LC/LUC and Impacts on Environment in SSEA –
Intl. Regional Science Team Meeting
Philippines, May 28-30, 2018

Dynamics and Drivers of Land Cover & Land Use Changes in Bangladesh – Integration of Satellite Data with Socioeconomic Dataset

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Acknowledgements

Xiaoming Xu and Regional and US CO-Is & Collaborators

NASA LCLUC Program & University of Illinois

Overall Objective

- Improve our understanding of the dynamics and drivers of LCLUC

Why?

  - Improve the understanding of the impacts of LCLUC dynamics on the quantities and pathways of land carbon and nitrogen fluxes at various scales
  - Improve the projection of the impacts of climate change on agriculture and land use

Global Change Biology (2016), doi: 10.1111/gcb.13447

Assessing uncertainties in land cover projections

PETER ALEXANDER[1,2], REINHARD PRESTELE[3], PETER H. VERBURG[3], ALMUT ARNETH[4], CLAUDIA BARANZELLI[5], FILIPE BATISTA E SILVA[5], CALUM BROWN[1], ADAM BUTLER[6], KATHERINE CALVIN[7], NICOLAS DENDONCKER[8], JONATHAN C. DOELMAN[9], ROBERT DUNFORD[10,11], KERSTIN ENGSTRÖM[12], DAVID EITELBERG[3], SHINICHIRO FUJIMORI[13], PAULA A. HARRISON[11], TOMOKO HASEGAWA[13], PETR HAVLIK[14], SASCHA HOLZHAUER[1], FLORIAN HUMPENÖDER[15], CHRIS JACOBS-CRISIONI[5], ATUL K. JAIN[16], TAMÁS KRISZTIN[14], PAGE KYLE[7], CARLO LAVALLE[5], TIM LENTON[17], JIAYI LIU[6], PRASANTH MEIYAPPAN[16], ALEXANDER POPP[15], TOM POWELL[17], RONALD D. SANDS[18], RÜDIGER SCHALDACH[19], ELKE STEHFEST[9], JEVGENIJS STEINBUKS[20], ANDRZEJ TABEAU[21], HANS VAN MEIJL[21], MARSHALL A. WISE[7] and MARK D. A. ROUNSEVELL[1]

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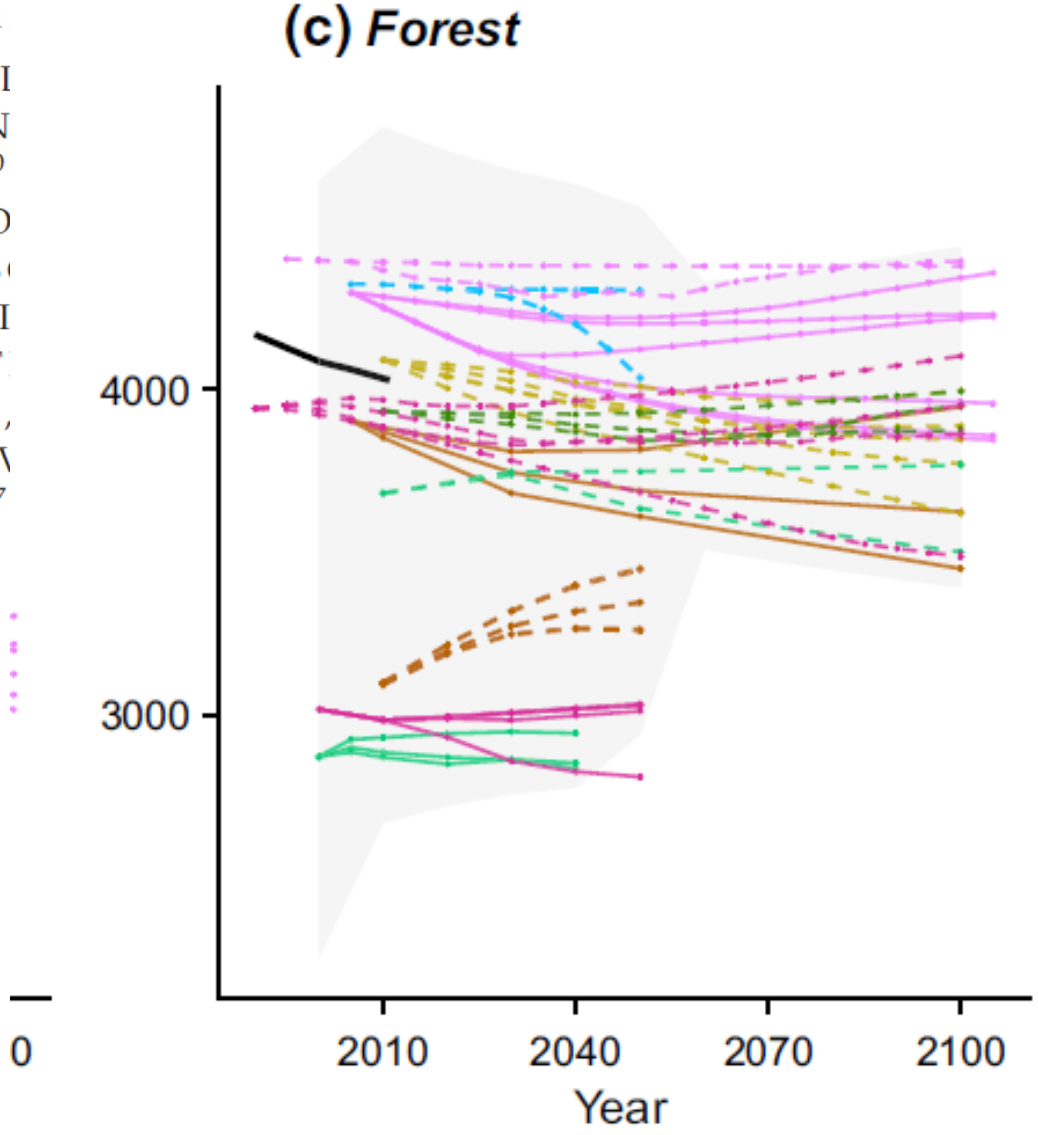

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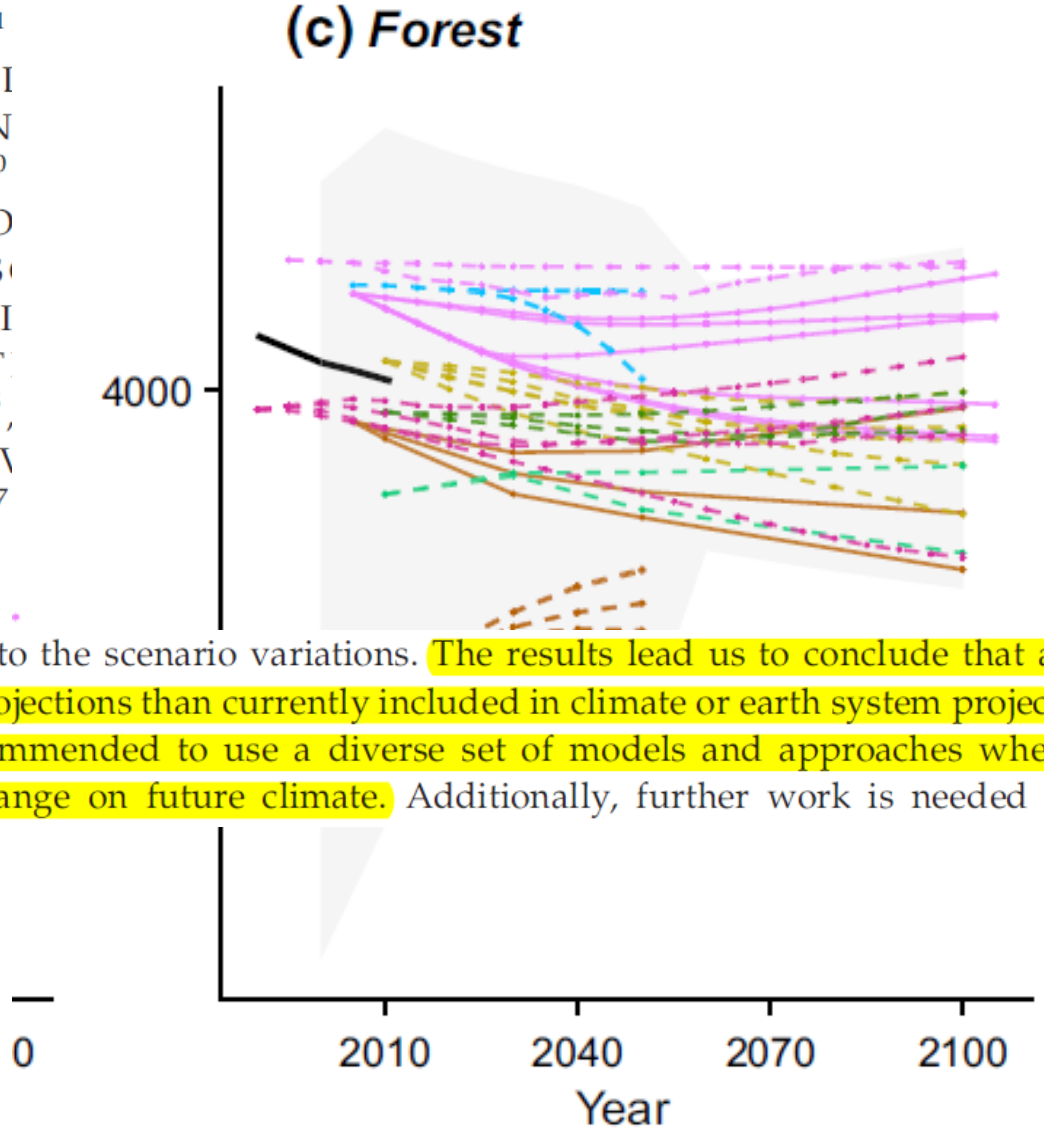


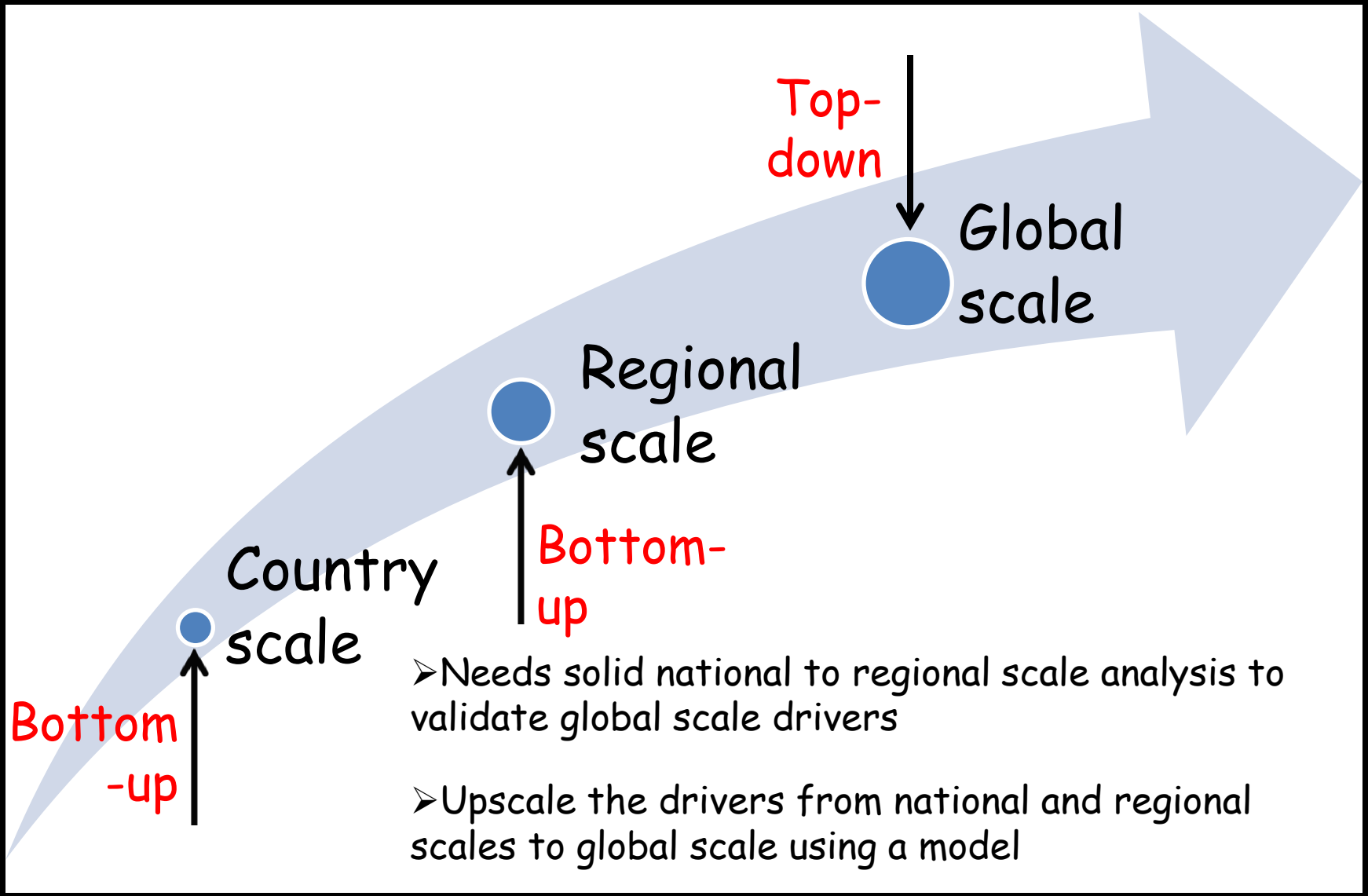
the differences attributed to the scenario variations. The results lead us to conclude that a higher degree of uncertainty exists in land use projections than currently included in climate or earth system projections. To account for land use uncertainty, it is recommended to use a diverse set of models and approaches when assessing the potential impacts of land cover change on future climate. Additionally, further work is needed to better understand the

Accepted for Publication in *Nature Communication*

Land-use emissions play a critical role in effectiveness of land-based climate mitigation for 1.5C target

Anna B. Harper[1*], Tom Powell[2], Peter M. Cox[1], Joanna House[3], Chris Huntingford[4], Timothy M. Lenton[2], Stephen Sitch[2], Eleanor Burke[5], Sarah E. Chadburn[1,6], William J. Collins[7], Edward Comyn-Platt[4], Vassilis Daioglou[8,9], Jonathan C. Doelman[8], Garry Hayman[4], Eddy Robertson[5], Detlef van Vuuren[8,9], Andy Wiltshire[5], Christopher P. Webber[7], Ana Bastos[10], Lena Boysen[11], Philippe Ciais[12], Narayanappa Devaraju[12], Atul K. Jain[13], Andreas Krause[14], Ben Poulter[15], Shijie Shu[13]

LCLUC Drivers at Global Scale - Mix of top-down and bottom-up approach



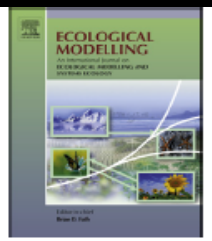
- Needs solid national to regional scale analysis to validate global scale drivers
- Upscale the drivers from national and regional scales to global scale using a model

Top-down Approach: Global Scale Modeling of LCLUC

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel



Spatial modeling of agricultural land use change at global scale

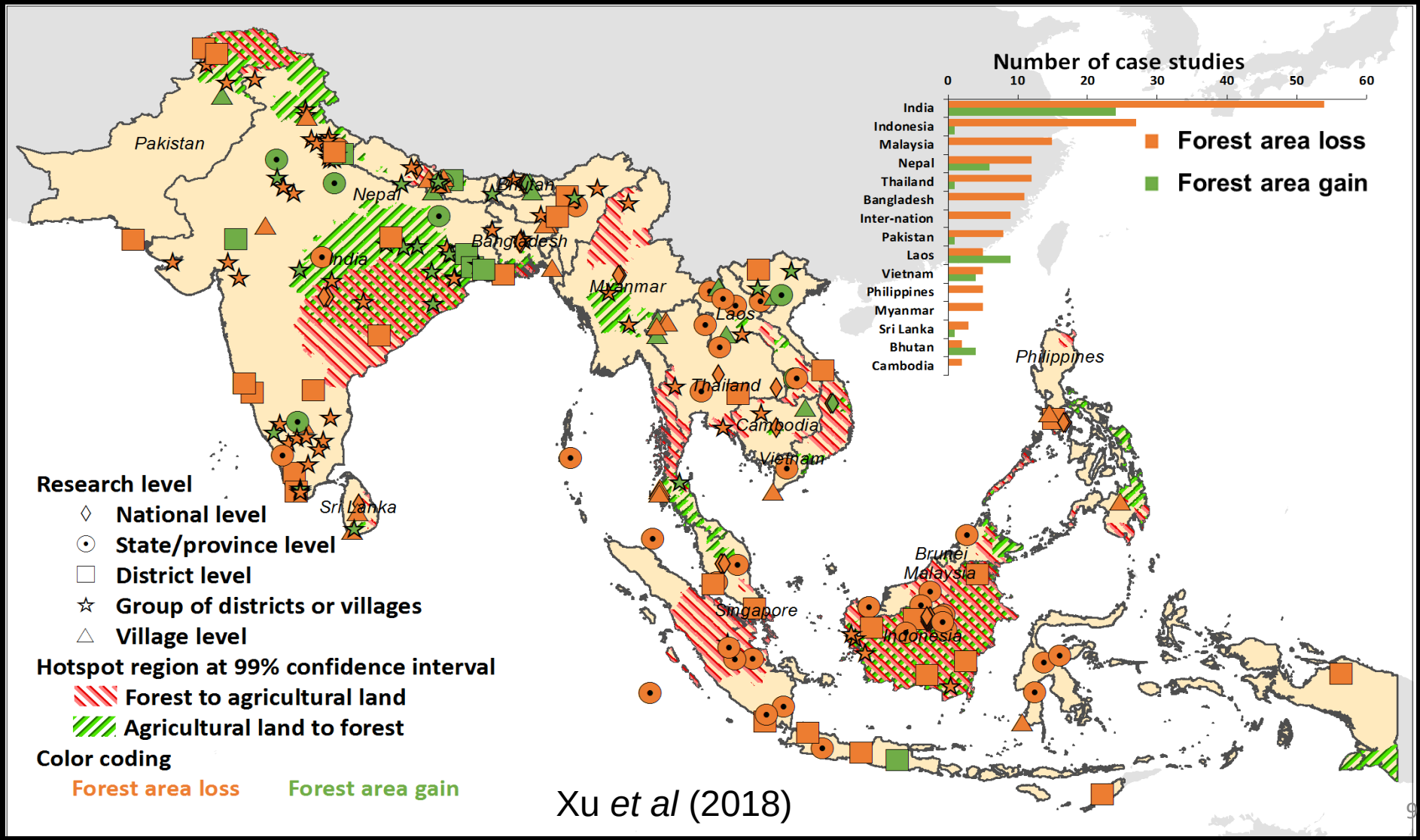
Prasanth Meiyappan[a,*], Michael Dalton[b], Brian C. O'Neill[c], Atul K. Jain[a,**]

Implementation of Global-Scale Spatial Dynamic Allocation Model (SDAM) in a Coupled Modeling Framework

- Land use competition
- Spatial and temporal autocorrelation in land use patterns
- Spatial heterogeneity of the biophysical and socioeconomic drivers across geographic regions
- It can reproduce the broad spatial features of the past 100 years of cropland and pastureland patterns

Meiyappan *et al*, 2014

Synthesis of case studies & hotspot regions
Example: Forest areas gain and loss
Support by NASA LCLUC Program



Xu *et al* (2018)

Synthesis of case studies & hotspot regions
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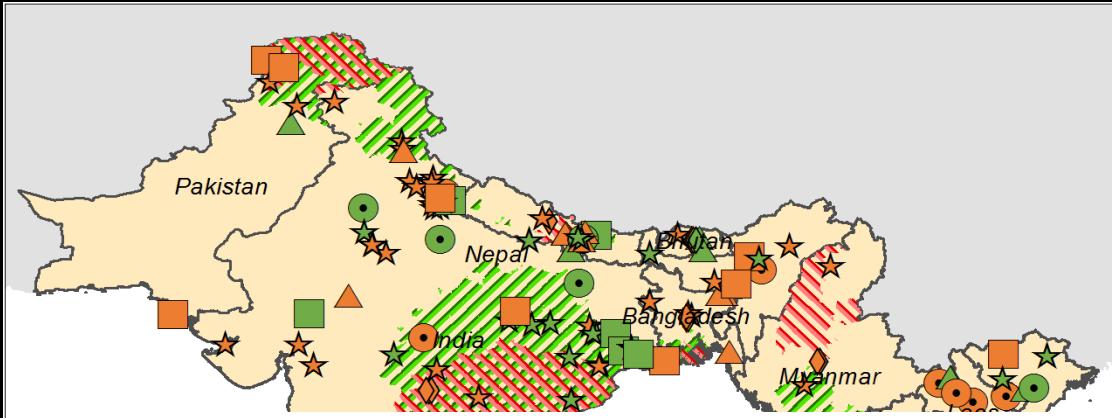
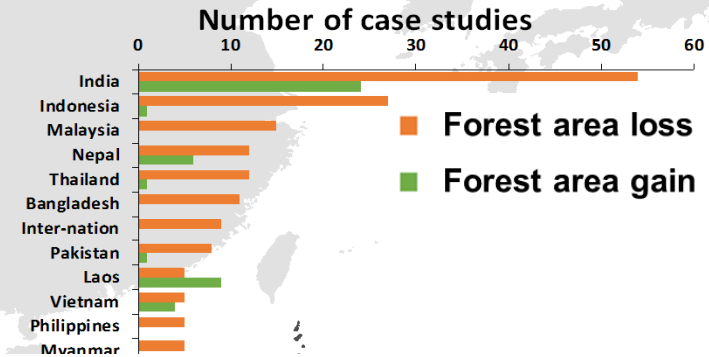
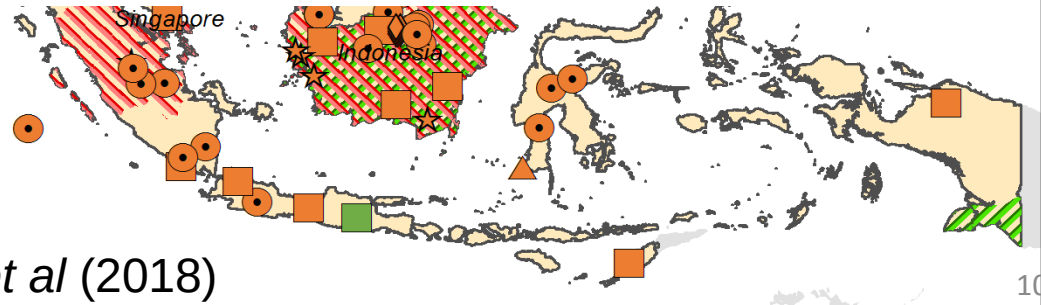




The driving processes for LCLUC vary with regions and countries, indicating the needs for further understanding of LCLUC dynamics at country and local scales.

Re

☆ Group of districts or villages
△ Village level
Hotspot region at 99% confidence interval
Forest to agricultural land
Agricultural land to forest
Color coding
Forest area loss Forest area gain



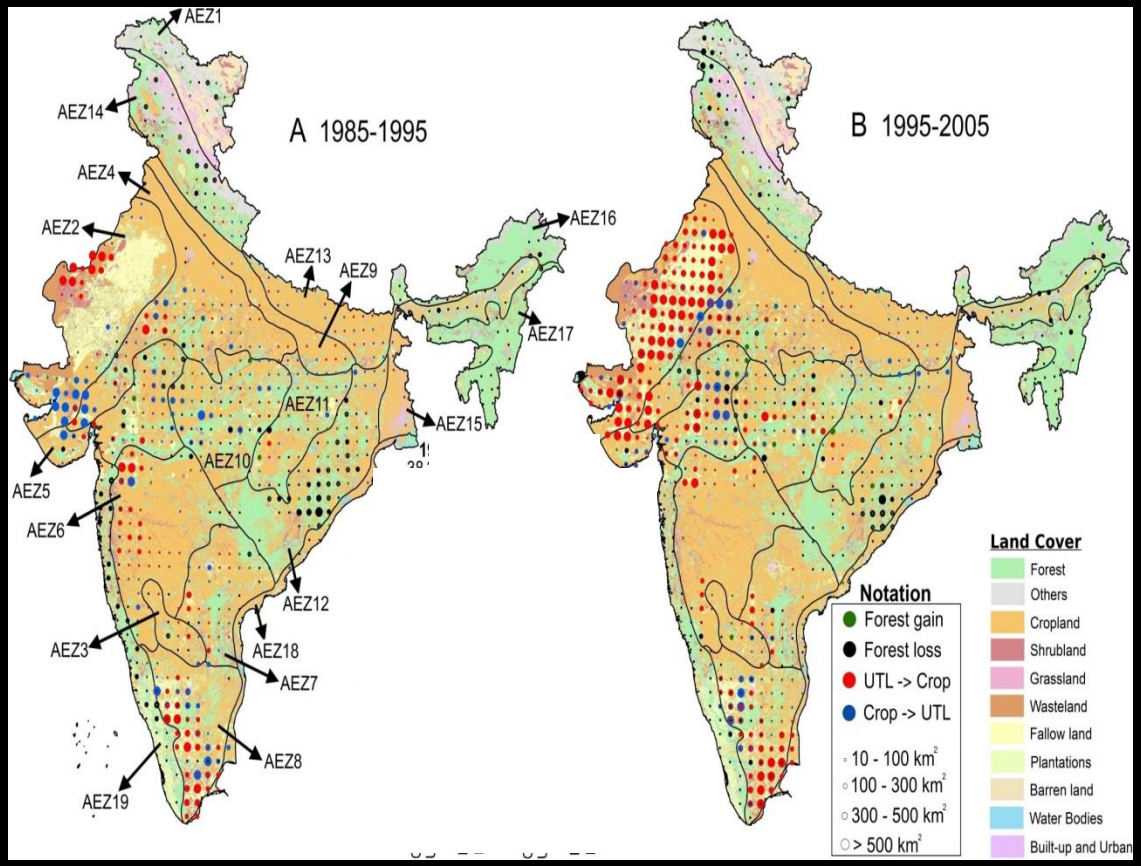
Xu *et al* (2018)

County to Local Scale Analysis

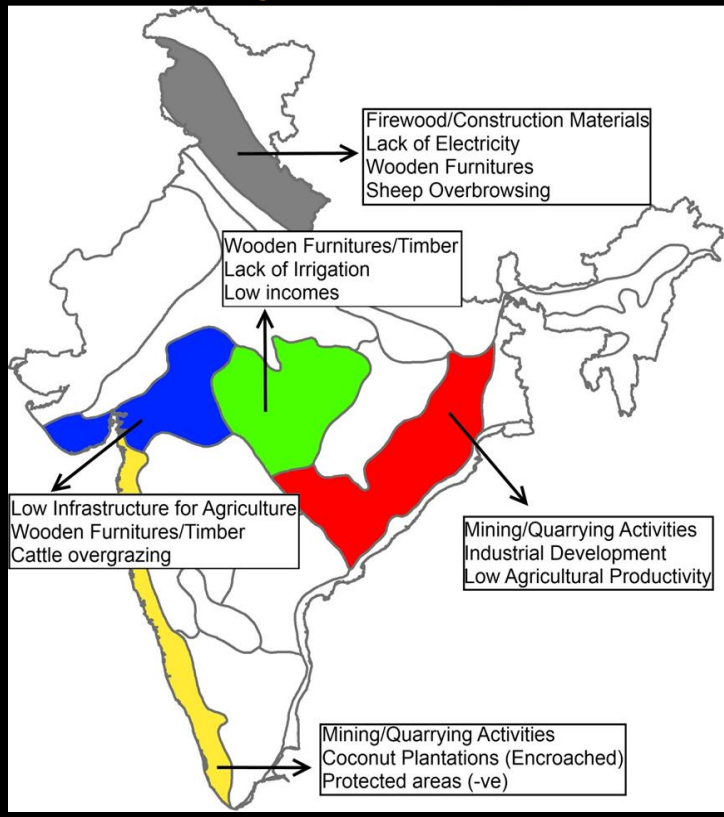
Dynamics and determinants of land change in India: integrating satellite data with village socioeconomics

Reg Environ Change
DOI 10.1007/s10113-016-1068-2

Prasanth Meiyappan[1] · Parth S. Roy[2] · Yeshu Sharma[3] · Reshma M. Ramachandran[2] · Pawan K. Joshi[4] · Ruth S. DeFries[5] · Atul K. Jain[1]



Major findings



Bangladesh Study - Background

- Rapid change between various land cover types and agricultural land over the years
  - growing population and economy, expanding infrastructure use, and climate change.
- It is becoming challenging for Bangladesh to ensure enough agricultural land for the growing population
- Shrinking agricultural land, because of the expansion of the aquaculture farms due to its extensive water resources in the form of natural ponds and lakes (Haors and Baors)

LCLUC and Driver Data

- **LCLUC data**
  - Landsat 5 TM images at 30 m spatial resolution in 2000 and 2010
- **Biophysical drivers**
  - Elevation
  - Annual precipitation and temperature
  - precipitation and temperature in monsoon and post-monsoon months
  - Soil moisture
  - Soil chemical composition
  - Soil chemical composition, depth, drainage, fertility, and texture
  - Distance to rivers
- **Socioeconomic drivers at sub-district level (Upazila)**
  - Population
  - Literacy rates
  - Rural and Urban household sizes
  - Rural and Urban household numbers, and their increasing rates from 2001 to 2011 (Bangladesh Bureau of Statistics)
  - Distances to highways and cities

Key Technical Algorithms Applied

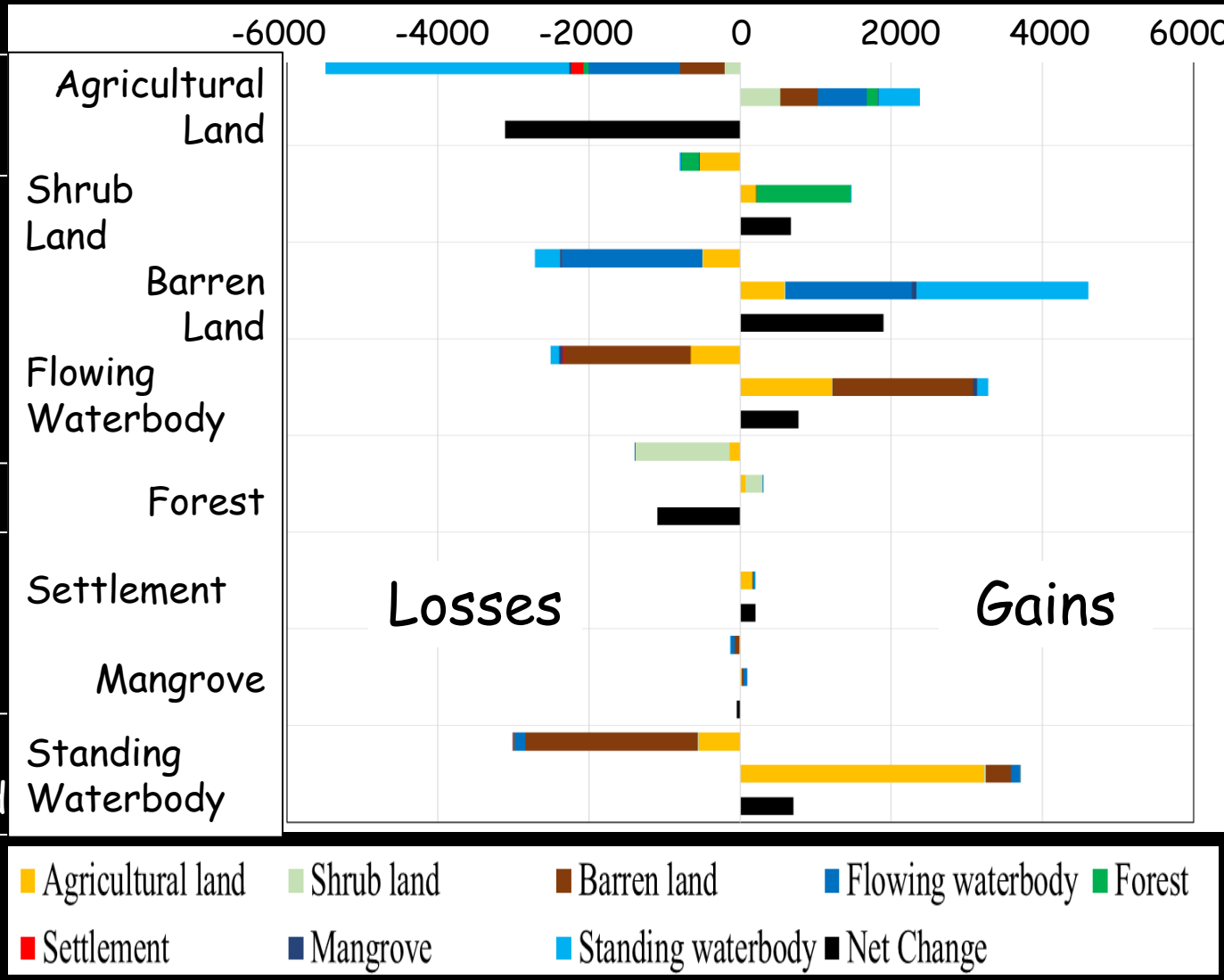
- Geographic object-based image analysis (GEOBIA) classification technique: To extract the LCLUC information
- Hot Spot Analysis (Getis-Ord Gi*): To identify the hotspot zones of major land use conversion activities
- Principle component analysis (PCA) : To address the multi-collinearity of driver data
- Logistic regression: To quantify the drivers of LCLUC
- Synthesis of case studies: To complement and evaluate the results

LCLUC Change Area (km^2) between 2000 and 2010

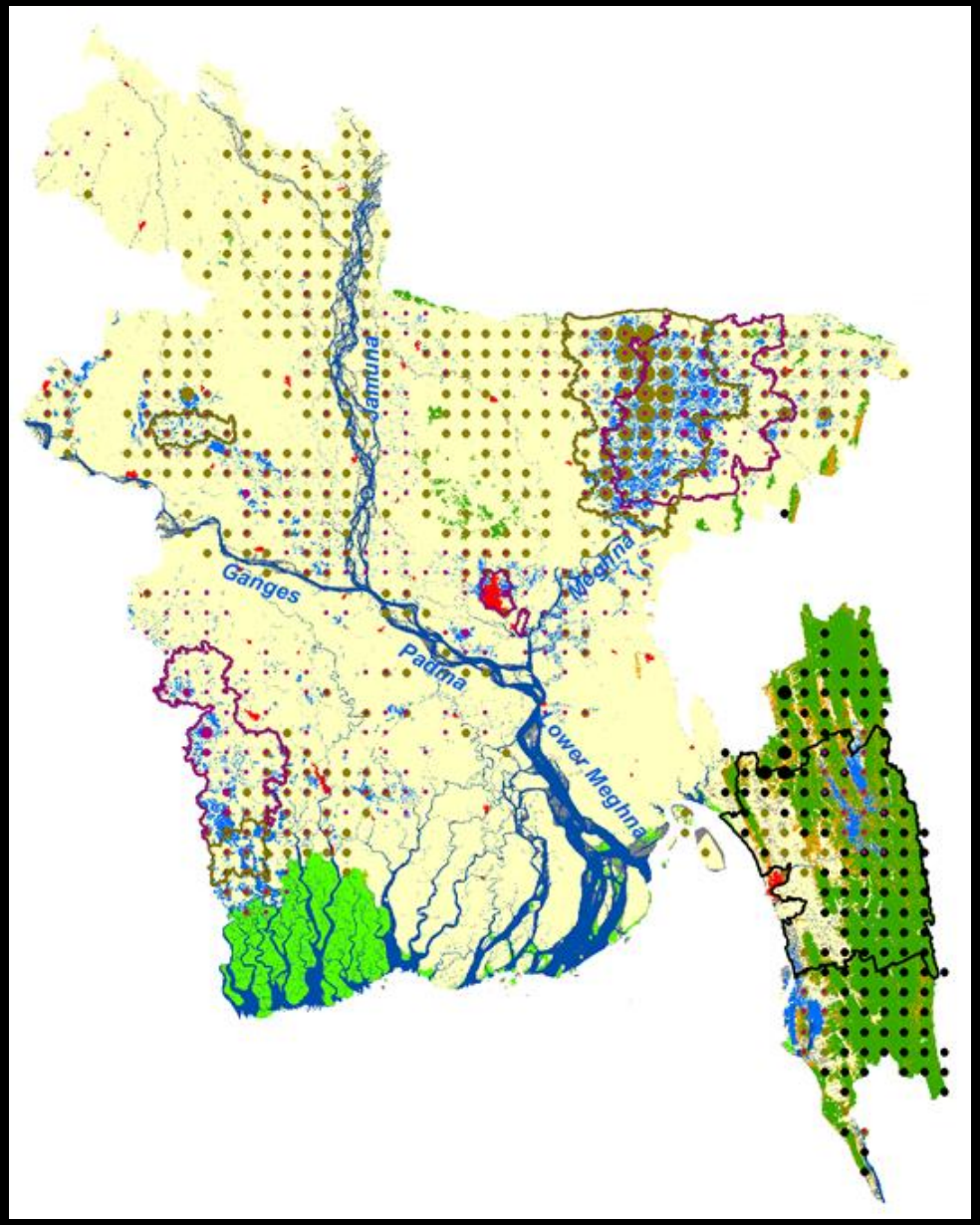
Standing and Flowing Waterbodies

Shrub land

Barren Land
Agricultural land



LCLUC Spatial Pattern and Hotspot Regions



Land cover and land use

- Agricultural land
- Settlement
- Barren land
- Shrub land
- Forest
- Flowing waterbody
- Mangrove
- Standing waterbody

LCLUC between 2000 & 2010

- Agricultural land to standing waterbody
- Standing waterbody to barren land
- Forest to shrub land

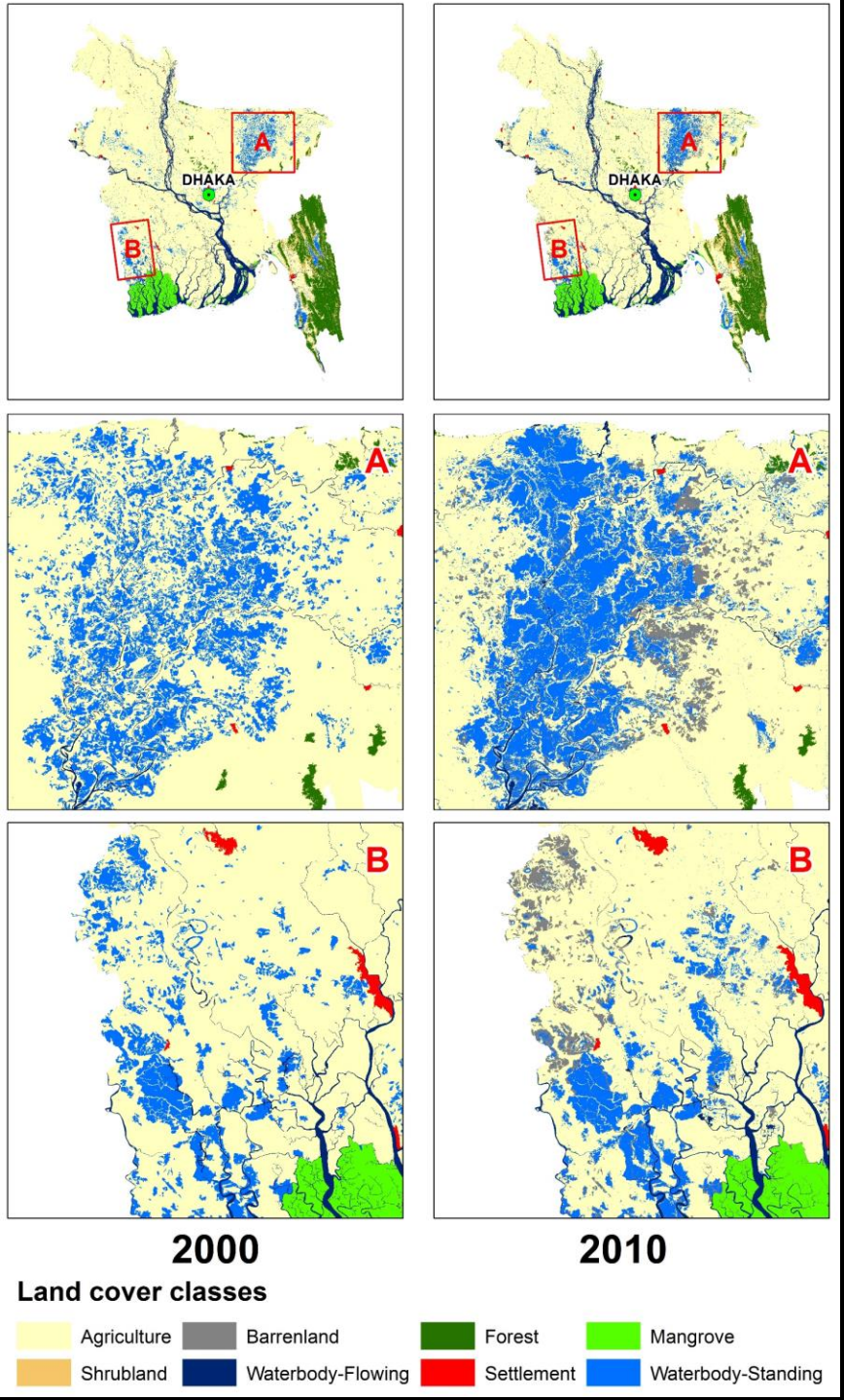
LCLUC areas

- 1 - 20 km^2
- 20 - 40 km^2
- > 40 km^2

Hotspot regions

- Agricultural land to standing waterbody
- Standing waterbody to barren land
- Forest to shrub land

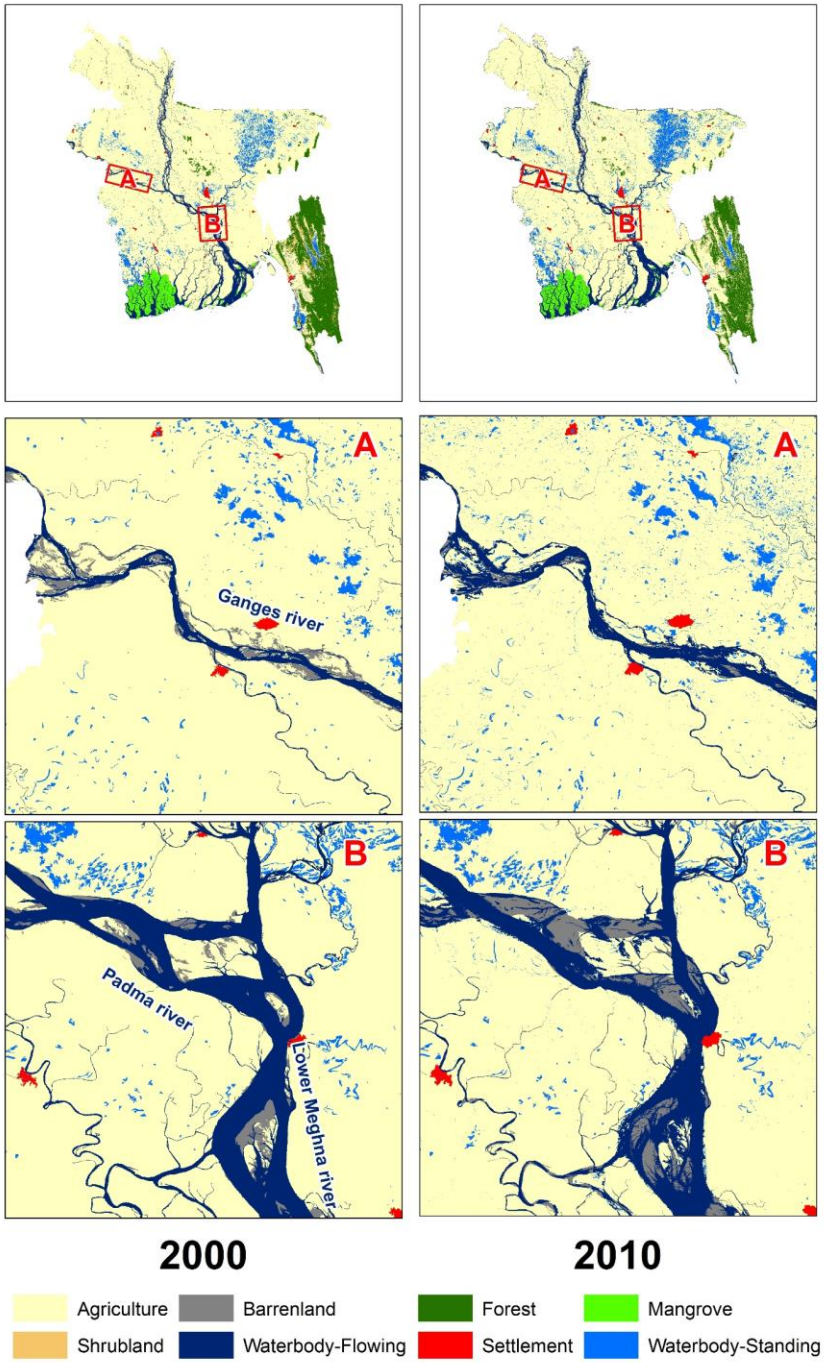
Hot-Spot Analysis



Conversions of agricultural land to standing waterbody

Conversions of standing waterbody to barren land

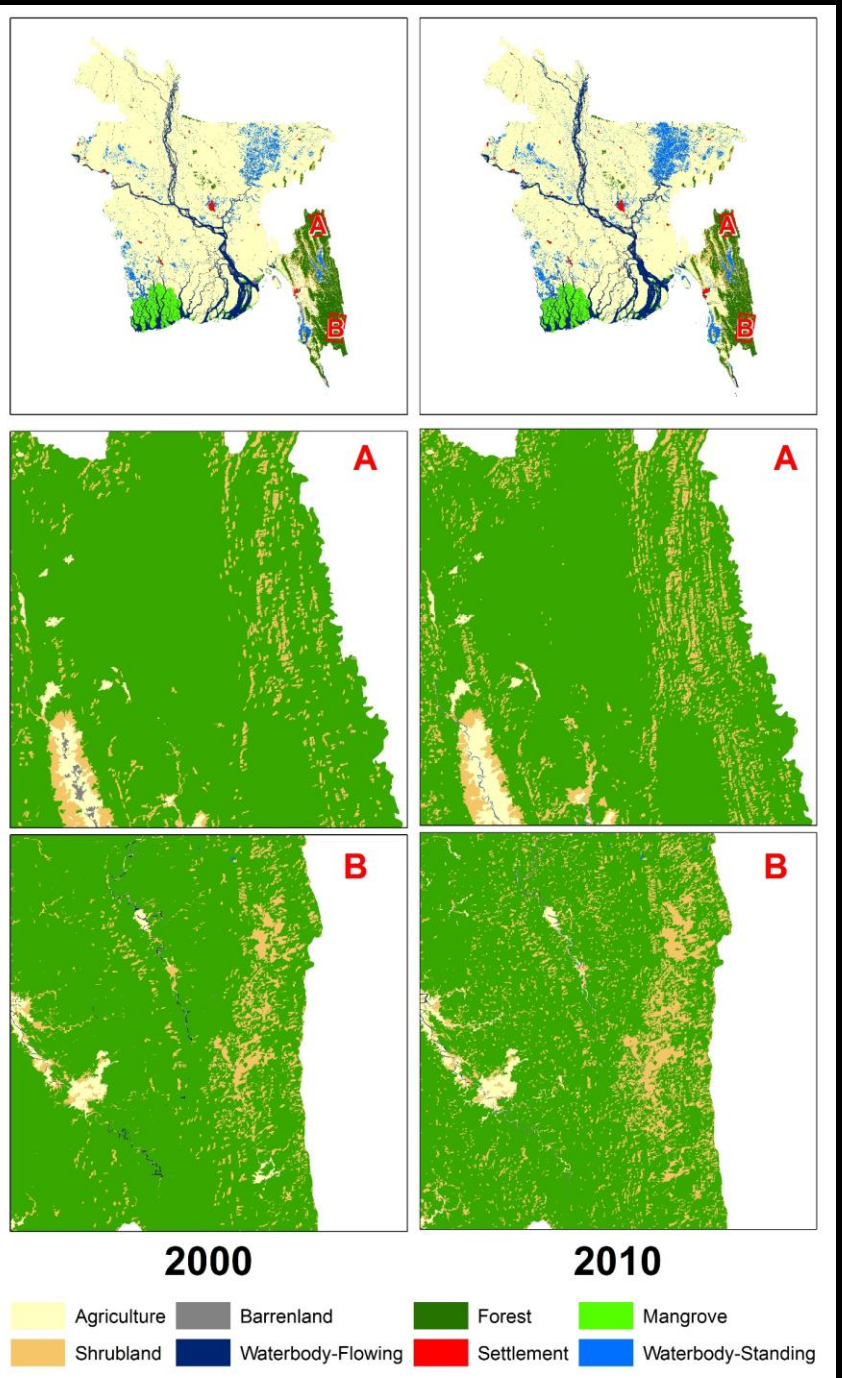
Hot-Spot Analysis



Conversions of agricultural land and barren land to flowing waterbodies

Conversions of flowing waterbodies to barren land

Hot-Spot Analysis



Conversions of forest to shrub land

Drivers of LCLUC

From Agricultural Land to Standing Waterbodies

Increasing rate of temperature during monsoon

Increasing rate of urban area

Increasing rate of precipitation during post-monsoon

Longer distance to rivers

Increasing rate of precipitation

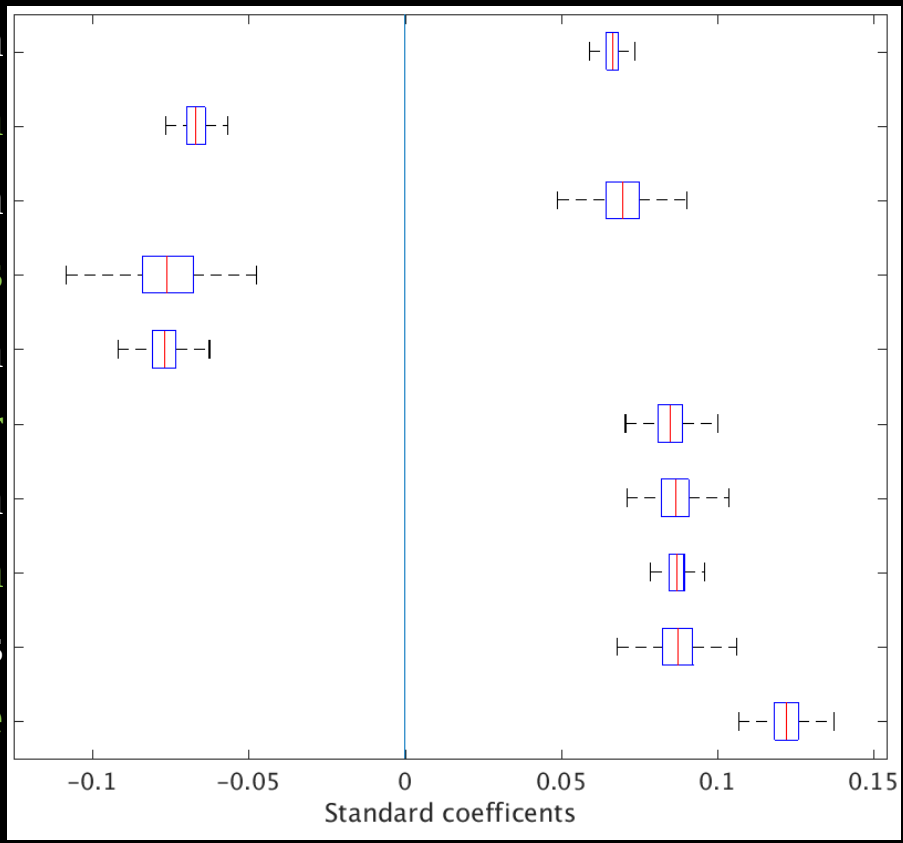
Increasing rate of rural household number

Increasing rate of population

Standard deviation of temperature during monsoon

Longer distance to highways

Increasing rate of urban household size



Standardized coefficients refer to how many standard deviations of dependent variable (LCLUC area) will change, per standard deviation change in the independent variable (drivers)

The LCLUC Drivers in General

- Longer distance to highways: Positive relationships with all three LCLUC types, demonstrating that these changes are occurred in the rural areas
- Shorter distance to rivers: Positive impact on conversion from agricultural land to standing waterbody.
- Higher climate variability, a proxy for extreme climate events such as floods and drought: Directly impacting the changes between agricultural land, barren land and standing waterbody.
- Urban/Population: Major factor of LCLUC.

Current and Future Directions

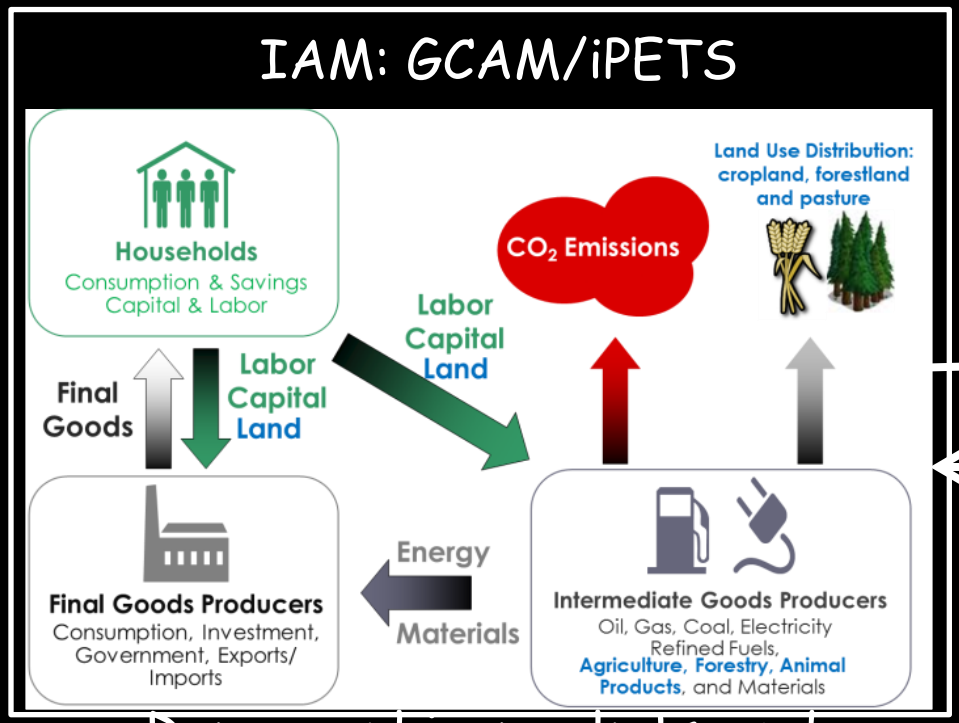
Objectives

- Improve the understanding of the impacts of LCLUC dynamics on the quantities and pathways of terrestrial carbon and nitrogen fluxes at various scales

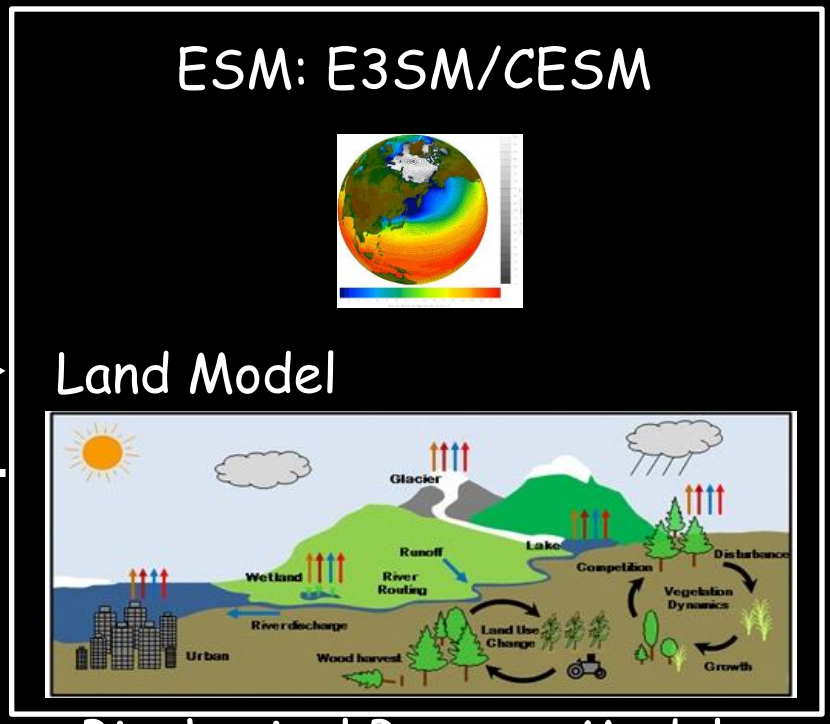
Next Step Improve the projection of the impacts of climate change on agriculture and land use

How linking" socio-economic and Earth System Model (ESM)?

"Linking" Socio-economic and ESM Models



Demographic, markets, and development behavior



Biophysical Process Models

- NSF Funded Project to Improve the LCLUC Projections in Community Earth System Model (CESM) : Jain et al.
- DOE Funded Project to Improve the LCLUC Projection in Energy Exascale Earth System Model (E3SM) : Jain et al.

Thank You