Joint NASA LCLUC Science Team Meeting -
Land Cover and Land Use Chang in SE Asia
Hanoi, Vietnam
Nov 7-9, 2011

Land Cover and Land Use Change and Its Effects of Carbon Dynamics in Monsoon Asian Region (MAR)

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LCLUC and Carbon (and Climate) Dynamics in MAR

LCLUC activities impacts the livelihood pattern of the people who are dependent on land directly

- agriculture - food production and raising livestock
- forestry - production of wood products (such as timber or paper), and biomass as an energy source

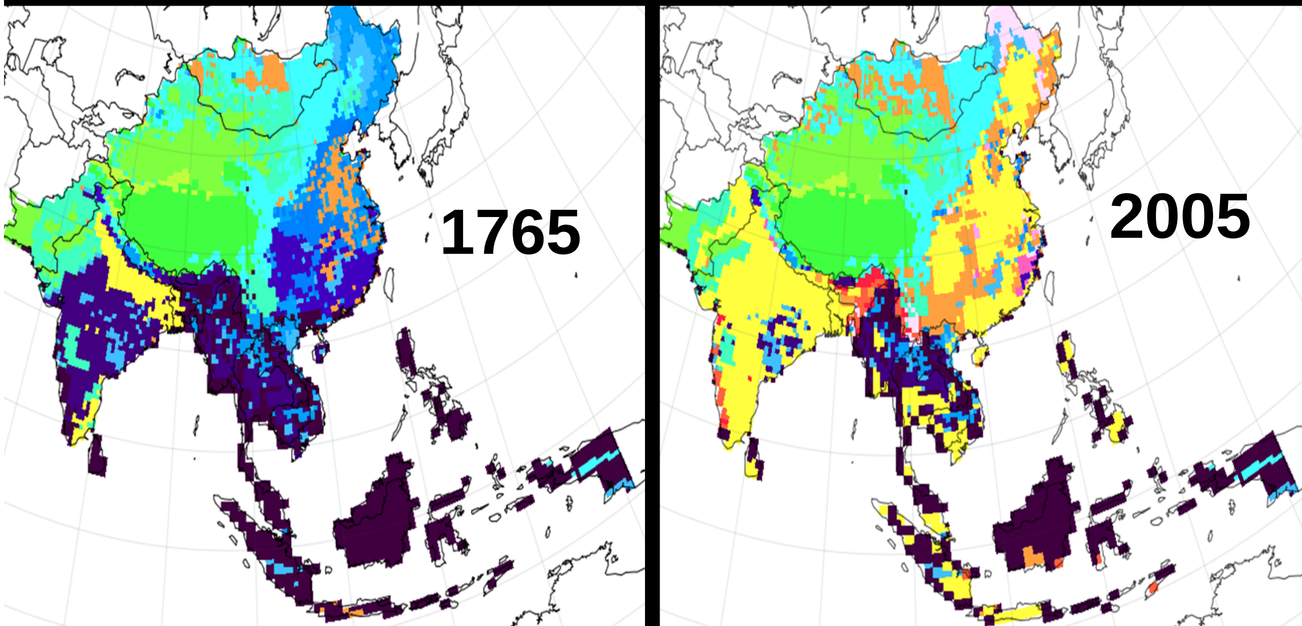
LUC activities impact our environment and climate

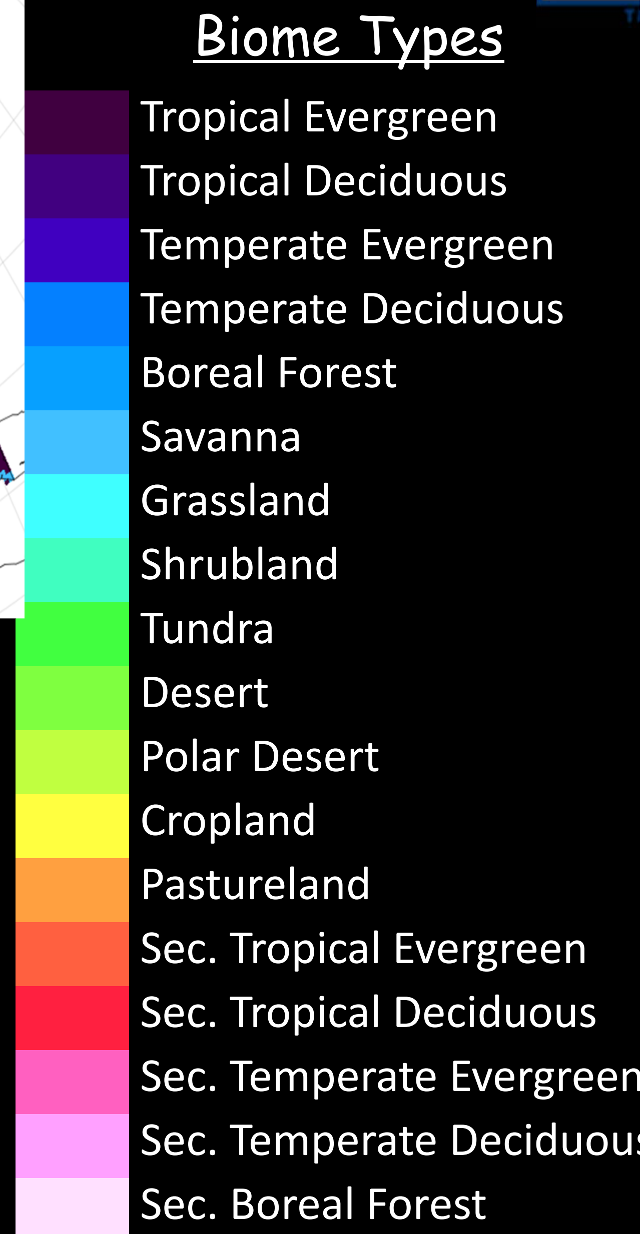
- source of atmospheric CO_2
- changes hydrological cycle and Earth's energy budget

MAR Forests – planetary savior – promote avoided deforestation, reforestation, or afforestation

Biofuel plantations to lower albedo and reduce atmospheric CO_2

Land Cover Change in MAR

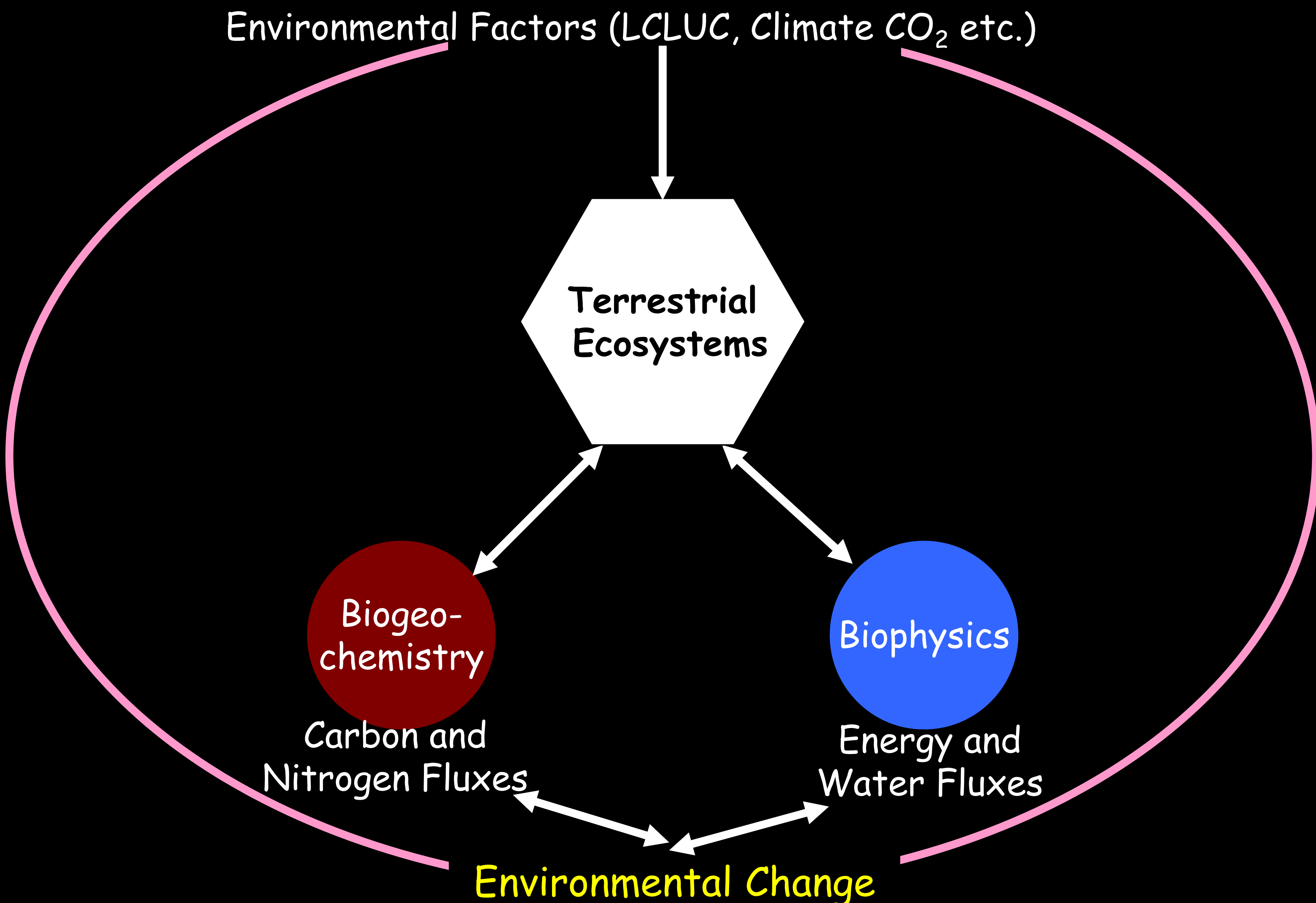




- Less primary land, more secondary land, more cropland and pastureland
- Land use alters : *Atmospheric CO_2, N cycle, albedo, runoff, soil water holding capacity, Biodiversity*

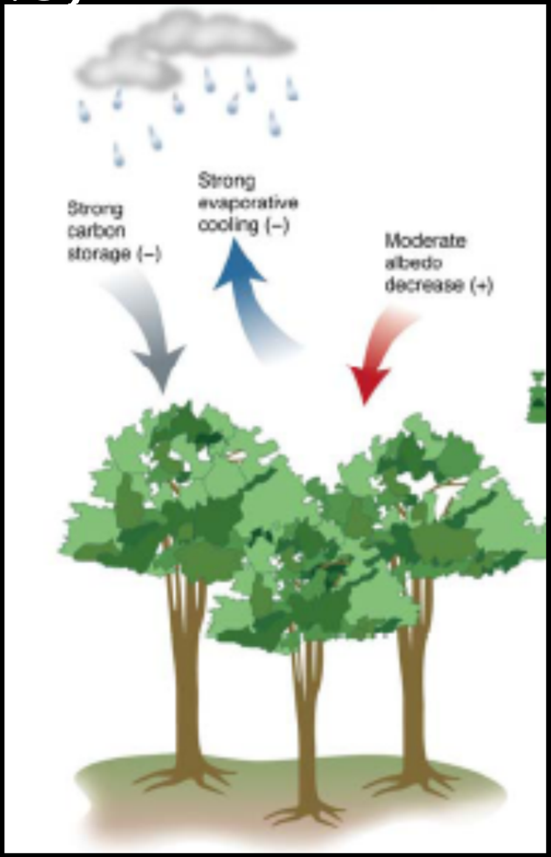
Jain and Yang (2005, GBC); Yang et al. (2009, GBC)

Environmental Factors and Processes



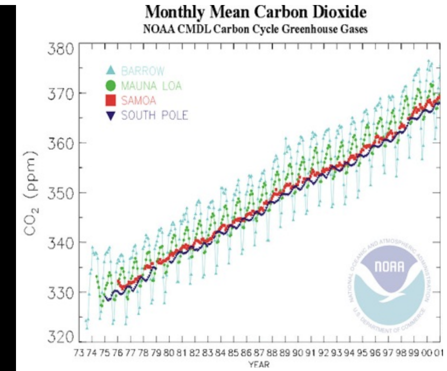
LCLUC and Biophysical Drivers on Land

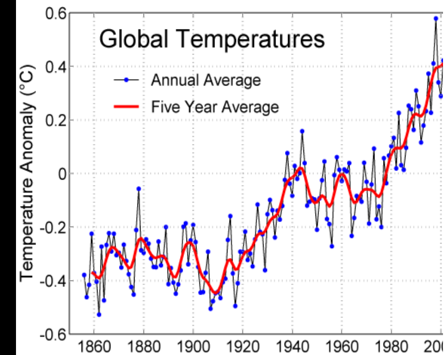
- Evapotranspiration (forests > crops > bare ground)
- Latent heat (forests > crops > bare ground)
- Albedo (bare ground > crops > forests)
- In tropics, LH effects dominate over albedo effects.
- Conversion of forests to crops in tropics increases albedo (cooling effect), but this is overwhelmed by large decrease in latent heat flux to atmosphere (warming effect), resulting in a net warming in tropics.

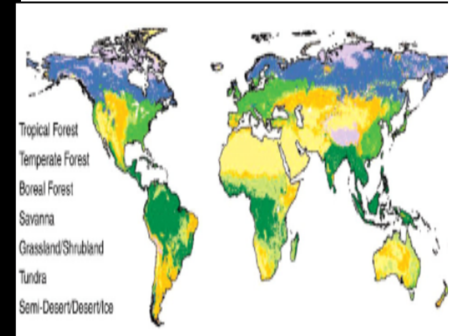


Today's Talk

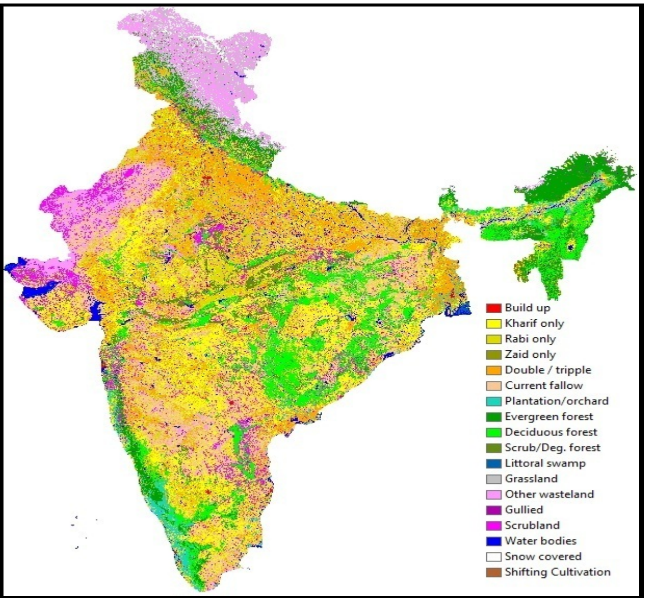
- Quantify the impacts of historical and future LCLUC on carbon and nitrogen dynamics in MAR
  - LCLUCs data (ground- and satellite-based)
    - LC distribution
    - Historical LUC data (e.g., cropland, pastureland and wood harvest, secondary forests)
  - Biogeochemistry model (ecosystems and carbon and nitrogen dynamics)
    - Measured data (ground- and satellite-based) for several model input and output variables (e.g., LAI, GPP, NPP)
    - Measured (or model-based) data for different environmental factors (e.g., CO_2, Temperature, Precipitation, N deposition)



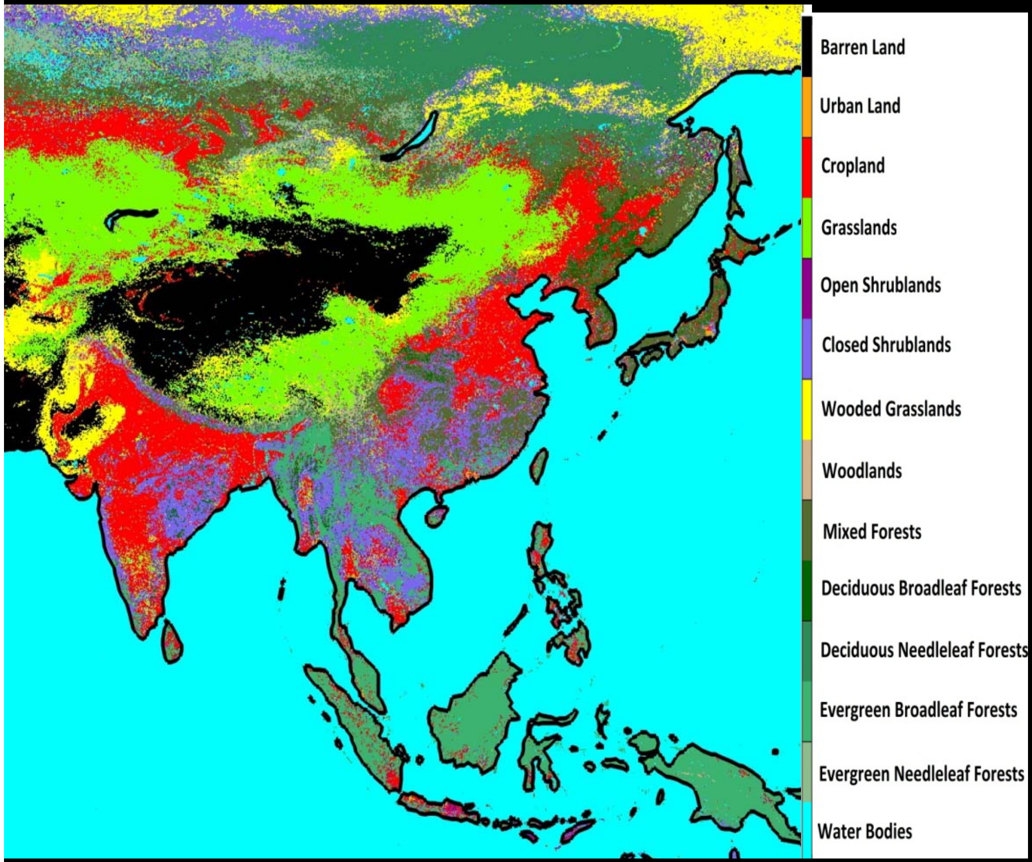




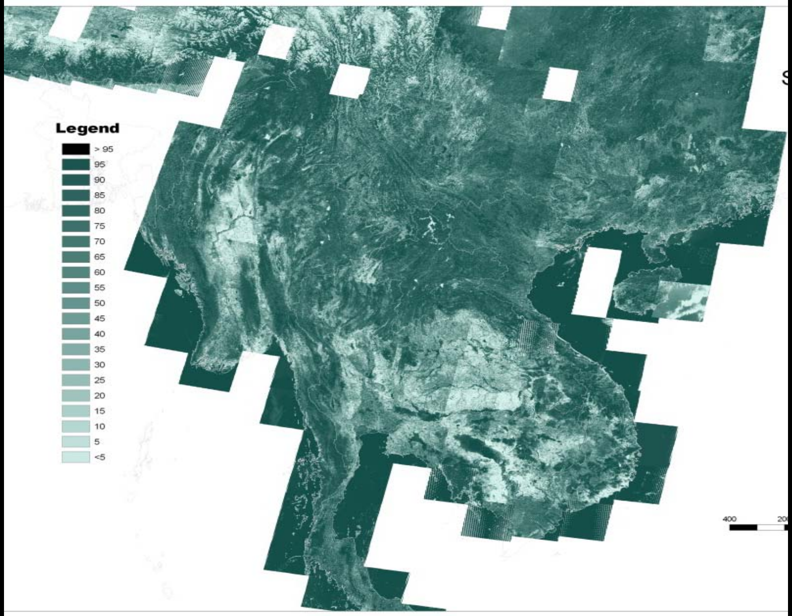
Application of Different Satellite Data Sets to Estimate LC Distribution for Historical time



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) .



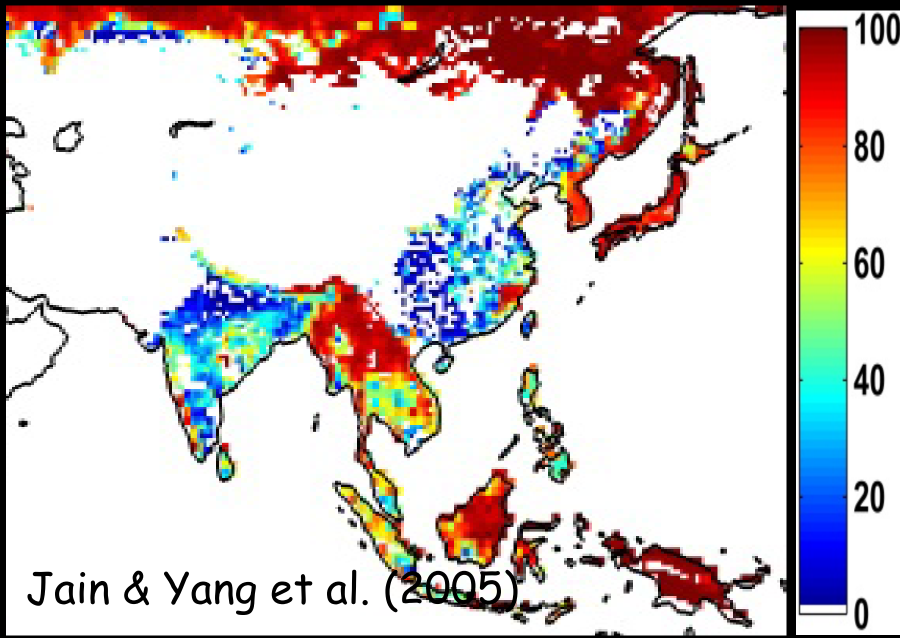
MODIS LCLU data resampled at 250 meter resolution for the year 2005. The land classifications are based on University of Maryland scheme (Courtesy: Matt Hansen and others, UM) .

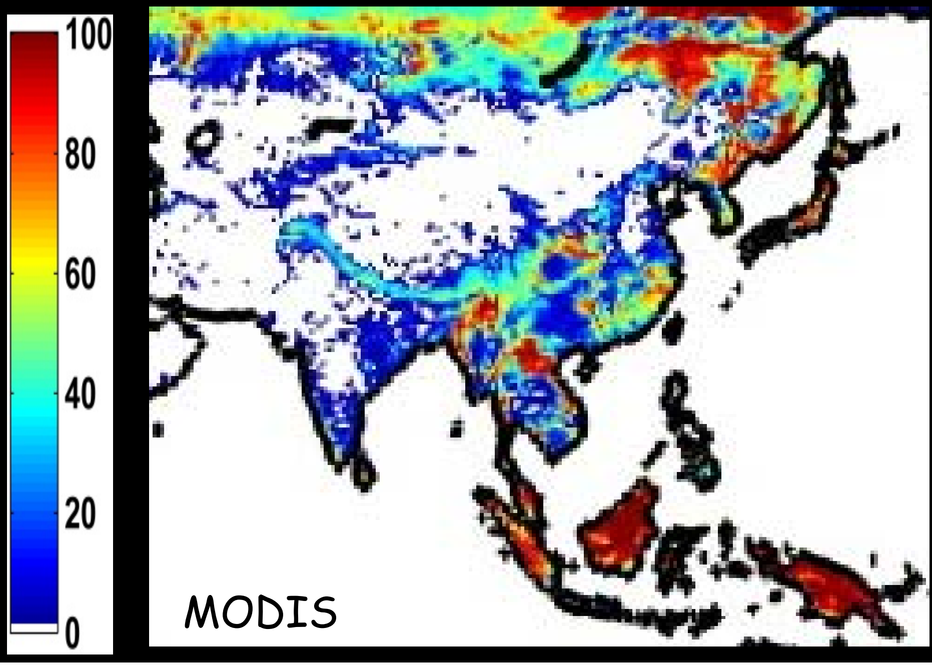


Remotely sensed forest fraction data for South East Asia at 30 m resolution (2005) based Landset satellite (Courtesy: Dave Skole, MSU).

Estimates of Forest During 2005

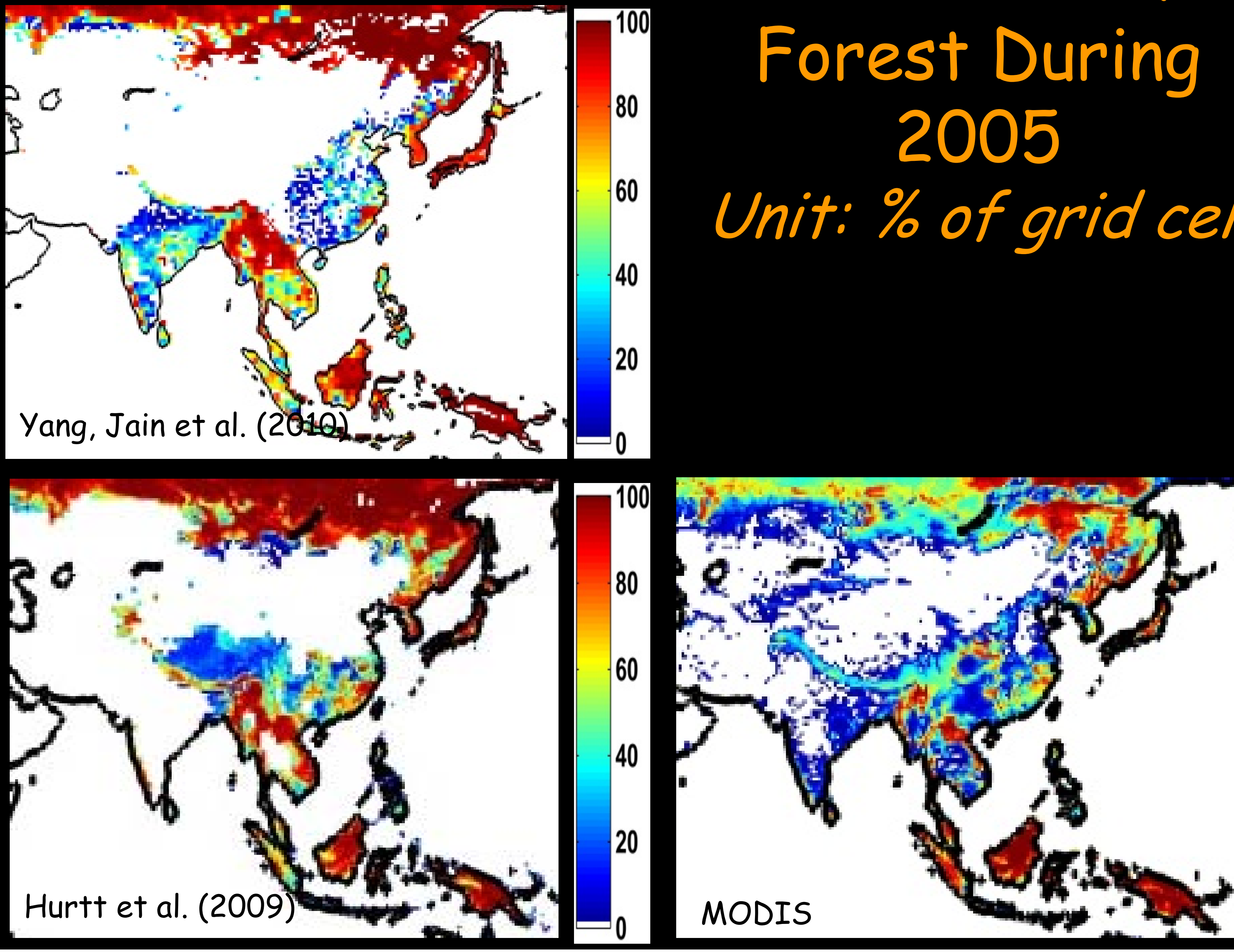
Unit: % of grid cell





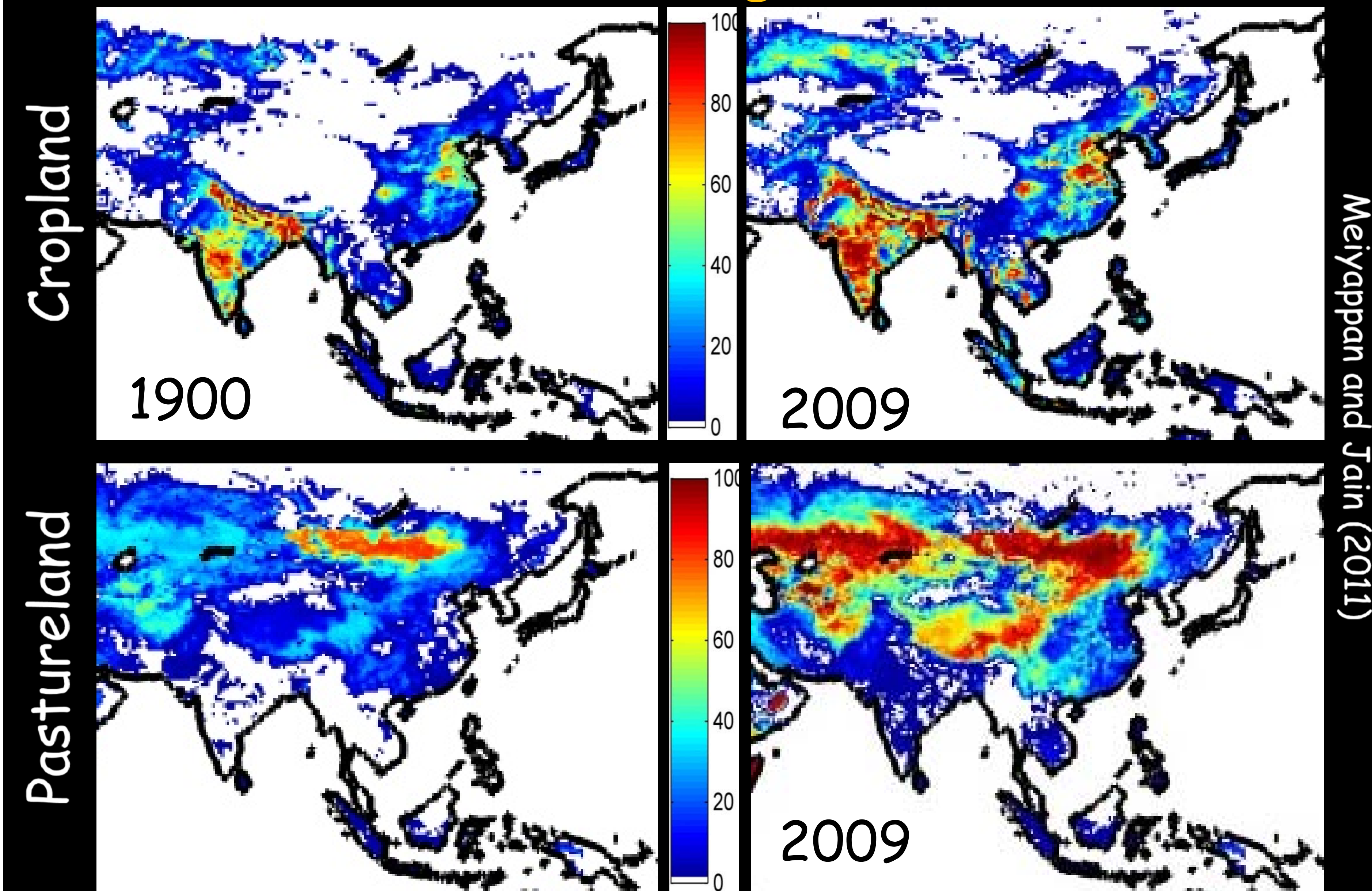
Estimates of Forest During 2005

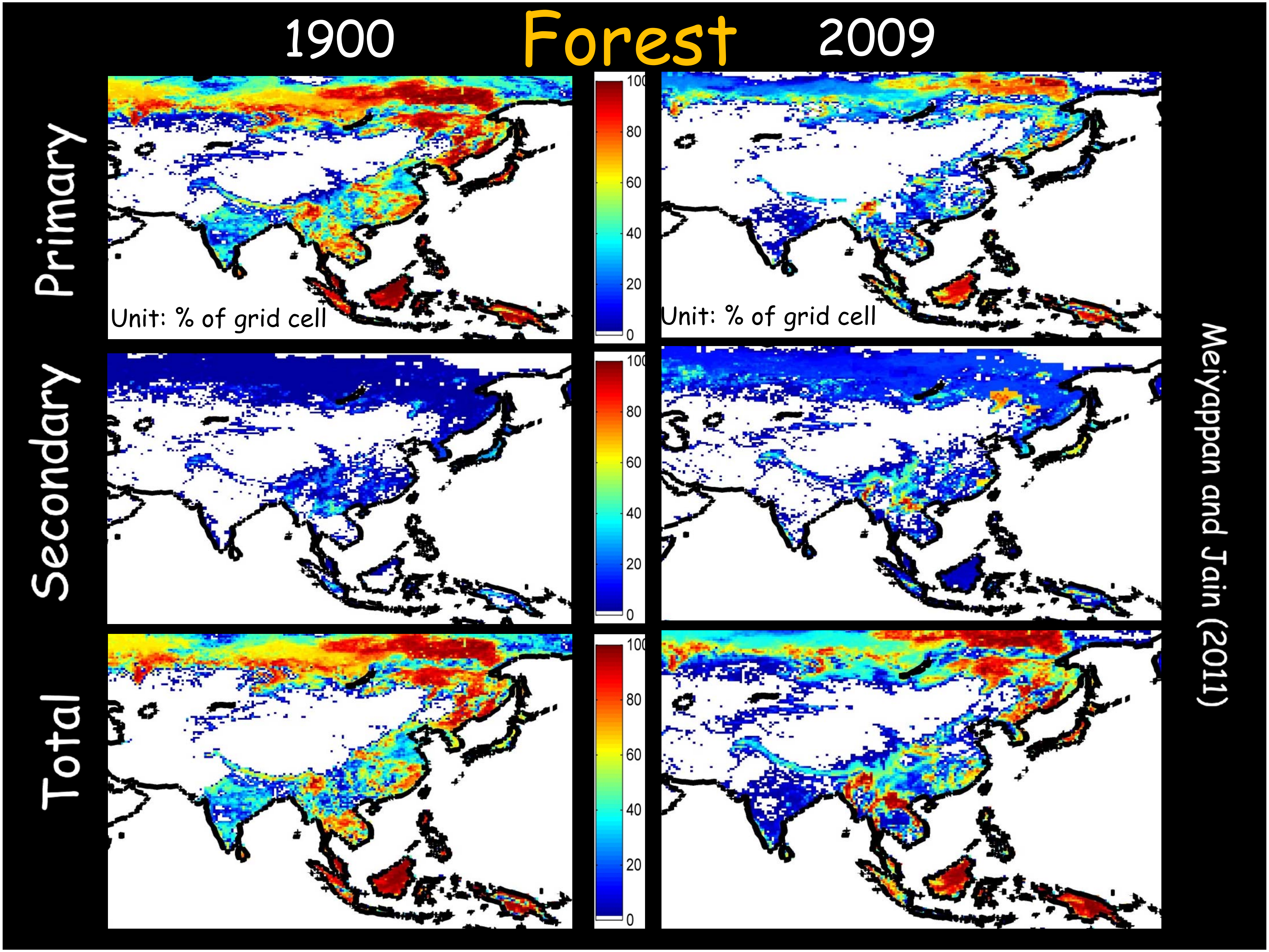
Unit: % of grid cell



Meiyappan and Jain (2011)

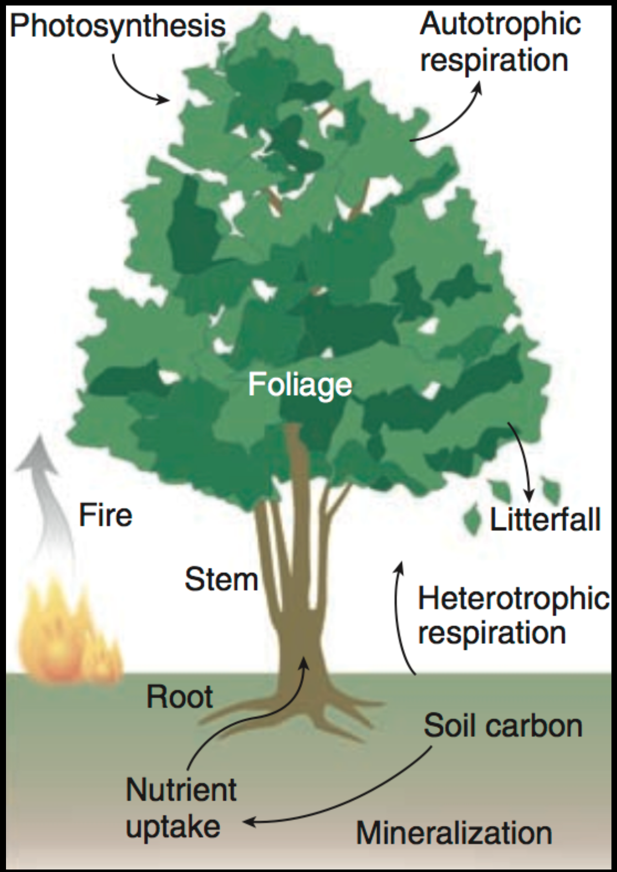
Land Use Changes Due to Human Activities
Unit: % of grid cell

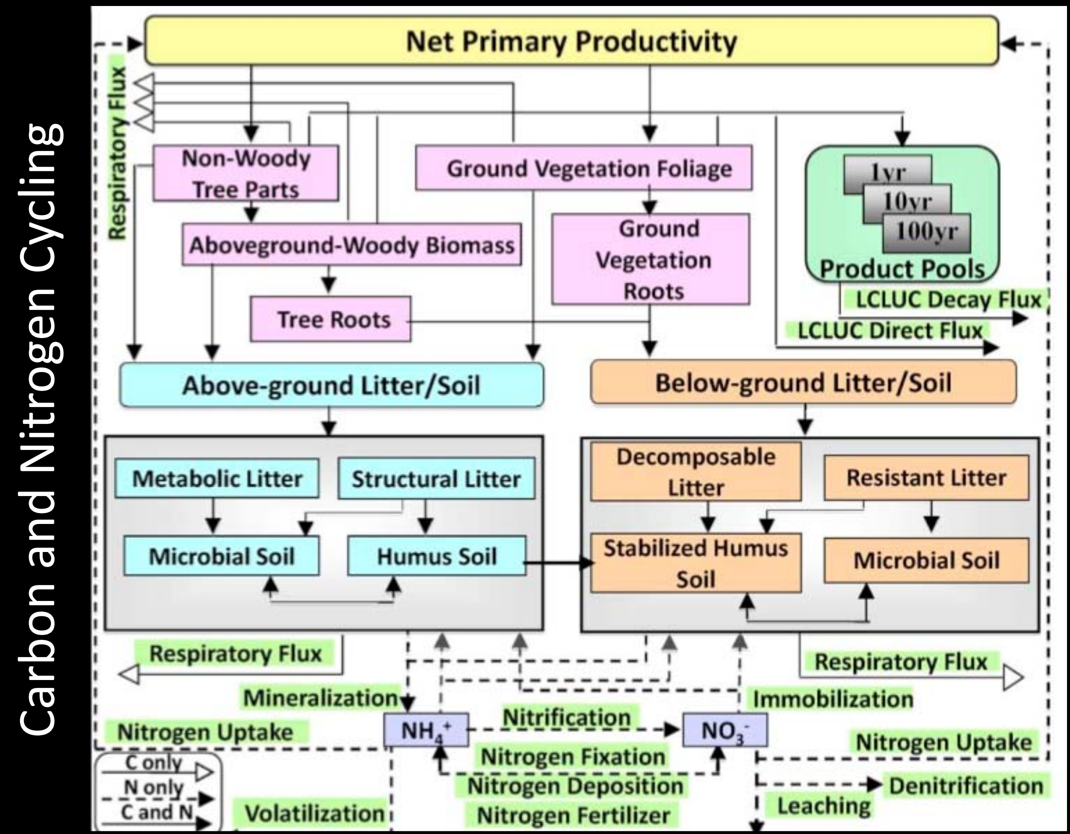




1900
Forest
2009
Primary
Secondary
Total
Unit: % of grid cell
Unit: % of grid cell
100
80
60
40
20
0
Meiyappan and Jain (2011)

ISAM Land-Surface Model

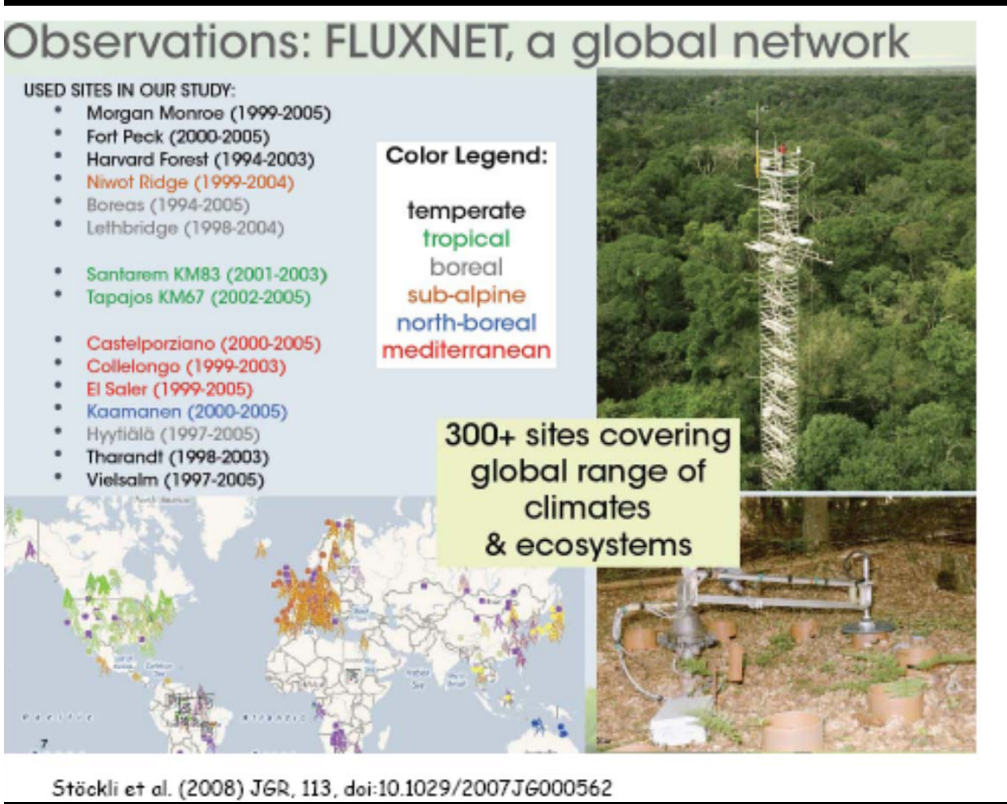




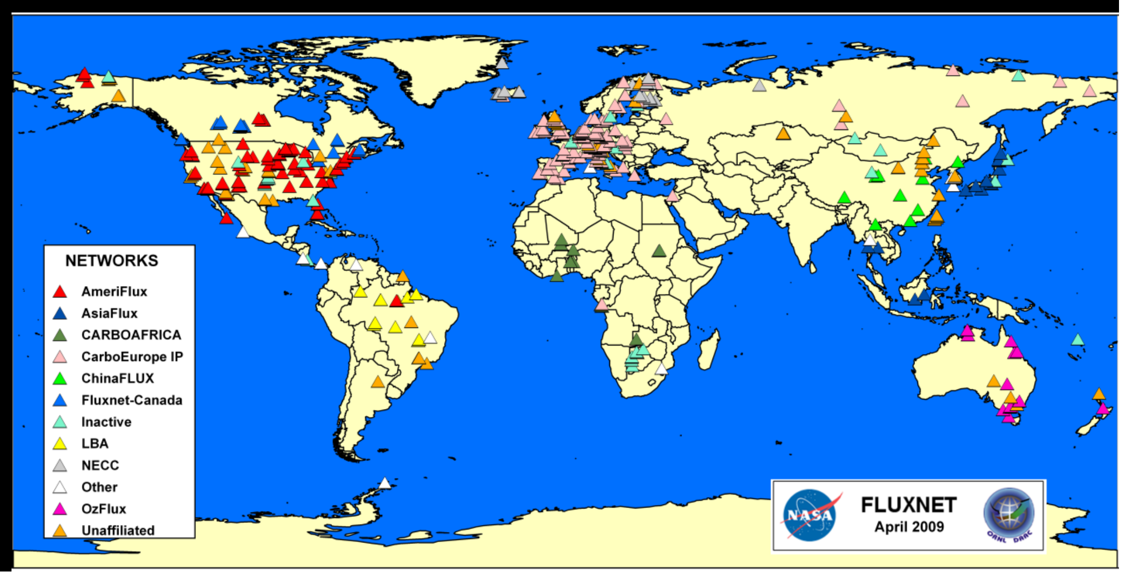
Jain and Yang (2005, GBC)
Jain et al. (2005, GRL)
Jain et al. (2006, JGR)
Jain et al. (2009, GBC)
Yang et al (2009, GBC)
Yang et al.(2010, Biogeoscience)

Calculate fluxes of carbon, nitrogen, energy, water, and the dynamical processes that alter these fluxes

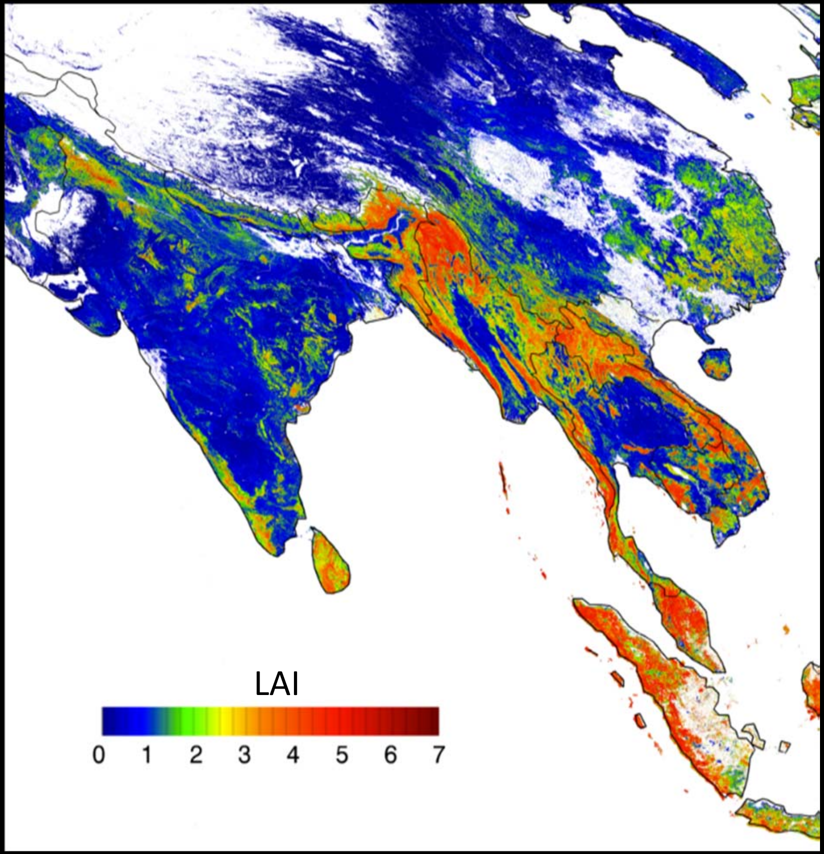
- 18 Biome types
- 0.5 x 0.5 degree resolution
- 30 minutes temporal scale
- Season-to-interannual variability (penology)



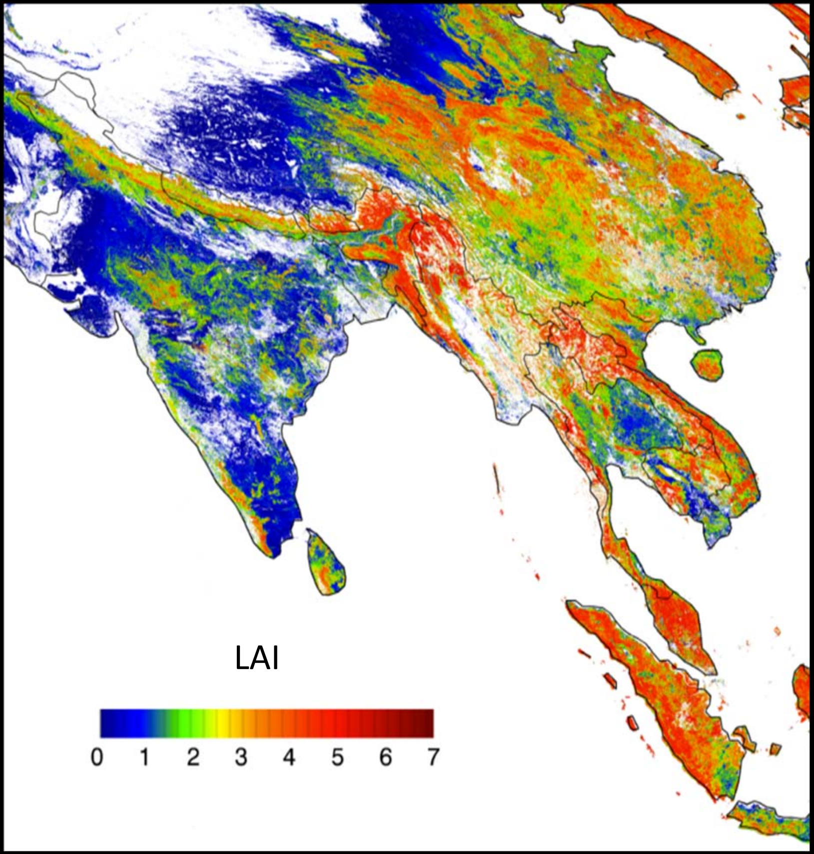
Use of FLUXNET and Other Ground-Based Data in the ISAM Land Surface Model Development



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



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

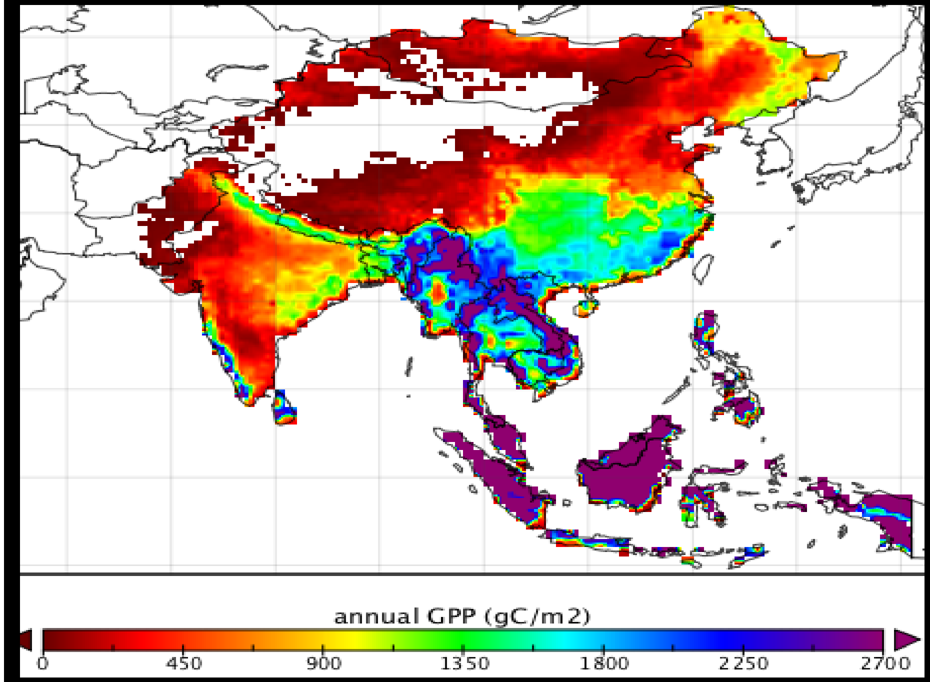


Peak LAI Averaged for the Summer Months (Jun., Jul., Aug)

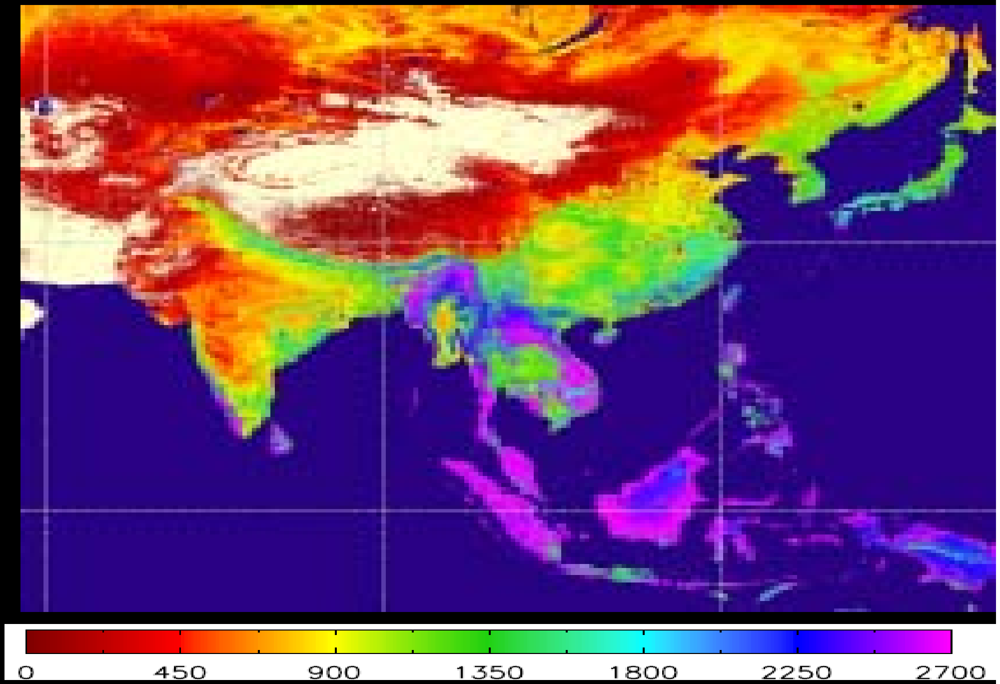
(Courtesy: Sangram Ganguly and Ramakrishna Nemani, NASA Ames).

Comparison of ISAM Estimated GPP for the time period 2000-2006 with MODIS GPP

ISAM



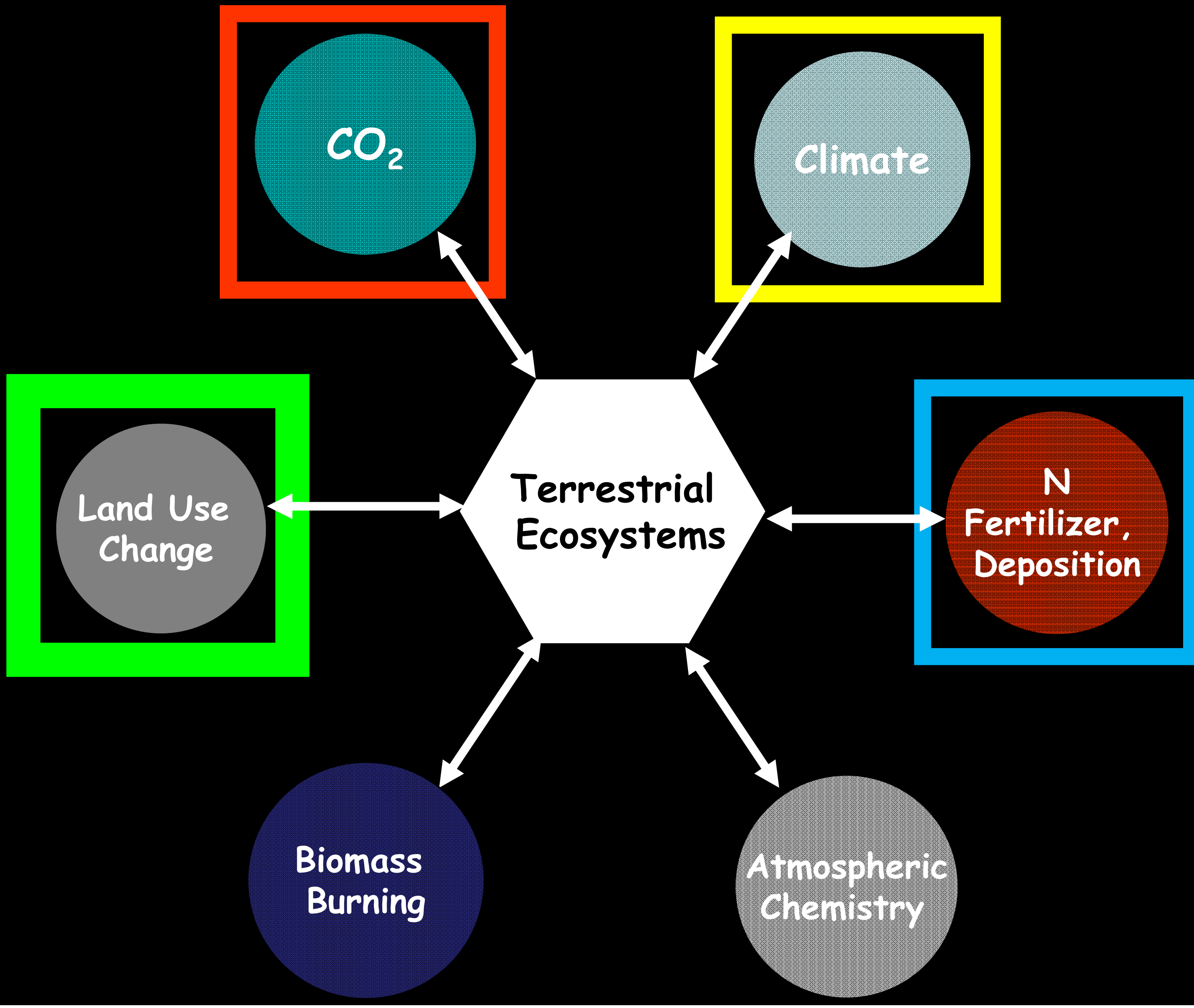
MODIS



MODIS GPP figure is directly downloaded from the MODIS data website

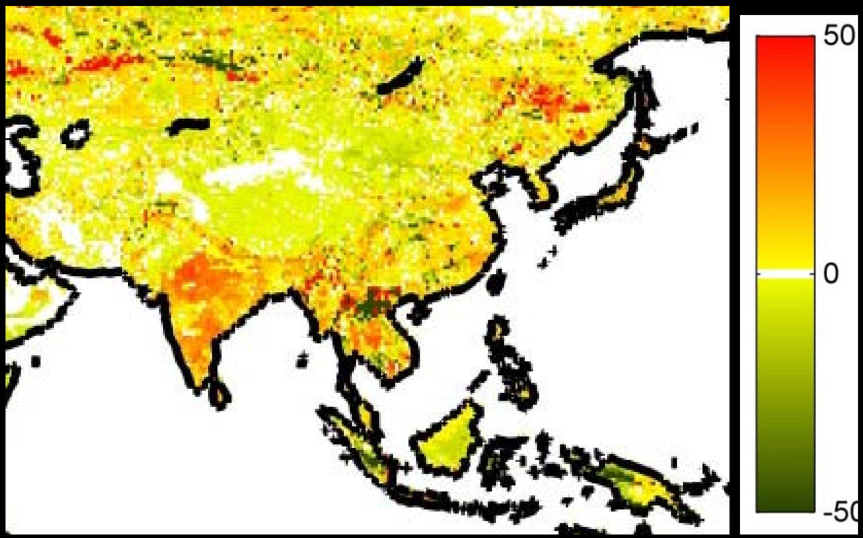
Environmental Factors impacting the Carbon Emissions from LU Changes Across MAR

LUC, Terrestrial Ecosystems and Environmental Factors



Carbon Emissions from LU Changes: Contributions of CO_2 *(Unit: $gC/m^2/yr$)*

Average for 2000-2009



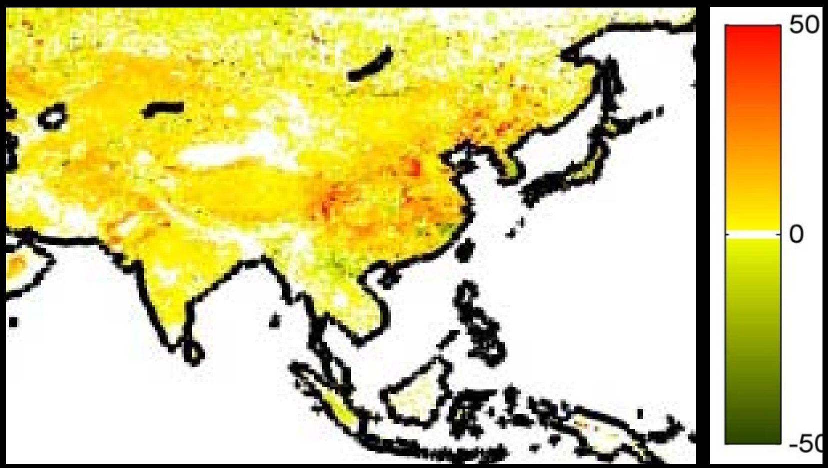
- CO_2 fertilization-enhanced productivity of plants
  - loss of VC is higher due to land cover changes for croplands
  - Release of higher SOC due to an increased soil decomposition rate as a result of LUC
- VC increases due to regrowth of forests

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

(Jain et al., 2011)

Carbon Emissions from LU Changes: Contributions of CO_2 *(Unit: gC/m²/yr)*

Average for 2000-2009

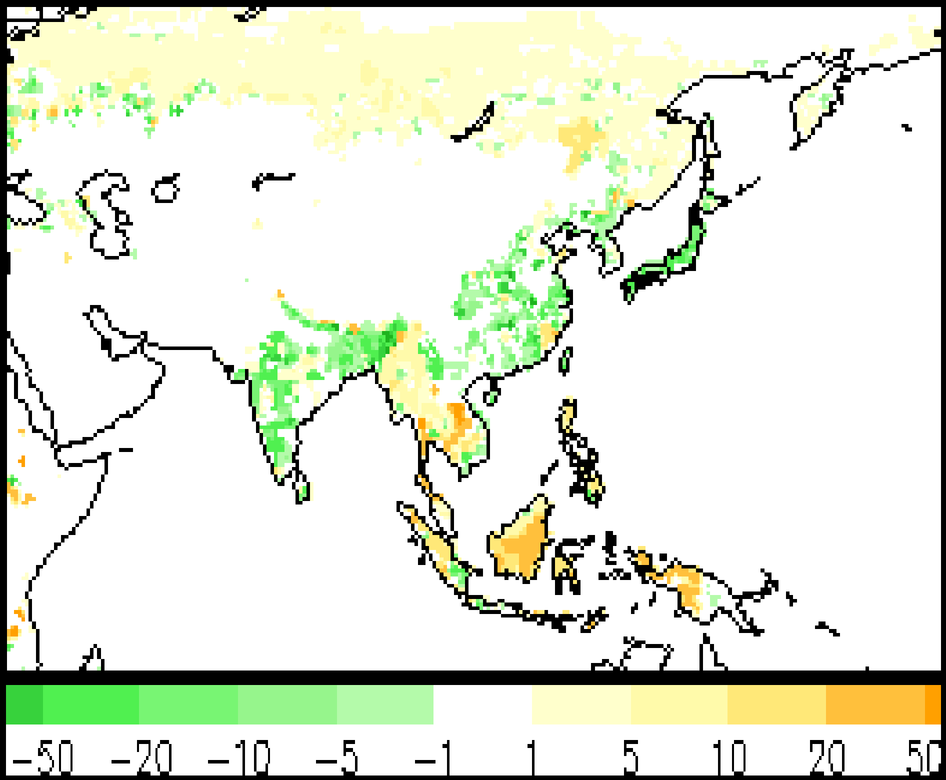


- In general, N is not a limiting nutrient in tropics
- But it can become nutrient limiting factor after LUC
  - C accumulation in secondary forests could be constrained due N limitation

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

(Jain et al., 2011)

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



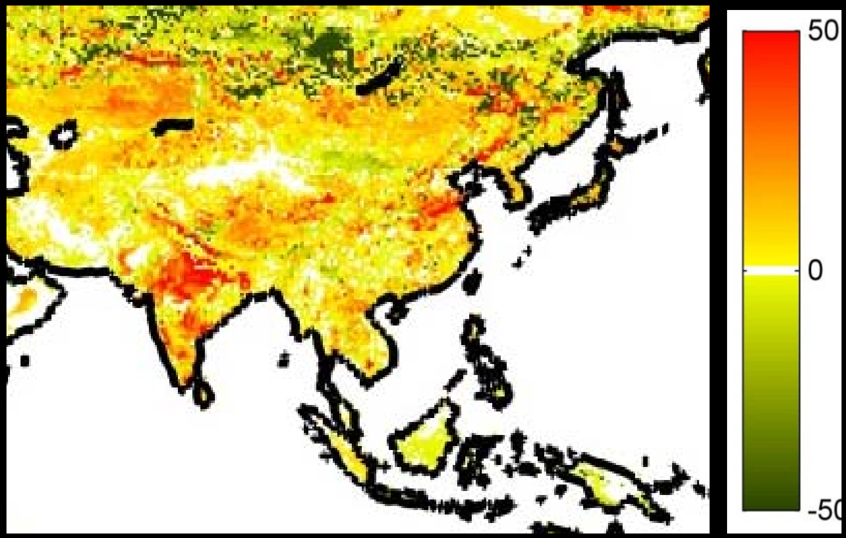
- In some regions accumulation of carbon is reduced where nitrogen is a limiting nutrient or enhanced if the additional N is deposited in the forest regrowing regions

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

Yang et. al. (2010, Biogeosciences)

Carbon Emissions from LU Changes: Contributions of Climate *(Unit: gC/m²/yr)*

Average for 2000-2009

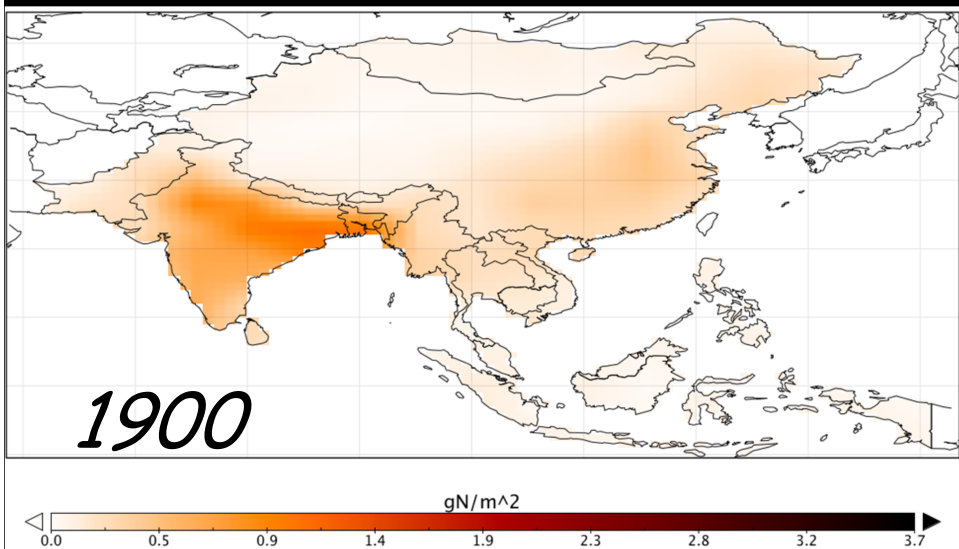


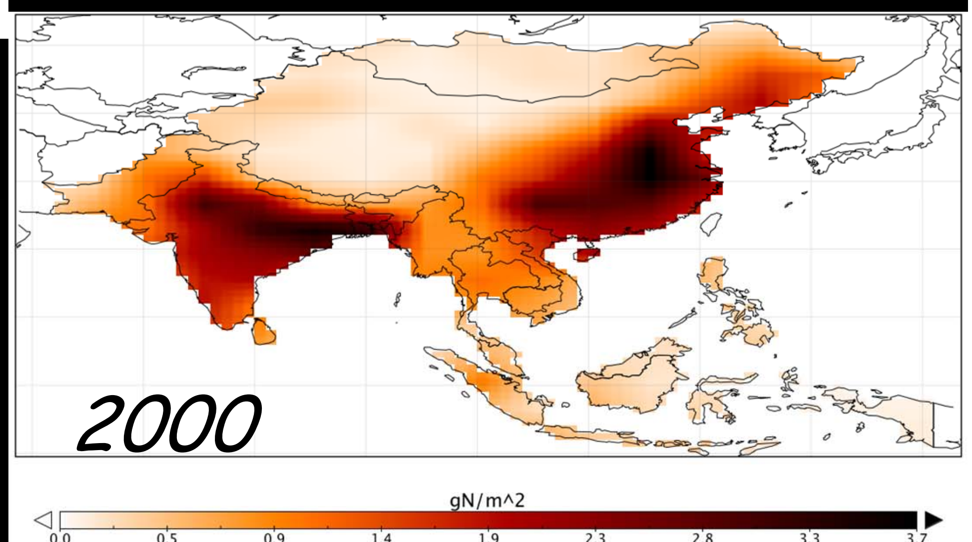
- LUC increases litter input to the soil, but LUC along with climate change further enhance the litter decomposition resulting in more C release
- The release of mineral nitrogen is enhanced as a result of LUC, which helps the plant growth

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

(Jain et al., 2011)

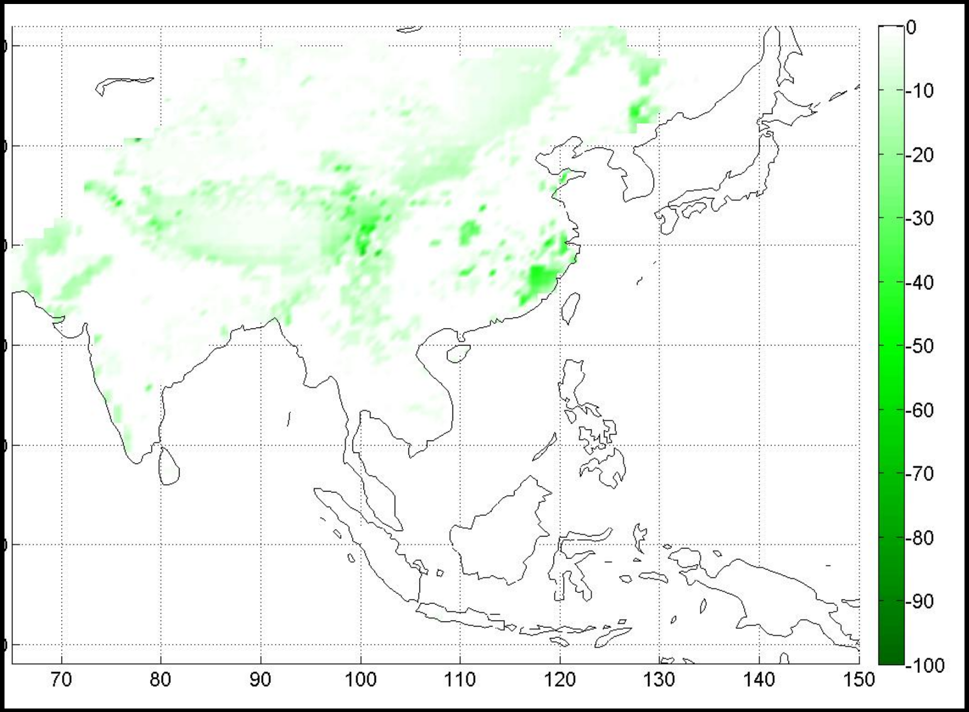
Nitrogen Deposition - Fossil Fuel Burning





Galloway et al. (2004)

2000s N Deposition Effect on Carbon Uptake (gC/m^2)

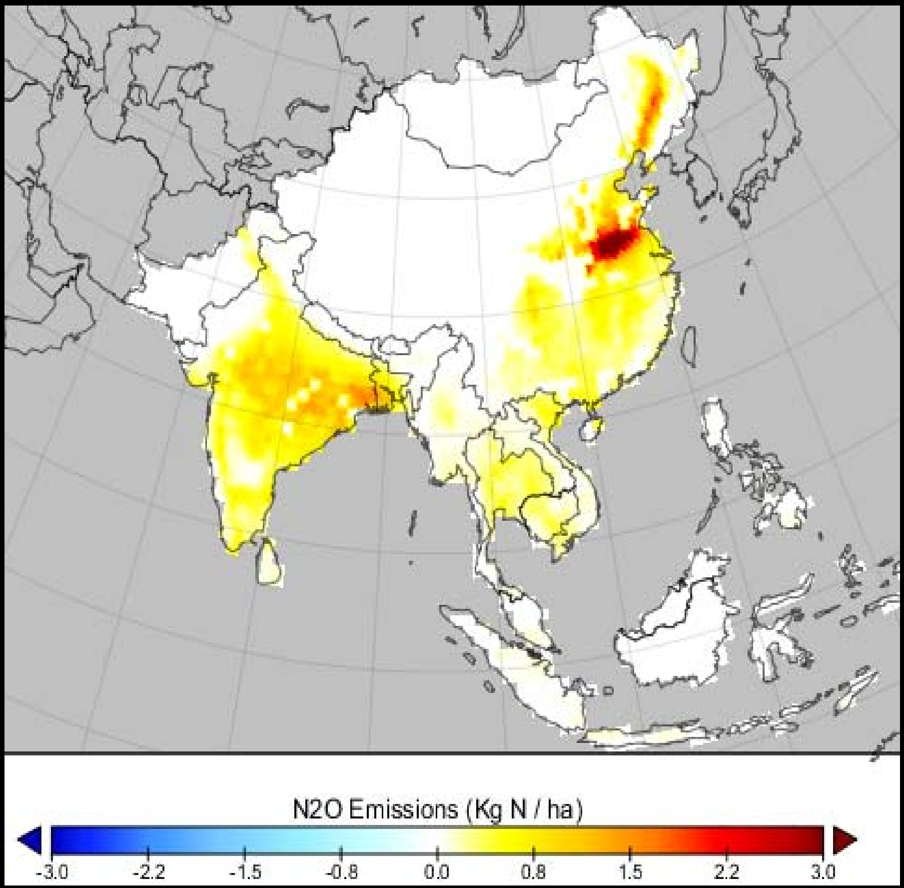


With LUCs

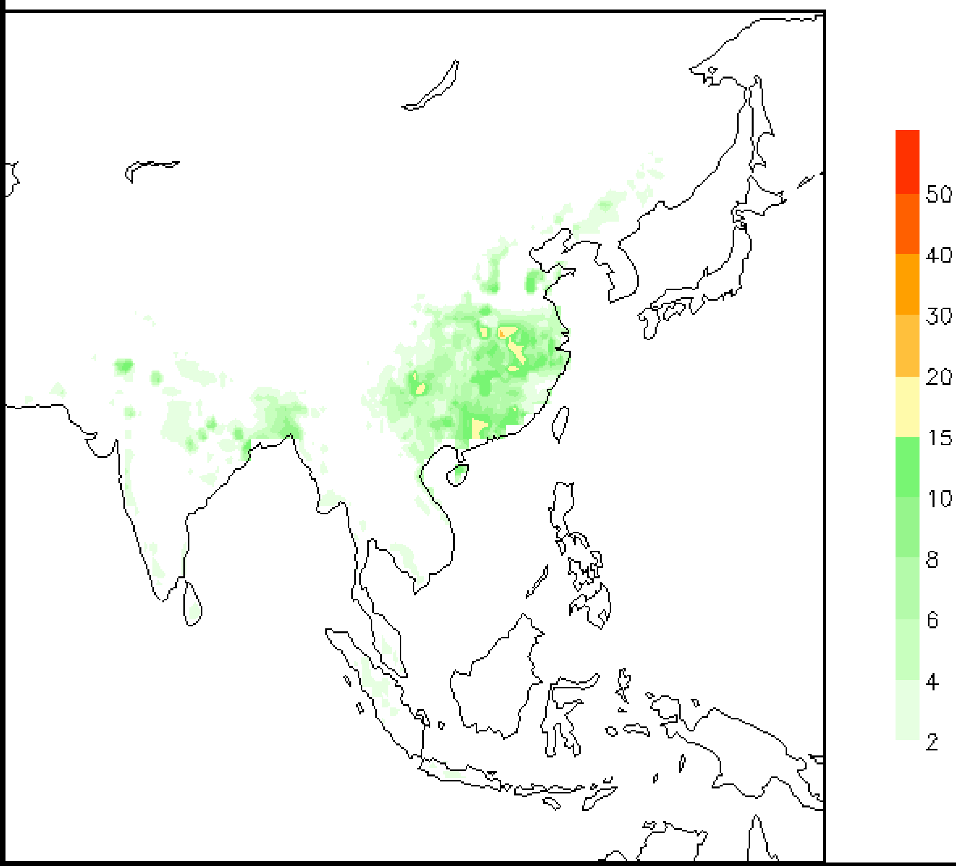
N deposition leads to additional terrestrial carbon <u>sink</u>

Yang et. al. (2010) Biogeosciences)

1990s N Deposition Effect on N_2O Emissions and Leaching



N2O Emissions (Kg N/ha)



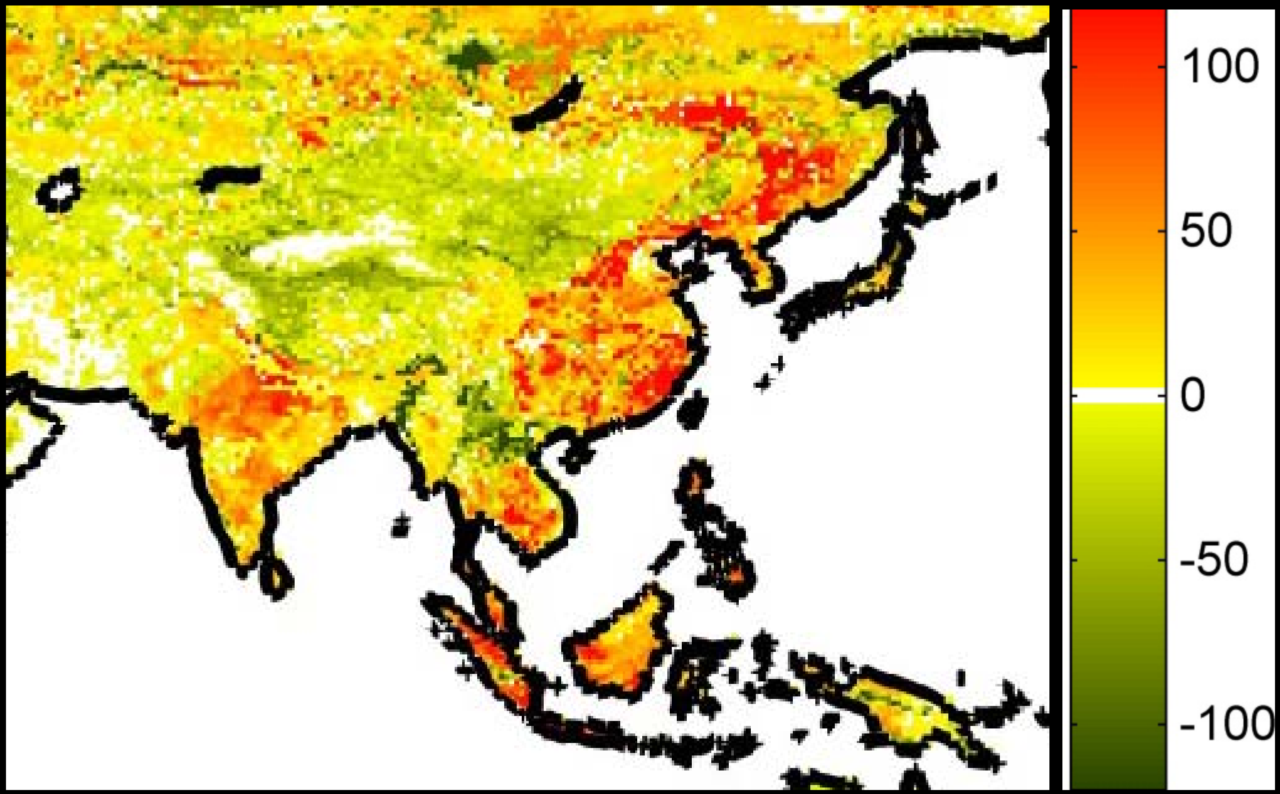
Leaching (gC/m2)

Yang et. al. (2010, Biogeosciences)

ISAM Estimated C Emissions due to LCLUCs

Average for the Period 2000-2009

Unit: $gC/m^2/yr$



1980s	1990s	2000s
0.27 GtC/yr	0.22 GtC/yr	0.19 GtC/yr

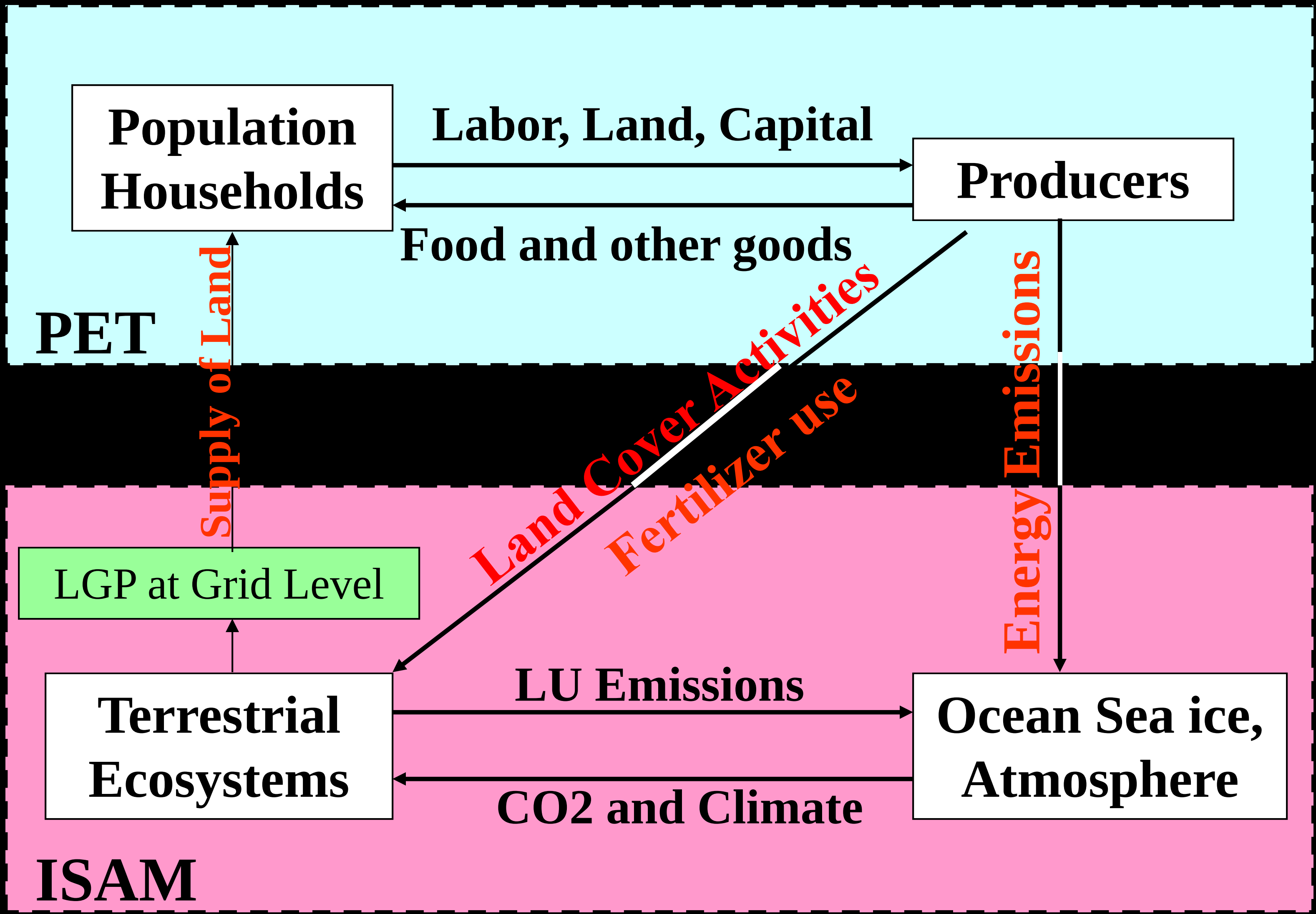
Yang et. al. (2010, Biogeosciences)

Conclusions

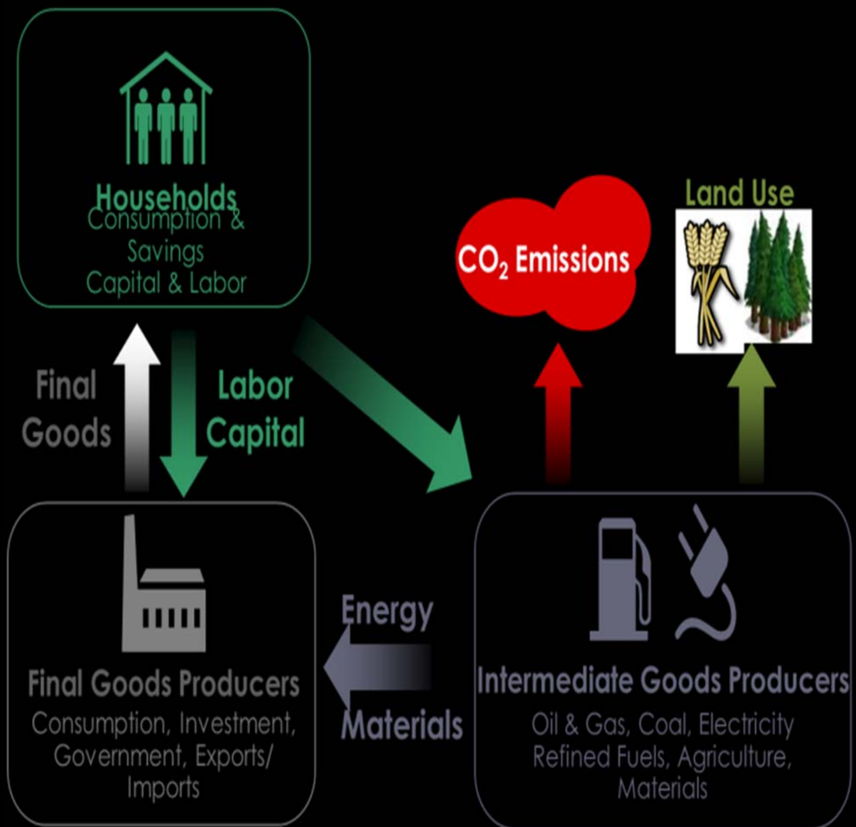
- Satellite data provide important information to study the impacts of historical LCLUC on carbon in MAR
  - but ground based measurement data is also needed to further improve our estimates
- Carbon emissions due to LCLUCs are not only due to LCLUC, but also due to several environmental factors and management practices
  - Contributions of these factors can only be studied using biogeochemistry models
- Understanding future LCLUC activities at a grid level is crucial for predicting future climate change
  - Emphasis should be given to develop such models

Future LCLUCs

PET-ISAM Modeling Framework



Linking Socio-Economic and Biophysical Systems

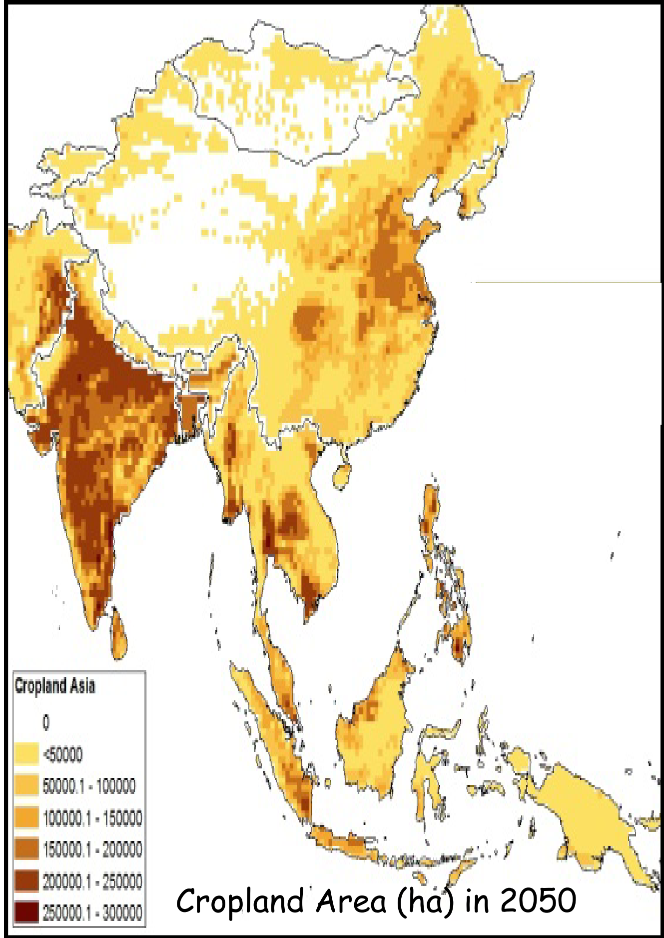


<u>PET Model IPCC A2 LU Scenario Development:</u>

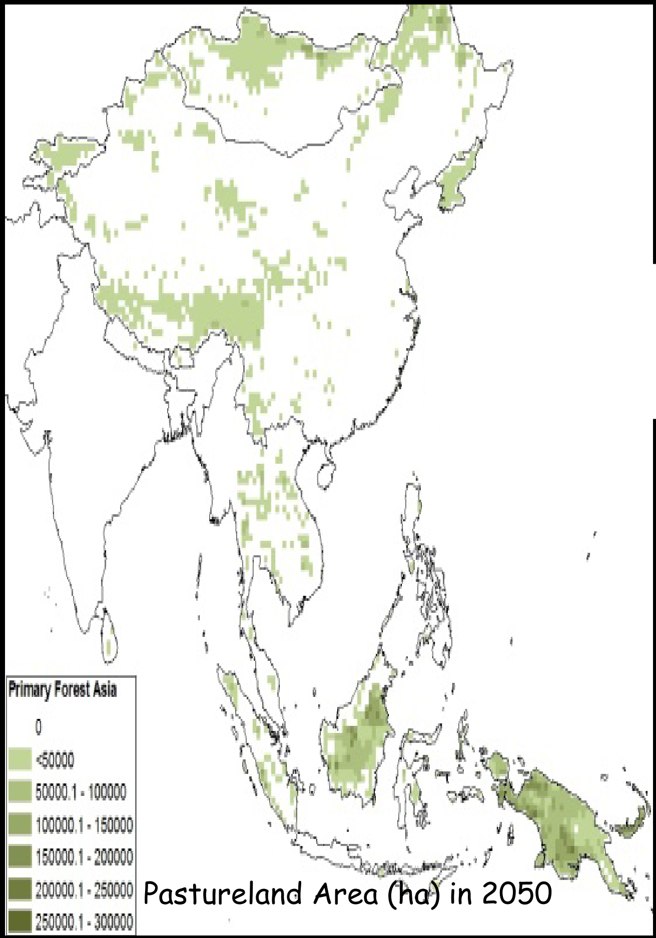
- Computable General Equilibrium model
- 9 world regions
- 5 economic sectors
- Input
  - A2 ;and use input assumptions - IIASA
  - Economic & land data - GTAP
  - Energy data - IEA

(Courtesy: Brain O'Neill, NCAR)

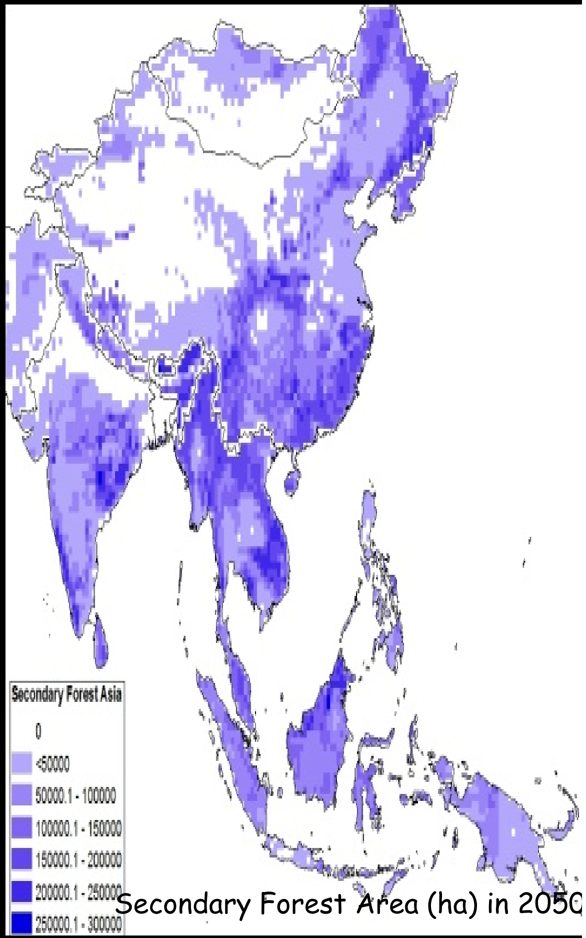
PET-ISAM IPCC A2 Scenario Results



Cropland Area (ha) in 2050



Pastureland Area (ha) in 2050



Secondary Forest Area (ha) in 2050

New Development..
Coupling Socio-Economics with Biophysical components

NCAR

CCR's Integrated Assessment Modeling
in CGD's Climate Change Research Section

Integrated Assessment Modeling: Modeling

About IAM

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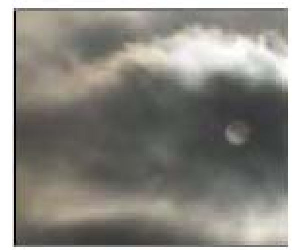
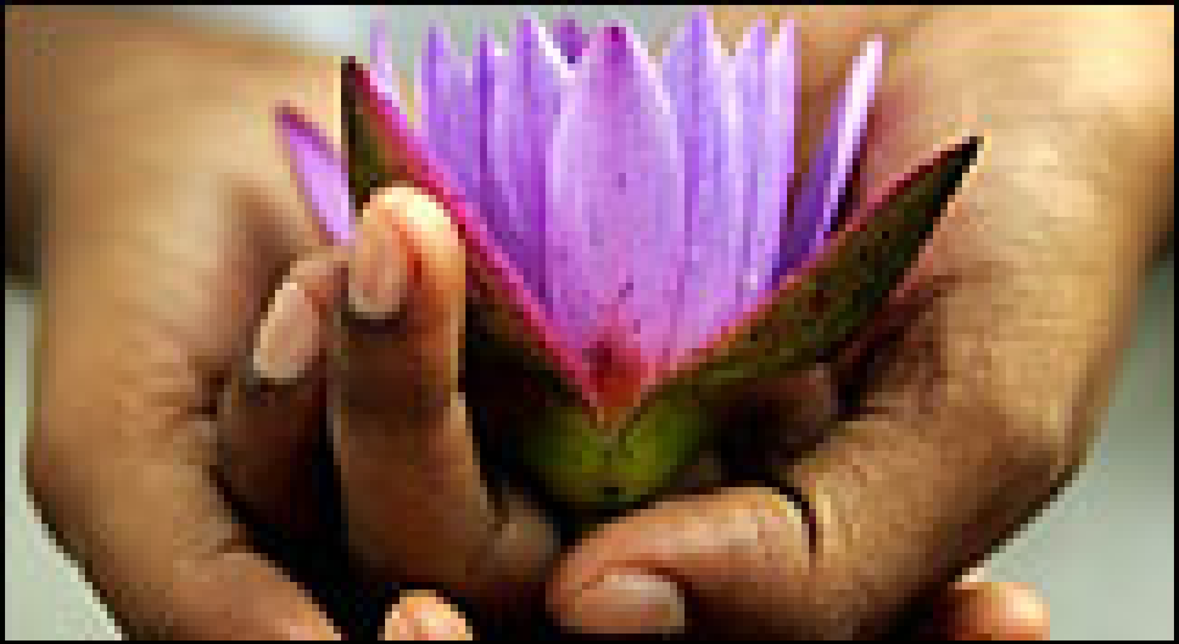
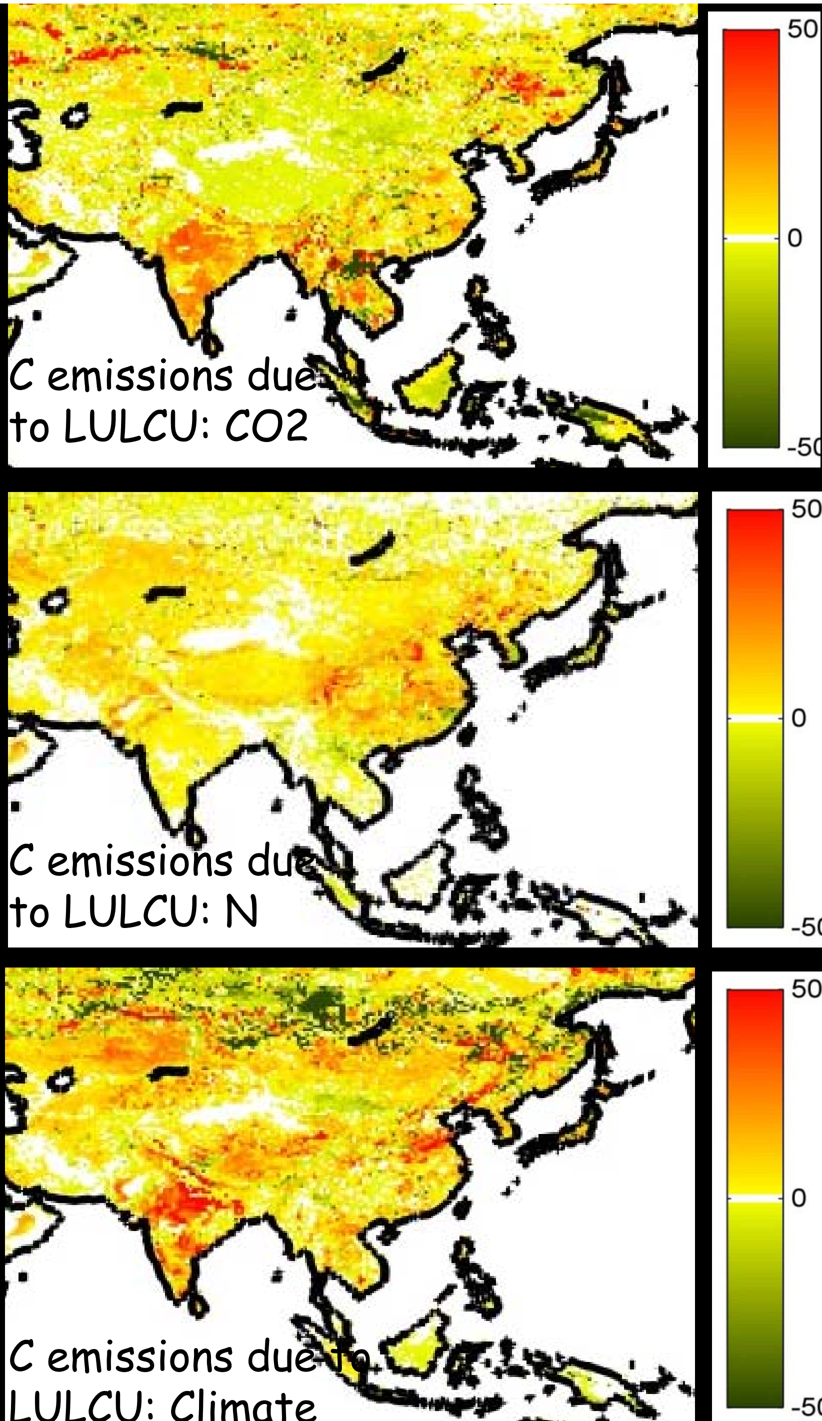
The iPETS model is an integrated assessment model under development in NCAR's IAM group that links three component models: a demographic model, an energy-economic model (PET), and a climate and greenhouse gas cycle model (ISAM). The name iPETS derives from the original PET and ISAM models.





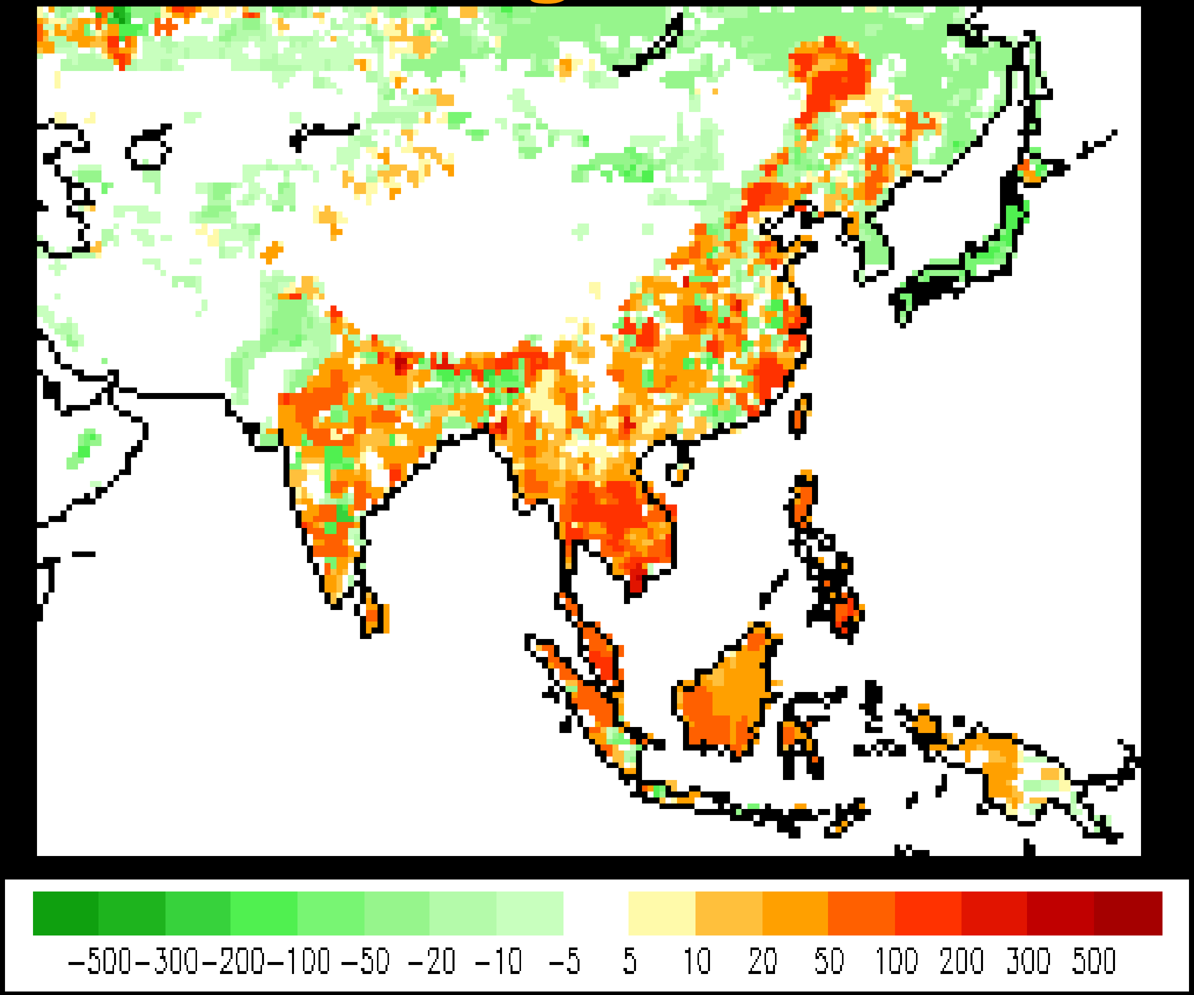
Thank you..


C emissions due to LULCU: CO2
50
0
-50
C emissions due to LULCU: N
50
0
-50
C emissions due to LULCU: Climate
50
0
-50

Satellite-Based LAI Data

Impact of LUC on Biogeochemistry: Carbon and Nitrogen Dynamics & Emissions

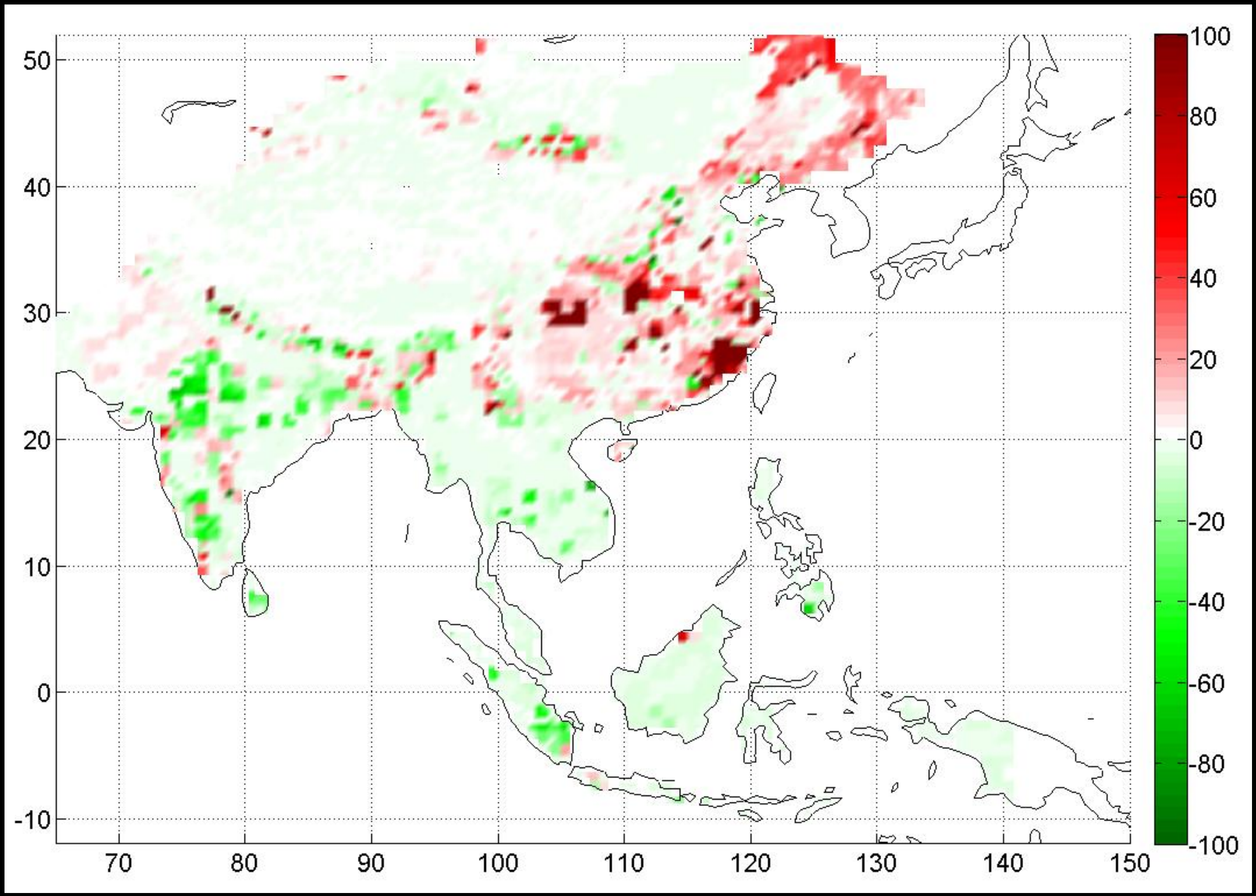
1990s Net Terrestrial C Flux due to LUCs (gC/m²)



SSEA forests were releasing more C than absorbing

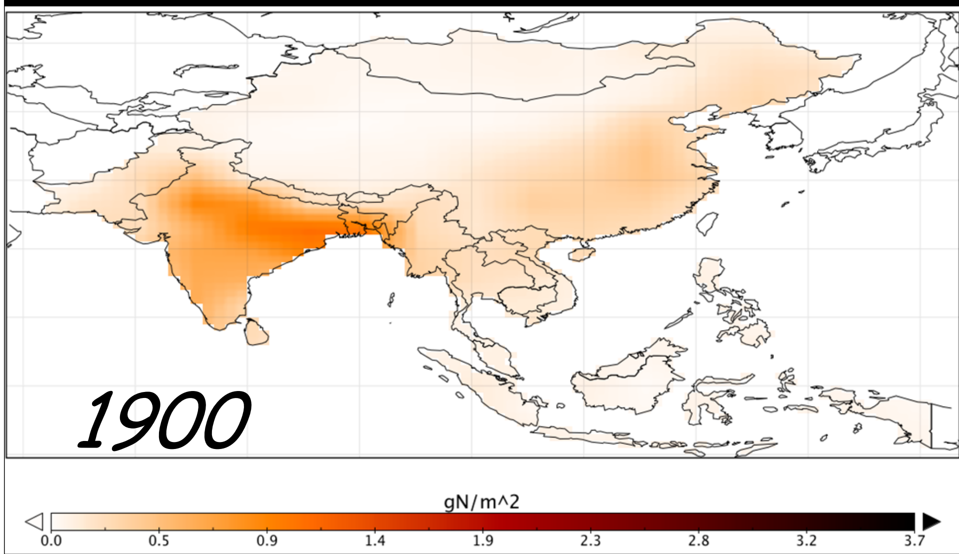
Yang et. al. (2010, Biogeosciences)

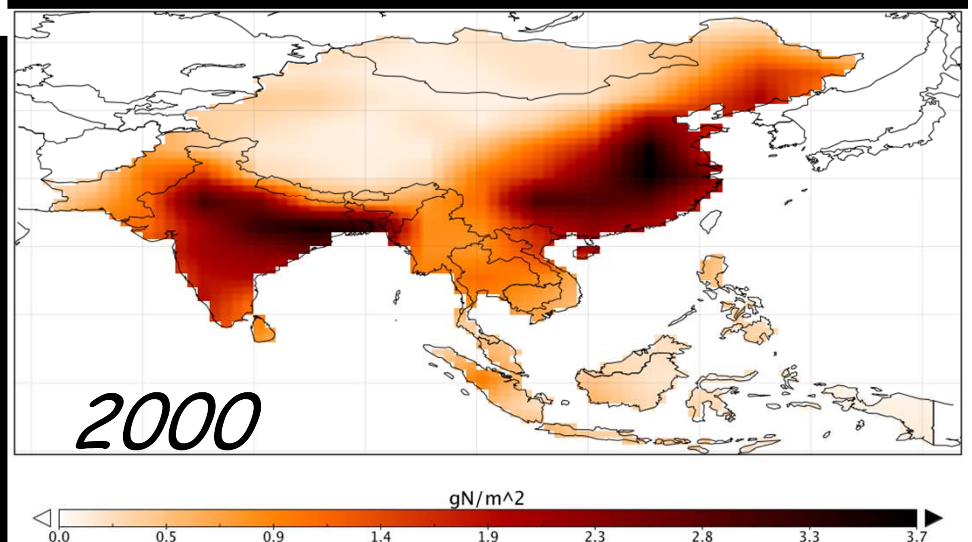
Impact of Nitrogen Dynamics on 1990s LUC Emissions (gC/m^2)



Richardson et al. (2010, *GCB*)

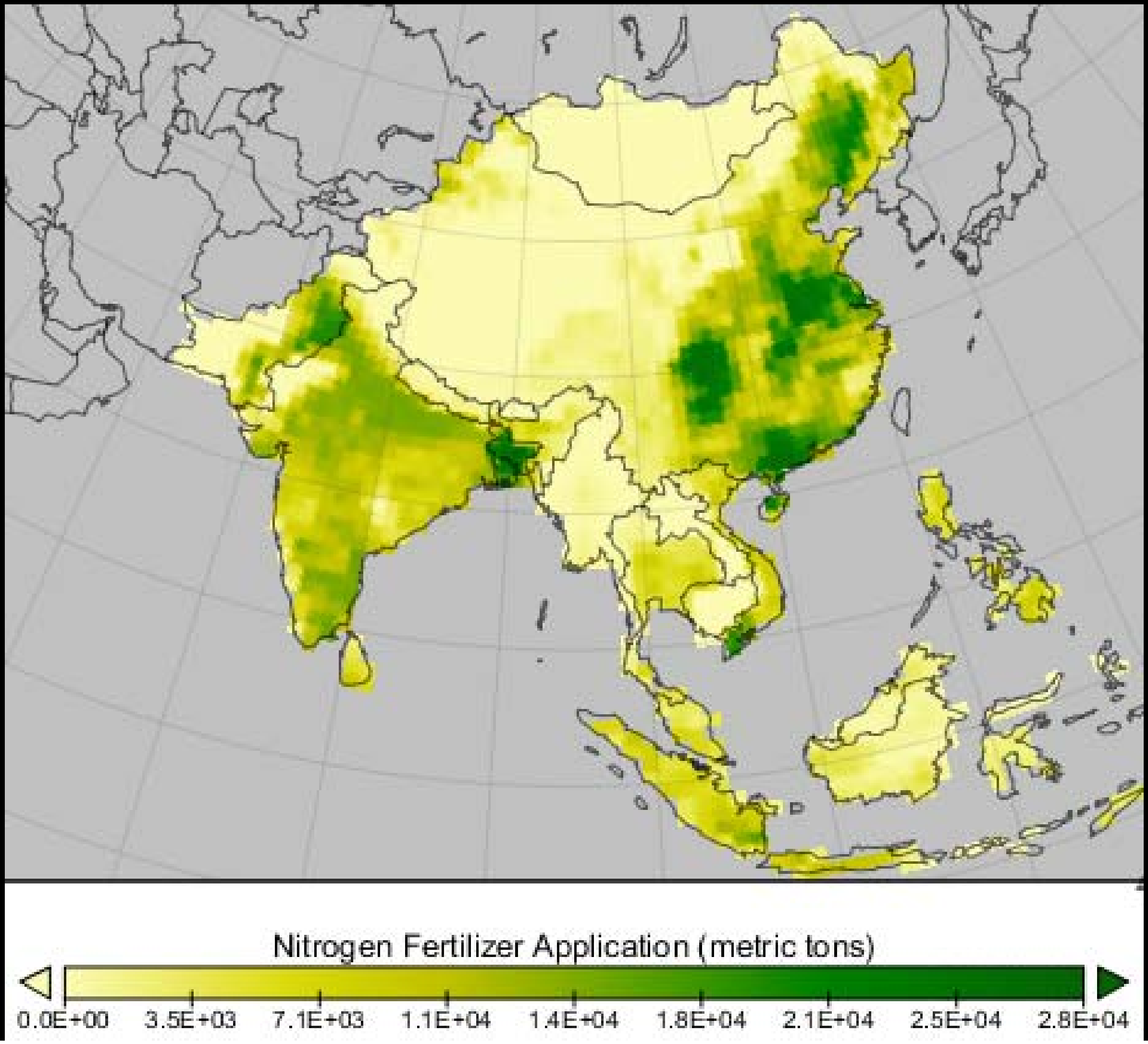
Nitrogen Deposition - Fossil Fuel Burning





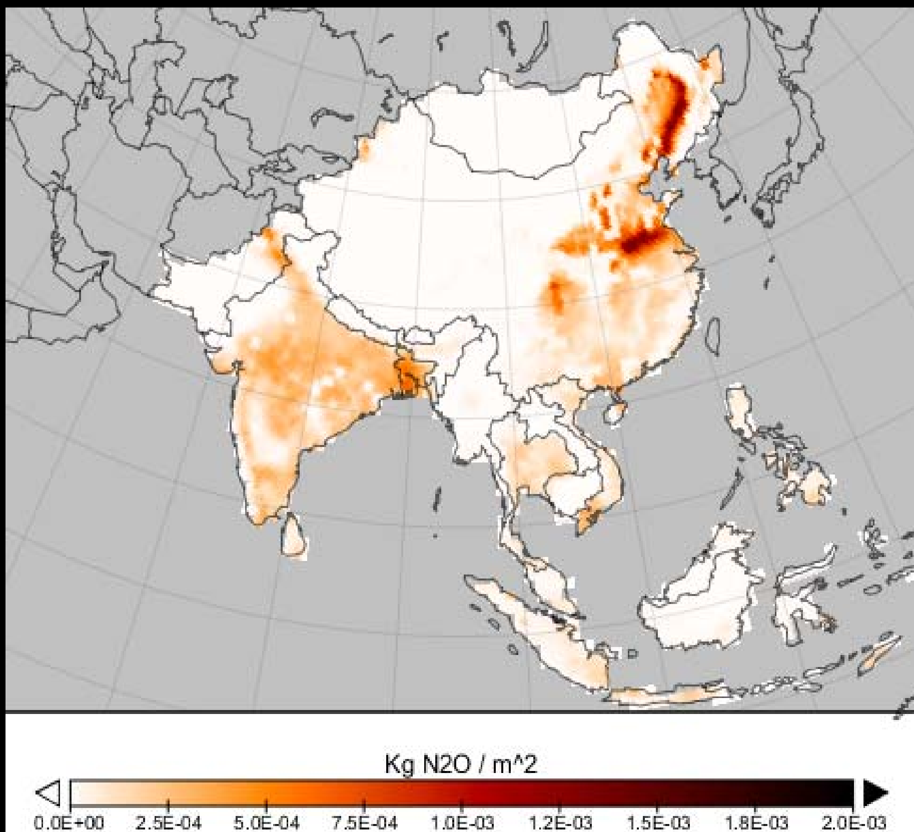
Galloway et al. (2004)

1990s Average Yearly Nitrogen Fertilizer Application (tons)

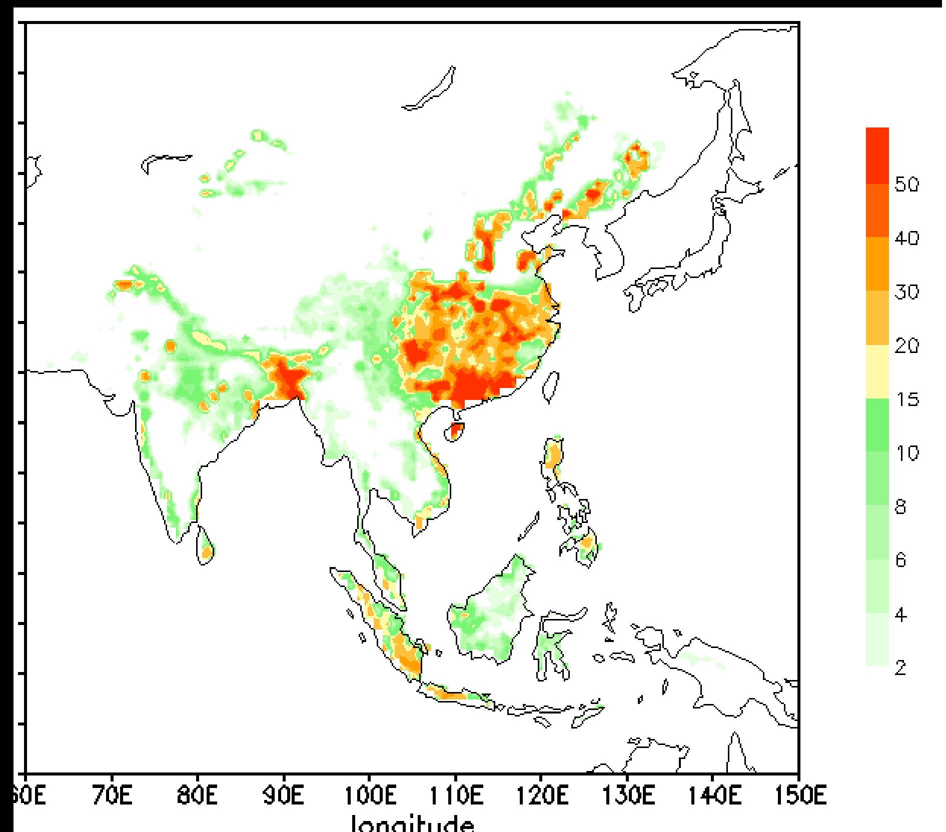


International Fertilizer Industry Association (2005)

Nitrogen Fertilizer Effect on 1990s N2O Emissions and Leaching



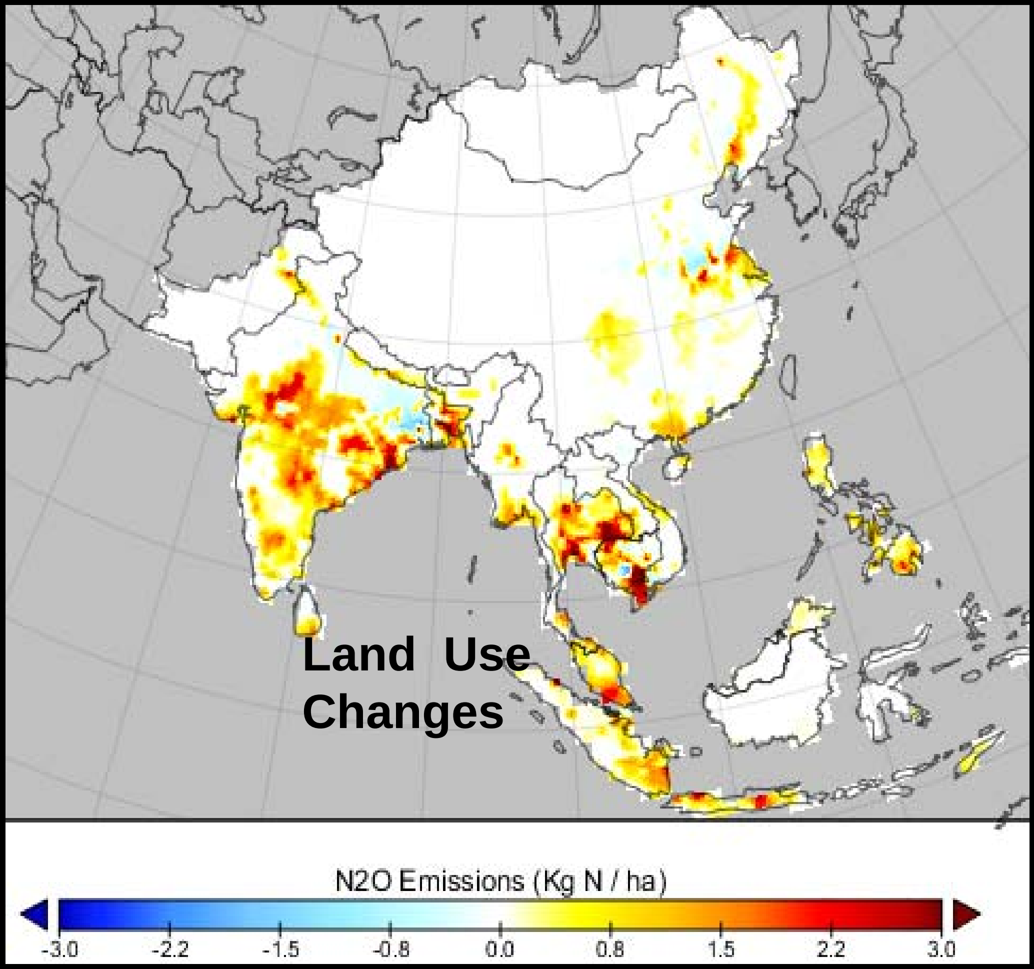
N2O Emissions (Kg N/ha)



Leaching (gN/m2)

Yang et. al. (2010, Biogeosciences)

1990s Contribution of Environmental Factors to N2O Emissions (KgN/ha/yr)

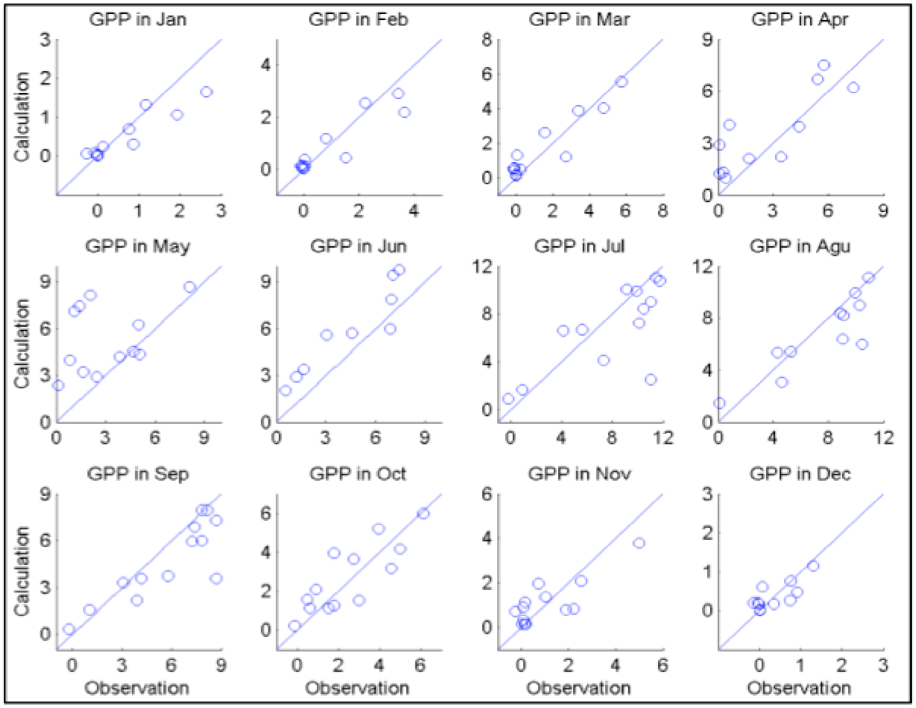


Impact of Land Cover and Land Use Changes on Biophysical Processes: Energy and Hydrology Fluxes

Experiments Performed for
the Period 1979-2004

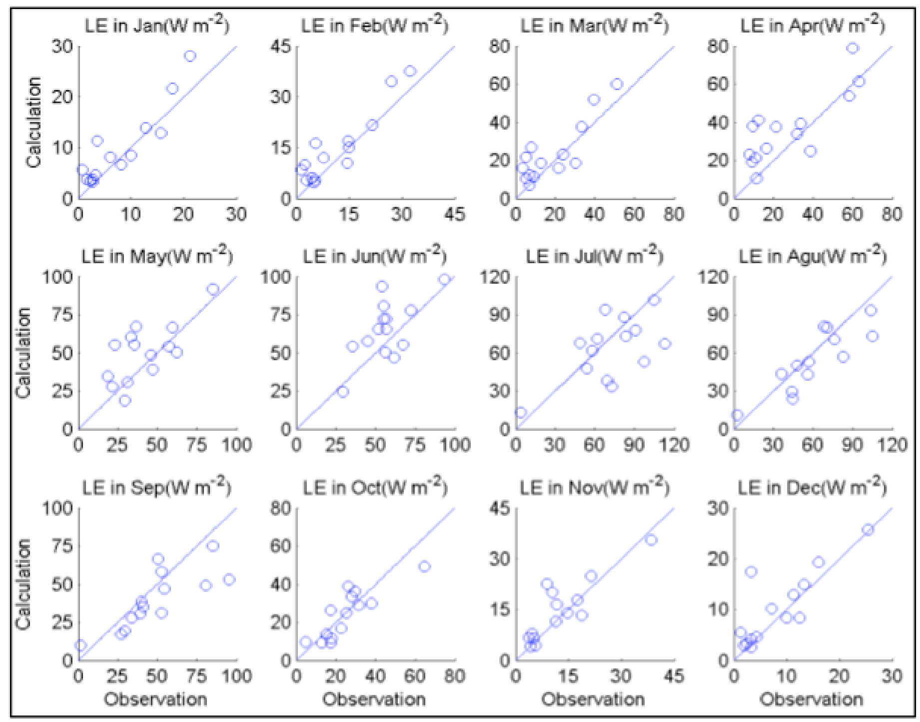
Model Evaluation Using Ground-Based Measurements

GPP



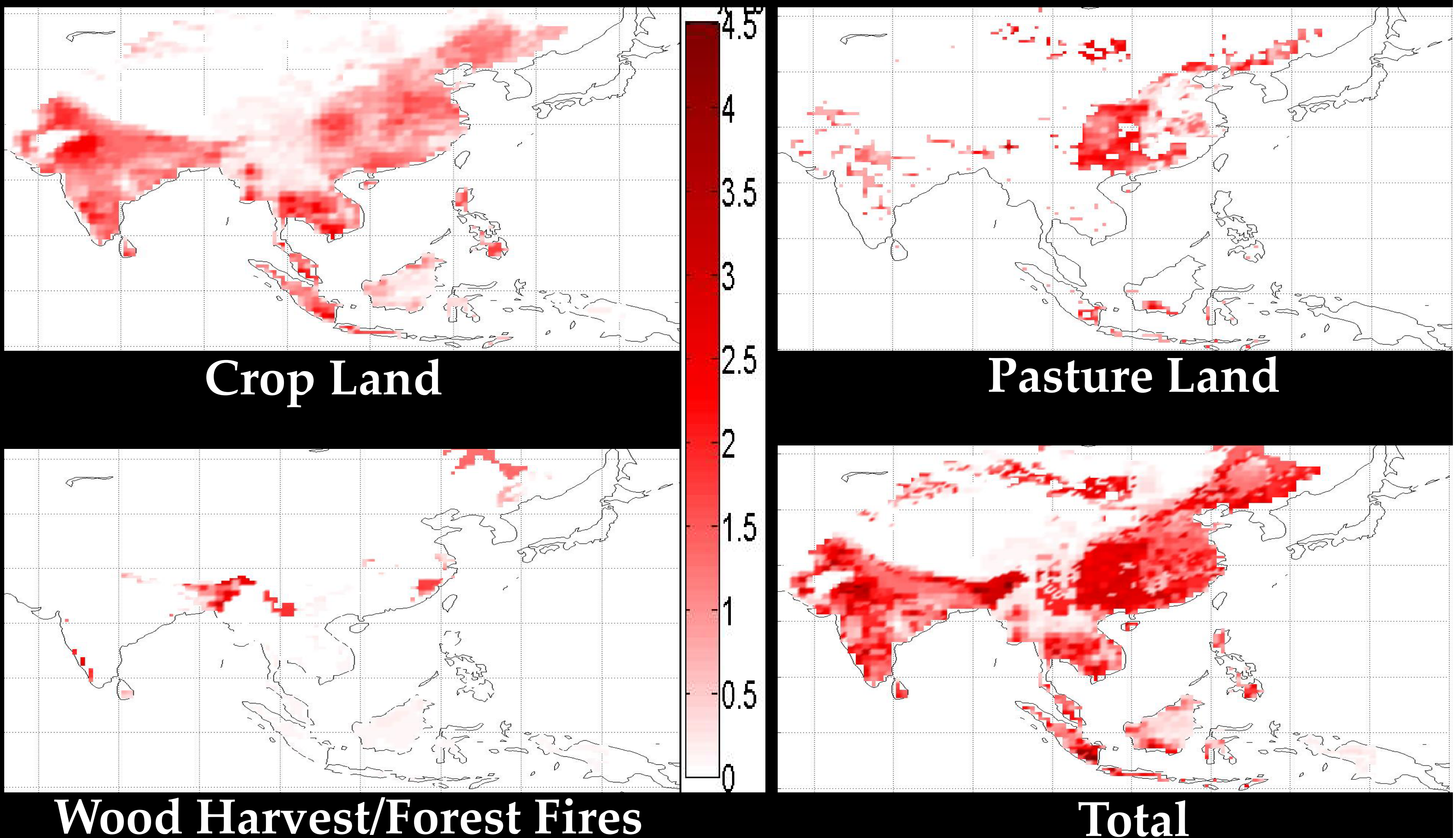
Gross Primary Production ($u$molCO$_2$ m^{-2} s^{-1}) for 12 months. Observation vs. Calculation for 14 sites

LH



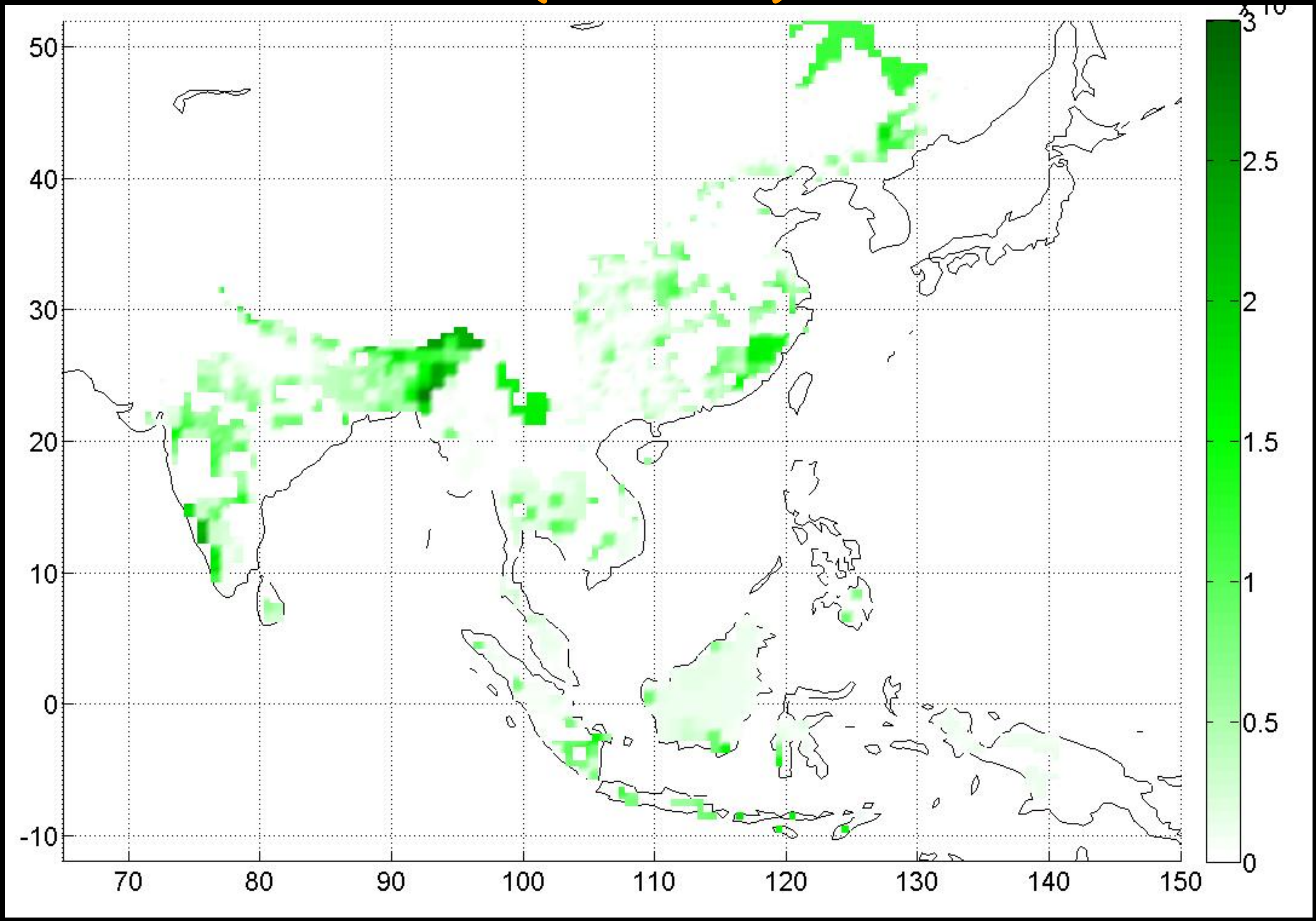
Latent Heat Flux (Wm^{-2}) for 12 months. Observation vs. Calculation for 14 sites

Land Use Changes due to Different Activities (10^9 m^2)



Sources: Hurtt et al. (2006), Ramanlutty and Foley (1999), FAO (2008), MODIS Satellite

Secondary Forest Area from Cropland, Pastureland, and Wood Harvest Activities (10^9 m^2)



Yang et. al. (2010, Biogeosciences)

The Dynamics of Irrigation

- The dynamics of irrigation in tropics can alter the relative importance of these biophysical drivers.
- The LH flux over well-watered crops may be more than that from forests.
- Globally, crop irrigation comprises of 70% of all human water withdrawals. India leads the world in total irrigated land where irrigation withdrawals represent 80-90% of all water use.
- Pre-monsoon season NDVI anomalies have increased in the Indian subcontinent. Increases are strongly correlated with increases in irrigated area, not preceding rainfall

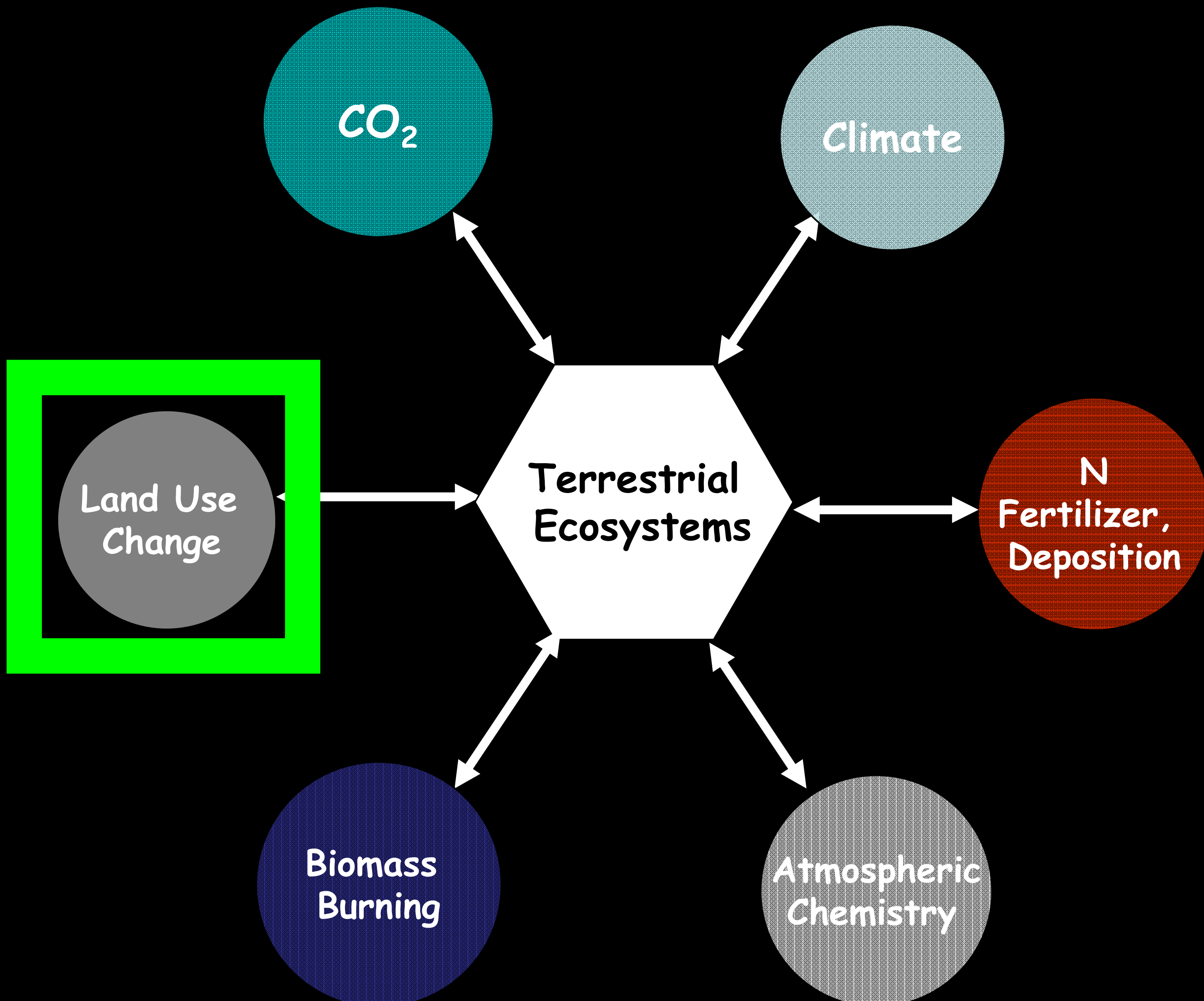
LUC and Biophysical Drivers on Land

- Surface roughness (forests > crops > bare ground)
- Stronger mixing due to greater surface roughness of forests (over crops or bare ground, increasing supply of moisture from surface and the microscale circulations

Effects of Energy, Hydrology, Irrigation and vegetation activity on Indian Summer Monsoon Variability

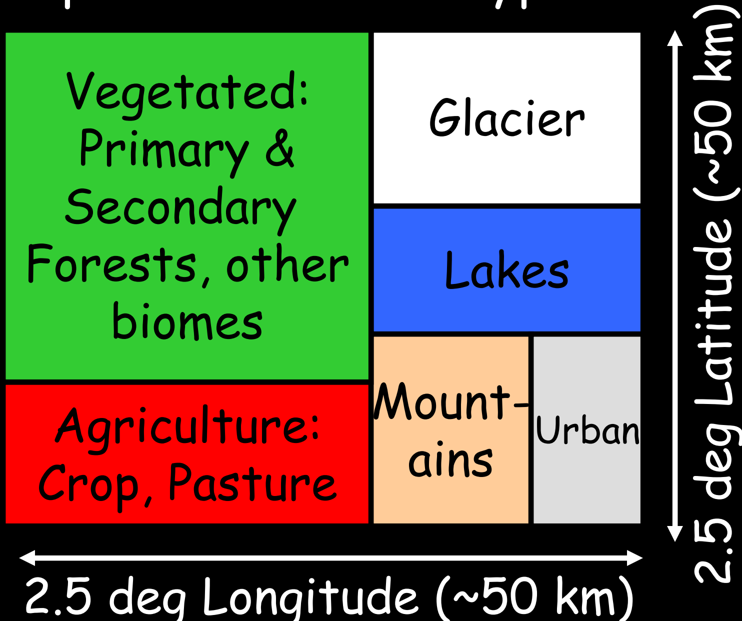
- Vegetation cover, surface roughness, and stomatal resistance all imparted to the development of convection and monsoon rainfall activities
- Vegetation and soil moisture introduce differential heating, which enhances frontal activity
- Stronger Asian summer monsoon associated with lower surface albedo (i.e., forests), greater soil moisture, less snow cover, and greater land-sea thermal contrast.
- Irrigation increases LH over land, which decreases sea-land temperature contrast, which can thereby decrease summer monsoon.
- Indian monsoon was significantly weakened by increase in surface albedo (cropland) and by a reduction in surface roughness

LUC, Terrestrial Ecosystems and Environmental Factors



Land Surface Heterogeneity in the ISAM

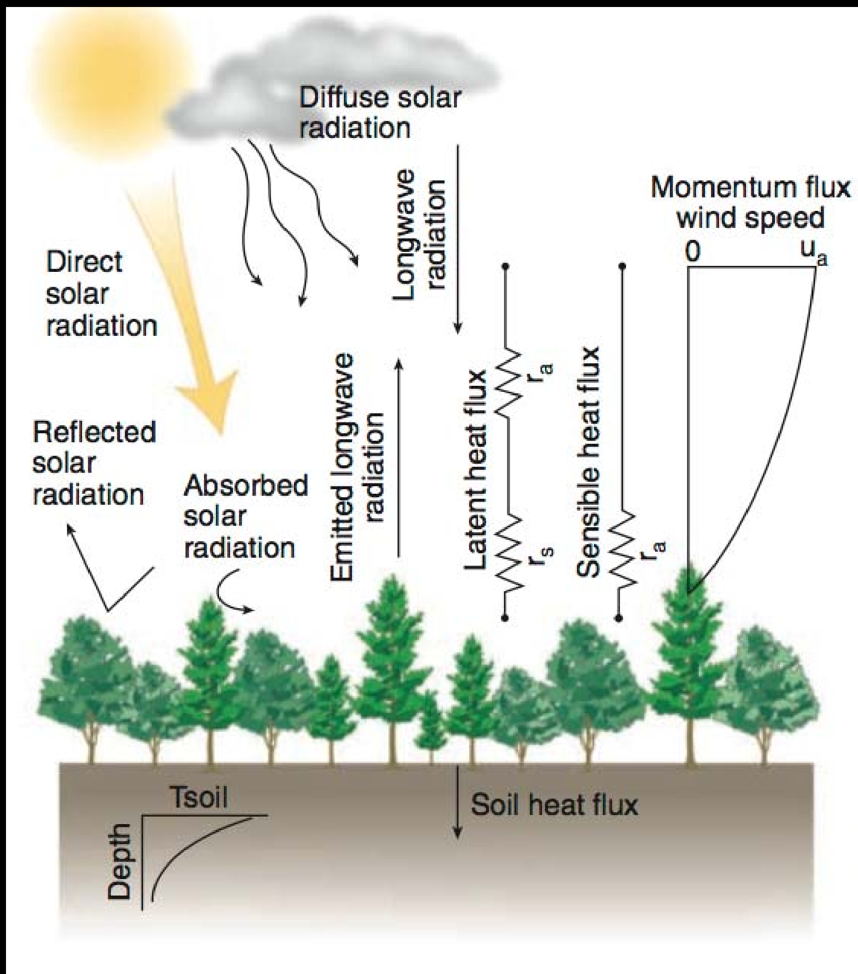
Sub-grid land cover and plant functional types



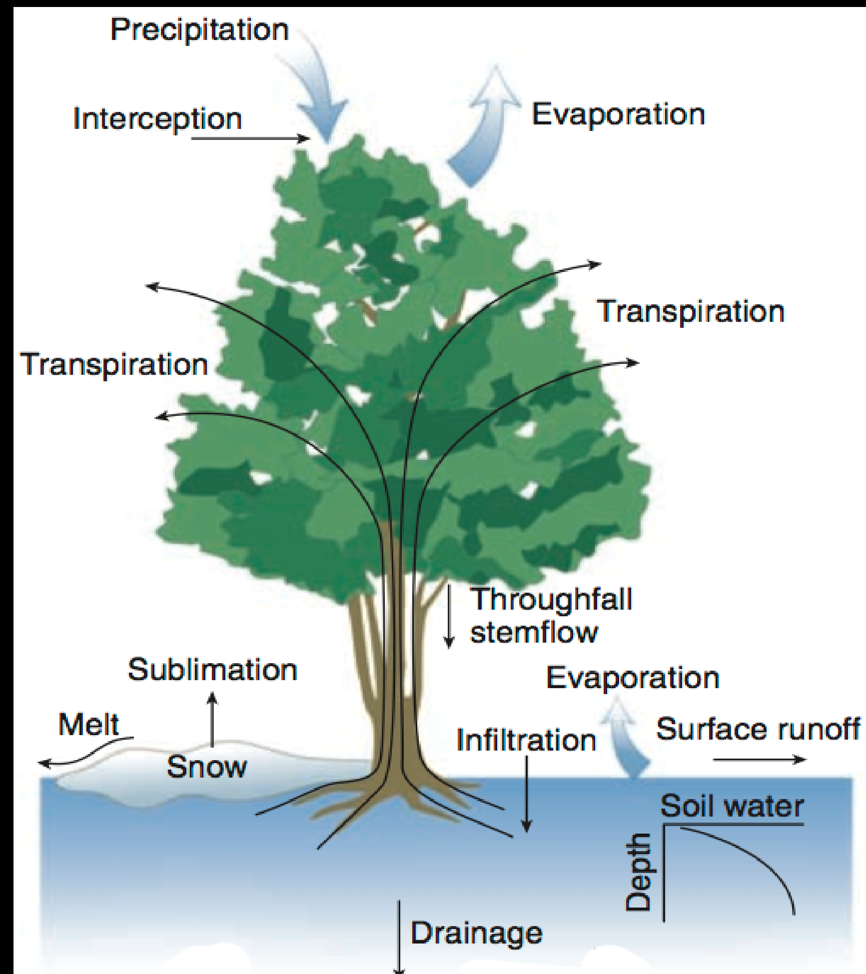
ISAM represents a model grid cell as a mix of up different land cover types. Vegetated land is further represented as a mix of several biome types

ISAM Land-Surface Model

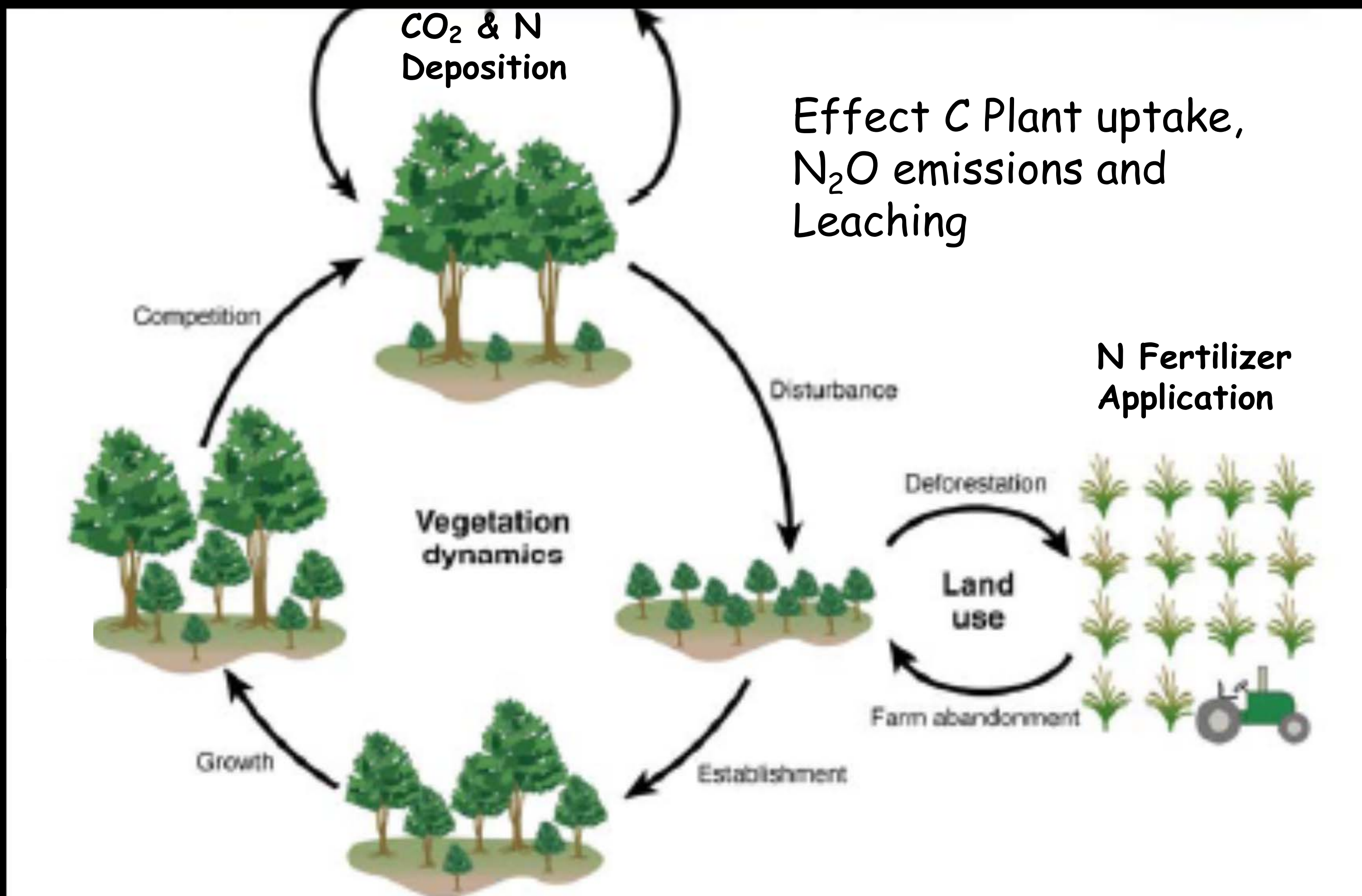
ENERGY



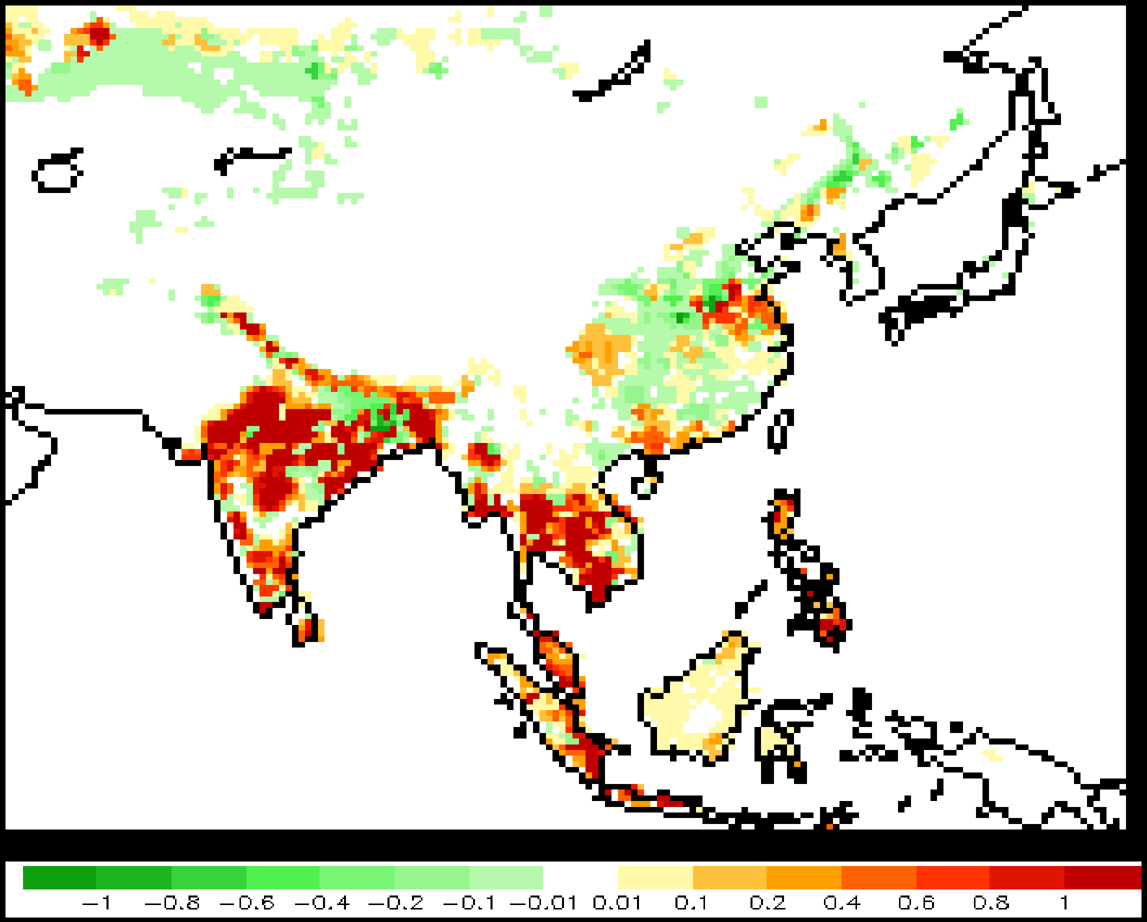
HYDROLOGY



The Impact of N Deposition and Fertilizer



ISAM Estimated N_2O Emissions due to LCLUC Unit: kg N/ha/yr)



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