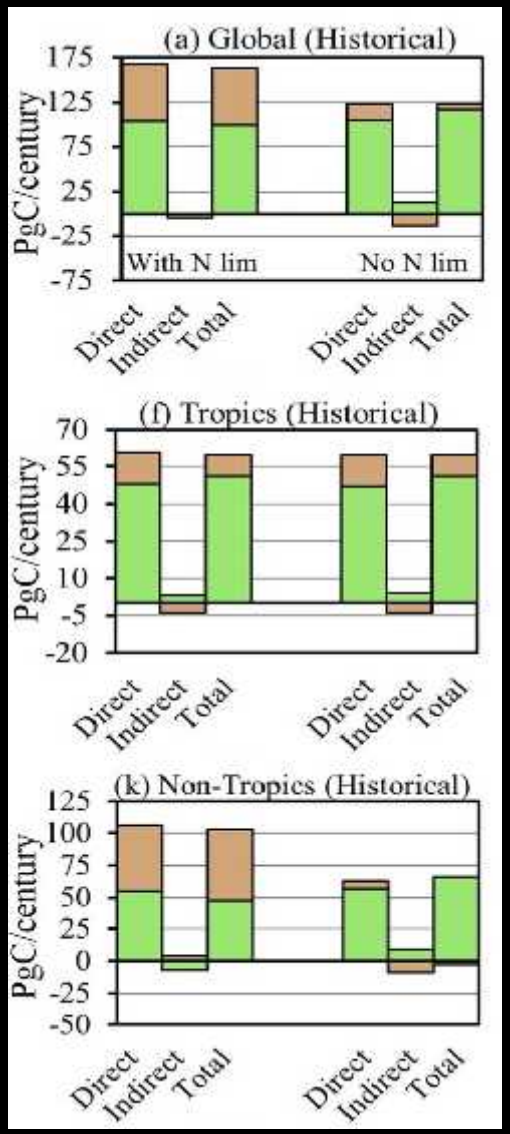

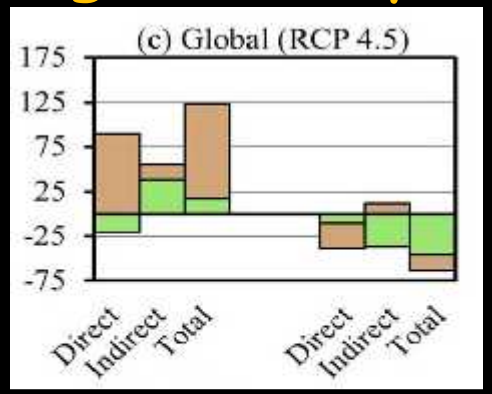

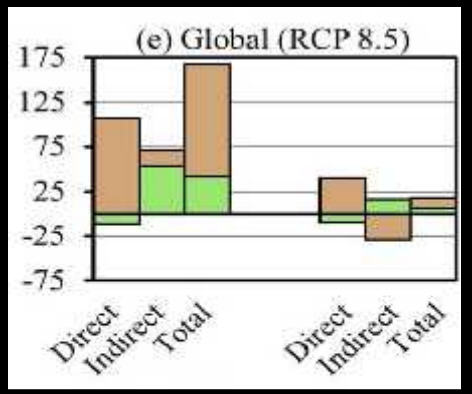

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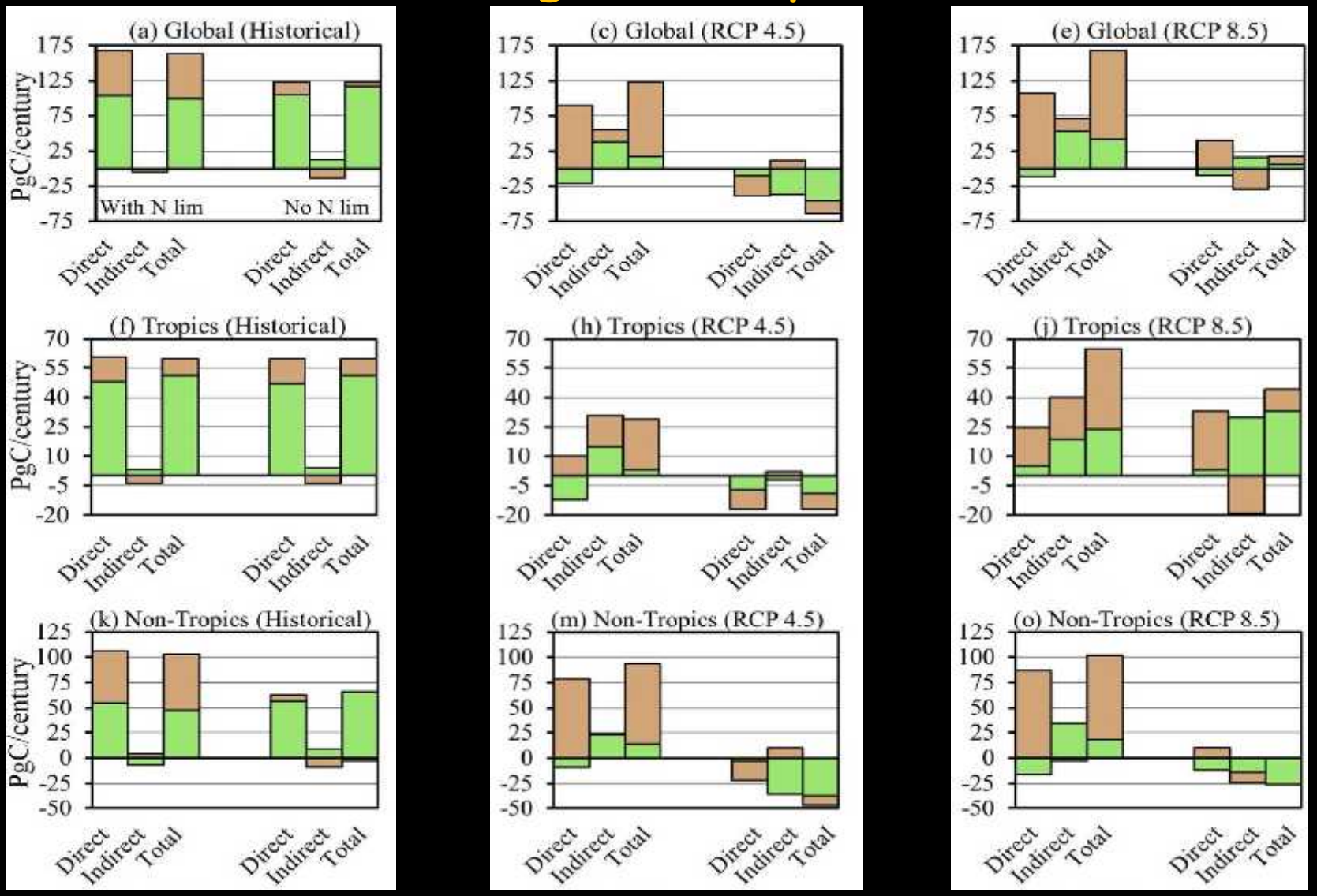


LUC (green bars) and LU (brown bars)

Conclusions

- N limitation reduces regrowth rates of vegetation in temperate areas resulting in higher net caron emissions.
- Exclusion of N dynamics leads to an underestimation of LULUC emissions by around 34-52 PgC (20-30%) during the 20th century and by 128-187 PgC (90-150%) during the 21st century

ISAM and Its Applications

Global Change Biology

Global Change Biology (2013) 19, 2893–2906, doi: 10.1111/gcb.12207

CO_2 emissions from land-use change affected more by nitrogen cycle, than by the choice of land-cover data

ATUL K. JAIN*, PRASANTH MEIYAPPAN*, YANG SONG* and JOANNA I. HOUSE†

AGU PUBLICATIONS

Global Biogeochemical Cycles

RESEARCH ARTICLE
10.1002/2015GB005086

Special Section:
Global Land-Use Change and Carbon/Climate Dynamics

Increased influence of nitrogen limitation on CO_2 emissions from future land use and land use change

Prasanth Meiyappan[1], Atul K. Jain[1], and Joanna I. House[2]

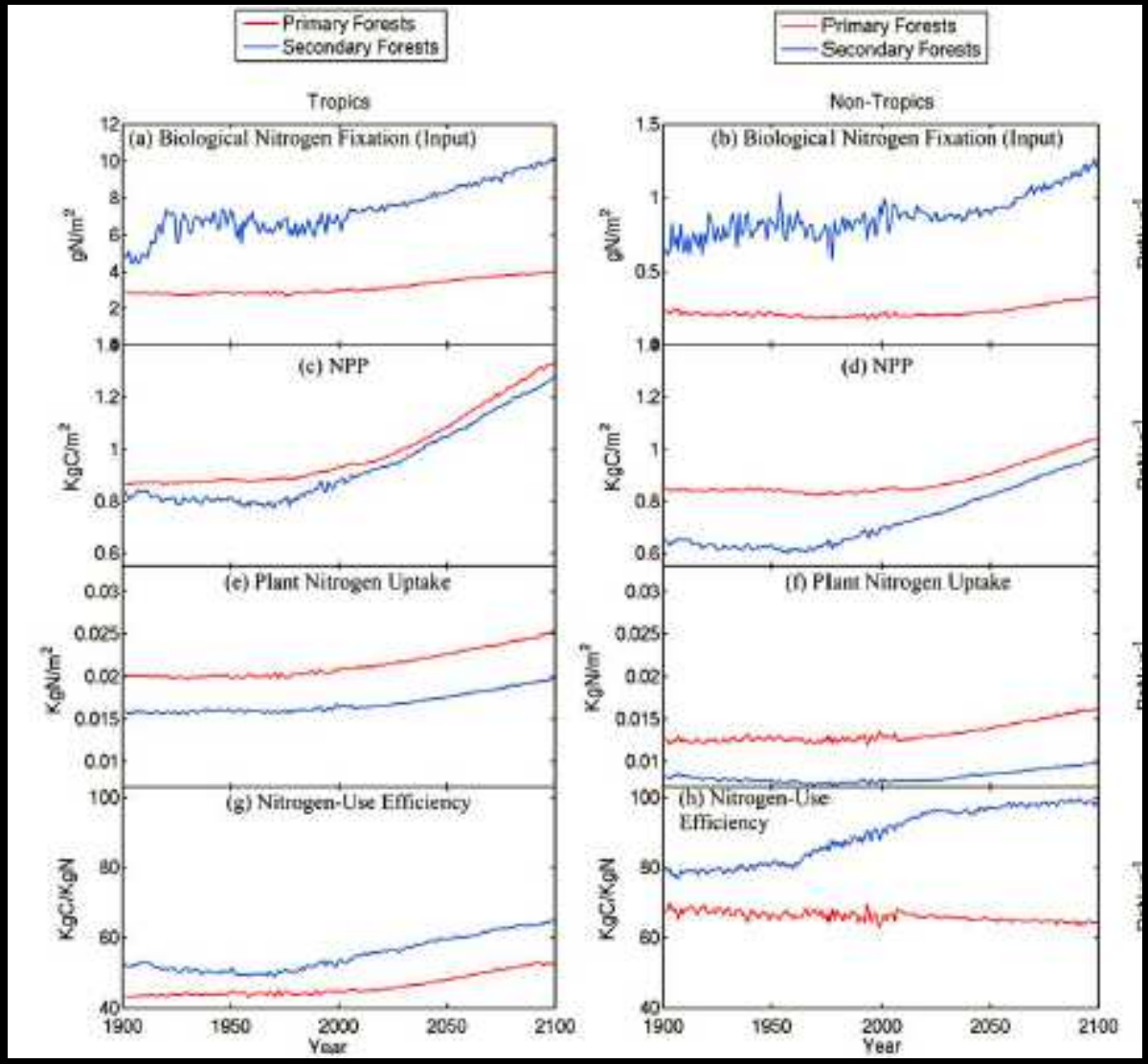
[1]Department of Atmospheric Sciences, University of Illinois at Urbana-Champaign, Urbana, Illinois, USA, [2]Department of Geography, Cabot Institute, University of Bristol, Bristol, UK

Key Points:

Thank You

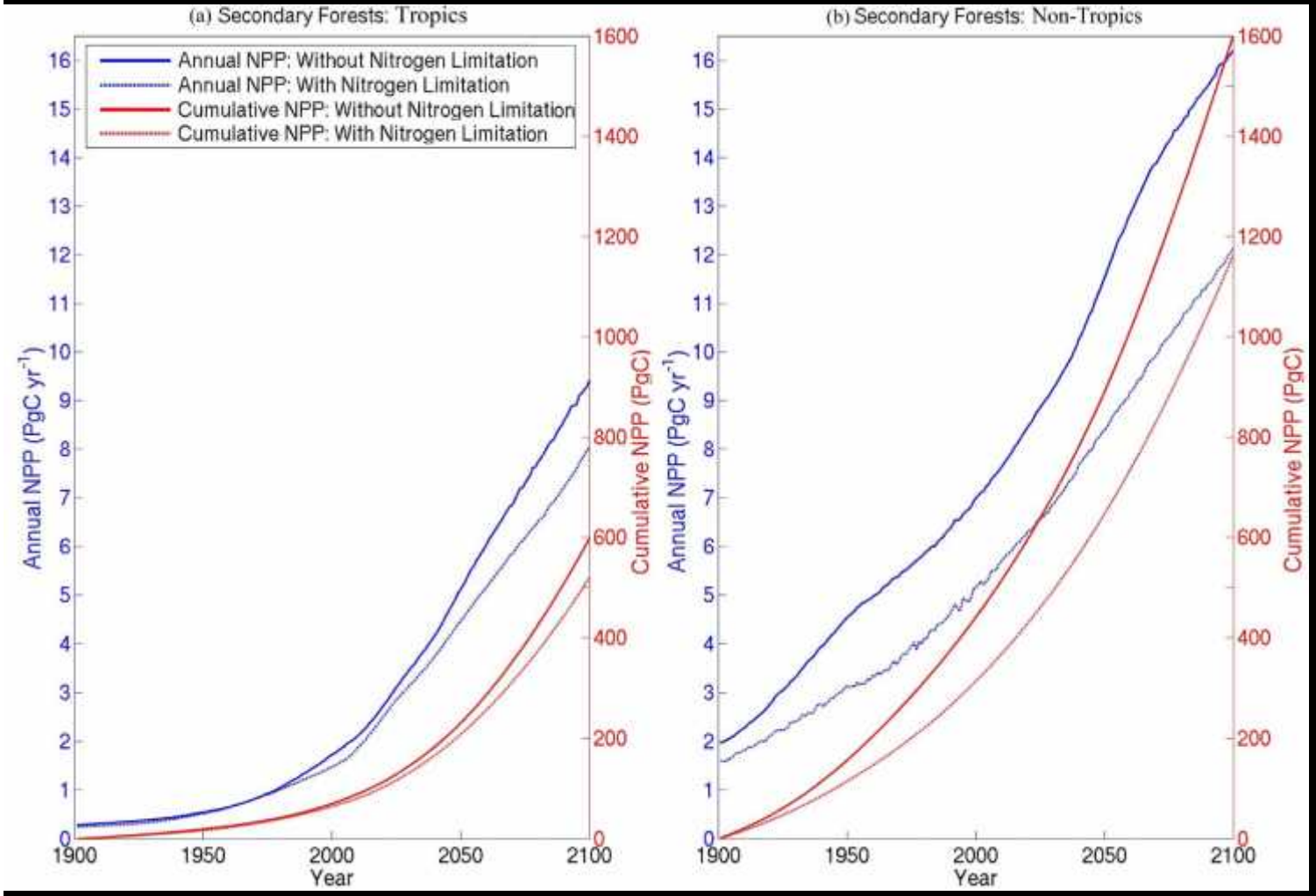
Extra Slides

Model-Simulated response to key Nitrogen variables illustrated using RCP8.5 simulations



Meiyappan et. al. (2015, GBC)

NPP for Secondary Forests - With and Without N limitation, RCP 8.5 Scenarios



Meiyappan et. al. (2015, GBC)

ISAM and Its Applications

Integration of nitrogen cycle dynamics into the Integrated Science Assessment Model for the study of terrestrial ecosystem responses to global change

Xiaojuan Yang,[1] Victoria Wittig,[1] Atul K. Jain,[1] and Wilfred Post[2]

Nitrogen attenuation of terrestrial carbon cycle response to global environmental factors

Atul Jain,[1] Xiaojuan Yang,[1] Haroon Kheshgi,[2] A. David McGuire,[3] Wilfred Post,[4] and David Kicklighter[5]

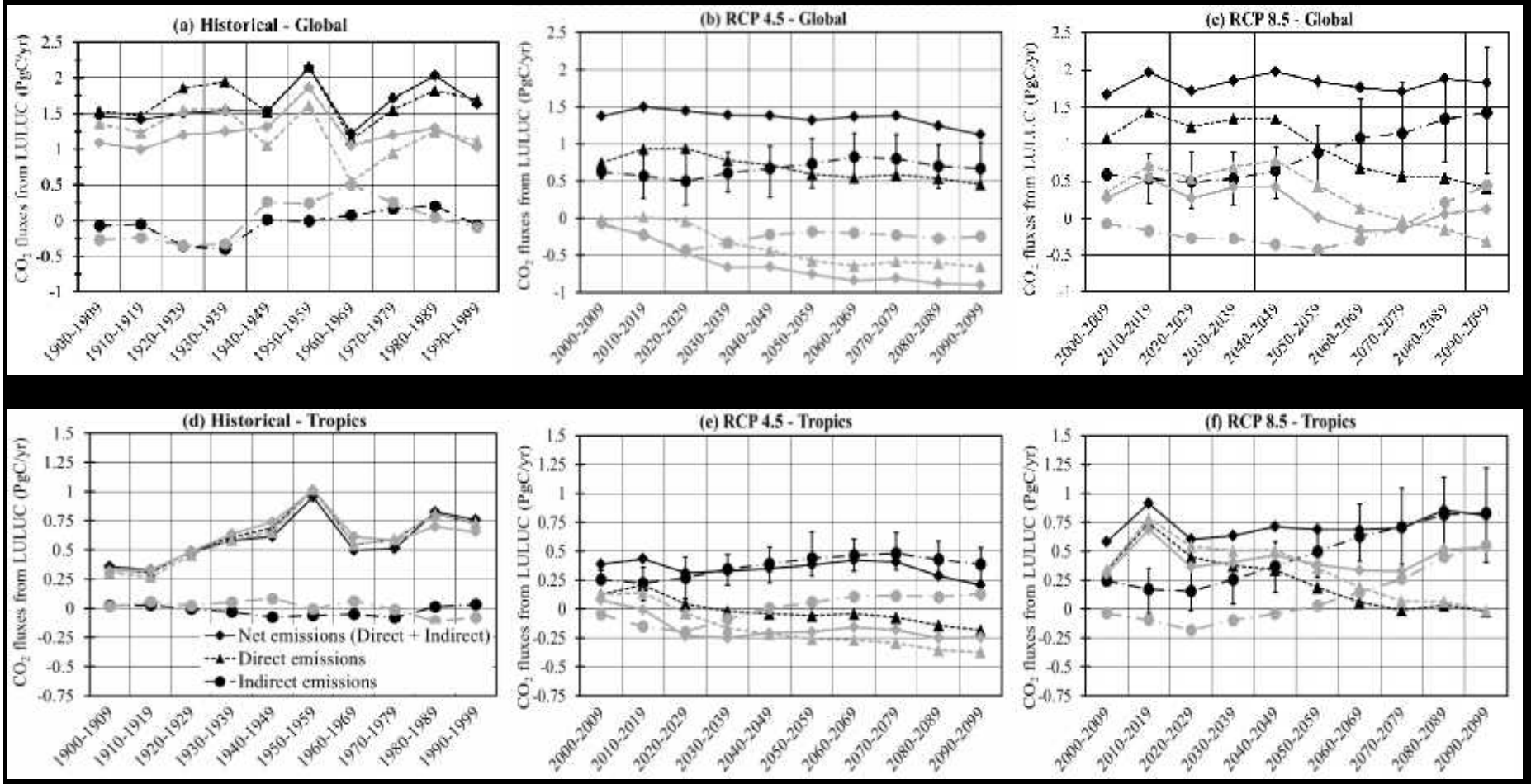
Biogeosciences, 7, 3041–3050, 2010
www.biogeosciences.net/7/3041/2010/
doi:10.5194/bg-7-3041-2010

Biogeosciences

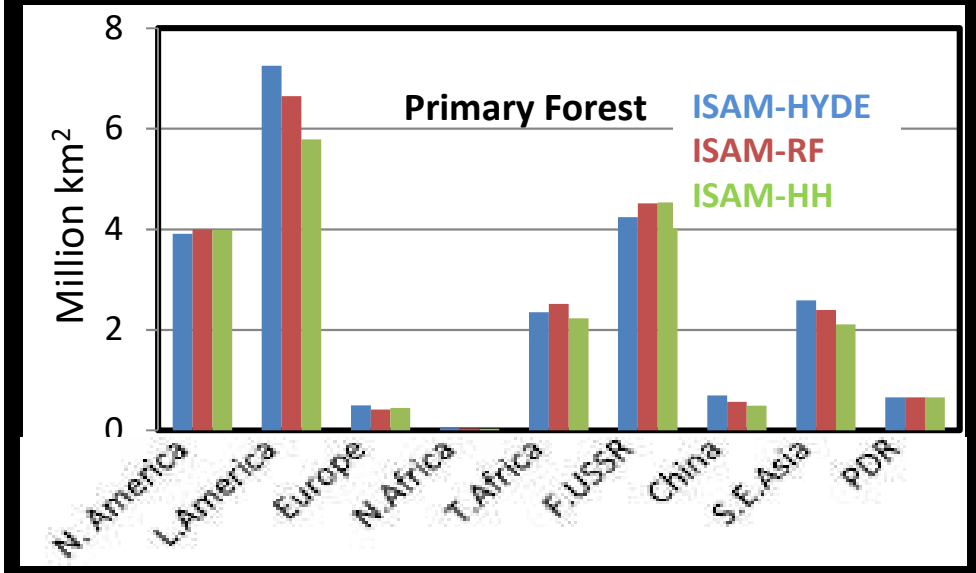
Contributions of secondary forest and nitrogen dynamics to terrestrial carbon uptake

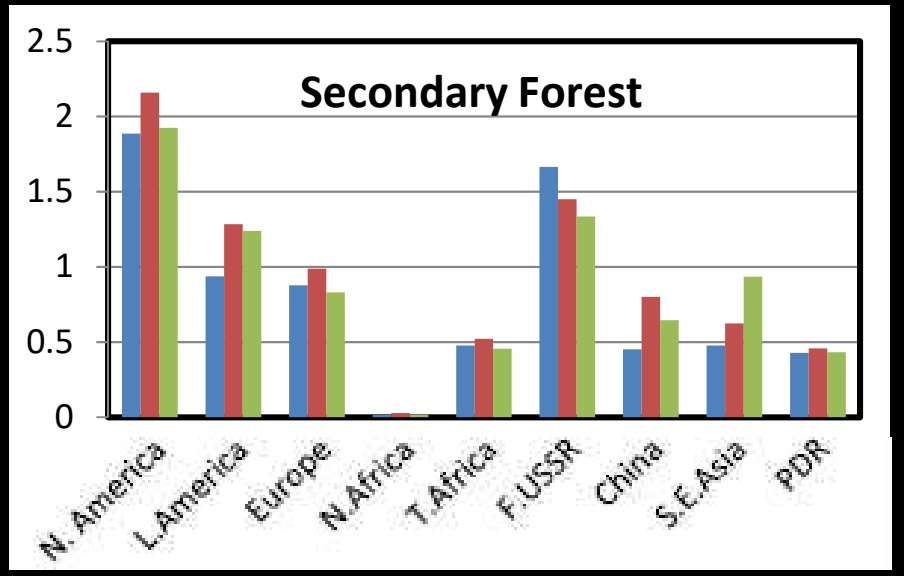
X. Yang, T. K. Richardson, and A. K. Jain

Climate, N Cycle, LULCC uncertainty



Primary and Secondary Forests Averaged for 2000s





Front. Earth Sci. , 6(2): 122–139
DOI 10.1007/s11707-012-0314-2

Three distinct global estimates of historical land-cover change and land-use conversions for over 200 years

Prasanth MEIYAPPAN, Atul K. JAIN (✉)

Meiyappan and Jain (2012)

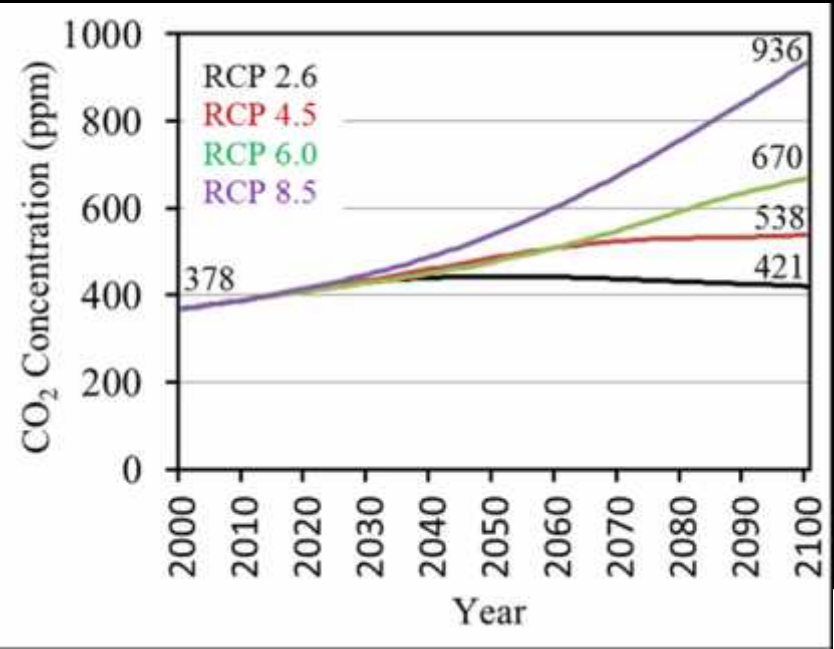
Net Change in Forest and Wood Harvest Areas

Table 1. Net Change in Forest Area Estimated by the Integrated Science Assessment Model (Net Forest Loss Including Afforestation and Forest Regrowth Following Cropland and Pastureland Abandonment; Negative Values Indicate a Net Loss in Forest Area) and the Annual Forest Harvested Areas Summed Over a Hundred Year Period (From *Hurtt et al.* [2011])[a]

	Net Change in Forest Area					Cumulative Wood Harvest Area From Forests [*Hurtt et al.*, 2011]				
	20th Century	21st Century				20th Century	21st Century			
Region	Historical	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5	Historical	RCP 2.6	RCP 4.5	RCP 6.0	RCP 8.5
Global	−4.6	−2.6	2.3	−0.5	−2.1	16	76	87	188	137
Tropics	−2.2	−1.1	0.9	−0.2	−1.0	6	45	60	98	72
Nontropics	−2.4	−1.5	1.4	−0.3	−1.1	10	31	27	90	65

[a]The historical estimates are averages of the three LULUC reconstructions described in *Jain et al.* [2013]. The data for the 21st century correspond to the four Representative Concentration Pathways (RCPs). All units in million km^2/century.

CMIP5 Dataset



RCP 8.5 – MESSAGE IAM
RCP 2.6 – IMAGE IAM