

Land Use – Ecosystem – Climate Interactions in Monsoon Asia:

Evaluating the impacts of current and projected LCLUC on climate, water and carbon cycling in the first half of 21st Century

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Why do we care about Monsoon Asia?



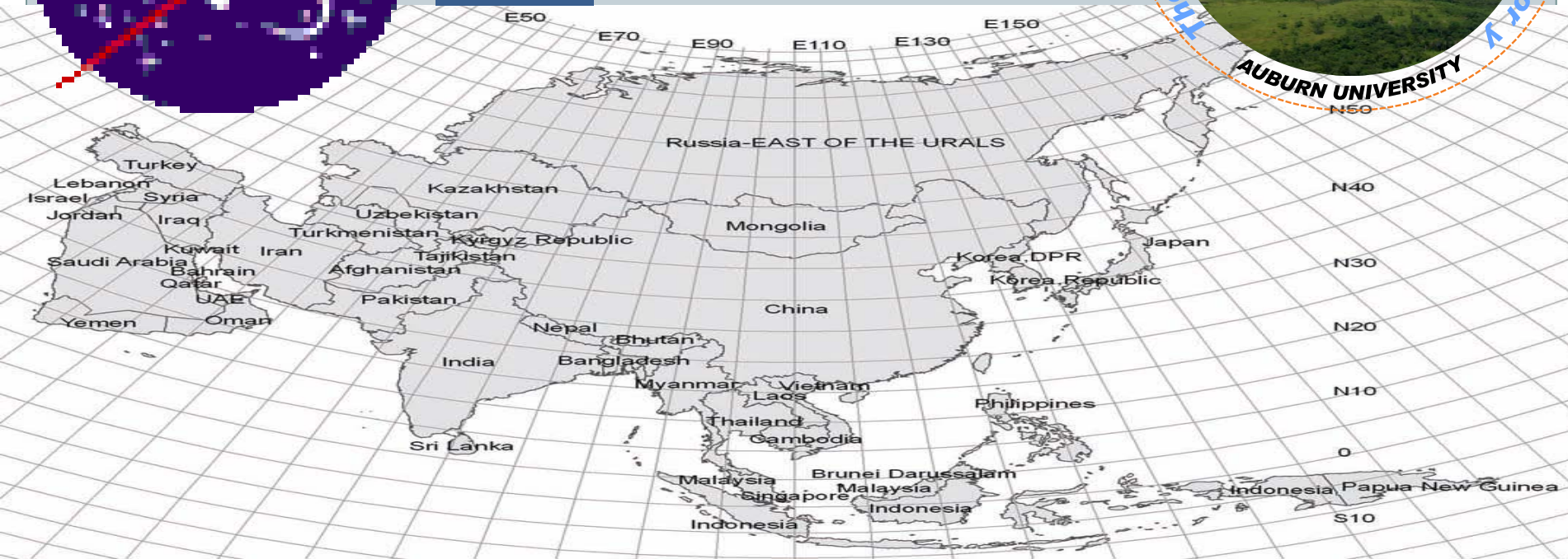
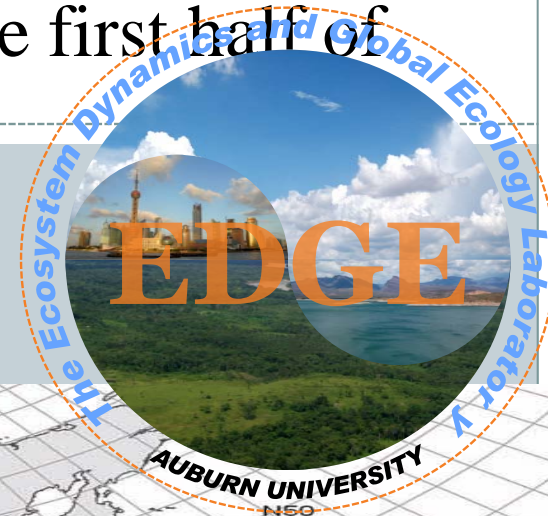
- Home of 60% of the world's population
- Covering about 30% of the global arable land
- Accounting for 20% of the global terrestrial NPP and for a similar fraction of carbon storage
- Large area of arid and semi-arid ecosystems
- pervasively influenced by monsoon
- experienced an unprecedented rate of land cover and land use change (LCLUC) in the past century

Multiple Stresses: Desertification, Urbanization, water quality, air pollution, deforestation, biofuel production...



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Investigators



PRINCIPAL INVESTIGATOR:

Hanqin Tian, *Auburn University (AU)*

US CO-INVESTIGATORS:

Jerry Melillo, *Marine Biological Laboratory (MBL)*

John Reilly, *Massachusetts Institute of Technology (MIT)*

Hassan Virji, *International START Secretariat (START)*

Robert Dickinson, *University of Texas at Austin (UTA)*

OTHER SENIOR PERSONNEL

Dengsheng Lu, Mingliang Liu, Chaoqun Lu, Wei Ren, Shufen Pan, Bo Tao (AU), ; David Kicklighter (MBL)

Collaborators

Congbin Fu, *Chinese Academy of Sciences - Institute of Atmospheric Physics, China*

Jiyuan Liu, *CAS Institute of Geographical Sciences and Natural Resources, China*

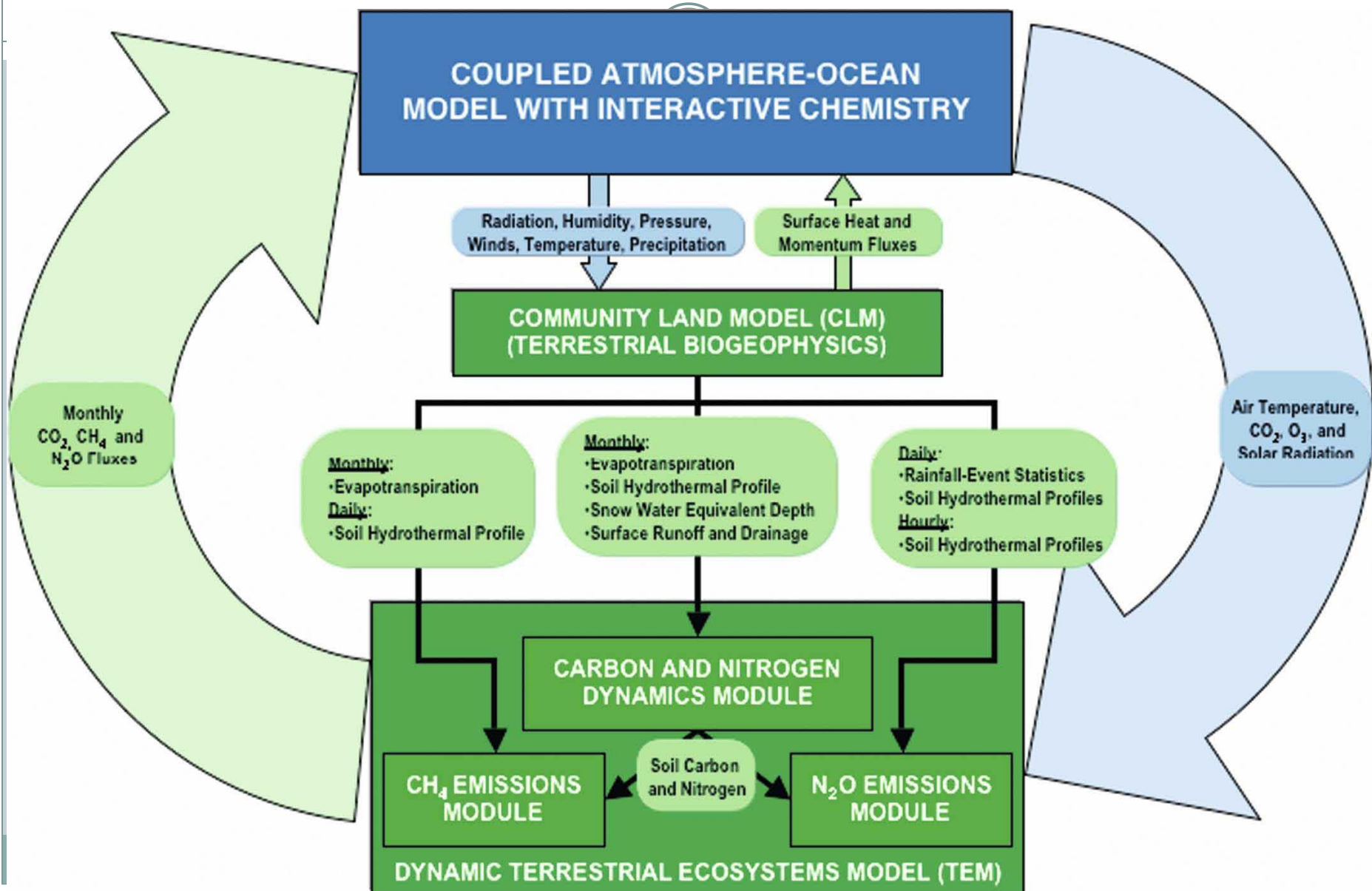
Qinxue Wang, *National Institute for Environmental Studies, Japan*

The Goal

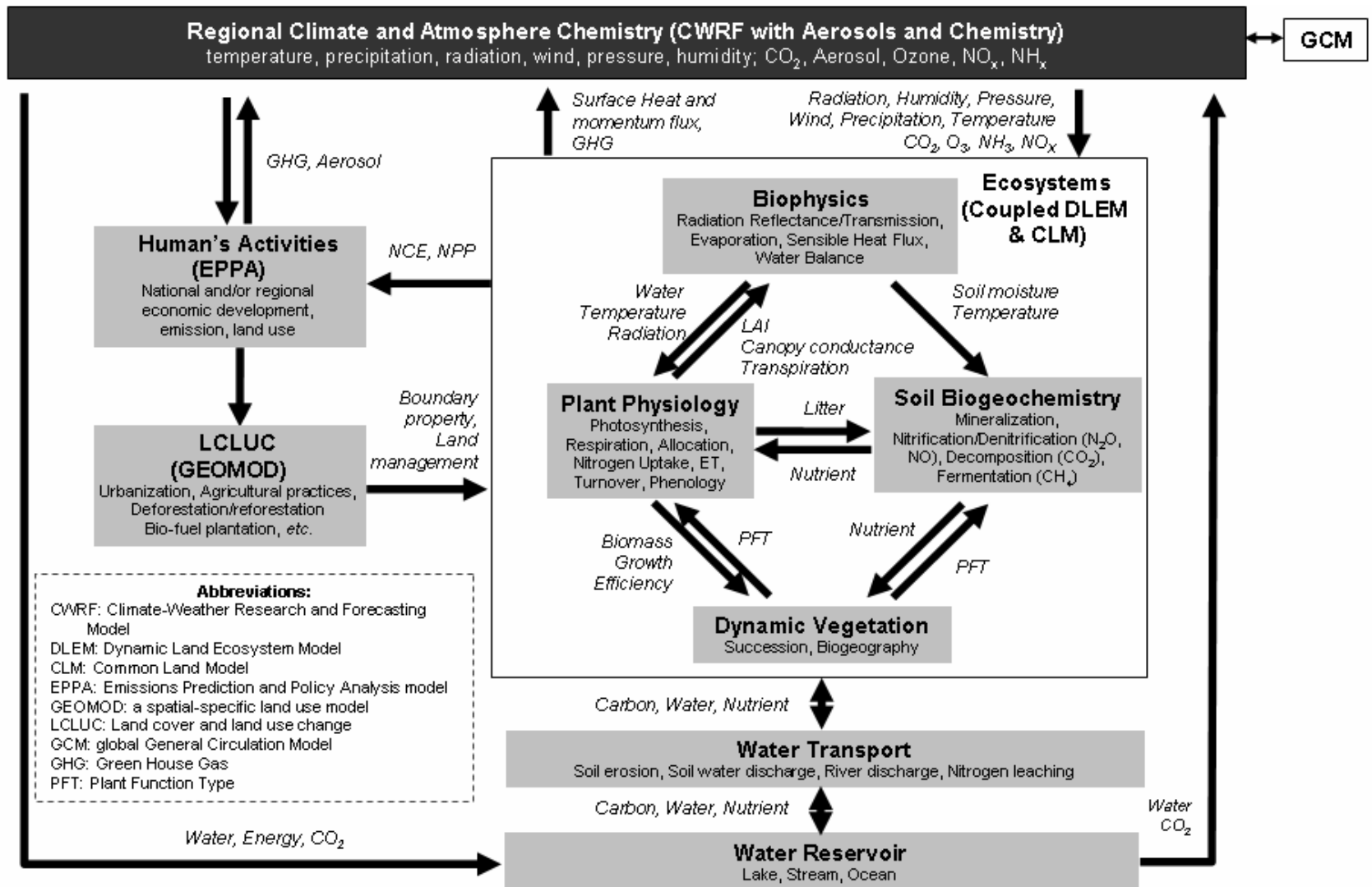


Understand complex interactions among land use, ecosystem and climate and to evaluate the impacts of current and projected LCLUC on climate, water and carbon cycling in the region of monsoon Asia in the first half of 21st century by using an copled regional earth system model (CRESM).

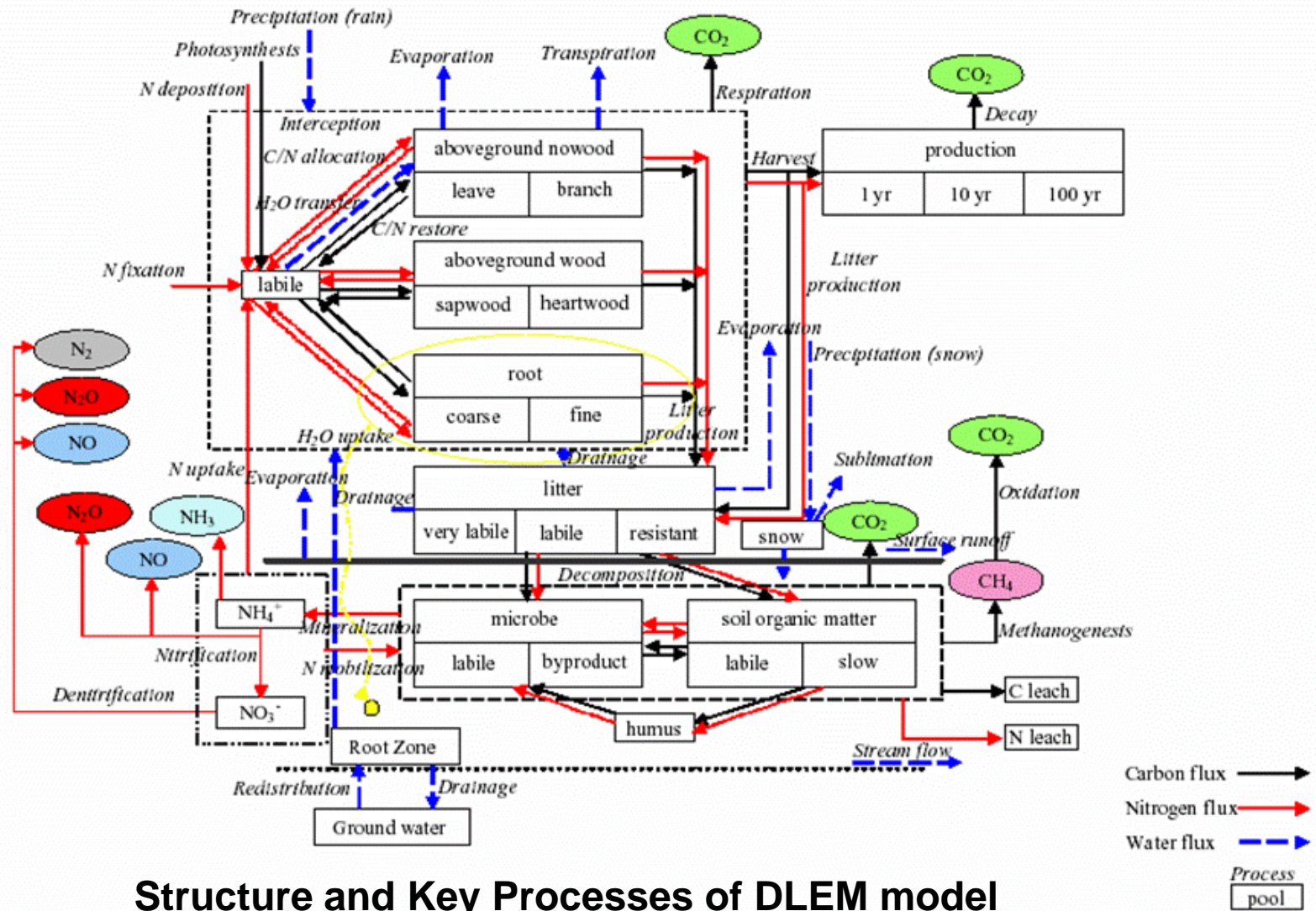
Global Land System Interactions



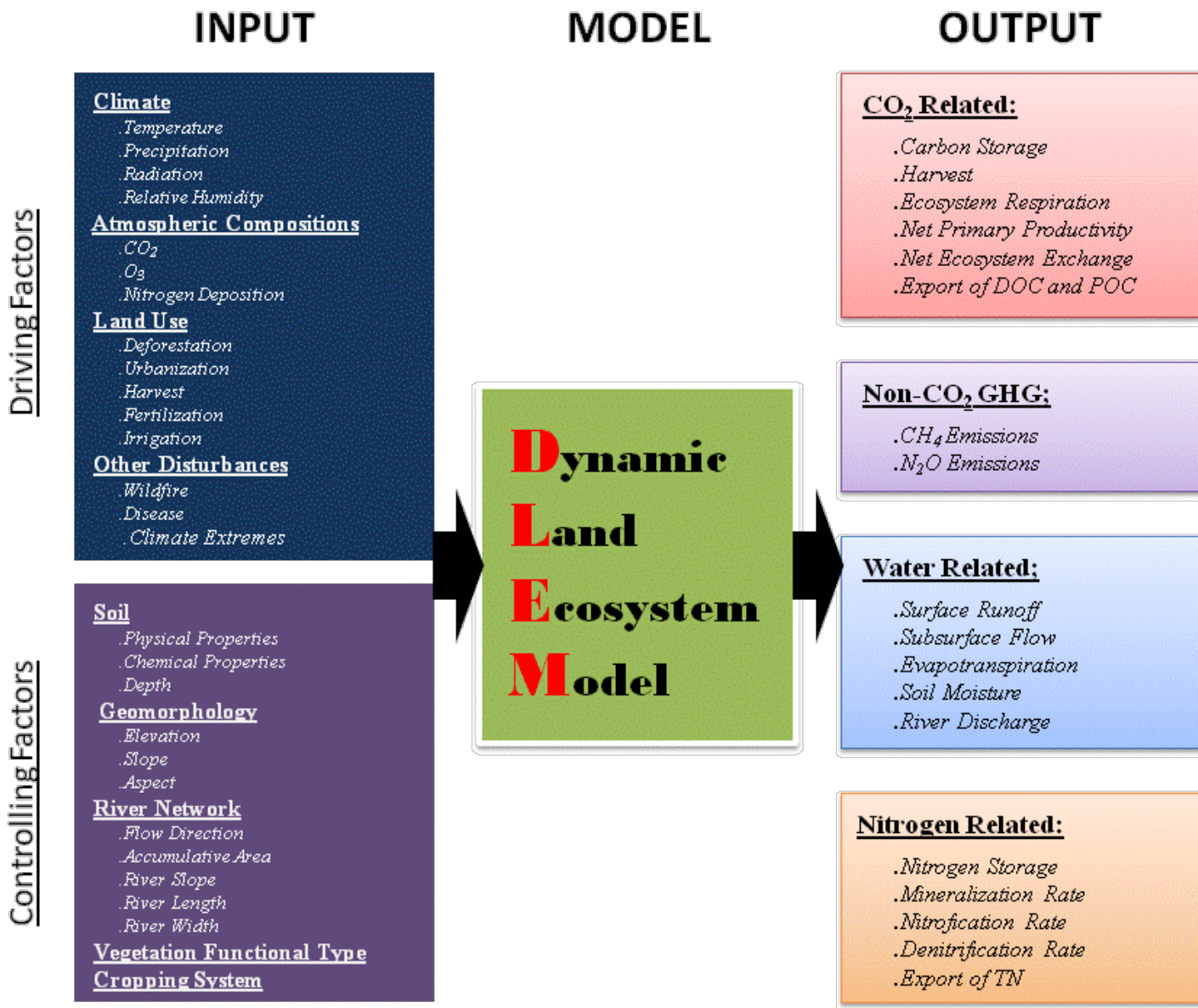
Coupled Regional Earth System Model (CRESM)



Dynamic Land Ecosystem Model (DLEM)



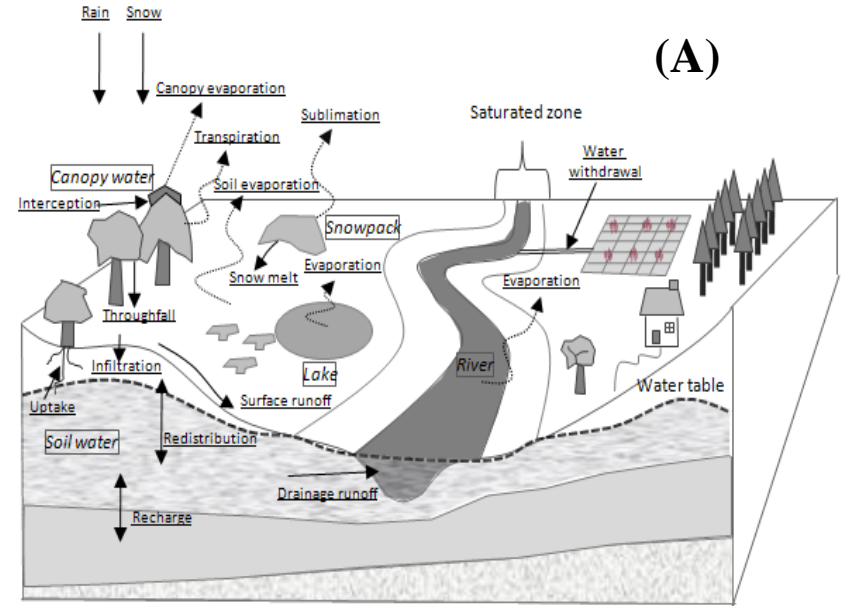
Structure and Key Processes of DLEM model



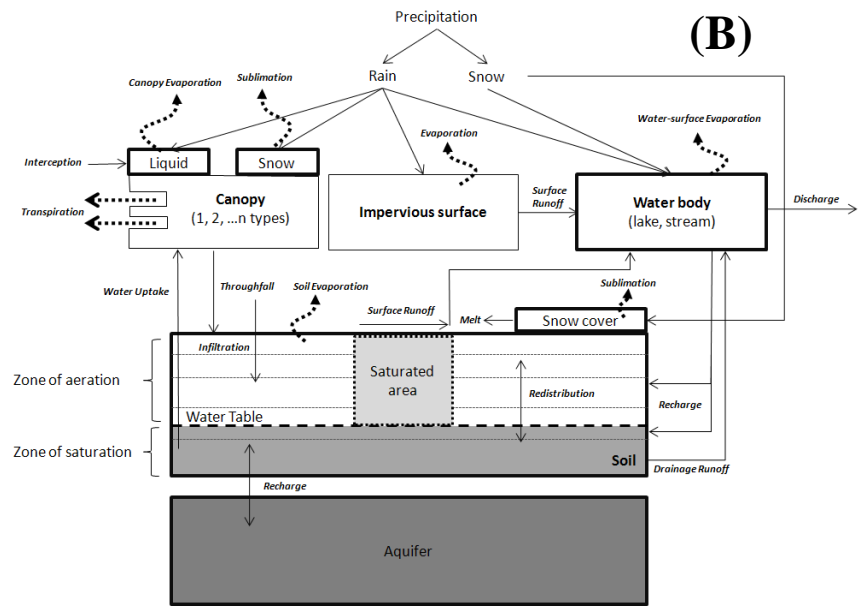
Major inputs and outputs in DLEM model

Land-Coastal Ocean Coupling

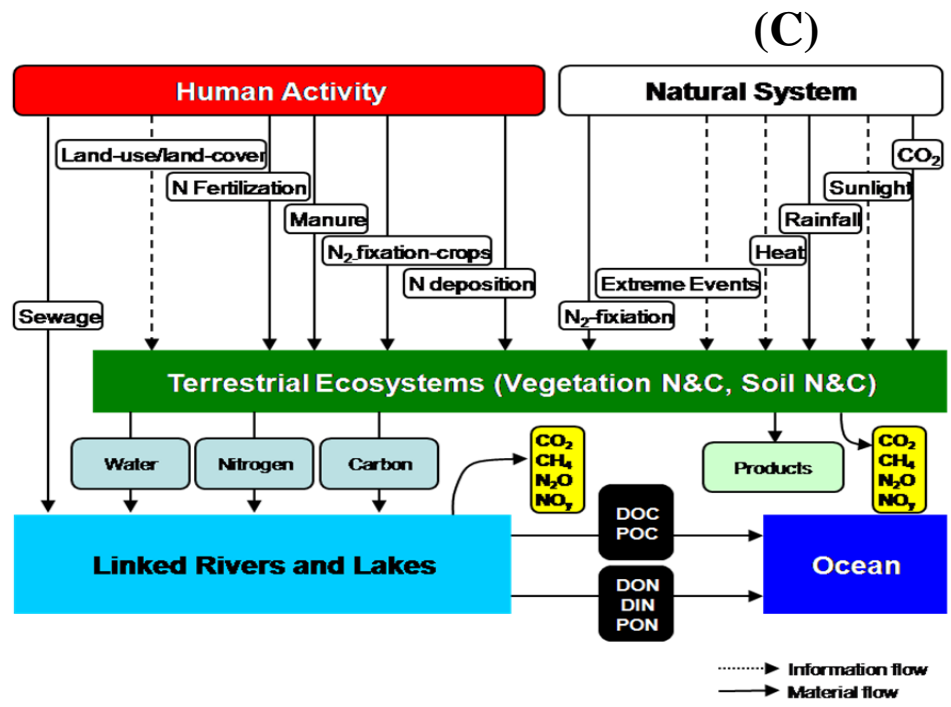
- A) Water/ Nutrients transport and soil erosion in CRESM
- B) Cohort scheme for representing heterogeneous land covers over the simulation unit in CRESM
- C) Multiple soil layer representation and TOPMODEL-based rainfall-runoff process in CRESM



(A)



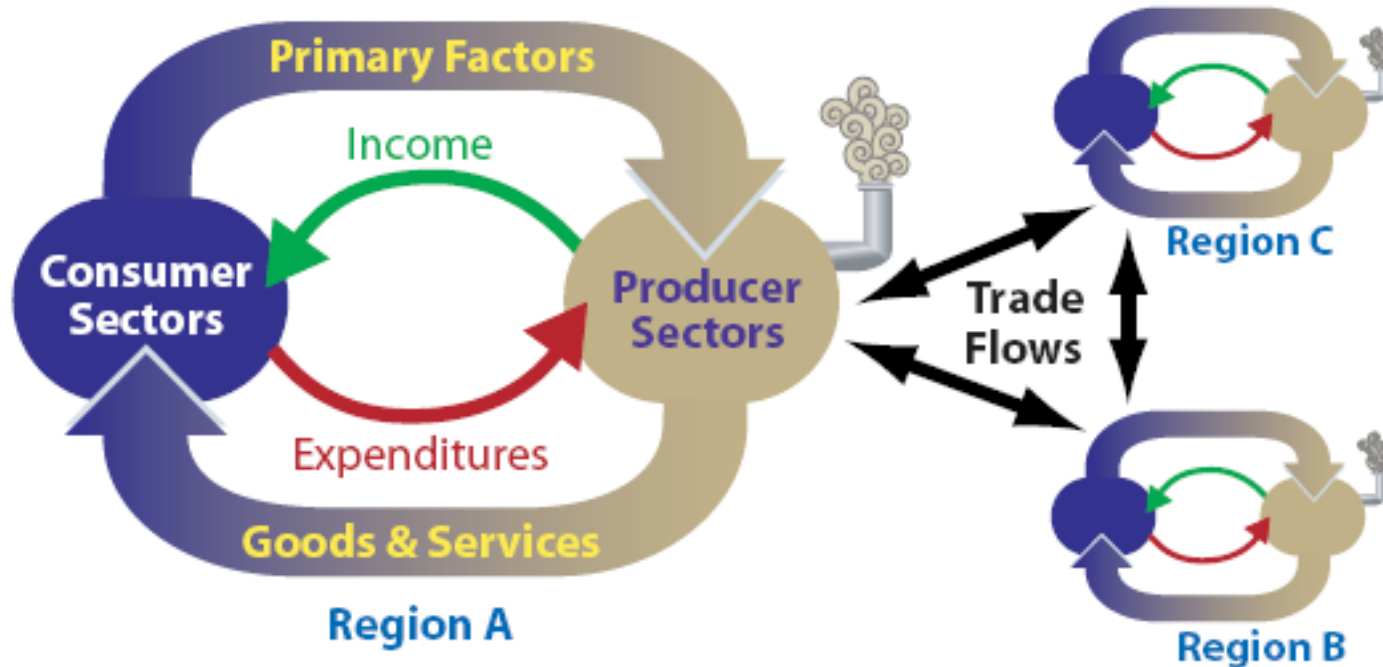
(B)



(C)

..... Information flow
 — Material flow

MIT Emissions Prediction and Policy Analysis (EPPA) model



Model Features

- All greenhouse-relevant gases
- Flexible regions
- Flexible producer sectors
- Energy sector detail
- Welfare costs of policies

Mitigation Policies

- Emissions limits
- Carbon taxes
- Energy taxes
- Tradeable permits
- Technology regulation

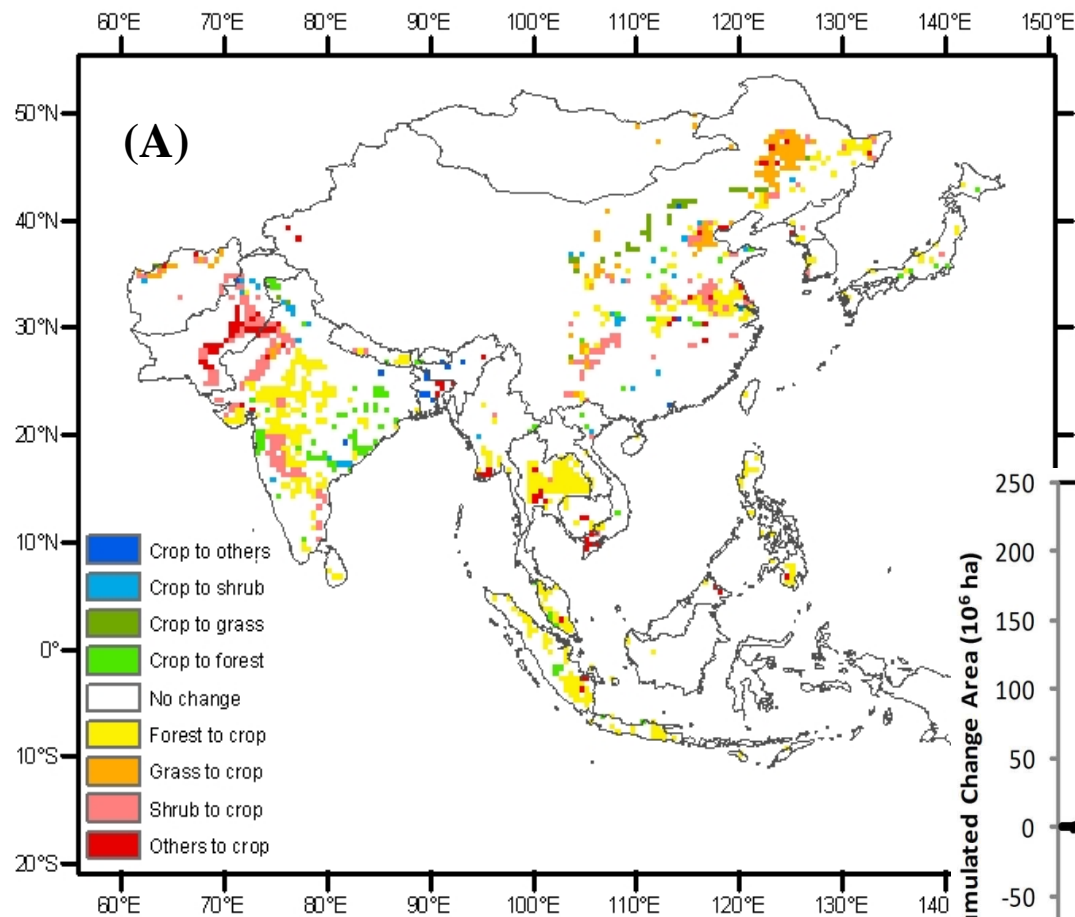
KEY RESULTS



Land-cover and land-use change in Monsoon Asia

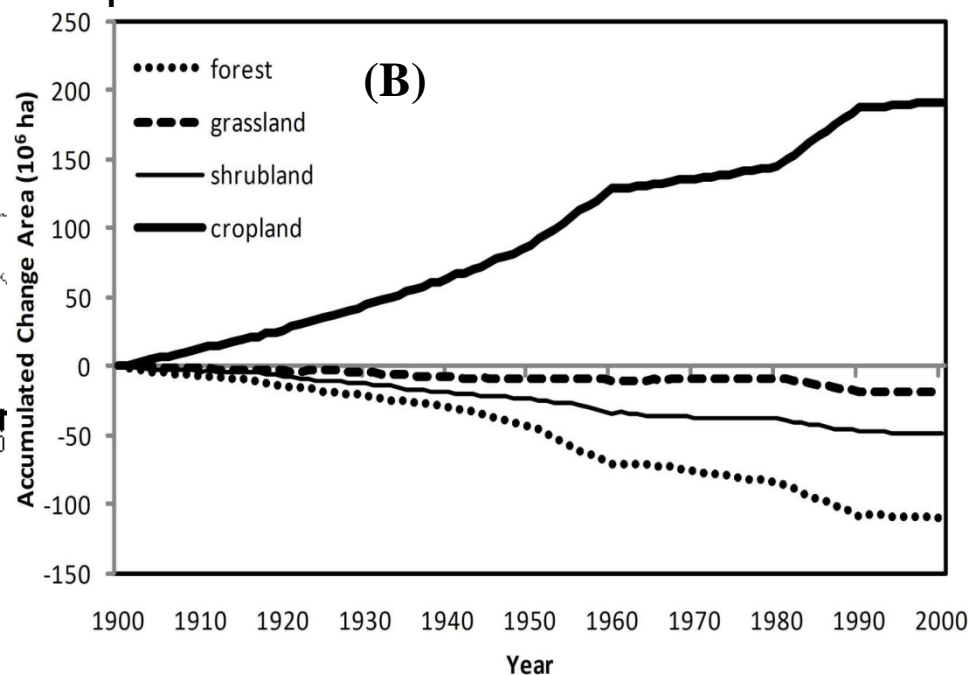
Historical & future projection
1900-2100

Spatial distribution of land use change in Monsoon Asia during 1900-2000

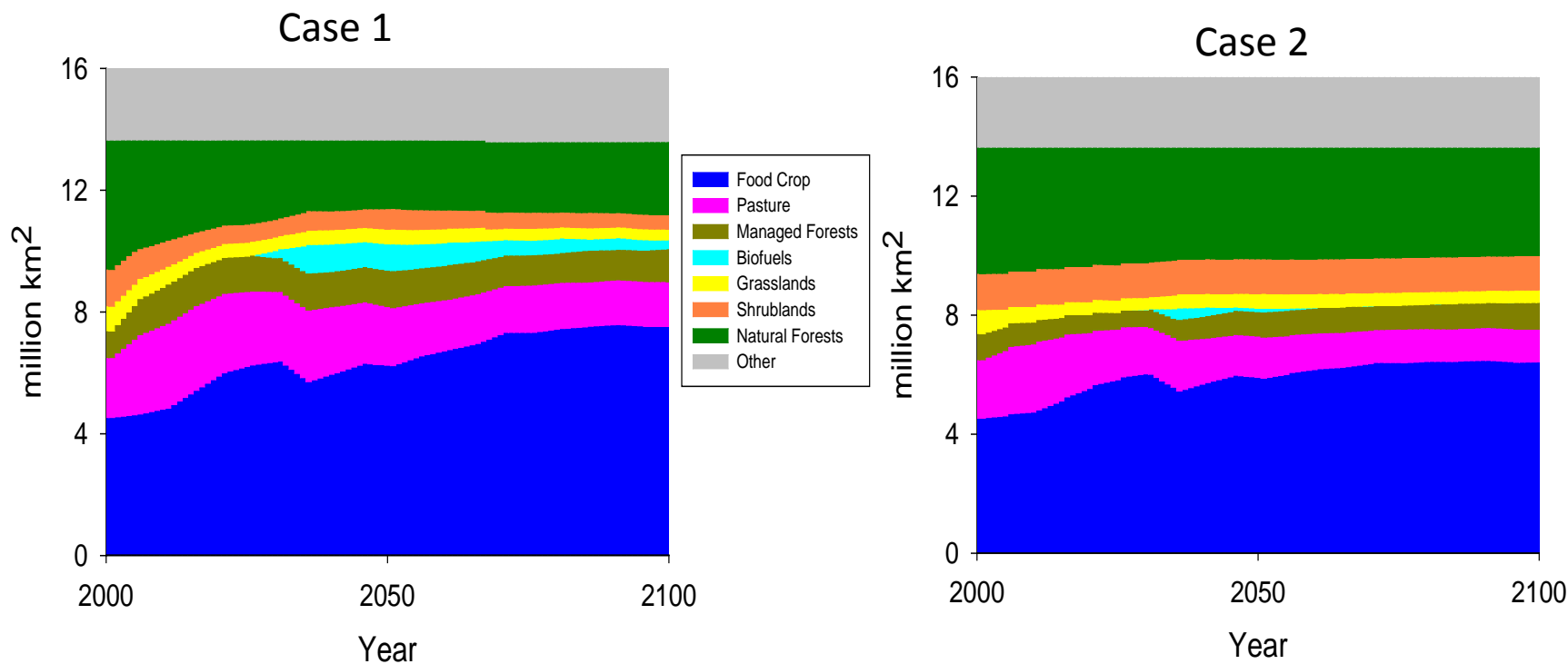


A) Spatial pattern of land use change in Monsoon Asia during 1900-2000

B) Accumulated change area of major biomes in terrestrial ecosystems of Monsoon Asia during 1900-2000

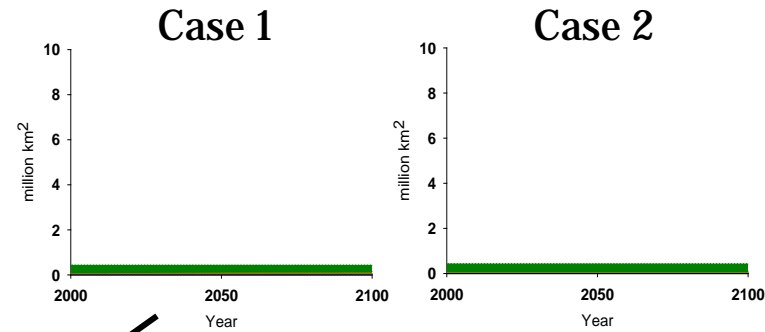
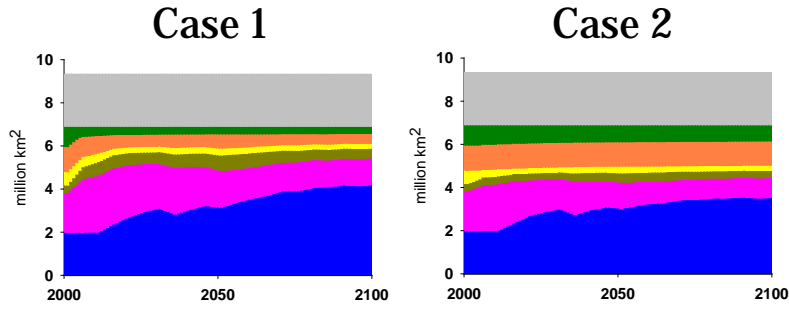


Future Land-cover and Land-use Change derived from biofuel scenarios in Monsoon Asia during 2000-2100

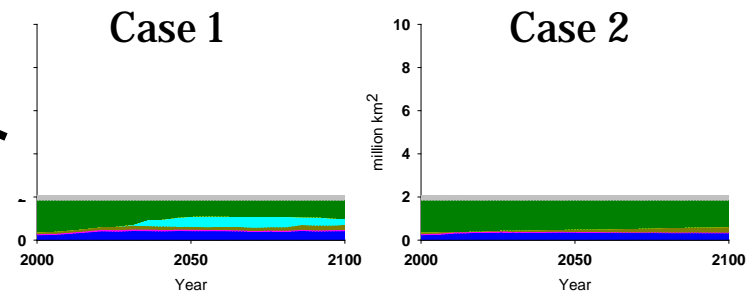
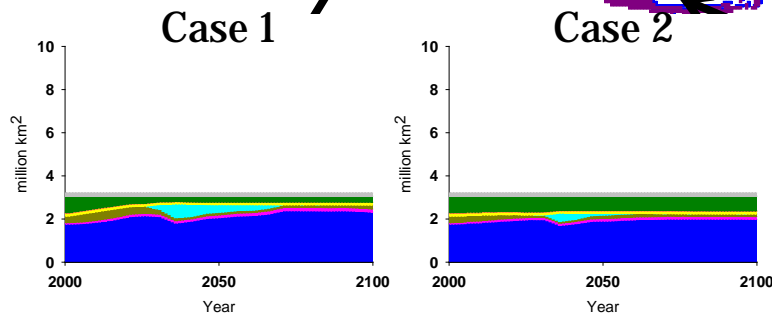
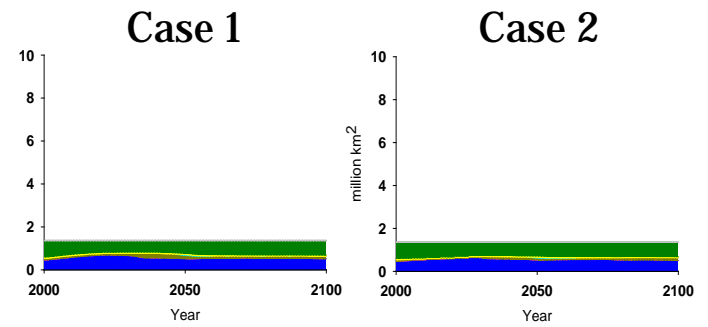
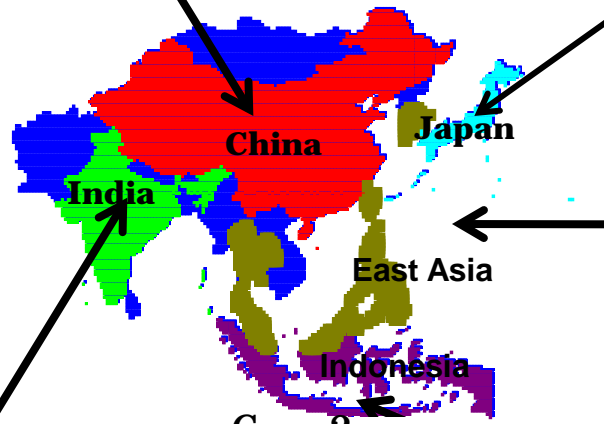
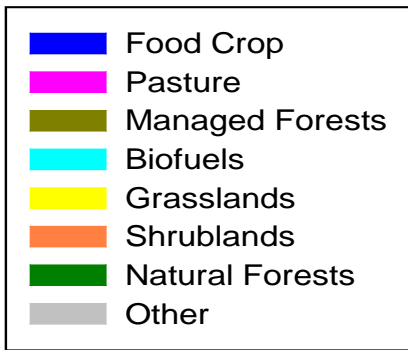


Projected changes in monsoon Asian land cover for land-use **Case 1** and **Case 2** estimated by EPPA model (case1 allows the conversion of natural areas to meet increased demand for land, case2 is driven by more intensive use of existing managed land) By the end of 2100, land-use area for Biofuel production increases about 33% in case 1 while 0% in case2. Pastures areas decrease less in case 1 (about 25%) than in case 2 (45%), on the contrary, forest area decline about 43% in case1, much more than 14% in case 2.

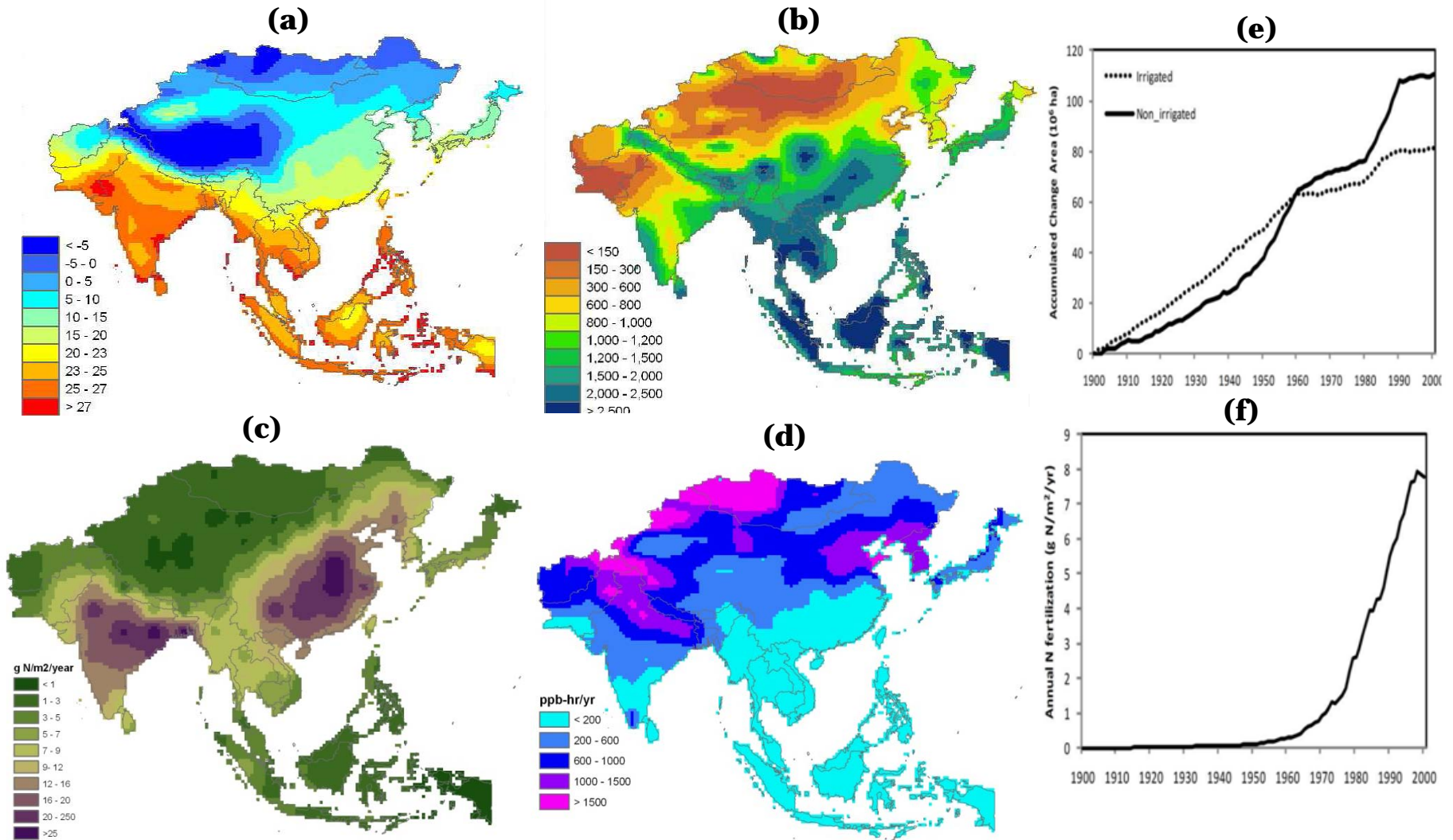
Regional Land-cover and land use change in Monsoon Asia during 2000-2100 derived from biofuel scenarios



Land Cover



Other major environmental forces



Spatial pattern of annual average for a) Temperature, b) Precipitation, c) Nitrogen deposition, and d) Ozone (AOT40) across Monsoon Asia over 1948-2000. Annual average of e) irrigation/non-irrigation land area, and f) fertilizer application rate from 1900 to 2000

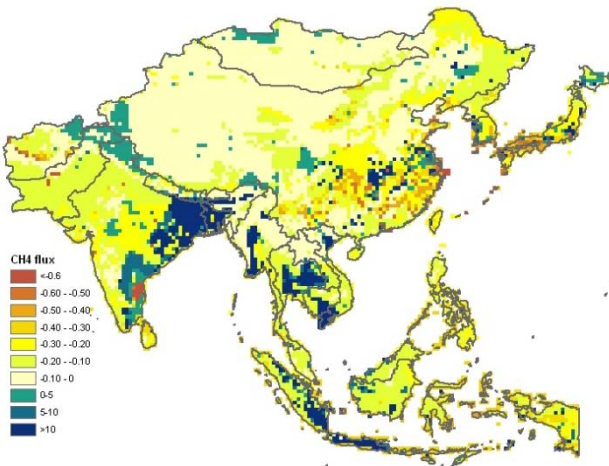


Impacts of land-cover and land-use change on terrestrial ecosystem (carbon & water cycles, GHGs) and climate in Monsoon Asia

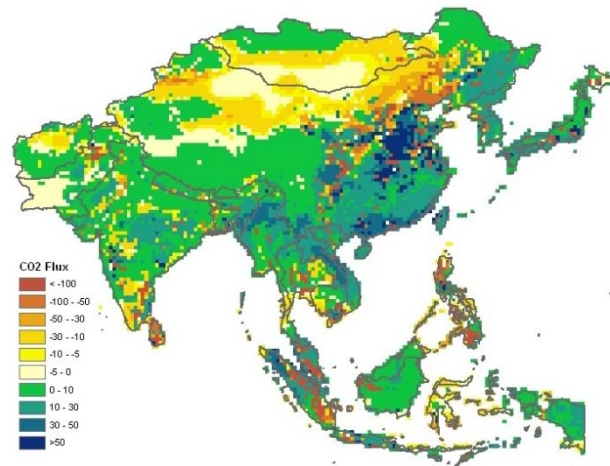
Historical & future projection
1700-2100

GHGs fluxes, Carbon & Water cycles in monsoon Asia over the 20th century

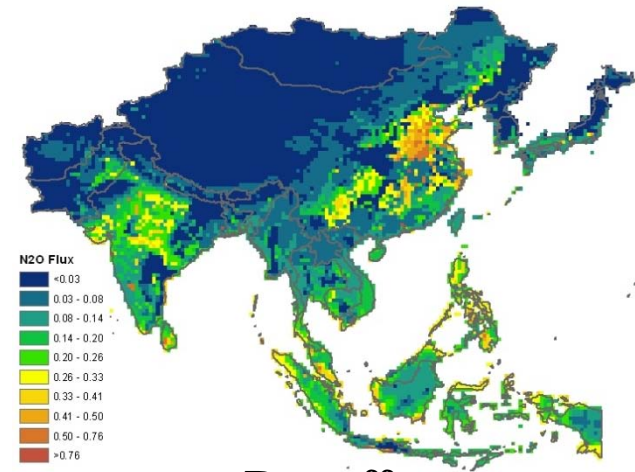
CH₄



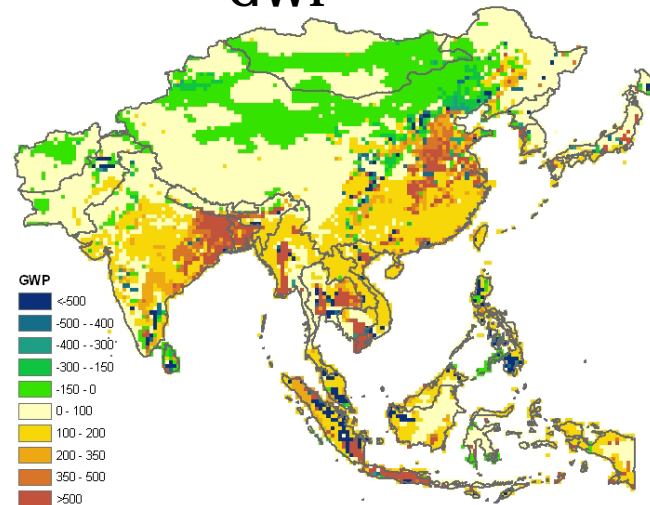
CO₂



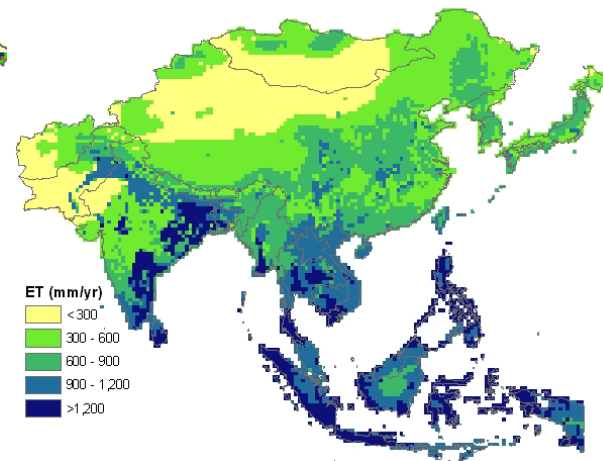
N₂O



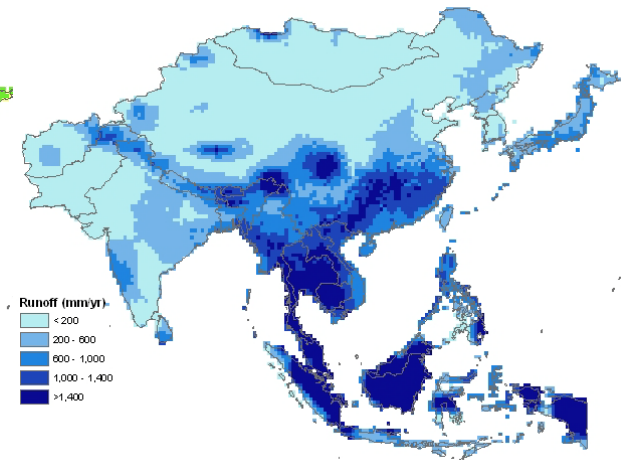
GWP



ET

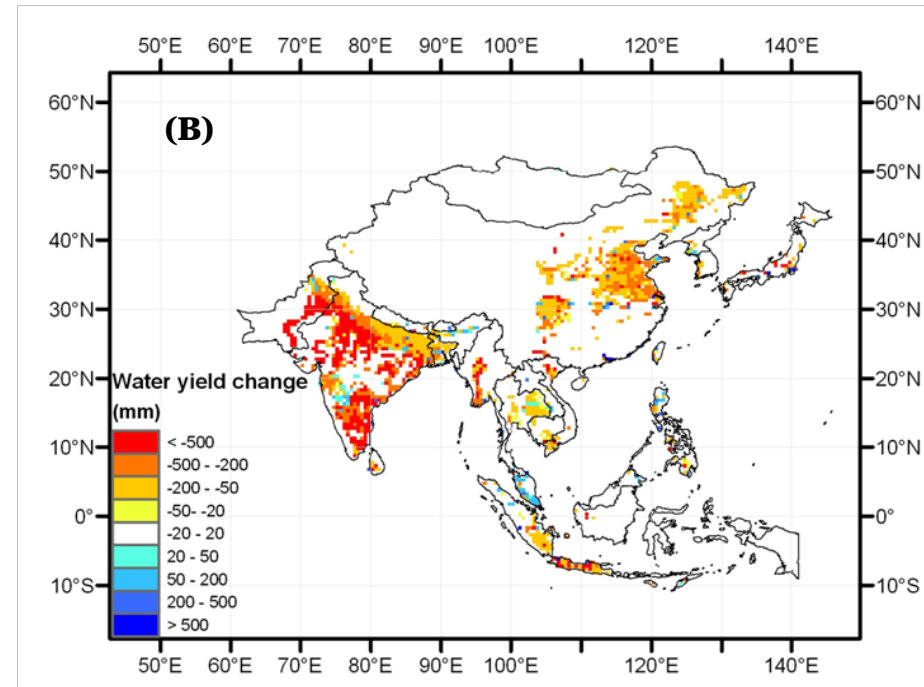
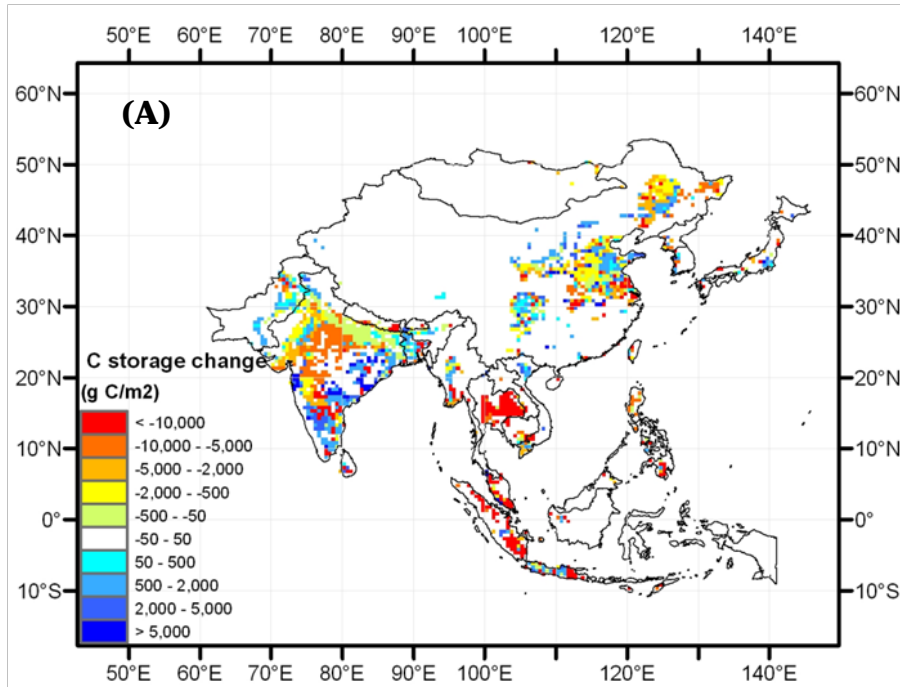


Runoff



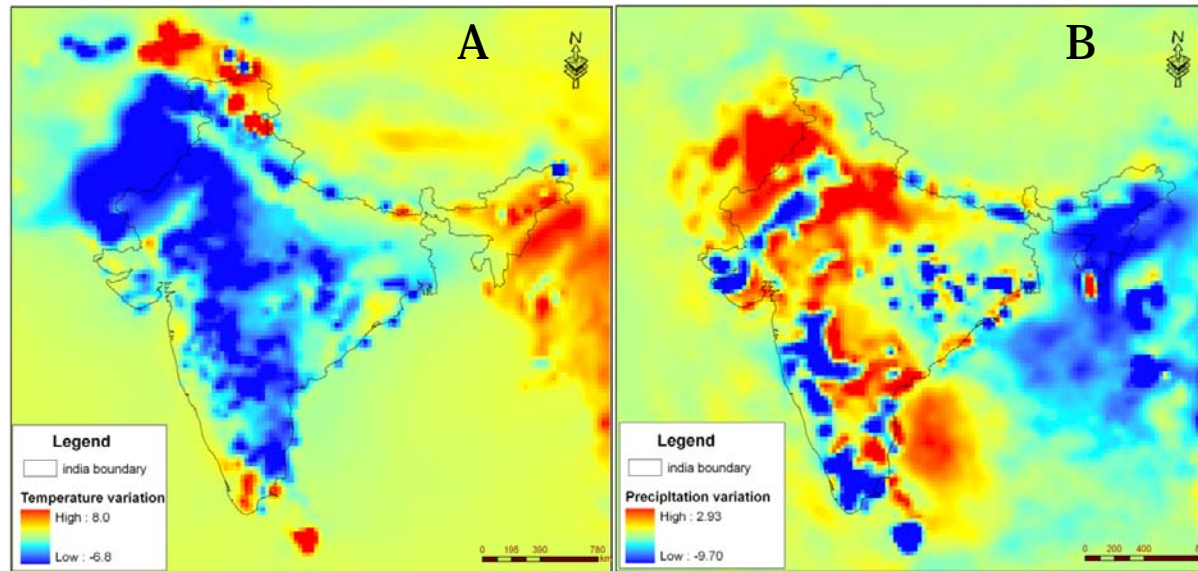
The 50-year average of ecosystem-atmosphere exchange of CO₂ (g Cm⁻²a⁻¹), CH₄(g Cm⁻²a⁻¹), and N₂O (N m⁻²a⁻¹), the resulted global warming potential GWP(CO₂ eq m⁻²a⁻¹), terrestrial evapotranspiration (ET, mm a⁻¹), and runoff (mm a⁻¹) during 1951-2000 estimated by DLEM model. *Tian et al., 2010b*

Changes in carbon storage and water yield induced by LCLUC



Changes in carbon storage (A) and water yield (B) in terrestrial ecosystems of Monsoon Asia induced by land-cover and land-use change during 1700-2005 as simulated by the Dynamic Land Ecosystem Model (DLEM).

Changes in India's temperature and precipitation induced by LCLUC

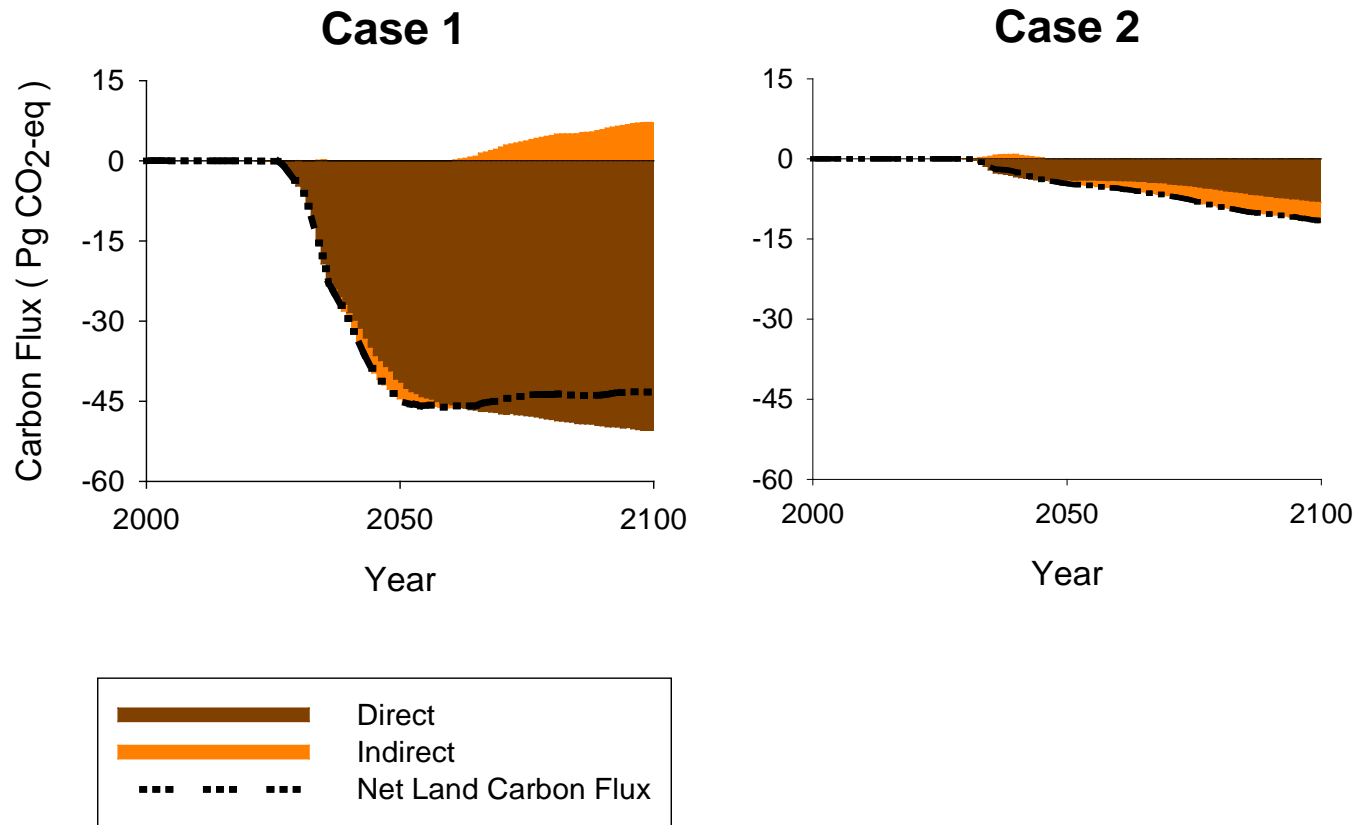


| Items of LULC | Temperature (°C/yr) | Precipitation (mm/day) |
|--|---------------------|------------------------|
| Total LULC effect | -0.52 | 0.0 |
| Conversion from potential vegetation to irrigated crop | -1.13 | 0.40 |
| Conversion from potential vegetation to non-irrigated crop | -0.56 | -0.37 |

Simulation experiments conducted to study the variations of climate system (A: temperature, B: precipitation) in response to historical land use change from 1700 to 2000 estimated by Regional Climate model.

EDGE lab, Mao et al., 2010

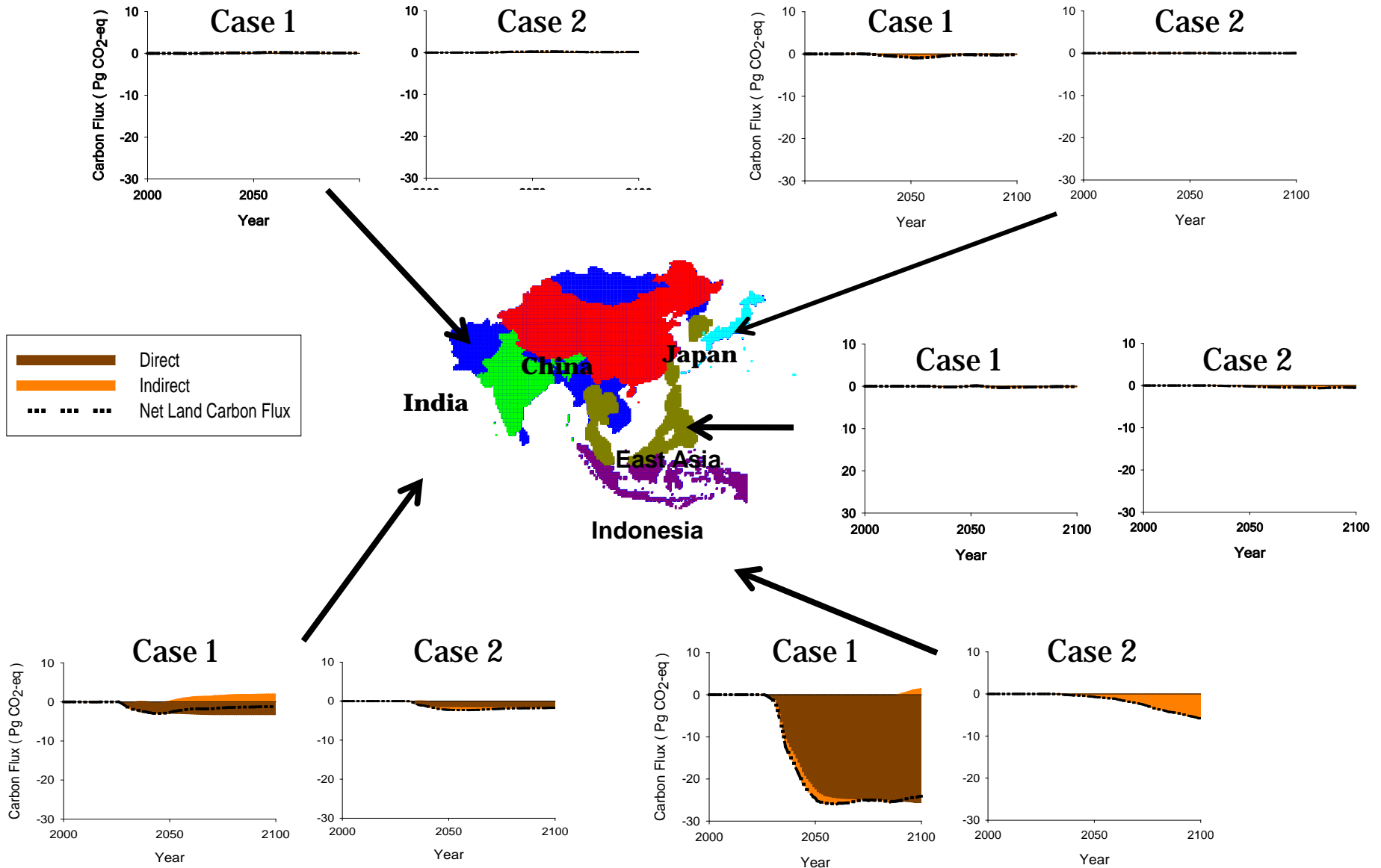
Cumulative Net Land Carbon Flux driven by biofuel production in two land use scenarios across Monsoon Asia over the 21st century



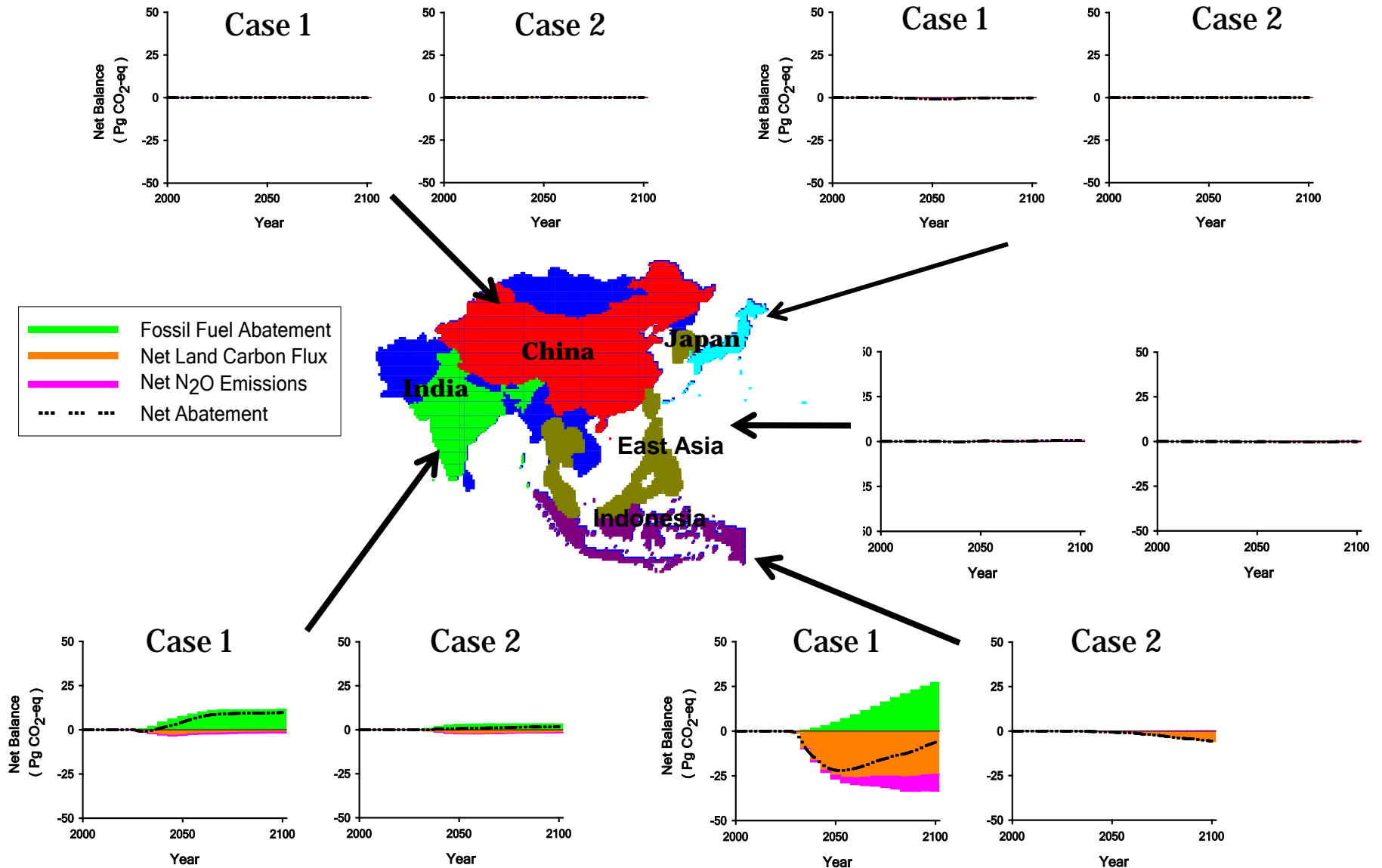
Partitioning of direct and indirect effects on projected cumulative land carbon flux from biofuel projection for land-use Case 1 and Case 2. Positive values represent carbon sequestration, whereas negative values represent carbon emissions by land ecosystems.

Melillo et al., 2009, Science 326:1397-1399

Regional partitioning of direct and indirect effects on projected cumulative land carbon flux in the 21st century



Regional partitioning of greenhouse gas balance in the 21st century driven by biofuel production in two land use scenarios



Messages from this work



- **Monsoon Asia has experienced rapid changes in land cover and land use pattern in the past century and is likely to undergo further rapid changes in the 21st century due to urbanization, deforestation, desertification etc. Land area devoted to biofuels in case 1 is larger than that in case 2 and the biofuel production is mainly distributed in the regions of India and Indonesia.**
- **Anthropogenic activities, such as land cover conversion, land management, have imposed significant impacts on carbon and water cycles (C storage and water yield), GHG emissions (CH₄, CO₂ and N₂O) and climate (temperature and precipitation). Future LCLUC, e.g. expanded global cellulosic bioenergy program, could considerably alter net carbon fluxes and GHGs balance in Monsoon Asia. In both land use cases, indirect effects of biofuel production contribute to more carbon uptake or less carbon release than direct effects do. The resulted GHG balance in terms of warming potential vary significantly among regions.**
- **The Coupled Regional Earth System Model (CRESM) has shown the potential to explore the complex interactions among land use, ecosystems and monsoon climate in Monsoon Asia, a critical area affecting the world environment and economic development. Future work is needed to further validate the CRESM model and to explore the likely uncertainties.**

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