LCLUC Dynamics and Impacts on C and N Emissions in South/South East Asia

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Acknowledgements
NASA LCLUC Program
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Overall Objective

- Improve our understanding of the historical effects of LCLUC dynamics on the quantities and pathways of terrestrial carbon and N fluxes <u>at a country level</u>
  - *achieve by systematically using data and terrestrial ecosystem model results for LCLUC CO_2 and N emissions.*

Countries in South/South East Asia

SOUTH ASIA

- Bangladesh
- Bhutan
- India
- Nepal
- Pakistan
- Sri Lanka

SOUTH EAST ASIA

- Cambodia
- Indonesia
- Laos
- Malaysia
- Myanmar
- Philippines
- Thailand, and
- Vietnam

Carbon Fluxes

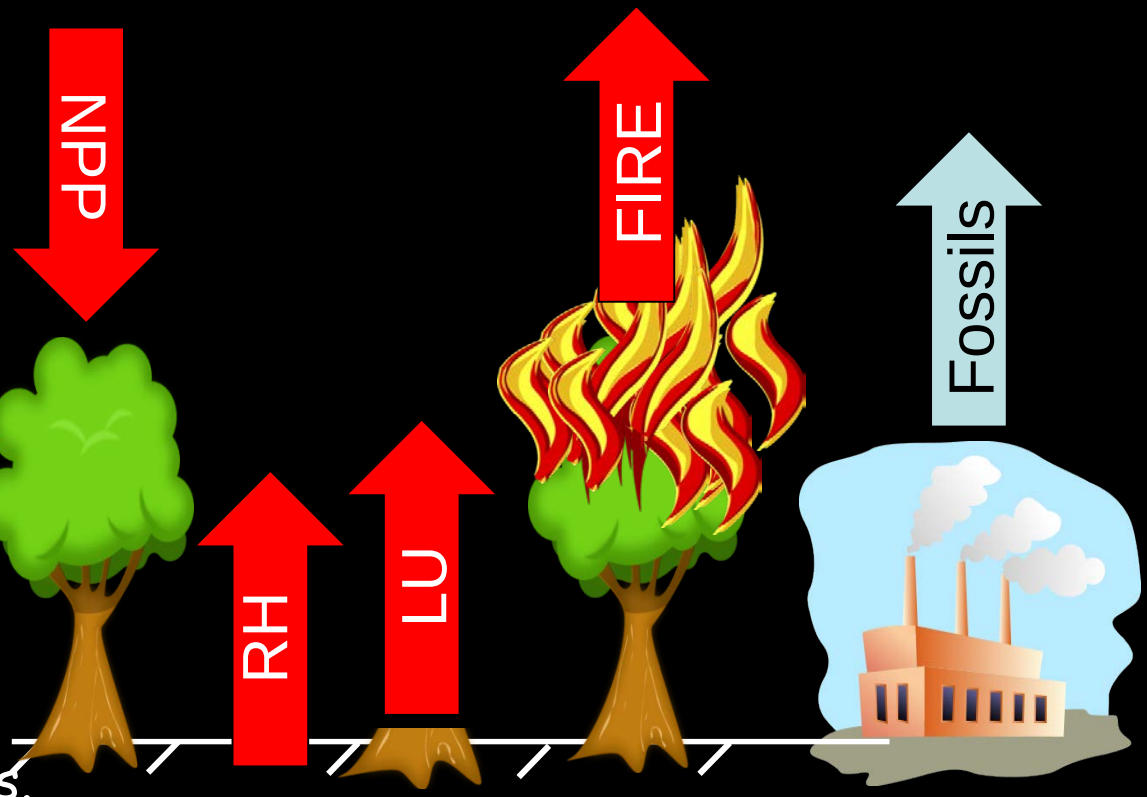
- Net Ecosystem Productivity

  NEP = NPP – RH

- Net Biome Productivity

  NBP = NEP – E_{LUC} – E_{FIRE}

- NPP: Net primary productivity
- RH: Heterotrophic respiration
- E_{LUC}: Emissions due to land use change
- E_{FIRE}: Emissions due to fires.
- Fossils: Emissions due to fossil fuel burning

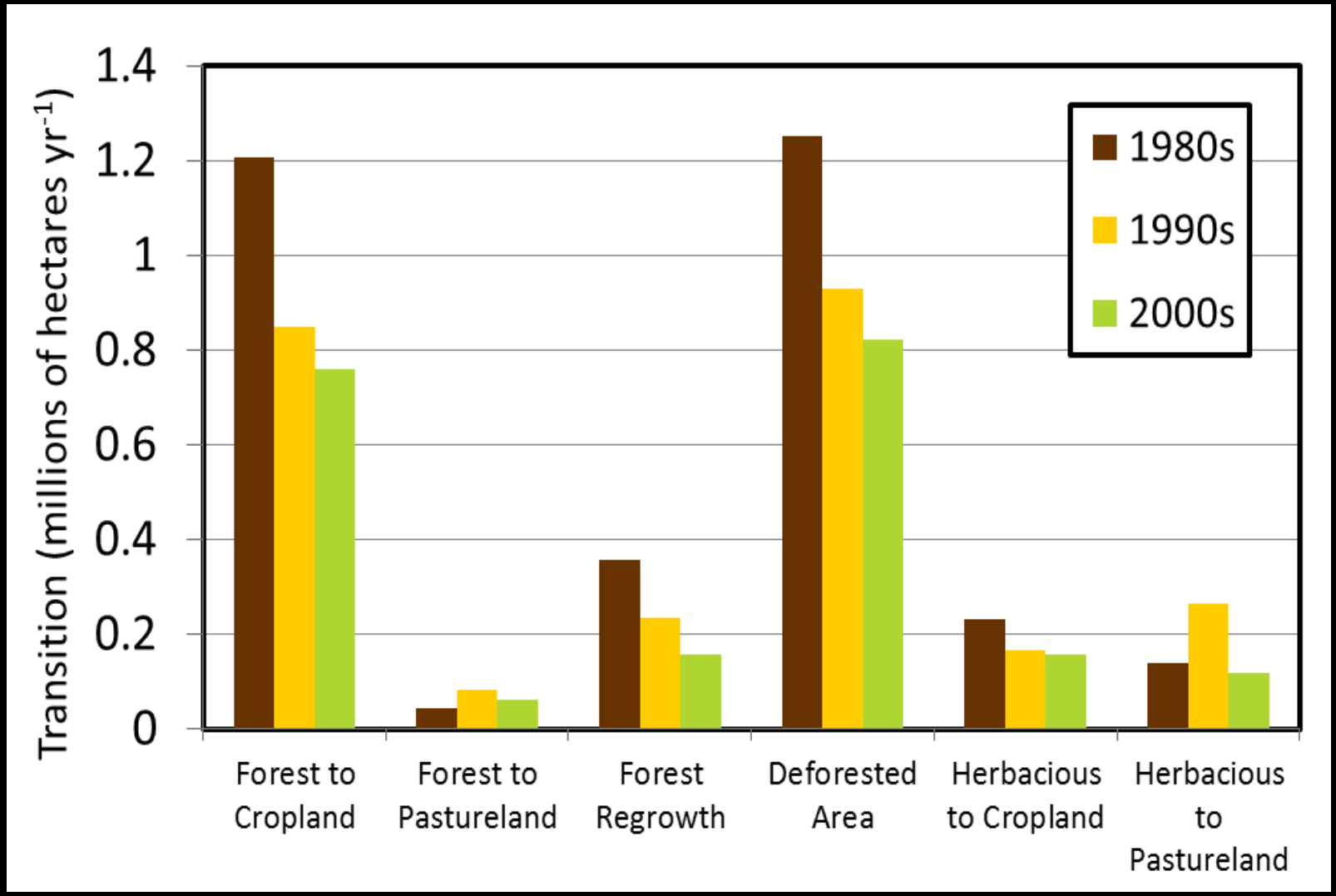


Estimations of NEP and E_{LUC} Emissions

- Used nine different dynamic vegetation model results, which are calculated based on one set of LCLUC data for SSEA (9 DGVM and 1 LCLUC Date Set)

Model	Resolution (lat x lon)
CLM	1.25° x 0.9375°
ISAM	0.5° x 0.5°
JULES	0.8° x 1.07°
LPJ	0.5° x 0.5°
LPJ_GUESS	0.5° x 0.5°
LPX	1.0° x 1.0°
ORCHIDEE	0.5° x 0.5°
VEGAS	0.5° x 0.5°
VISIT	0.5° x 0.5°

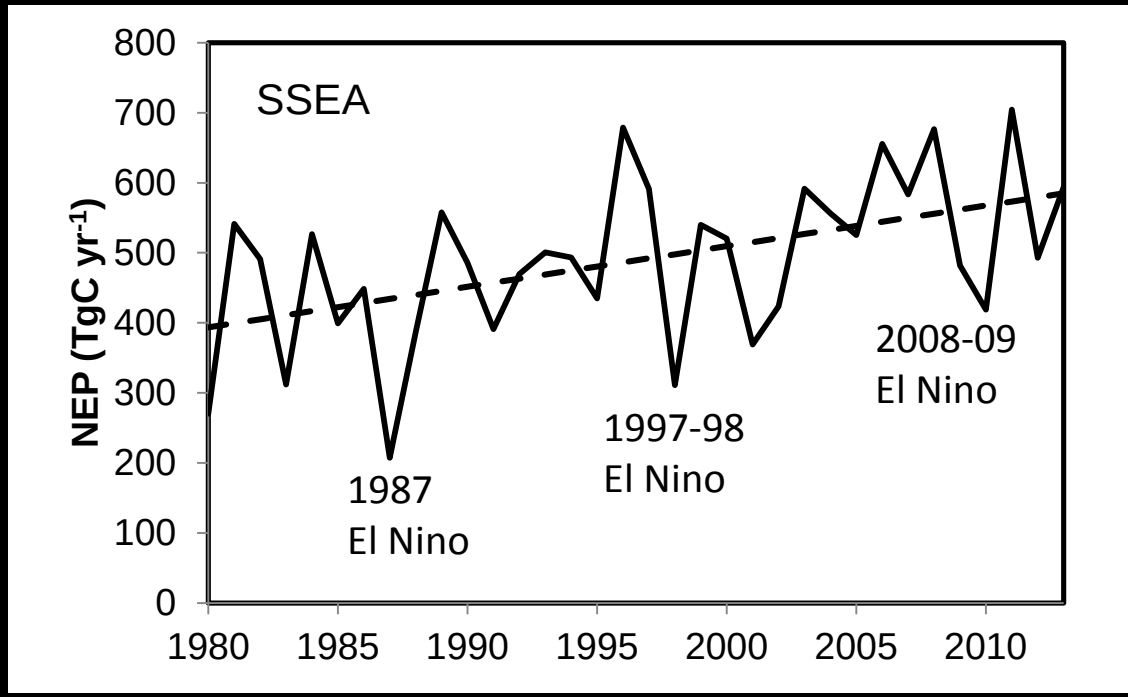
Models were forced with HYDE land cover data



Cervarich et al. (ERL, 2016)

Results: NEP

- NEP = NPP – RH
- SSEA NEP
  - 1980s: 410 Tg Cyr^{-1}
  - 1990s: 492 TgC yr^{-1}
  - 2000s: 547 TgC yr^{-1}

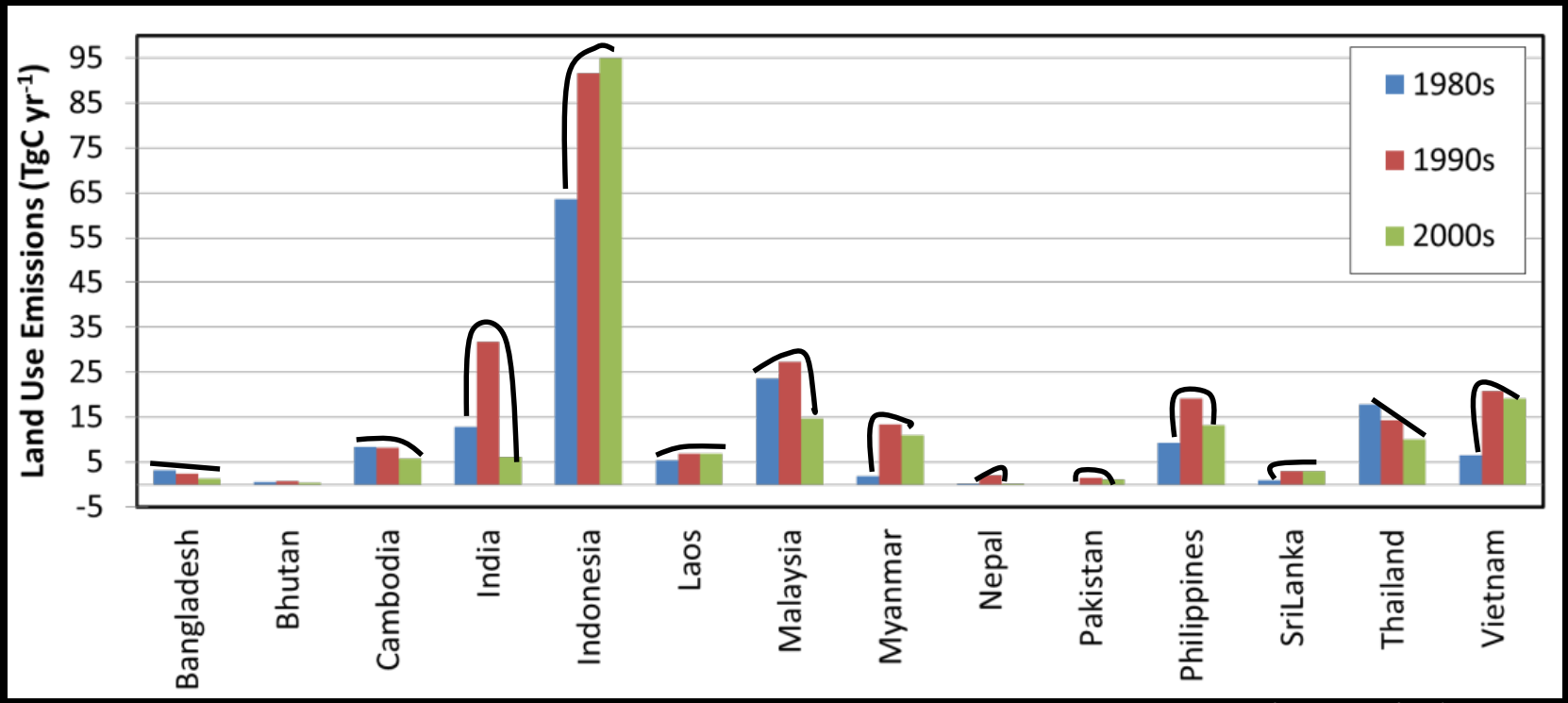


- General increasing trend has been attributed to CO_2 fertilization
- Yearly variations are driven by the temperature variations
- Standard Deviation of 122 TgC yr^{-1}.
  - CV is 25%

Cervarich et al. (ERL, 2016)

Results: E_{LUC}

- Decadal emissions
  - 1980s: 199 TgC yr^{-1}
  - 1990s: 304 TgC yr^{-1}
  - 2000s (Average for the period 2000-2013): 244 TgC yr^{-1}
- Indonesia (95 TgC yr^{-1}) and Malaysia (14 TgC yr^{-1}) were the greatest emitters in the 2000s



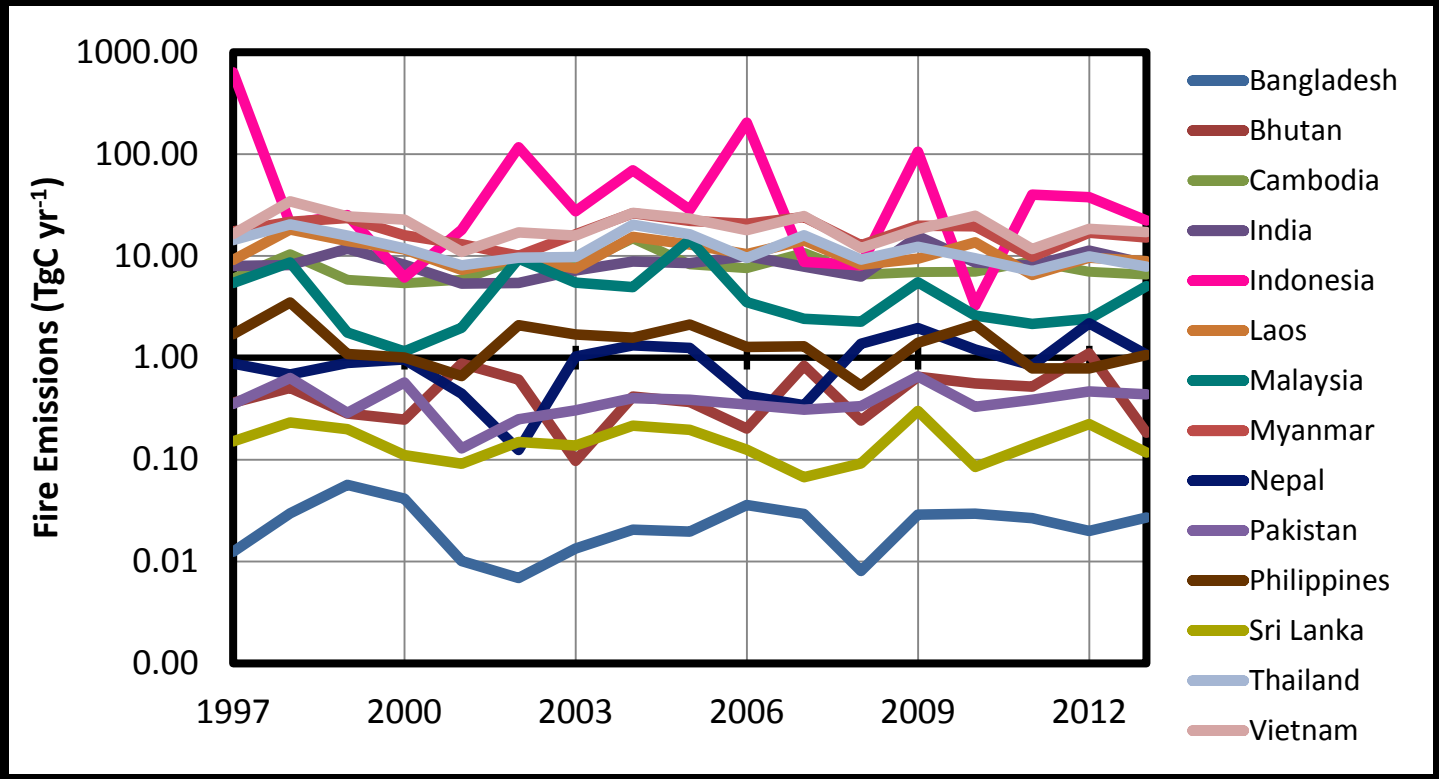
Cervarich et al. (ERL, 2016)

Net Biome Production

$$NBP = NEP - E_{LUC} - E_{FIRE}$$

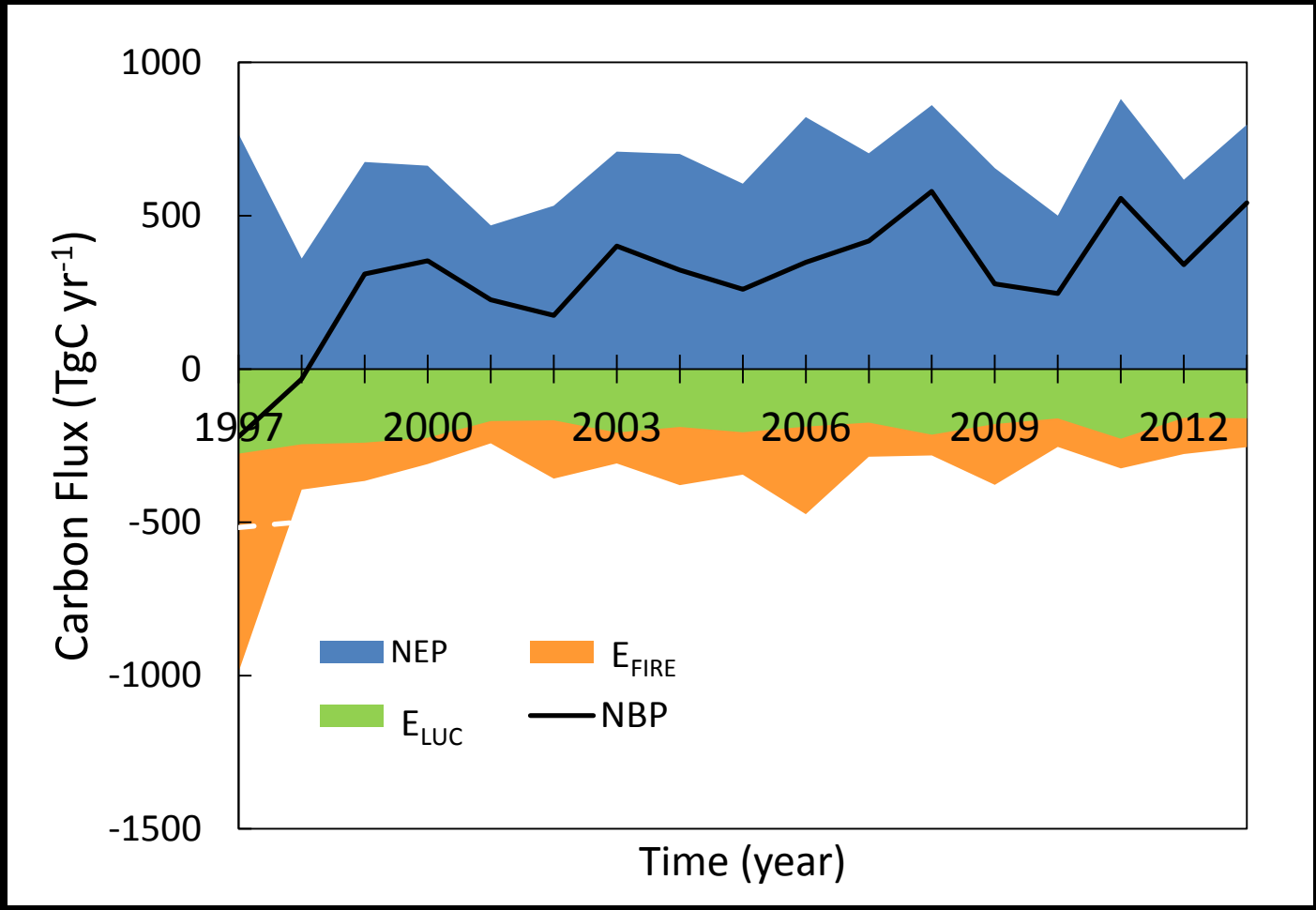
Results: E_{FIRE}

- Fire emissions were obtained from the Global Fire Emissions Database (GFED)
  - Calculated based on satellite data model.



Giglio et al. (2013)

Components of the Terrestrial Carbon Budget for SSEA (1997-2013)



*Positive values are the land sink of carbon

Cervarich et al. (ERL, 2016)

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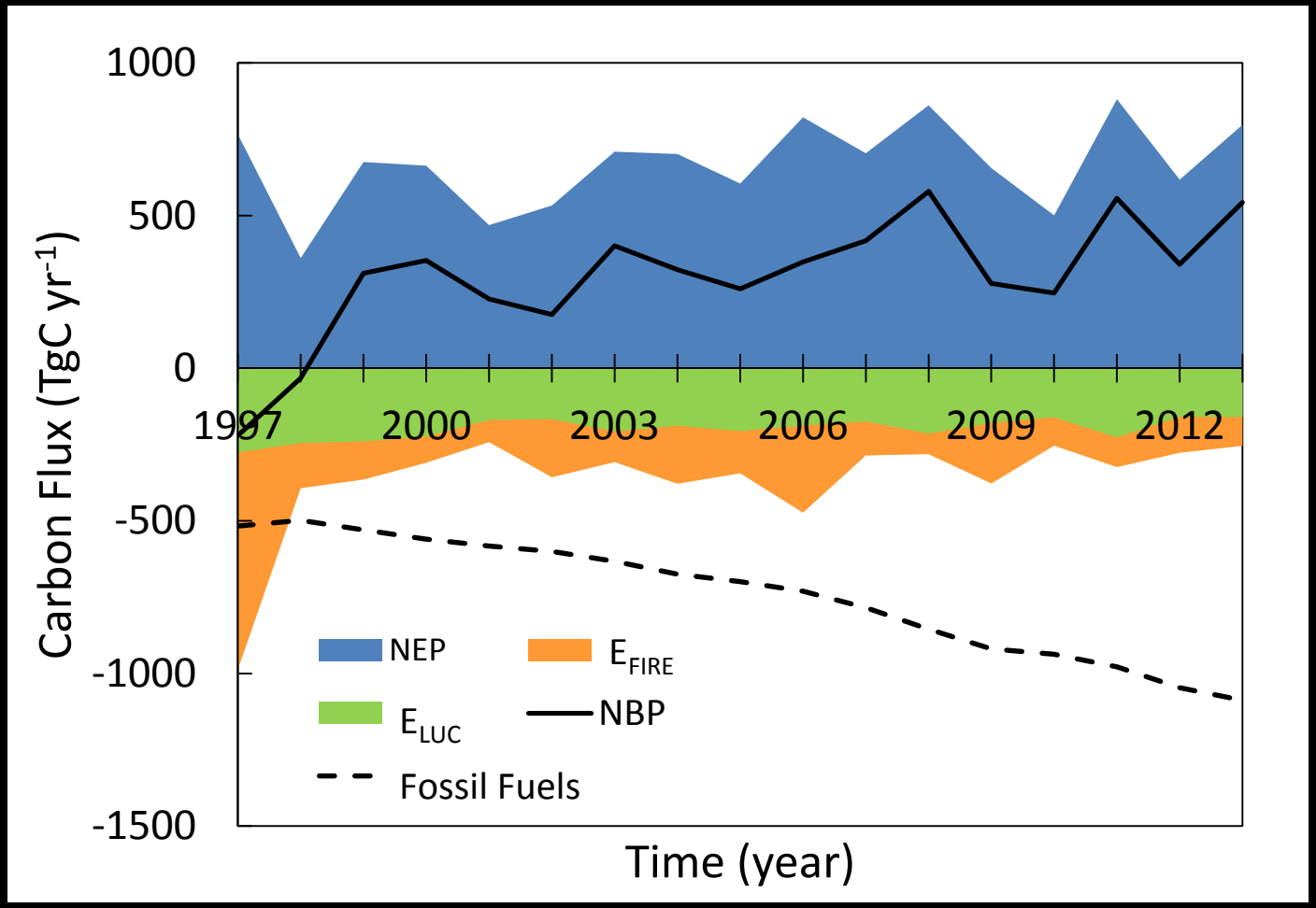

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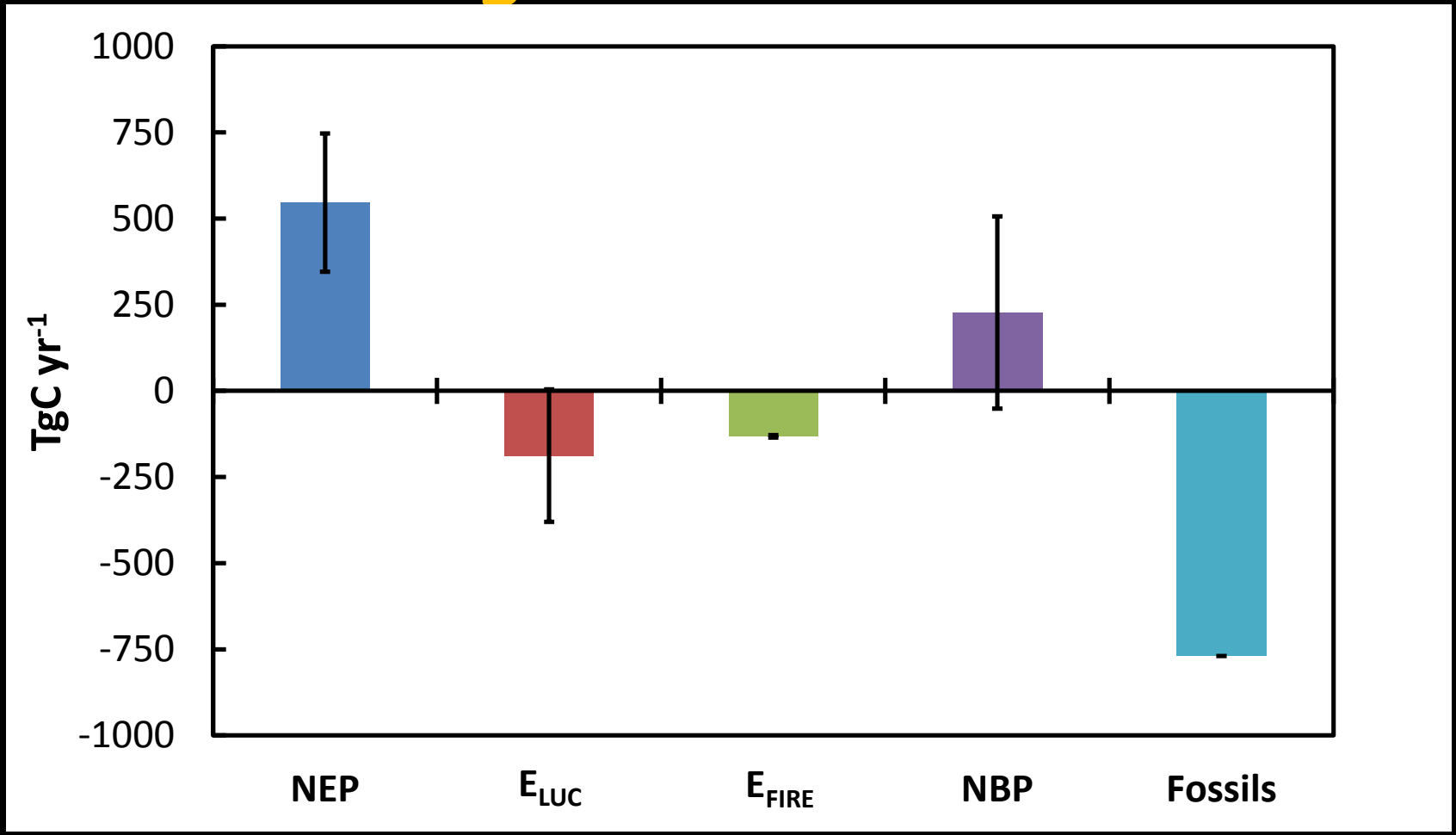
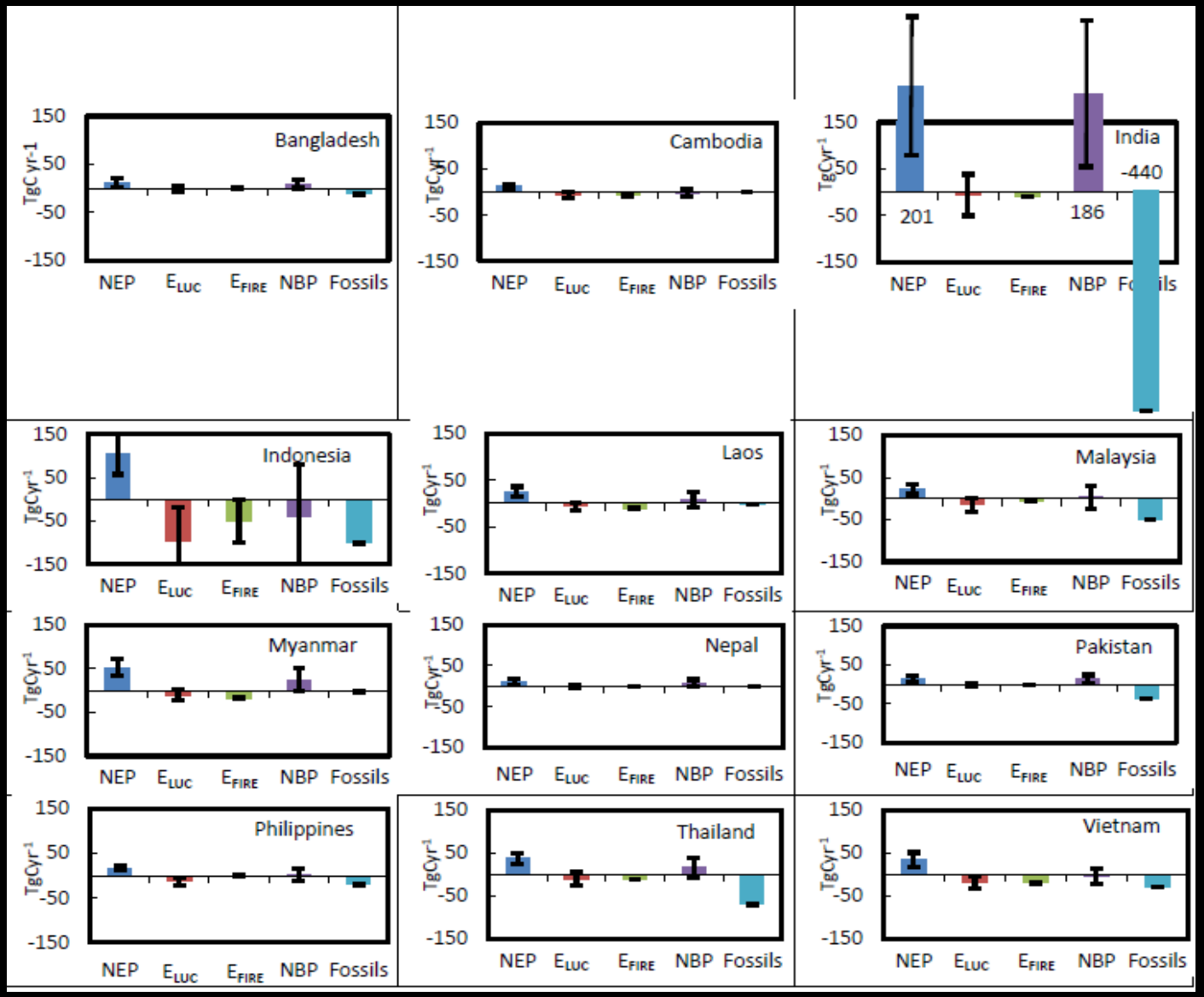
Mean Carbon Fluxes SSEA Average for 2000-2013



*Positive values are the land sink of carbon

Cervarich et al. (ERL, 2016)

Country Specific Mean Carbon Fluxes Average for 2000-2013



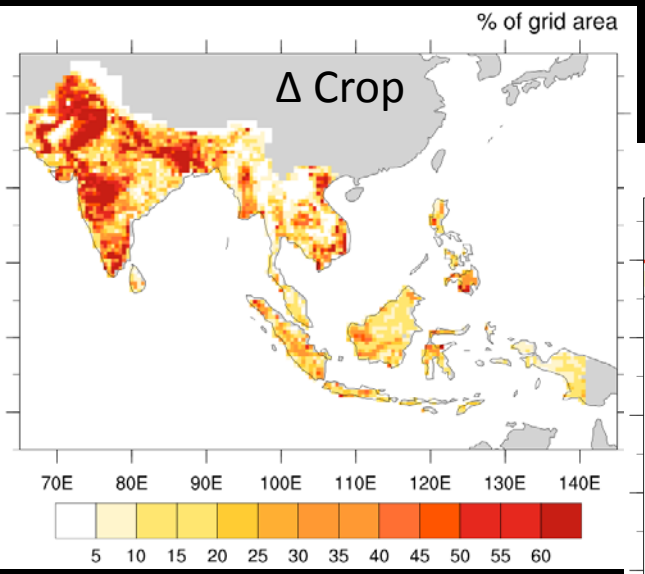
Cervarich et al. (ERL, 2016)

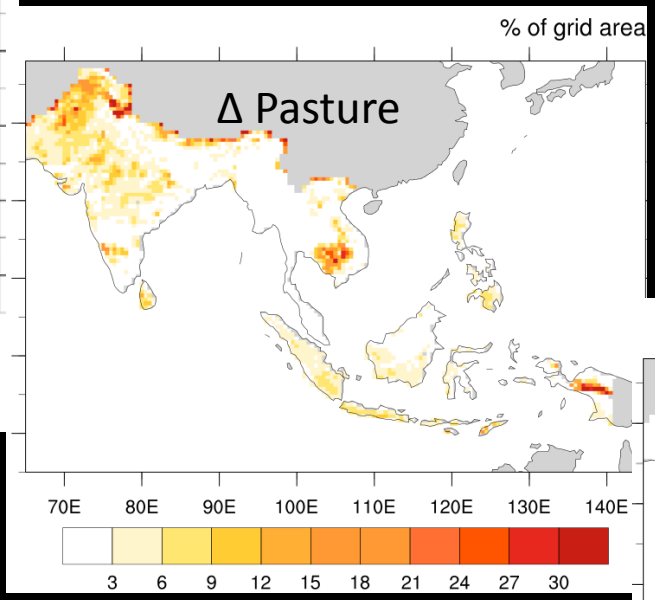
Major Issues

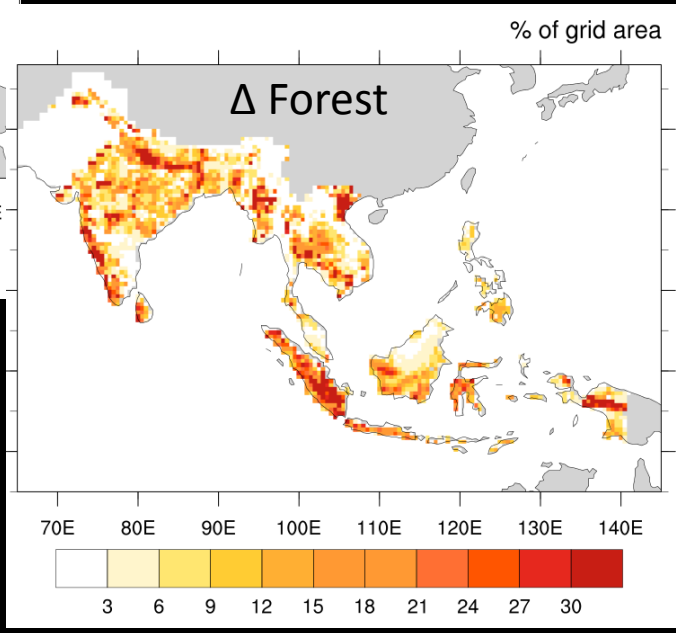
- (1) Multi-model syntheses suggest large uncertainties in the estimated CO_2 fluxes
  - Missing data to validate the carbon fluxes inherent in these modeling approaches.
- (2) Overestimated the CO_2 sink amount due to overestimation of the CO_2 fertilization effect
  - Missing N dynamics

(3) Uncertainty in Land Use Change Data

Maximum grid-level differences using Various Realizations of LCLUC (Average for the period 2001-2013)



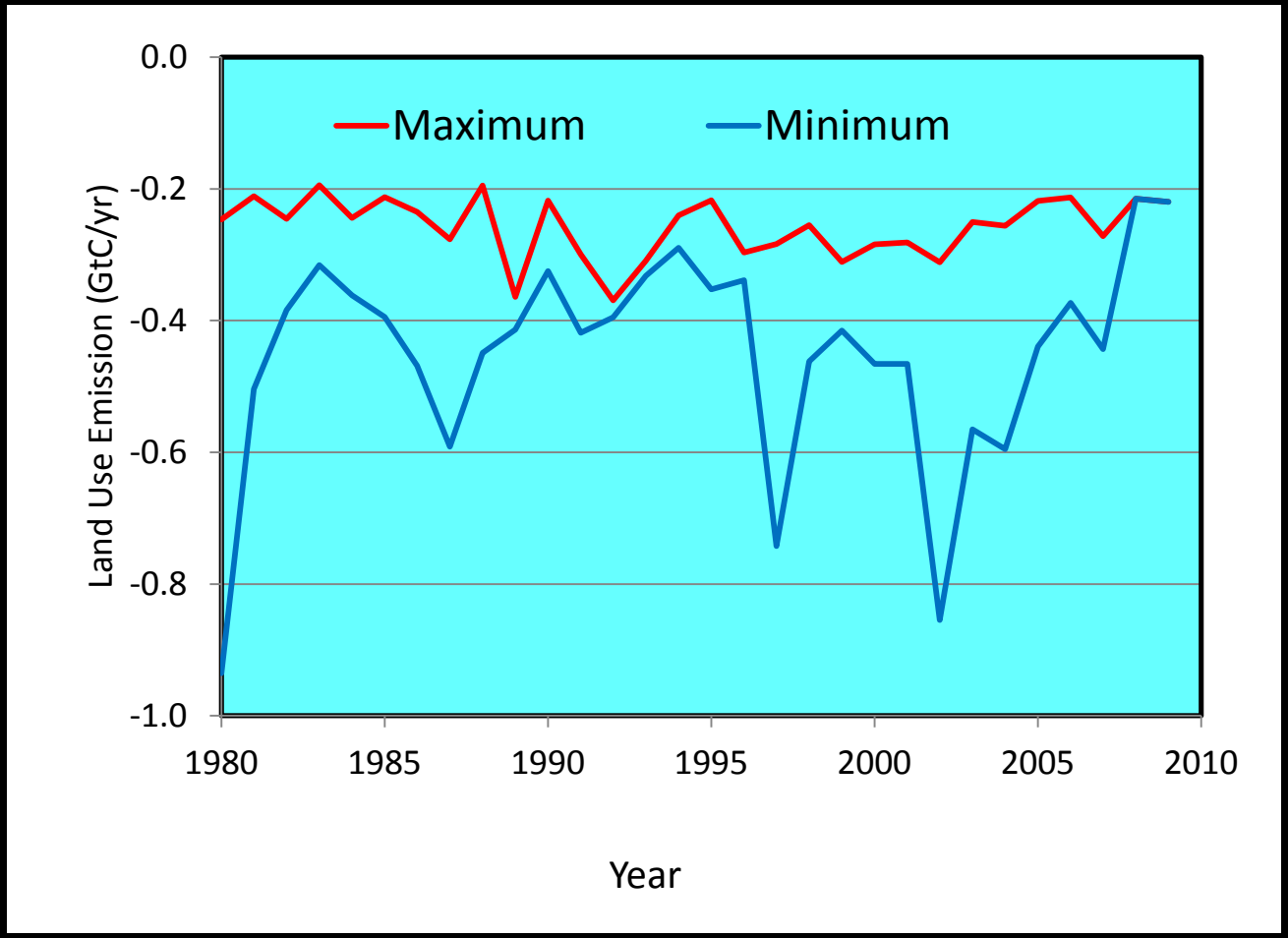




Various Realizations:

- HYDE
- SAGE (RF)
- Houghton (HH)
- Satellite data sets

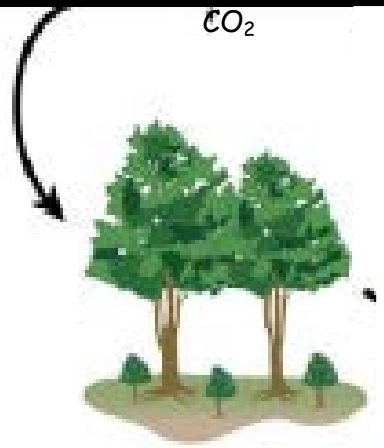
Impacts of Range of LUC Data sets on Land Use Emissions Estimates Based on ISAM Model



Jain et al. (*GCB*, 2013)

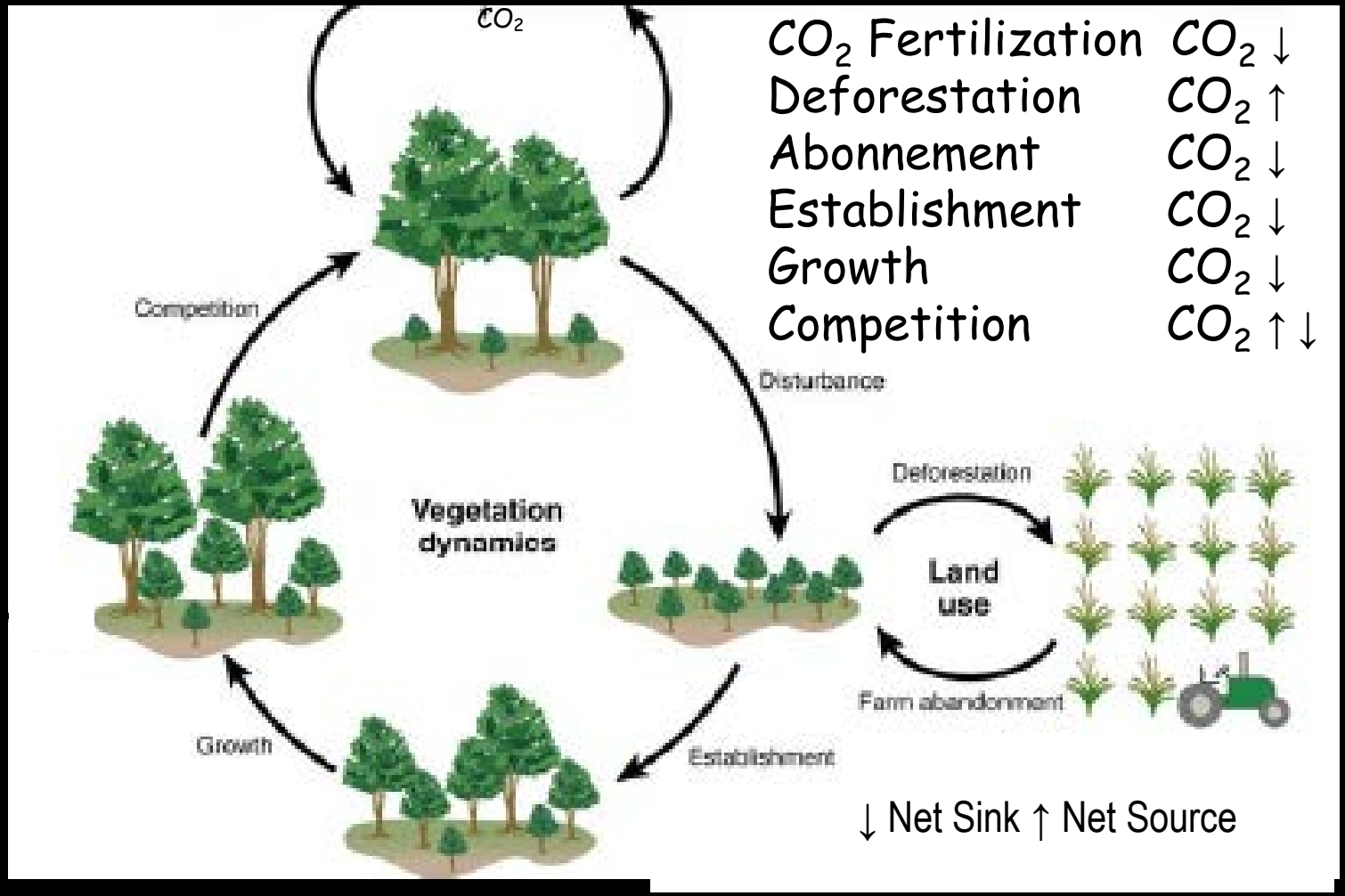
(2) C and N Dynamics

C Dynamics, Plant Productivity and Disturbances

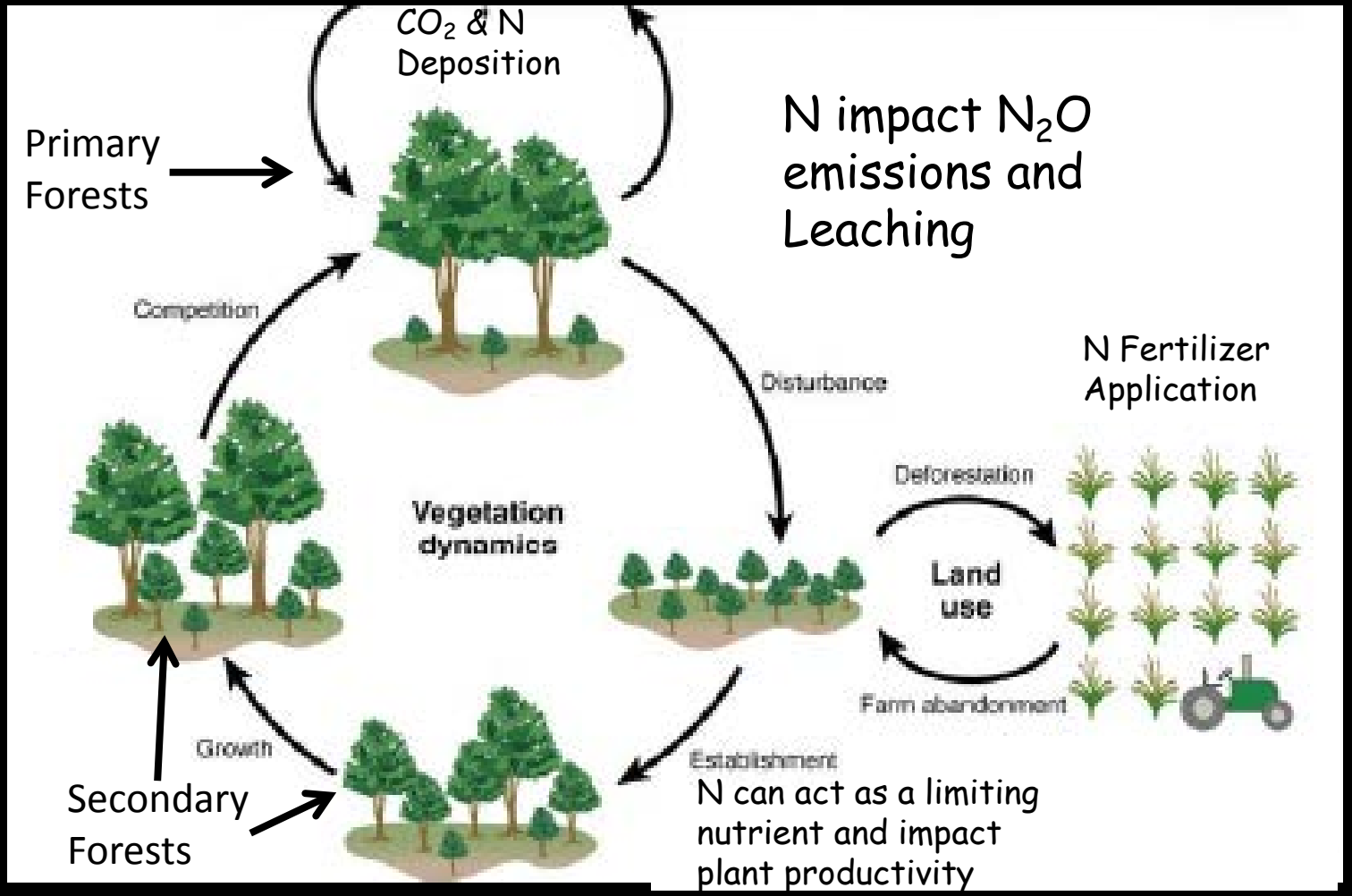


CO_2 Fertilization CO_2 ↓

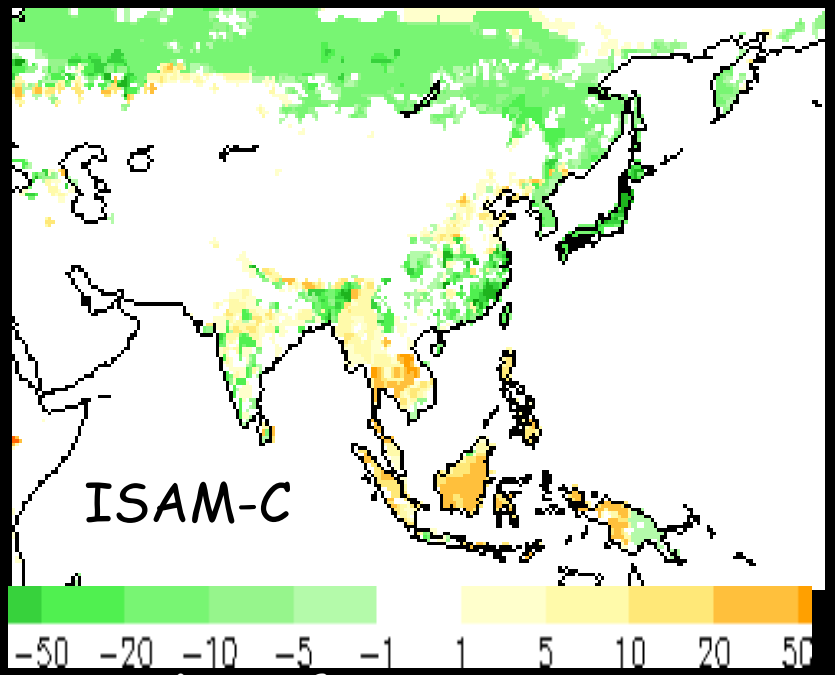
C Dynamics, Plant Productivity and Disturbances (ISAM-C)



C & N Dynamics, Plant Productivity and Disturbances (ISAM-NC)



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, abandonment and management (wood harvest)

***Positive values represent net C release to the atmosphere**

Jain et al. (*GCB*, 2013)
Meiyappan et al. 2015

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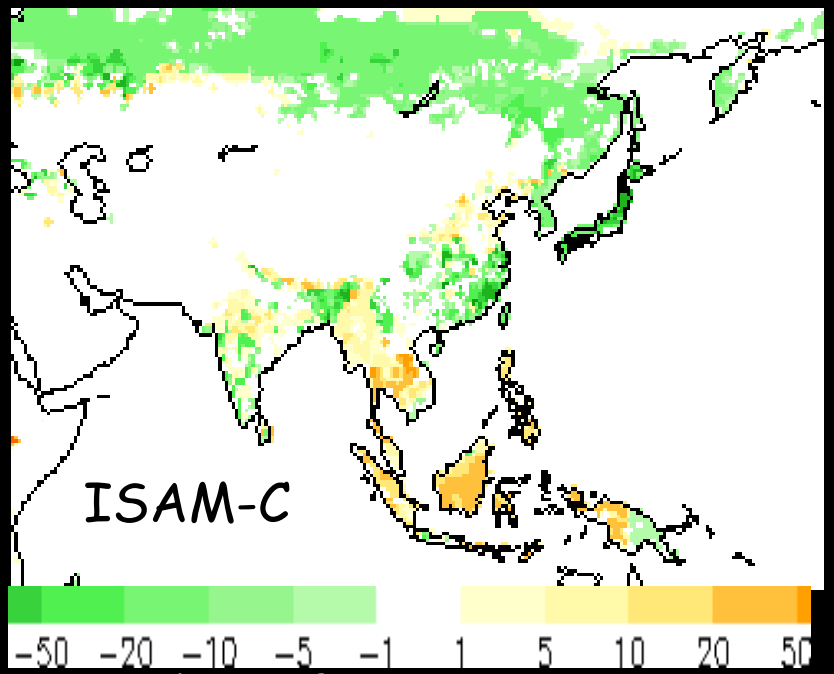
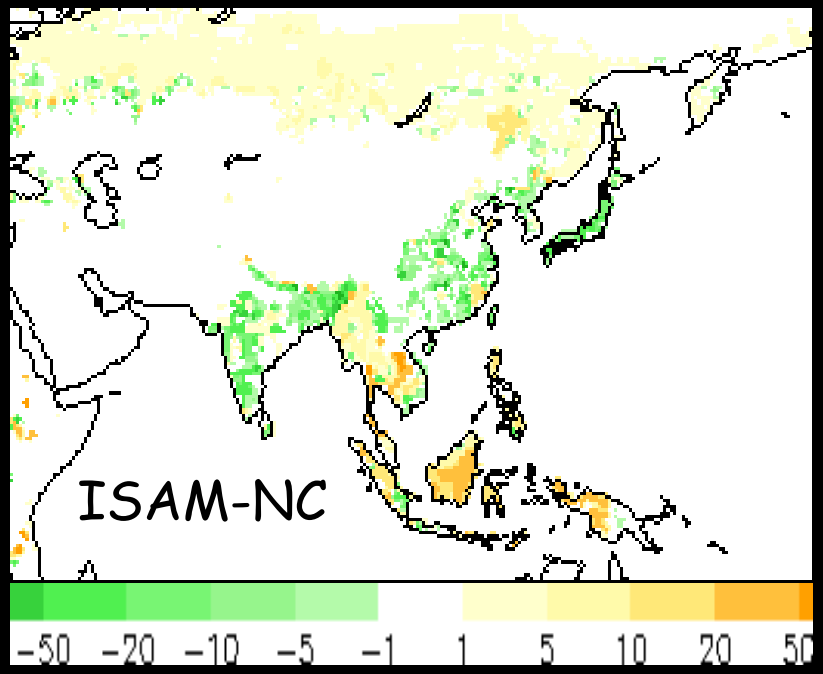


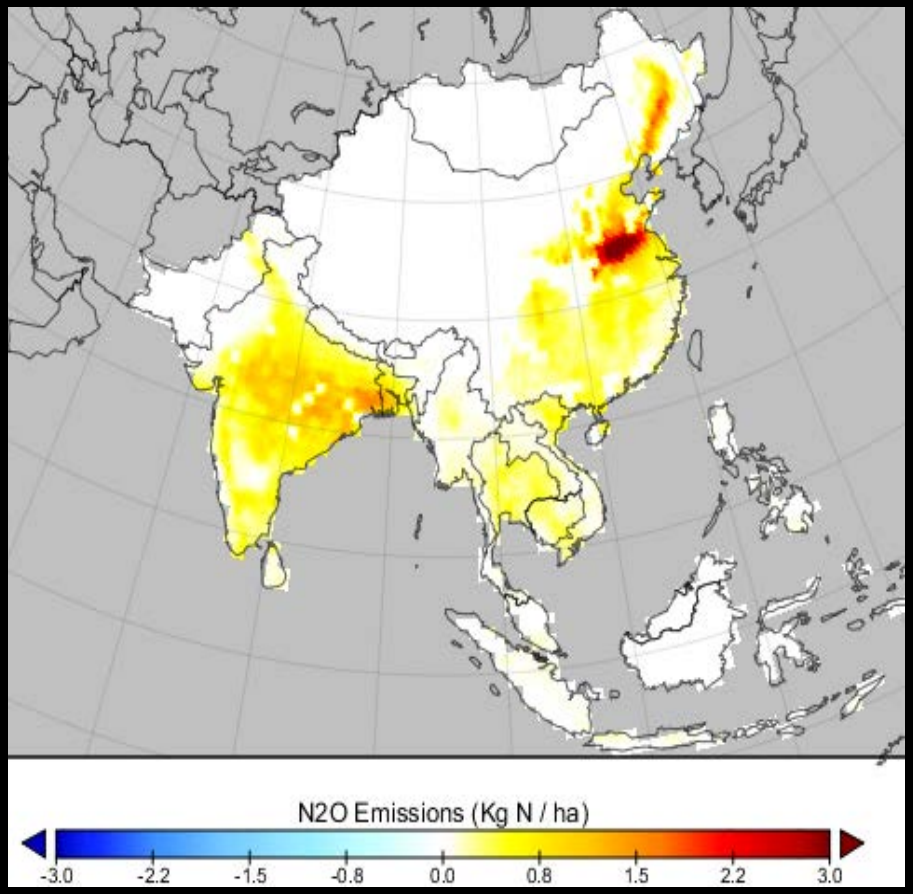


- C stocks in forests are increasing in recent years due to reforestation, abandonment and management (wood harvest)
- In some regions accumulation of C is reduced where N is a limiting nutrient or enhanced if the additional N is deposited in the forest regrowing regions

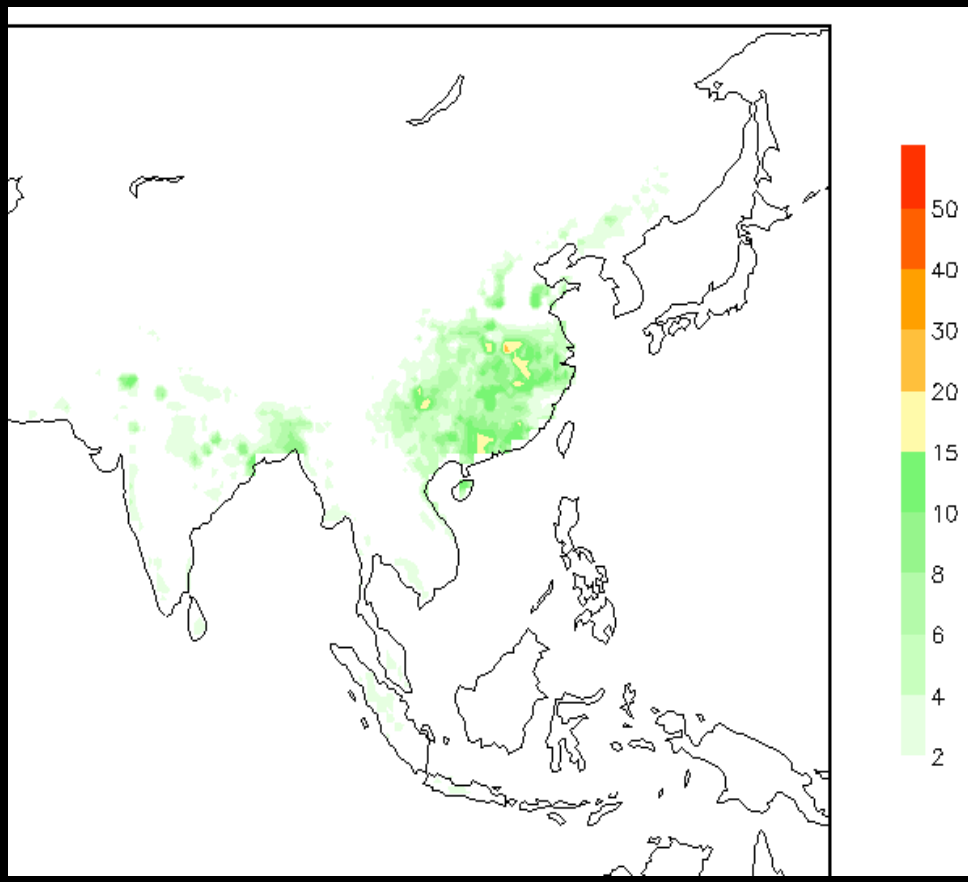
***Positive values represent net C release to the atmosphere**

Jain et al. (*GCB*, 2013)
Meiyappan et al. 2015

2000s N Deposition Effect on N_2O Emissions and Leaching



N_2O Emissions (Kg N/ha)

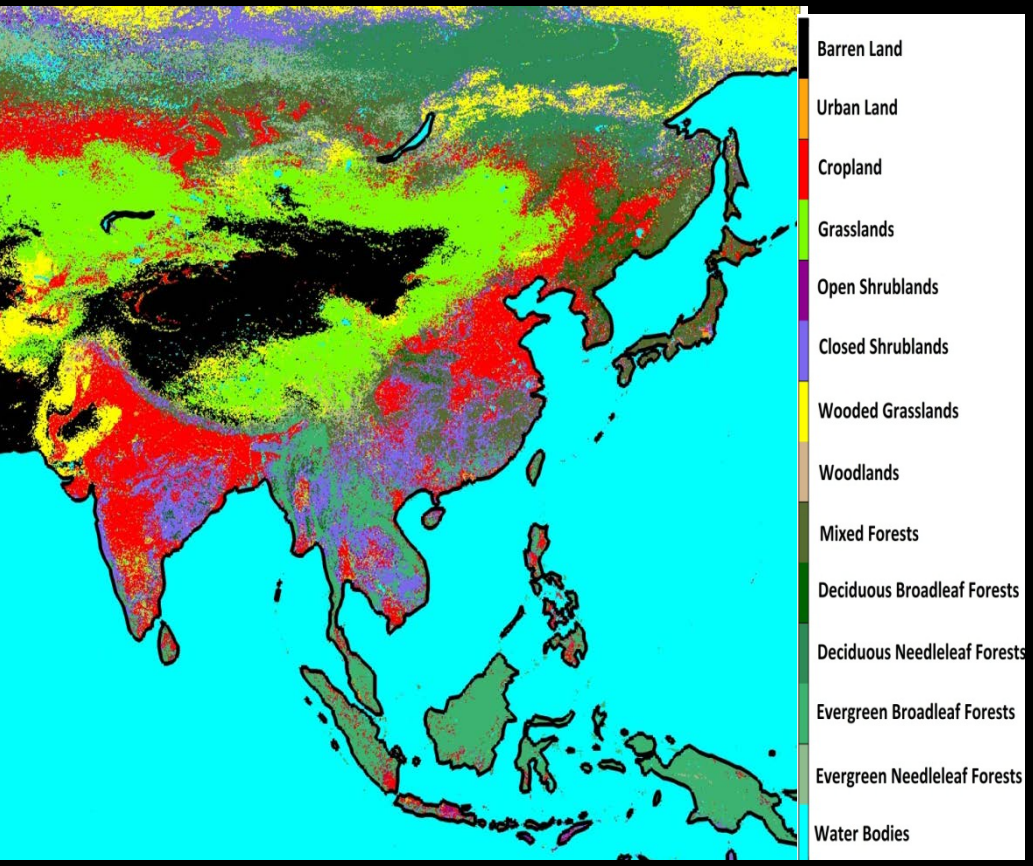


Leaching (gC/m^2)

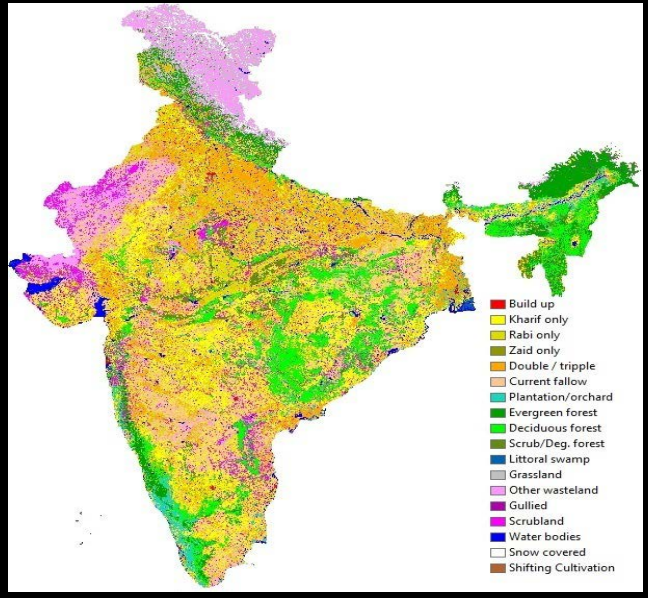
Yang et. al. (2010, Biogeosciences)

(3) Land Cover Change Data

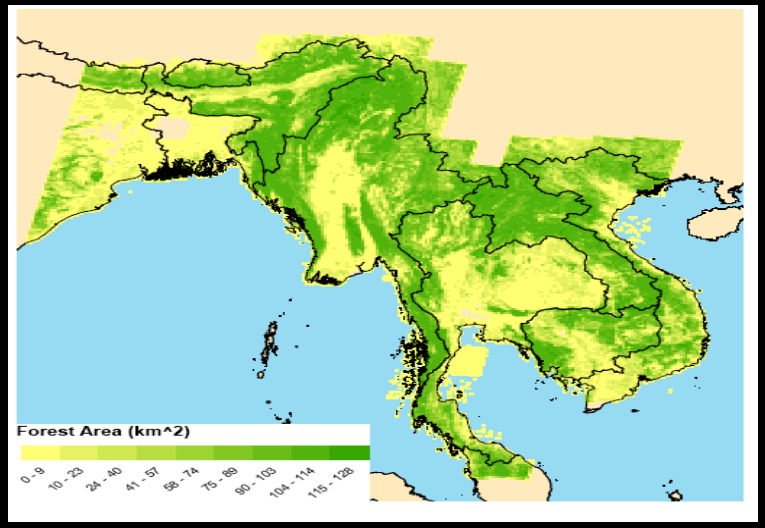
Application of Different Satellite Data Sets to Estimate LC Distribution for Historical time



MODIS LCLU data resampled at 250 meter resolution for the year 2005. The land classifications are based on University of Maryland scheme (Courtesy: Matt Hansen and others, UM) .

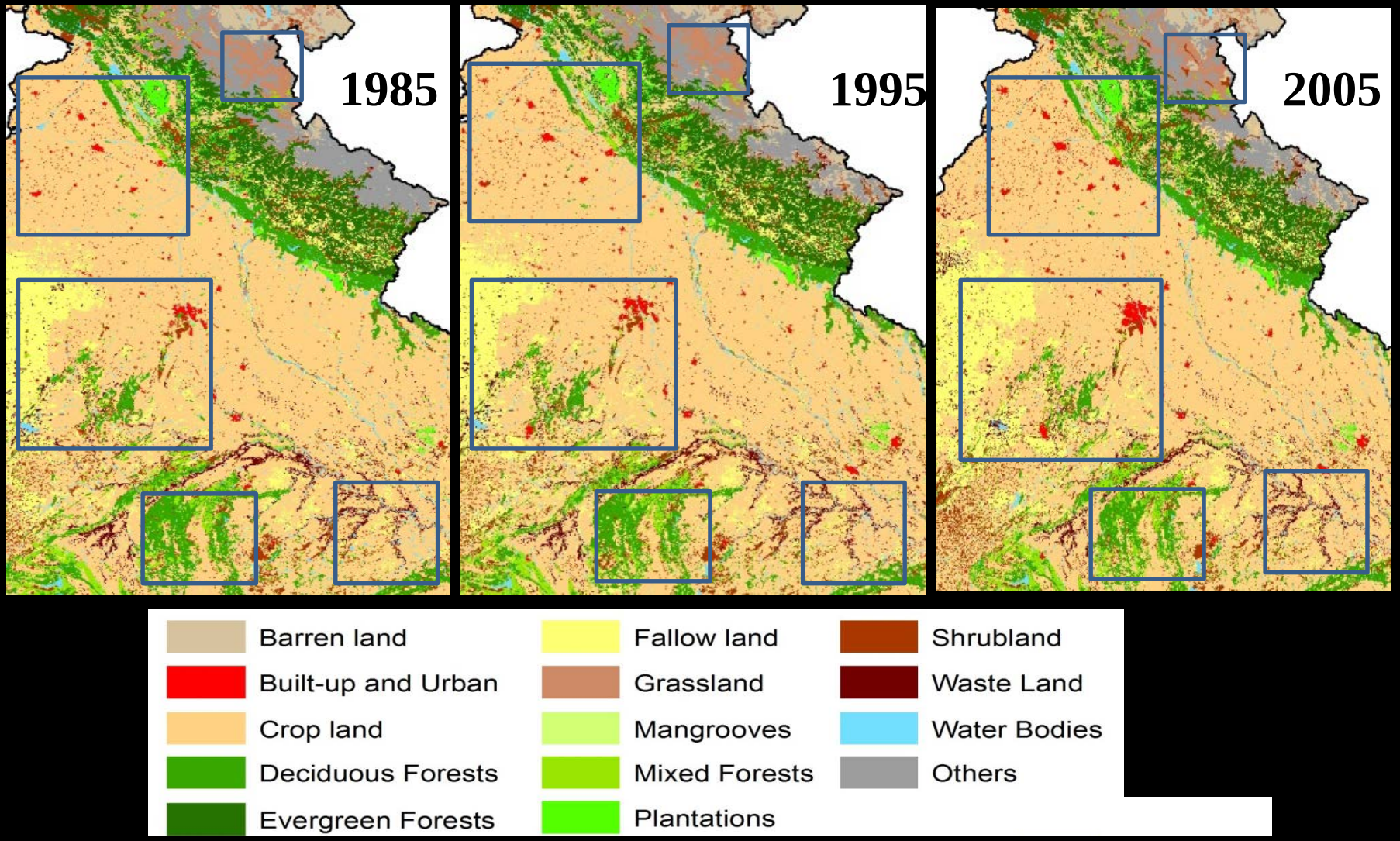


Remotely sensed LCLU data for India region at 56 m resolution (2004-2005) based on Indian satellite IRS-P6 (AWiFS) (Courtesy: P.S. Roy, ISRO) .



Remotely sensed forest fraction data for South East Asia at 30 m resolution (2005) based Landset satellite (Courtesy: Dave Skole, MSU).

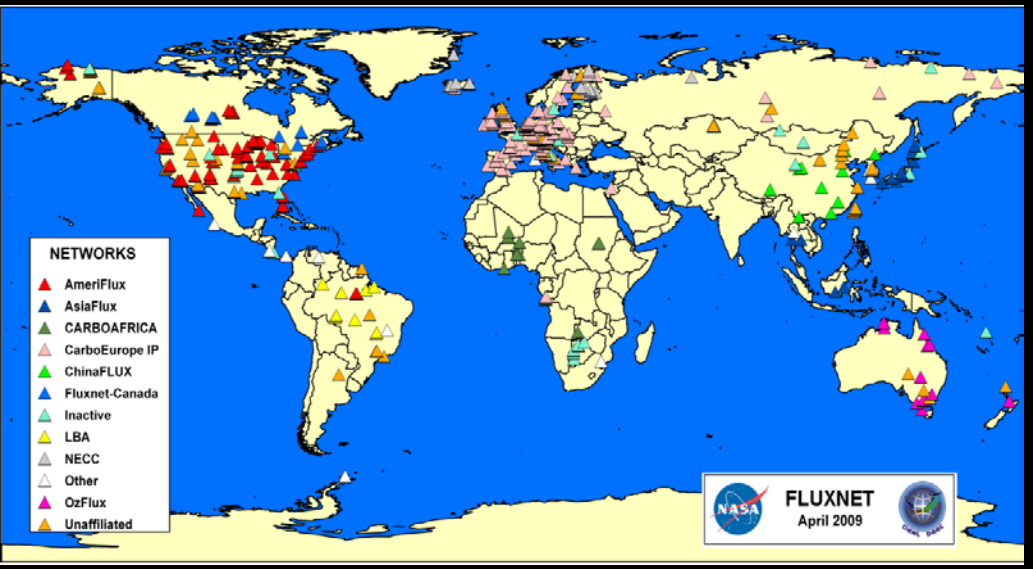
Application of Satellite Date to Estimate the LU Changes (India)



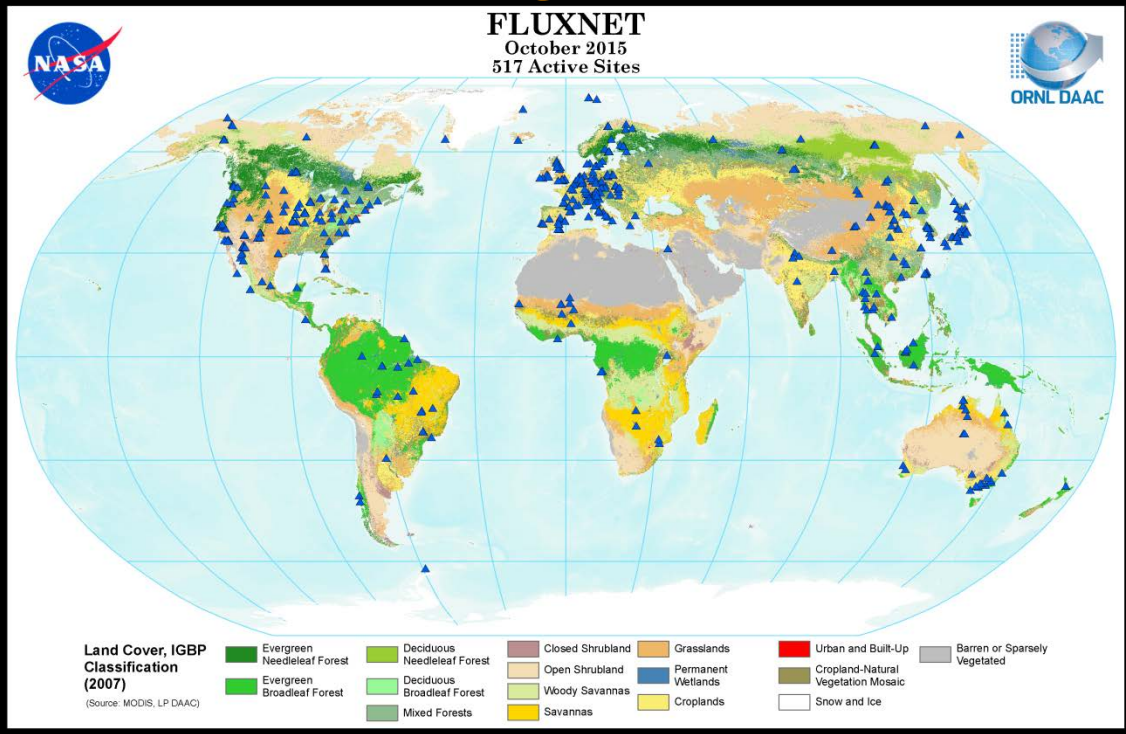
* Data available from NASA LCLUC Site

Roy et al. (Remote Sensing, 2015)

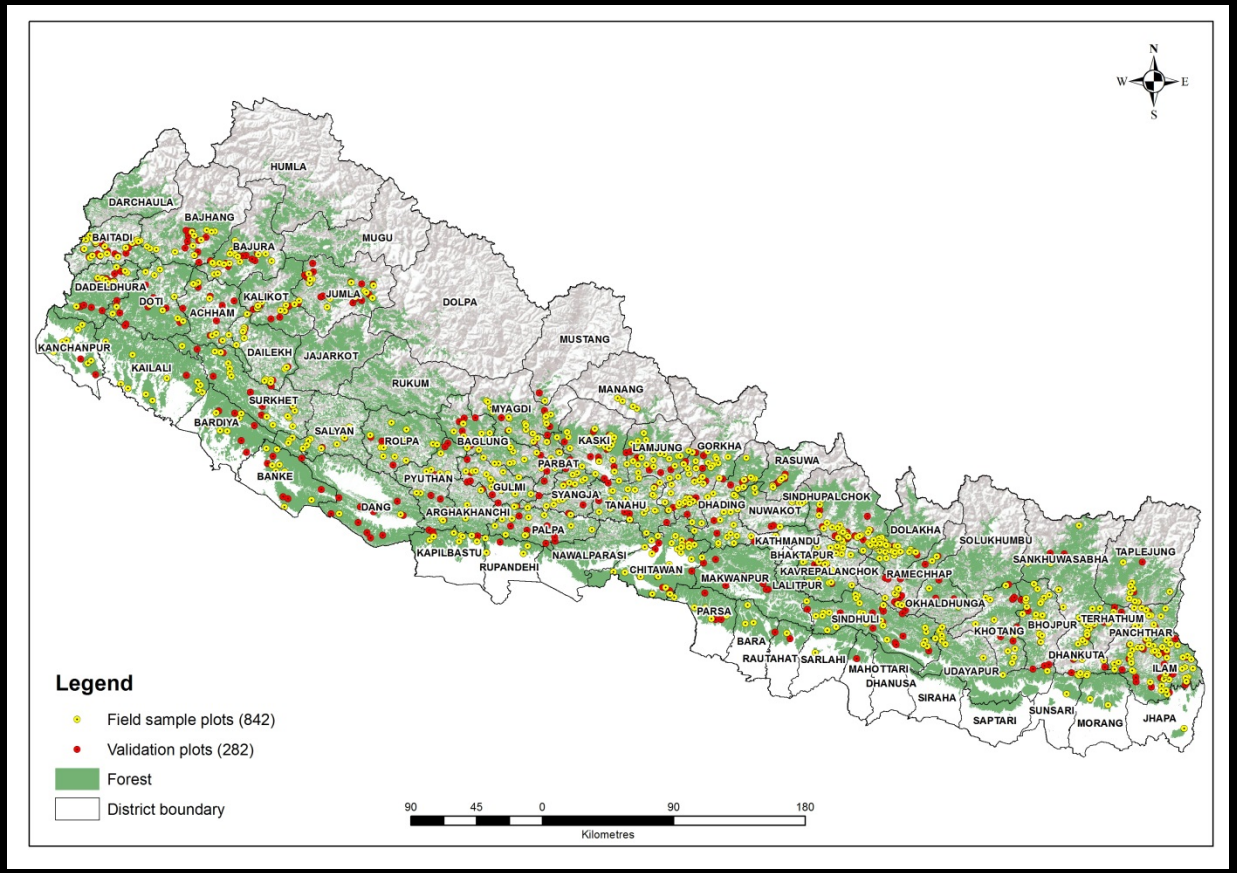
(1) Validation of DGVMs



Use of FLUXNET and Other Ground-Based Data to Validate DGVMs

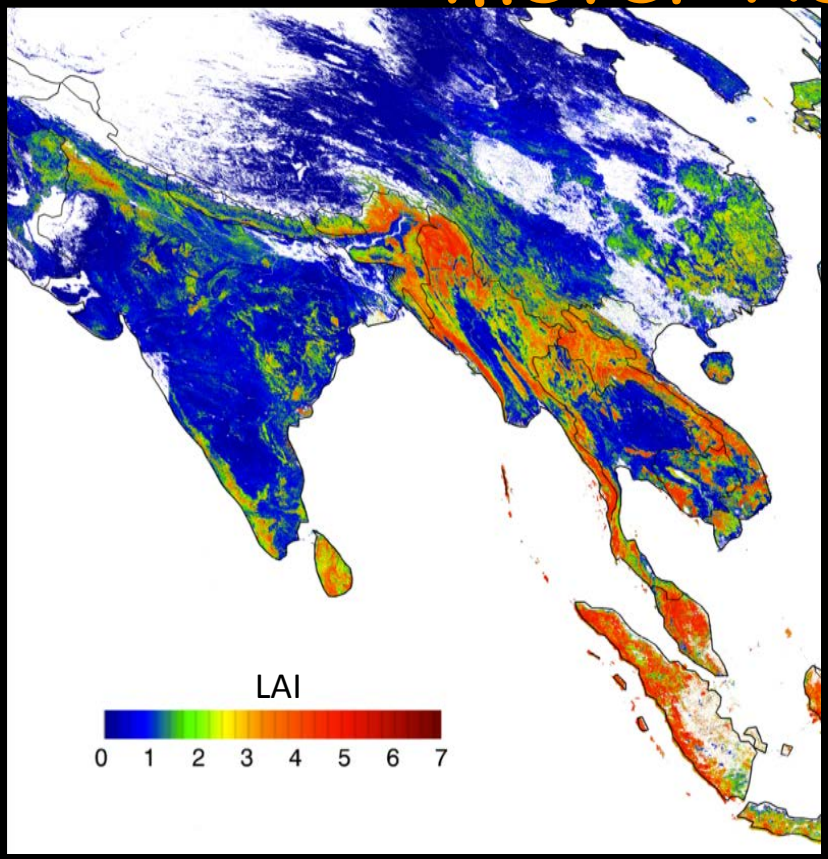


Above and Below Ground Biomass Data

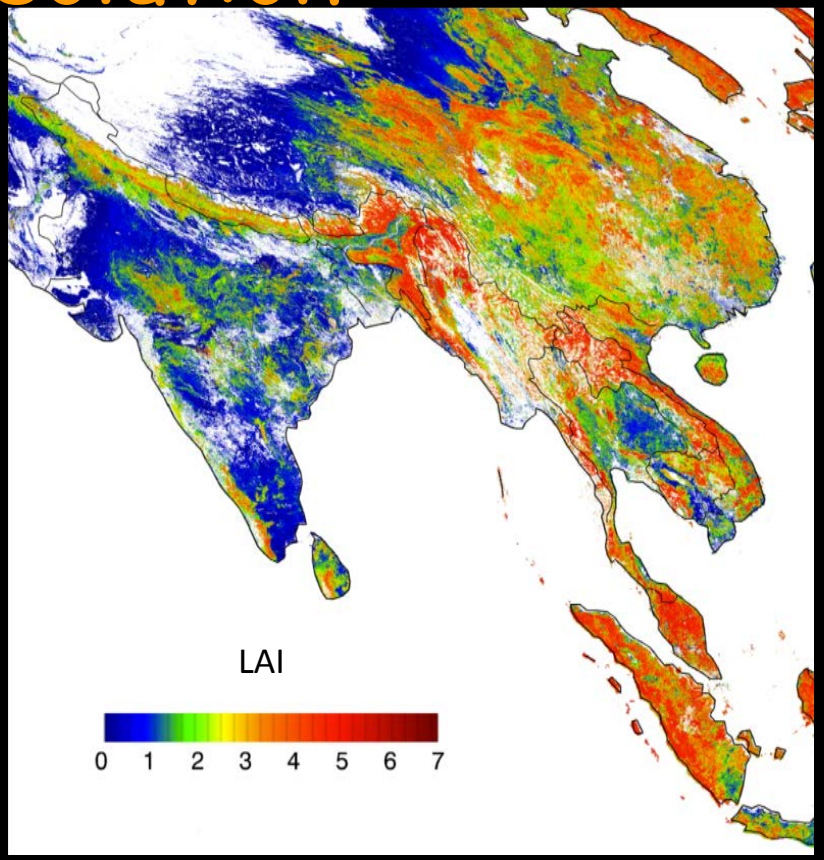


Total **1236 sample plots in NEPAL** measured AG Biomass between 2013 -2015

Application of MODIS and LANDSET Satellite Data to Calculate LAI at 30 meter Resolution



Peak LAI Averaged for the Winter Months (Dec., Jan., Feb)

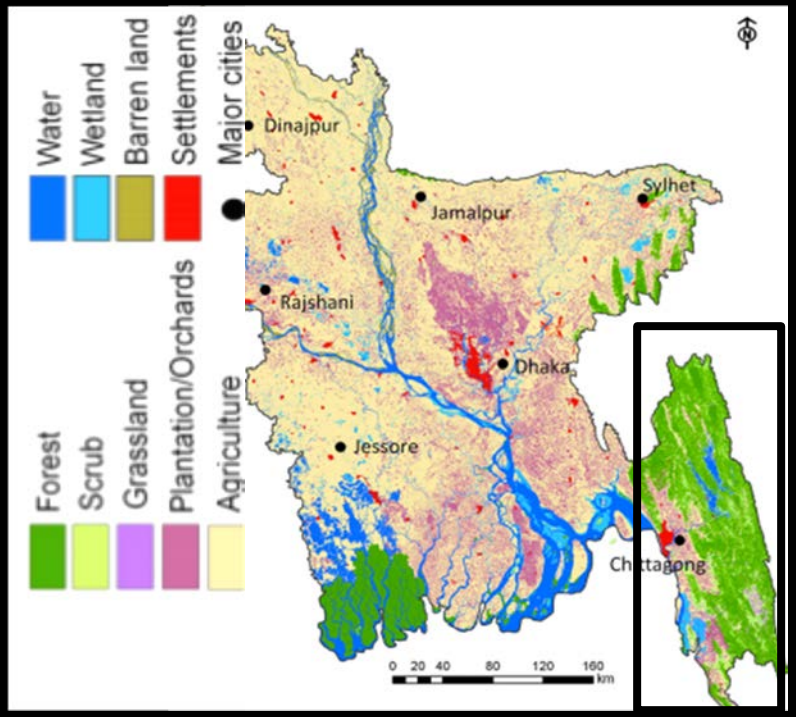


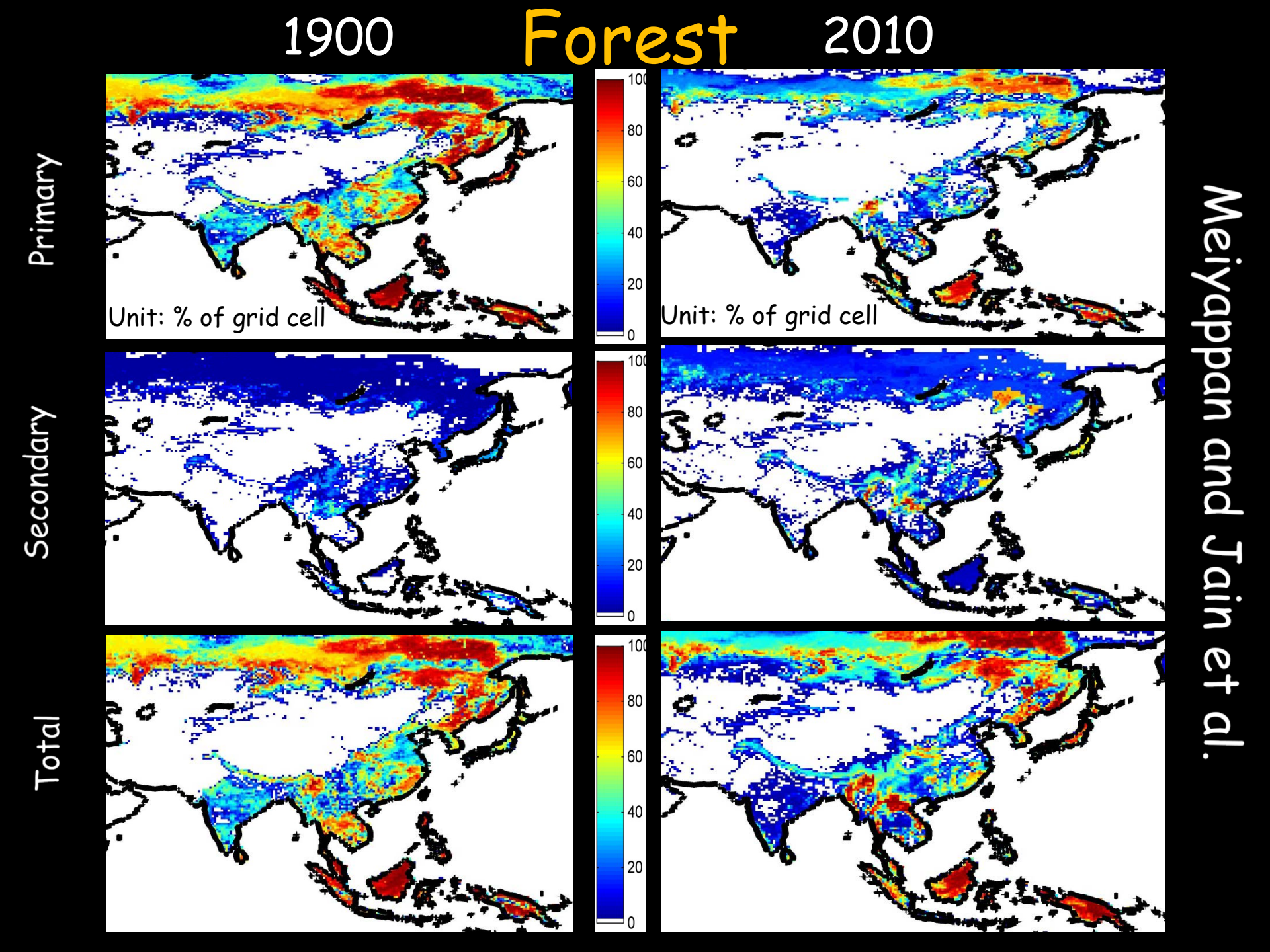
Peak LAI Averaged for the Summer Months (Jun., Jul., Aug)

(Courtesy: Sangram Ganguly and Ramakrishna Nemani, NASA Ames).

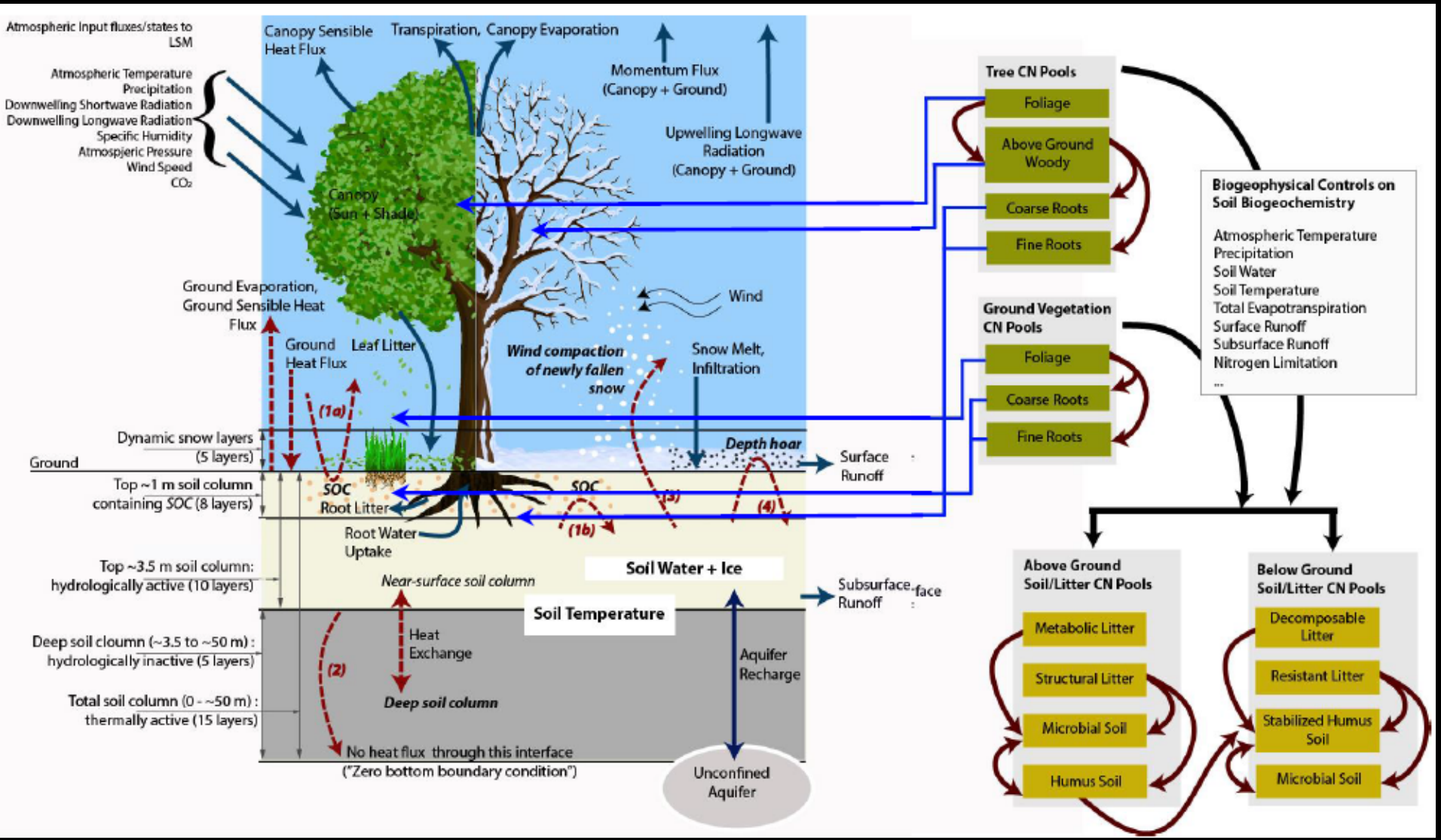
Thank You

Application of Satellite Date to Estimate the LU Changes (Bangladesh)

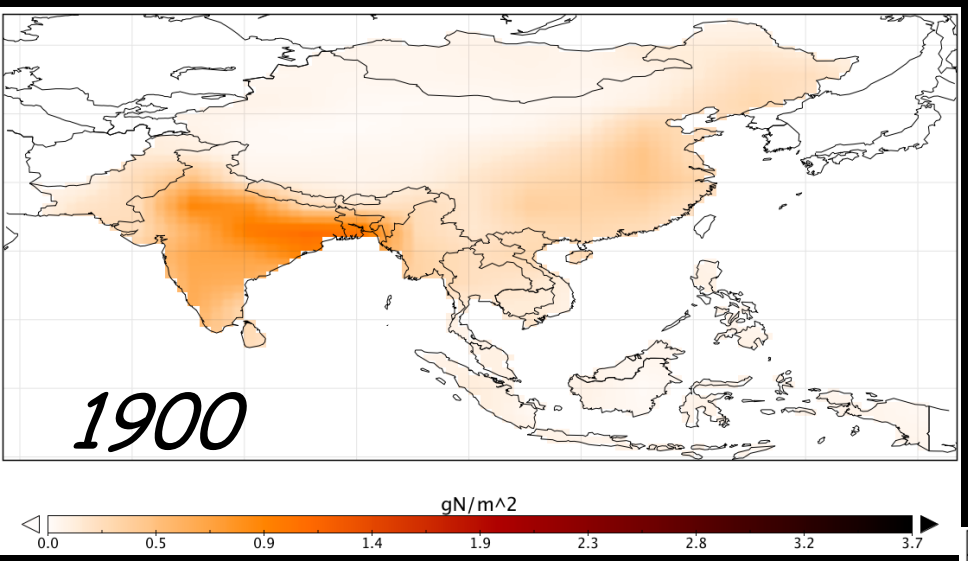


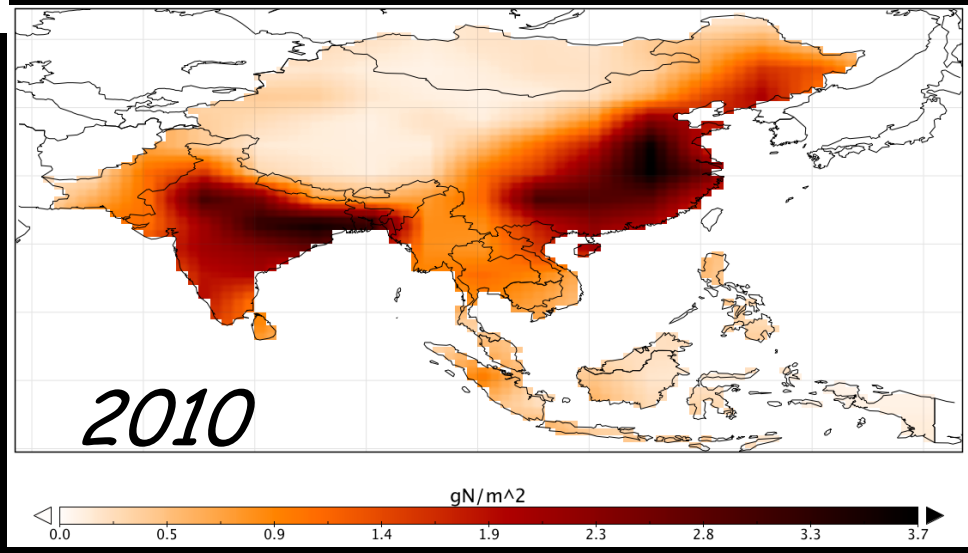

1900
Forest
2010
Primary
Secondary
Total
Unit: % of grid cell
Unit: % of grid cell
100
80
60
40
20
0
Meiyappan and Jain et al.

ISAM Land-Surface Model - Conceptual Diagram



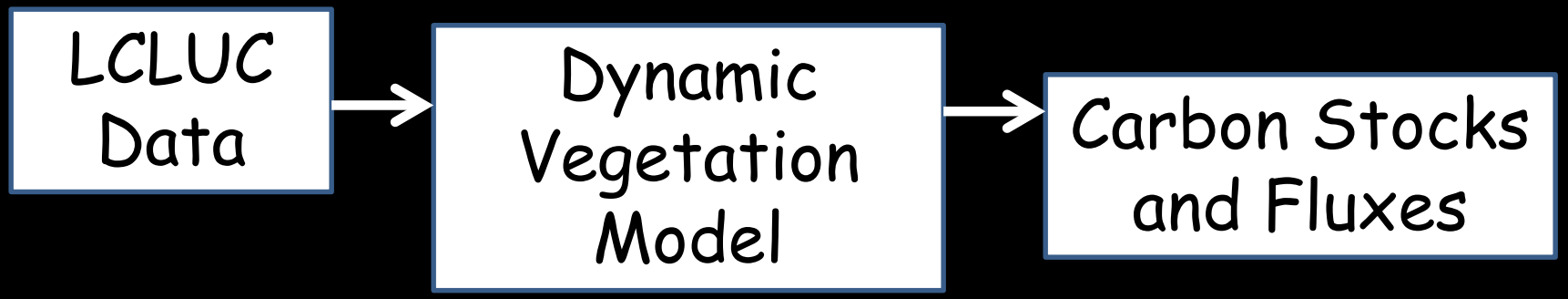
Nitrogen Deposition - Fossil Fuel Burning





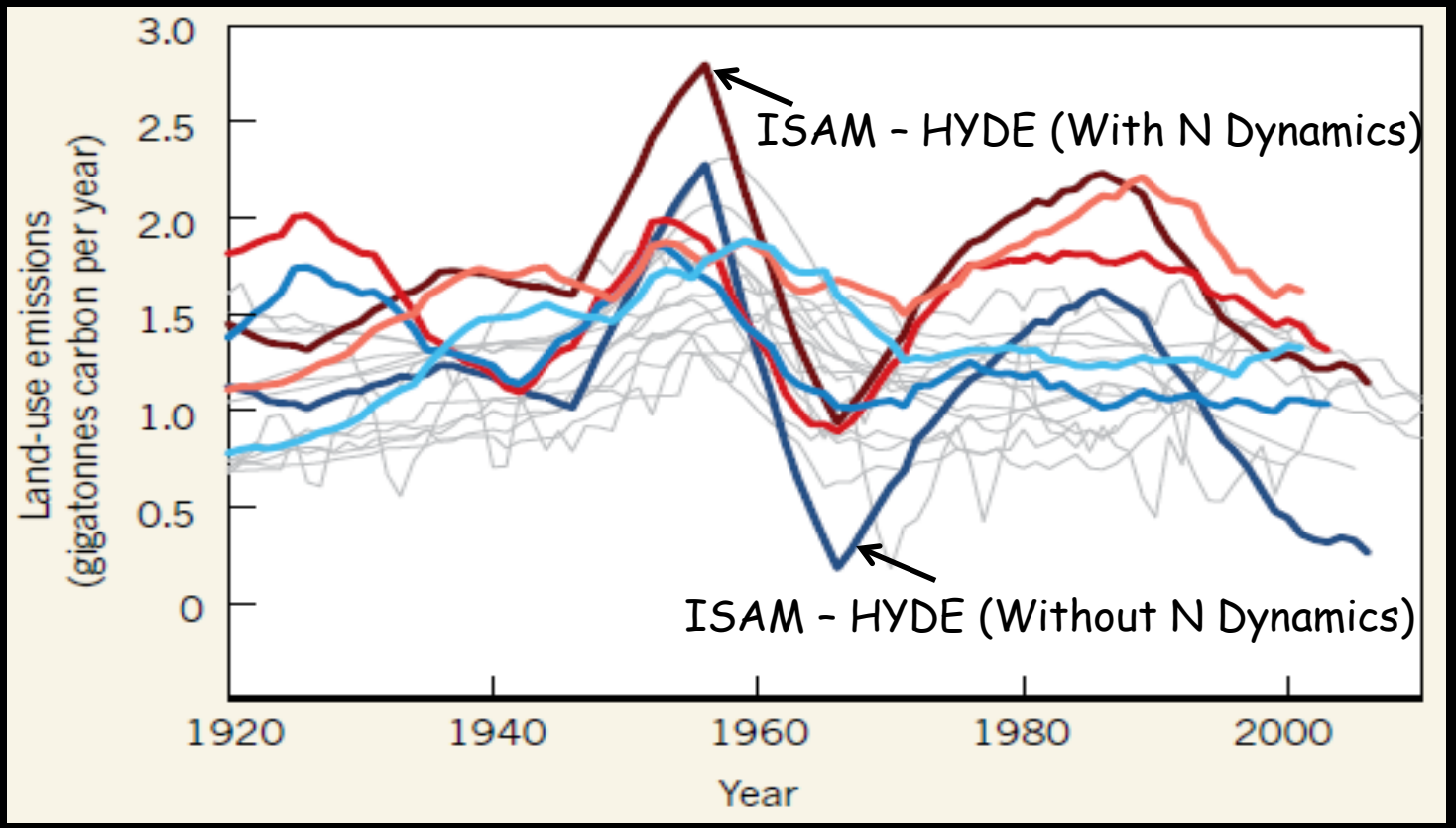
Galloway et al.

Estimating the Impact of LCLUC on Carbon Stocks and Fluxes



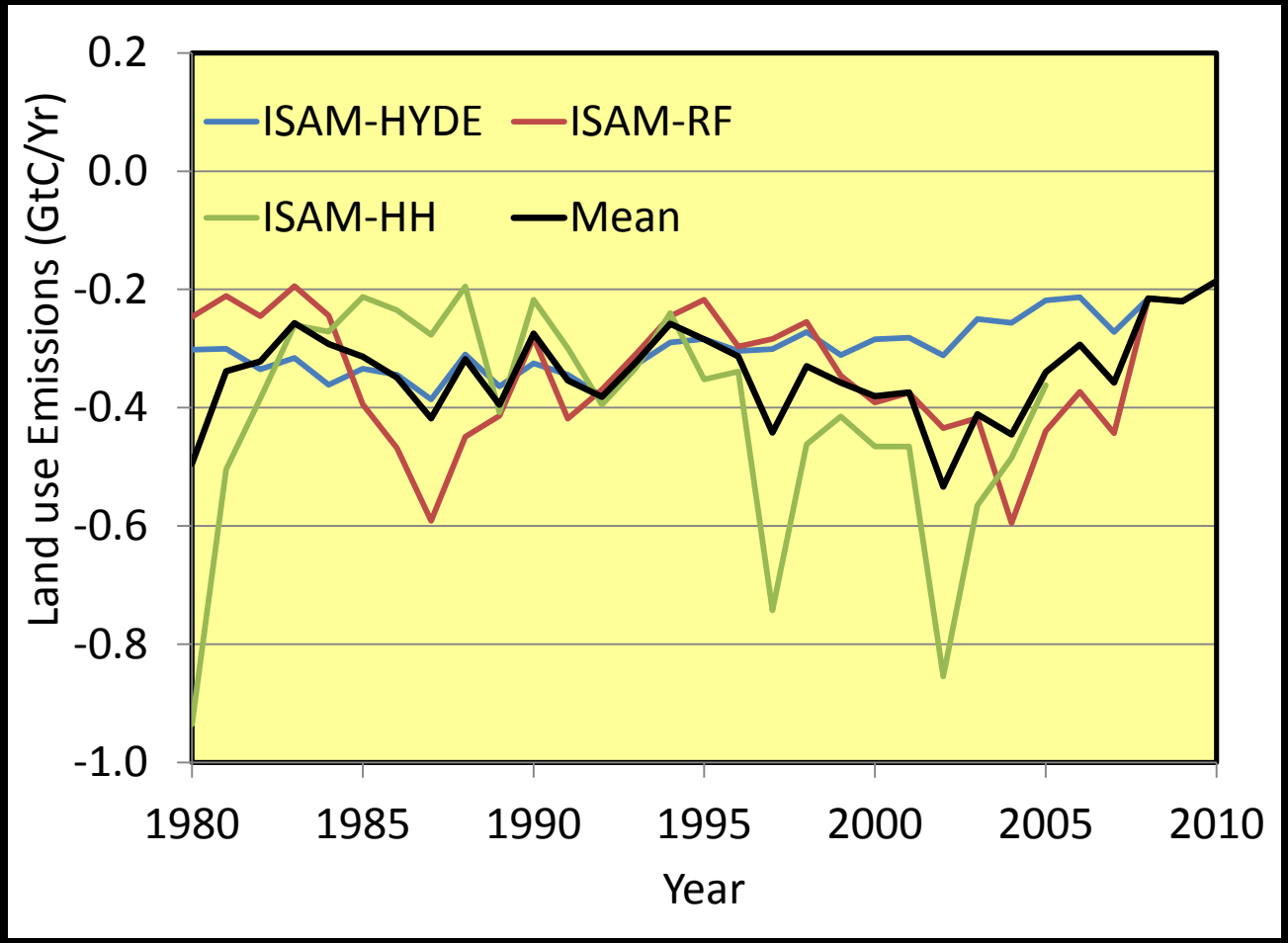
- Uncertainty in Carbon Stocks and Fluxes could be due to
  - Uncertainty in LCLUC Data
  - Uncertainty in process level understanding of parameterization of different biogeochemical (BGC) and biophysical (BGP) processes

Estimates of Land Use Emissions for CO_2 Calculated based on Various Dynamic Vegetation Models



Pongratz (2013, Nature)

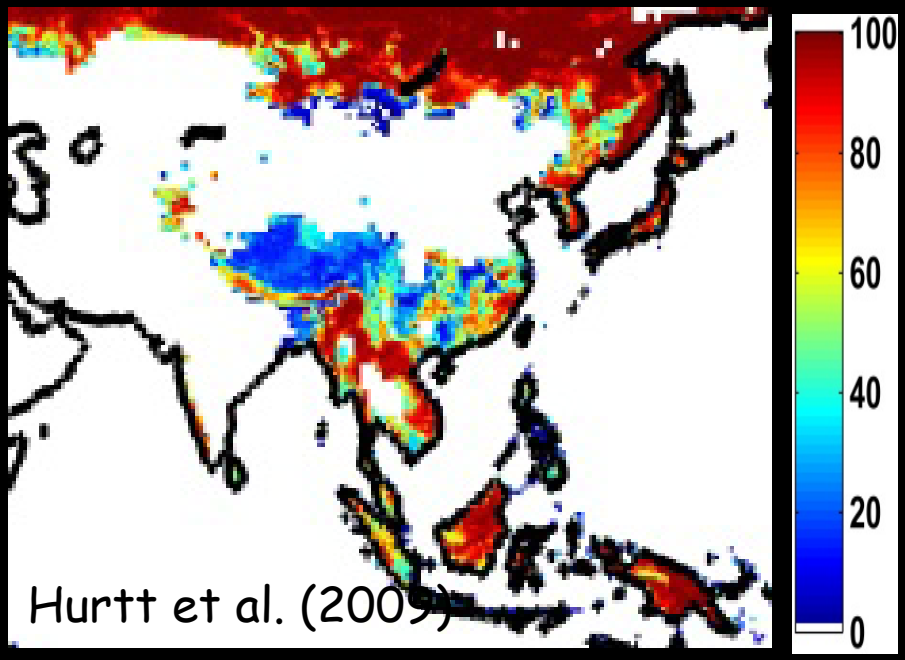
ISAM Estimated Land use Emissions based on three different data sets (GtC/yr)

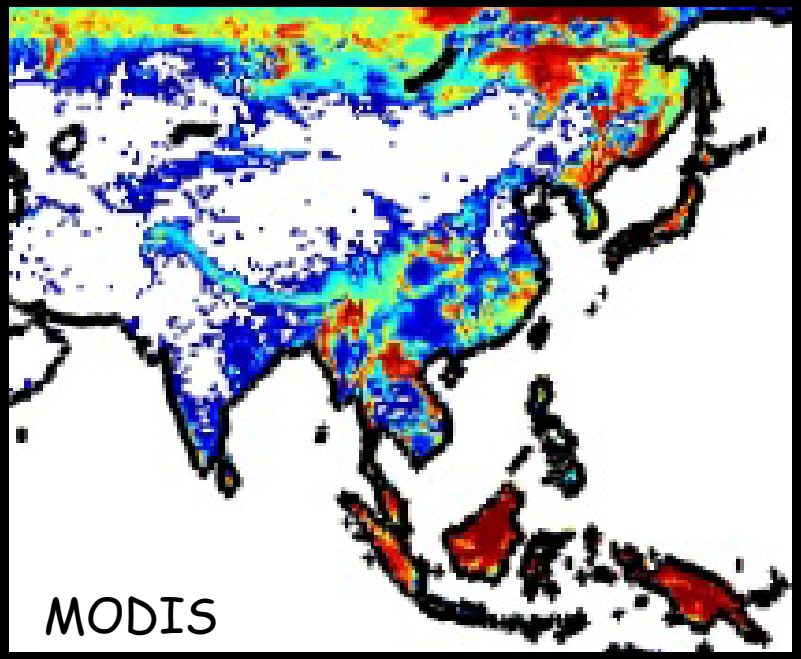


Negative values represent net C release to the atmosphere

Jain et al. (GCB, 2013)

Estimates of Forests Unit % of Grid Cell

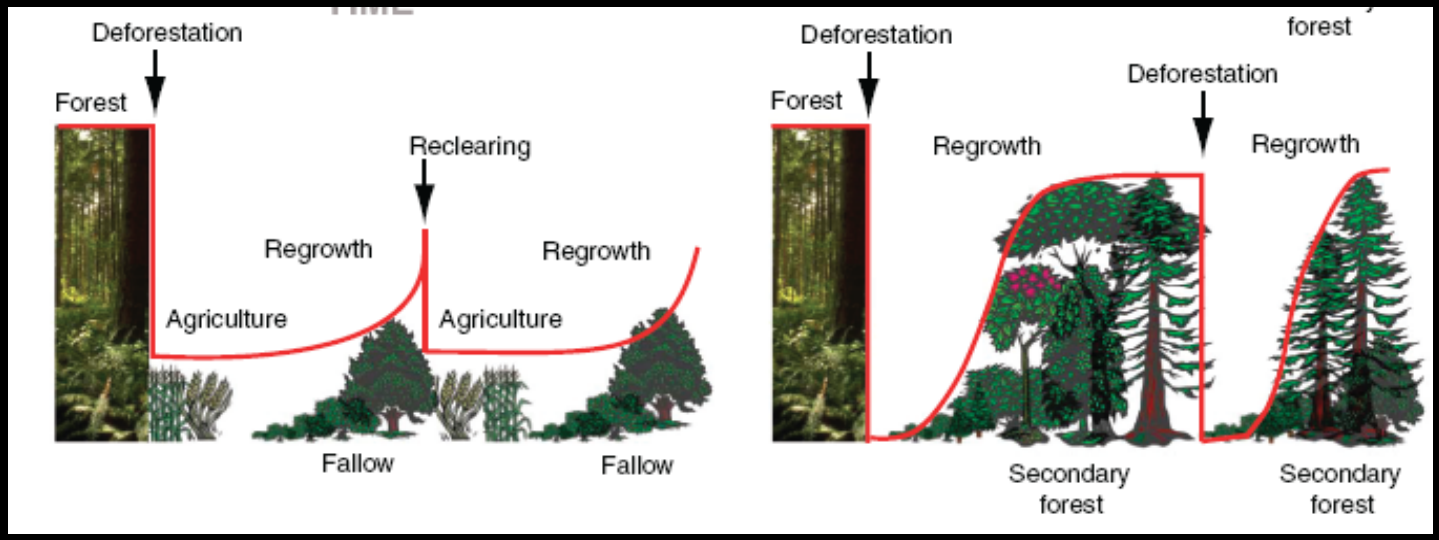




Data sets do not account of changes in land cover, which are resulting from both indirect anthropogenic and natural causes.

Meiyappan and Jain (2012)

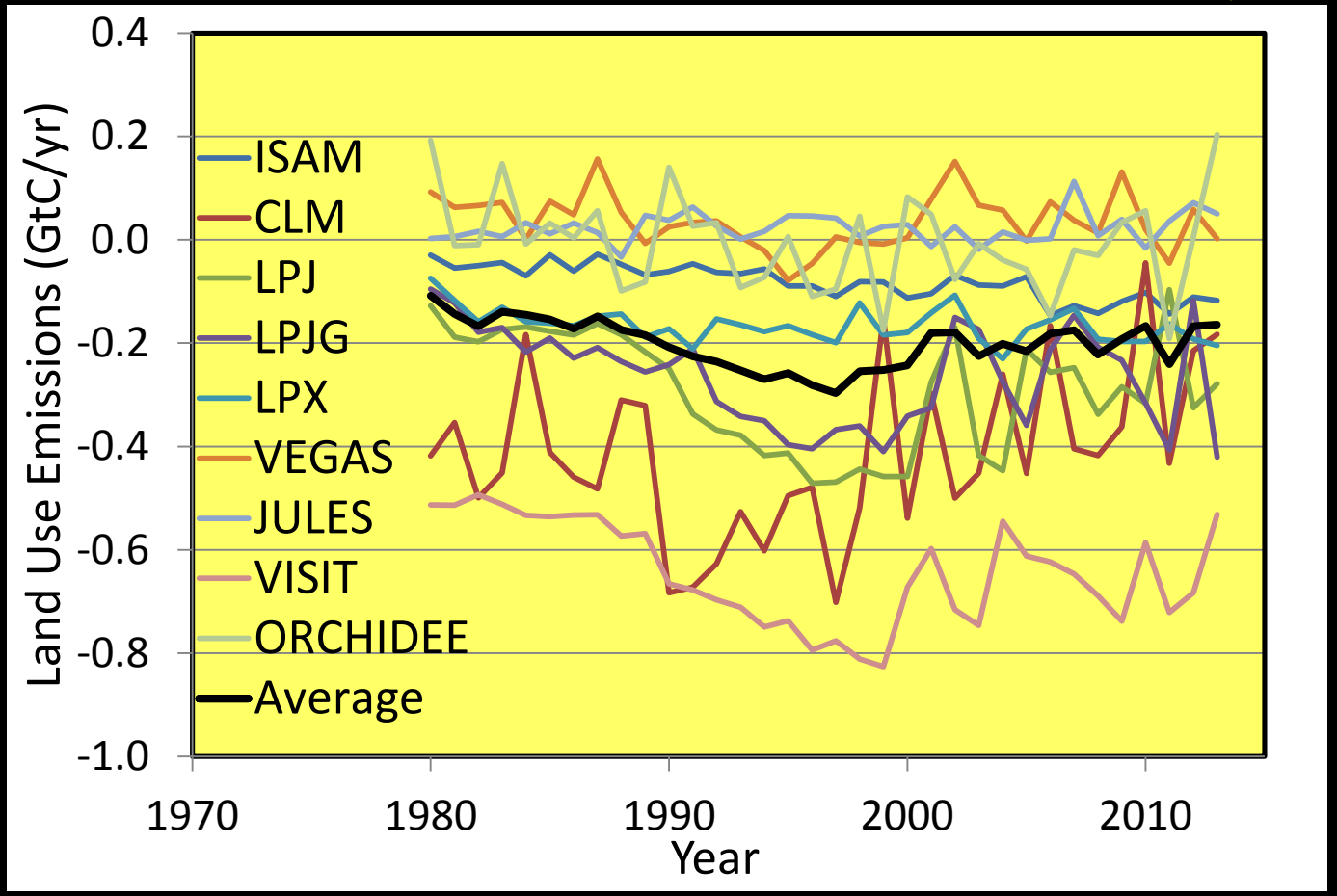
Land Use Change Data is Available at Decadal or Longer Time Scale



Over the decadal and longer time scales different pathways of carbon dynamics after deforestation

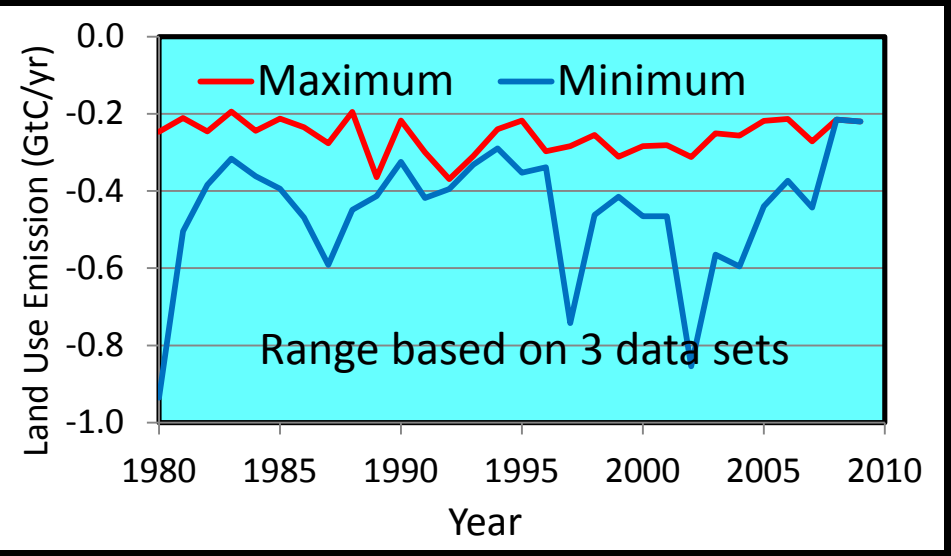
Ramankutty et al.

Land Use Emissions Estimated Based on 9 DGVMs (GtC/yr)



Negative values represent net C release to the atmosphere and positive values net C storage in terrestrial biosphere

Overall Uncertainty



Uncertainty range for recent decade
-0.43 – (-0.24) GtC/yr

Uncertainty range for recent decade
-0.65 – 0.07 GtC/yr