Quantify the Biophysical and Socioeconomic Drivers of Changes in Forest and Agricultural Land in South and Southeast Asia (SSEA)

Xiaoming Xu[1] Atul K. Jain[1] Katherine V. Calvin[2]

[1]University of Illinois, Urbana, IL 61801

[2]JGCRI, College Park, MD 20740

Overall Objectives

- Improve our understanding of the dynamics and drivers of LULCC at global scale.
- Link a socio-economic model (GCAM/iPETS) to an earth system model (ISAM/CLM/ELM).

Why do it?

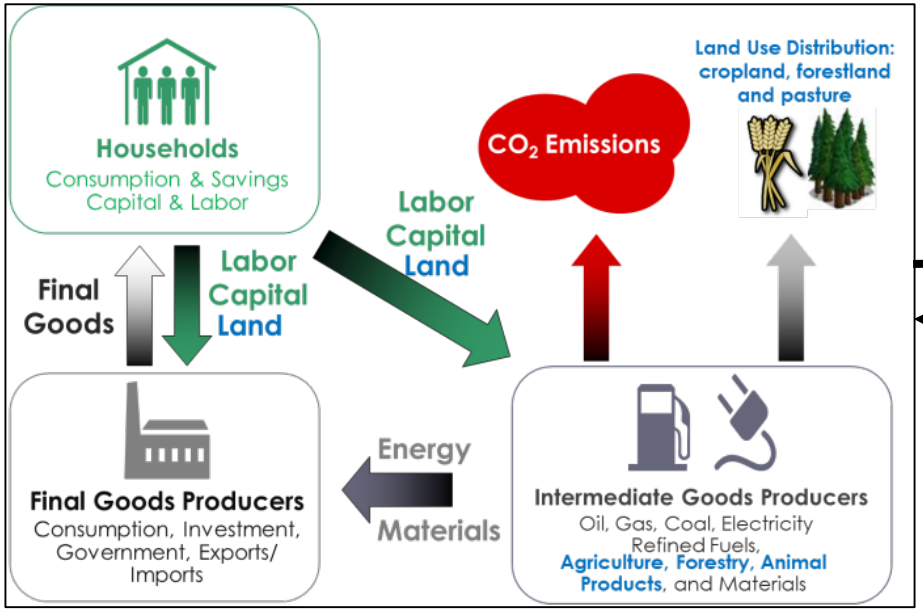
- Improve the understanding of the impacts of LULCC dynamics on the quantities and pathways of terrestrial carbon and nitrogen fluxes at different scales.
- Improve the projection of the impacts of climate change on agriculture and land use.

What does “linking” socio-economic and ESM models mean?

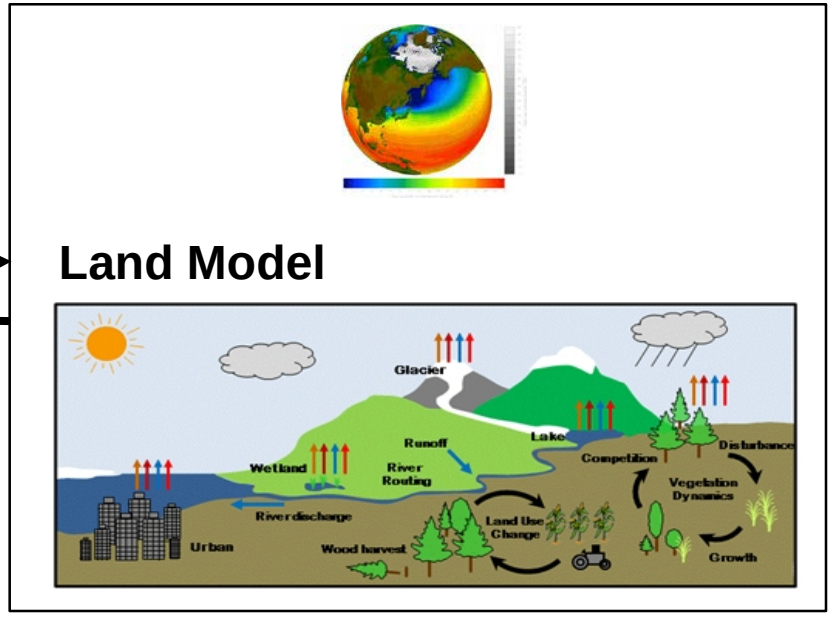
How can socio-economic models and ESM be linked ?

What Does "linking" Socio-economic and ESM Models Mean?

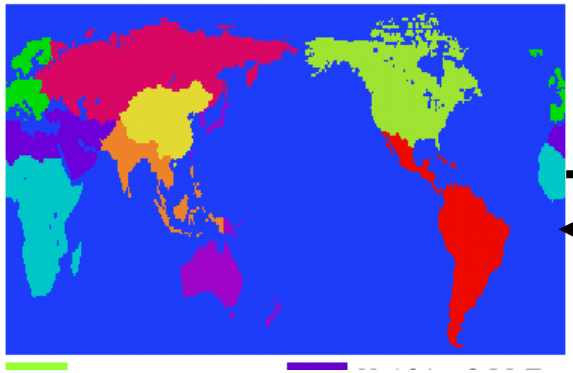
IAM: GCAM/iPETS



Earth System Model: E3SM/CESM

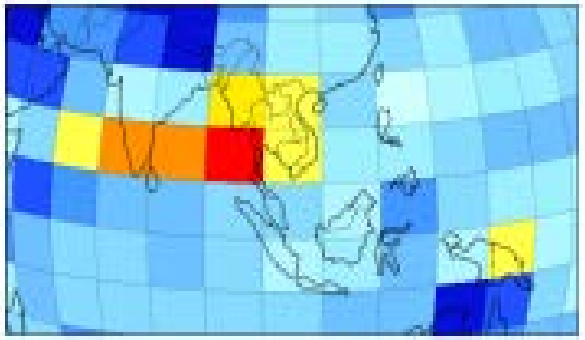


Demographic, markets, and development behavior



Downscaling Module

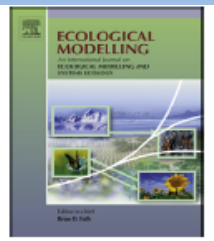
Biophysical Process Models



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,**]

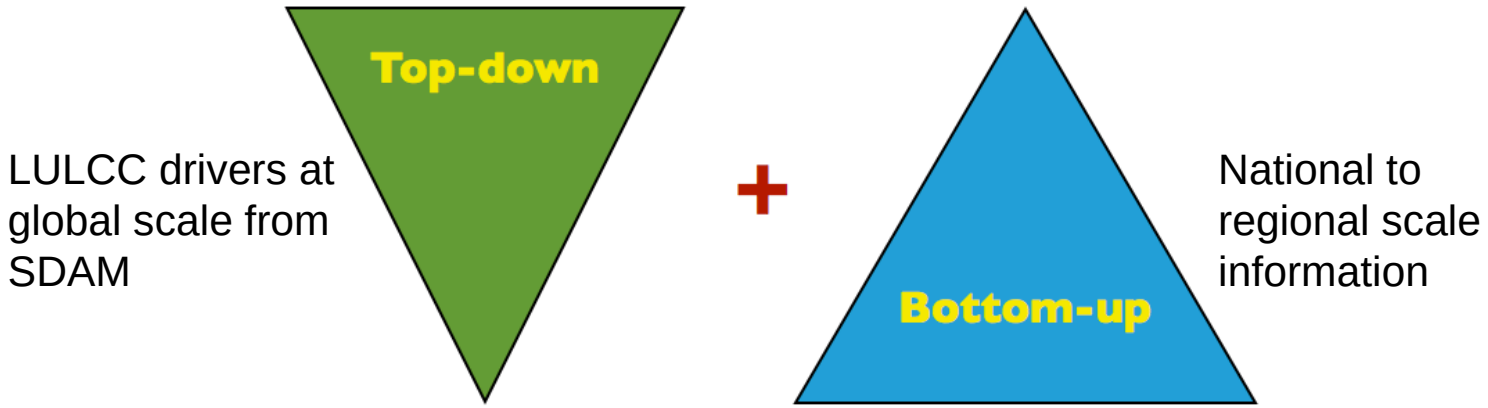
Implementation of Global-Scale Spatial Dynamic Allocation Model (SDAM) in a Coupled Modeling Framework

- 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.

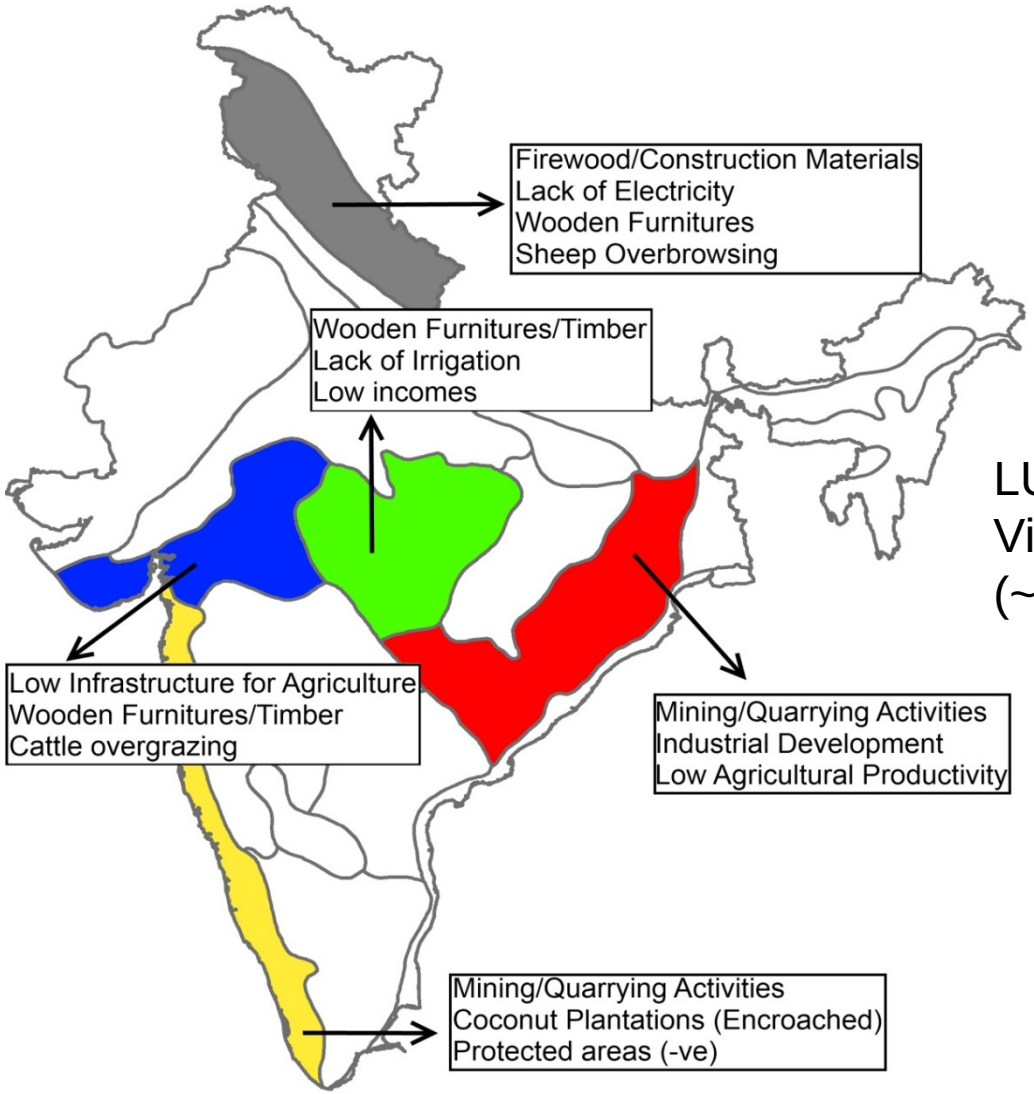
Meiyappan *et al*, 2014

LULCC Drivers at Global Scale

- Requires a mix of top-down and bottom-up approaches.
- Needs solid national to regional scale analysis to validate global scale drivers.
- Upscale the drivers from national and regional scales to global scale.



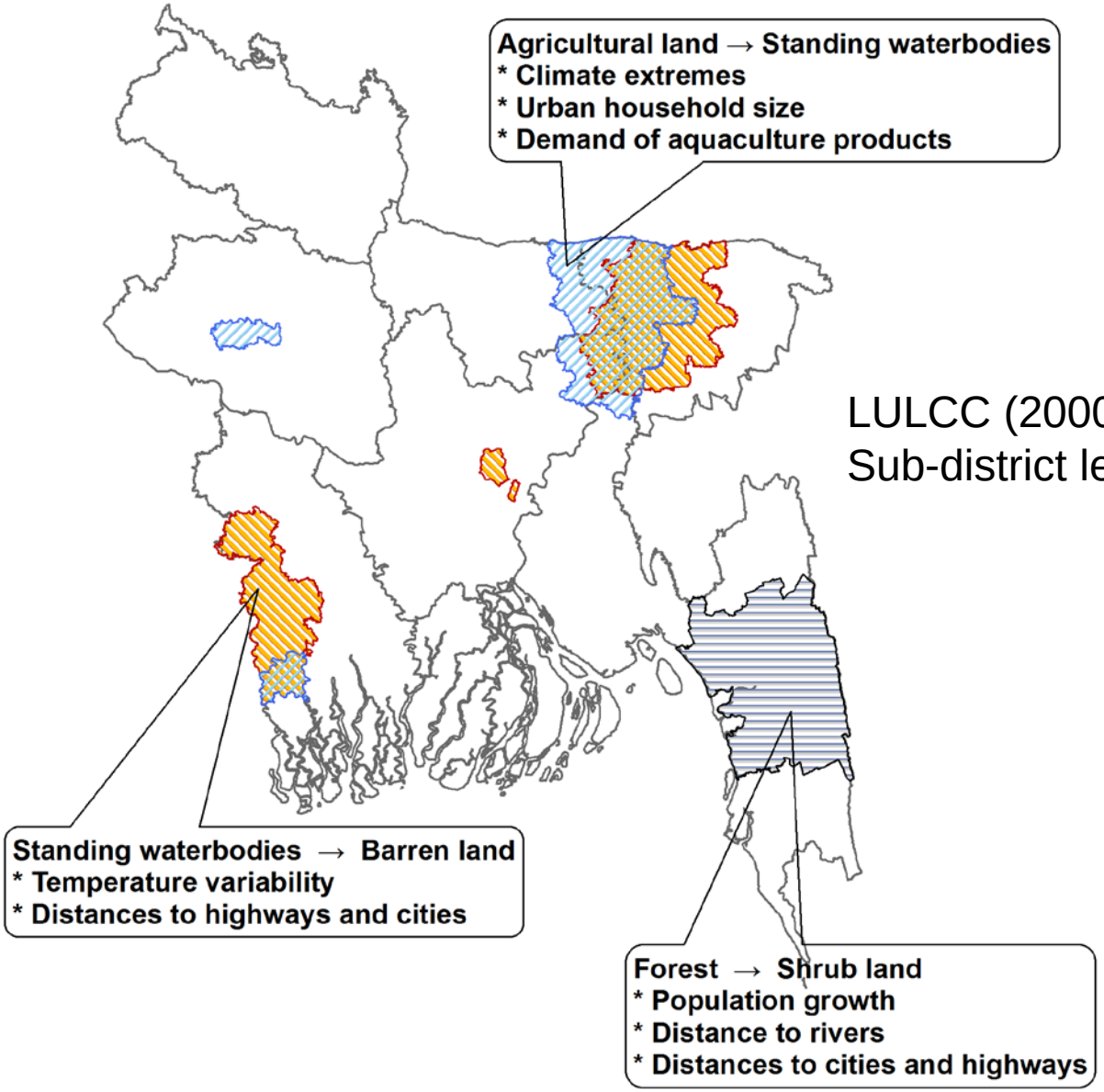
National Scale LULCC Driver Study Example: India



LULCC (1985-2005): 30m x 30m
Village-level socioeconomic data
(~ 630, 000 villages)

Meiyappan *et al*, 2017

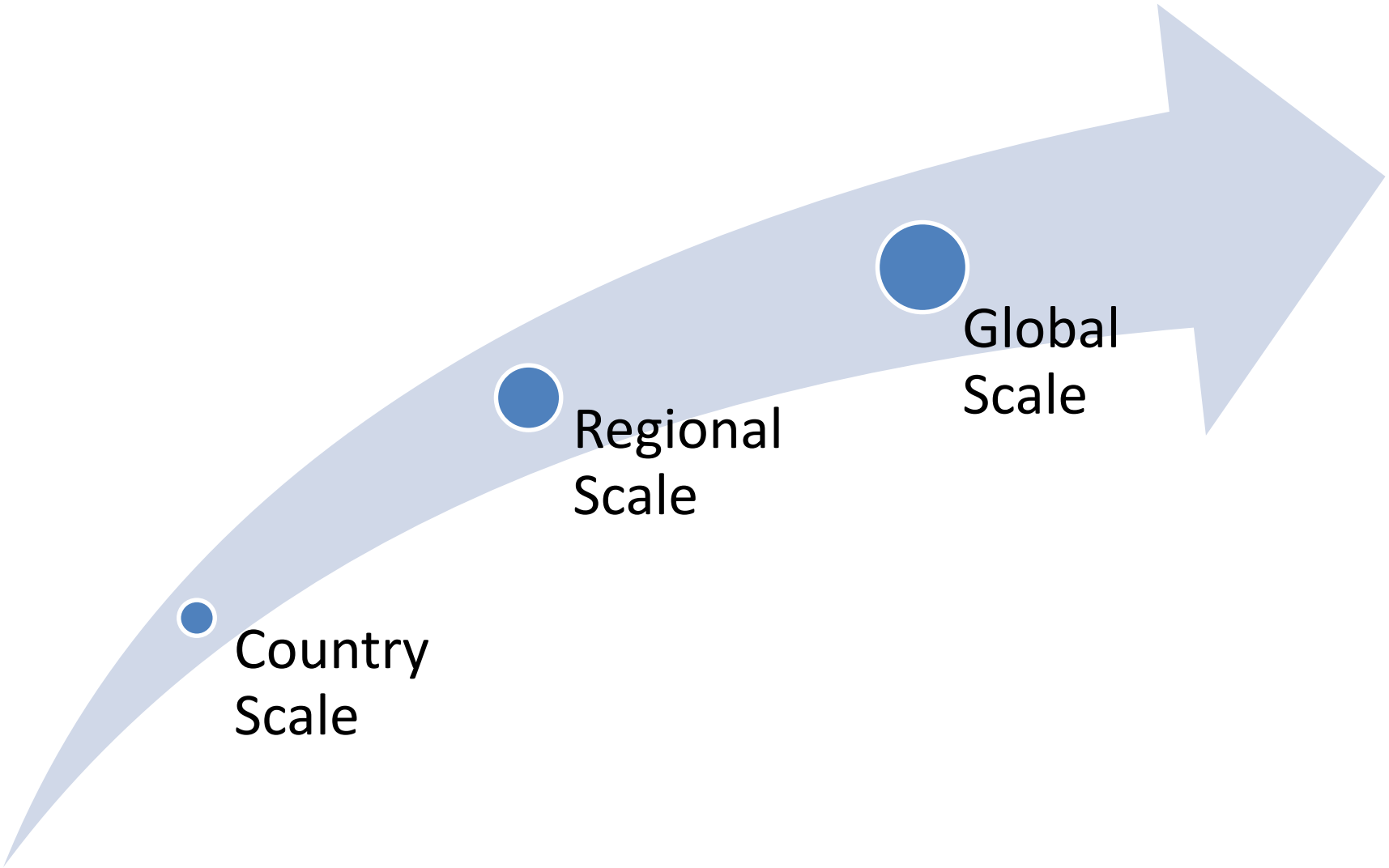
National Scale LULCC Driver Study Example: Bangladesh



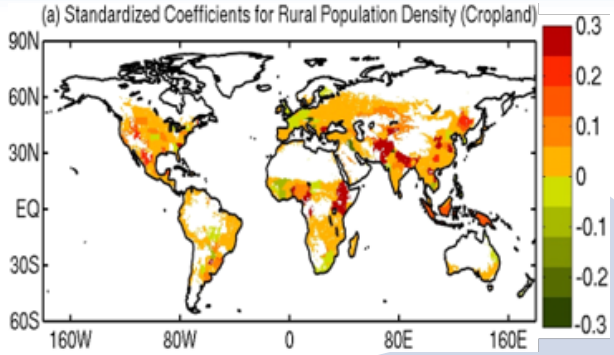
LULCC (2000-2010): 30m x 30m
Sub-district level socioeconomic data

Xu *et al*, submitted, 2018

Improved Global Scale LULCC Drivers



Improved Global Scale LULCC Drivers

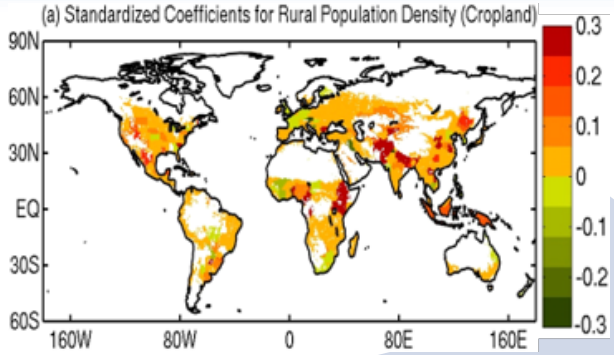


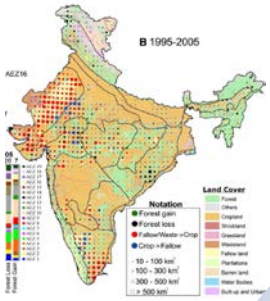
Country Scale

Regional Scale

Global Scale

Improved Global Scale LULCC Drivers



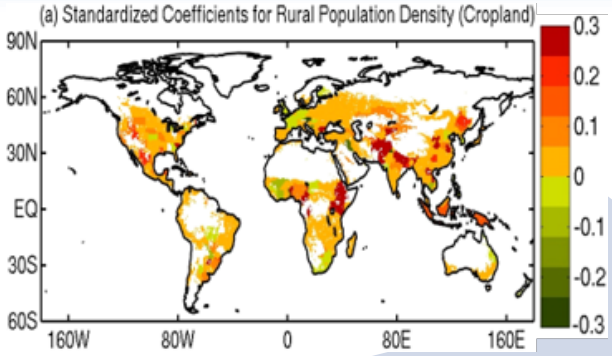


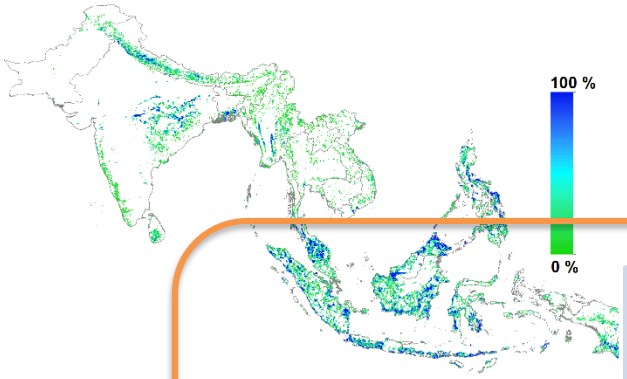
Country Scale

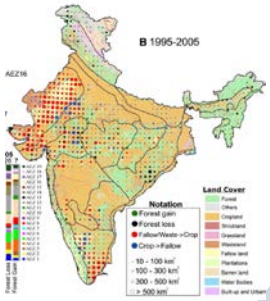
Regional Scale

Global Scale

Improved Global Scale LULCC Drivers





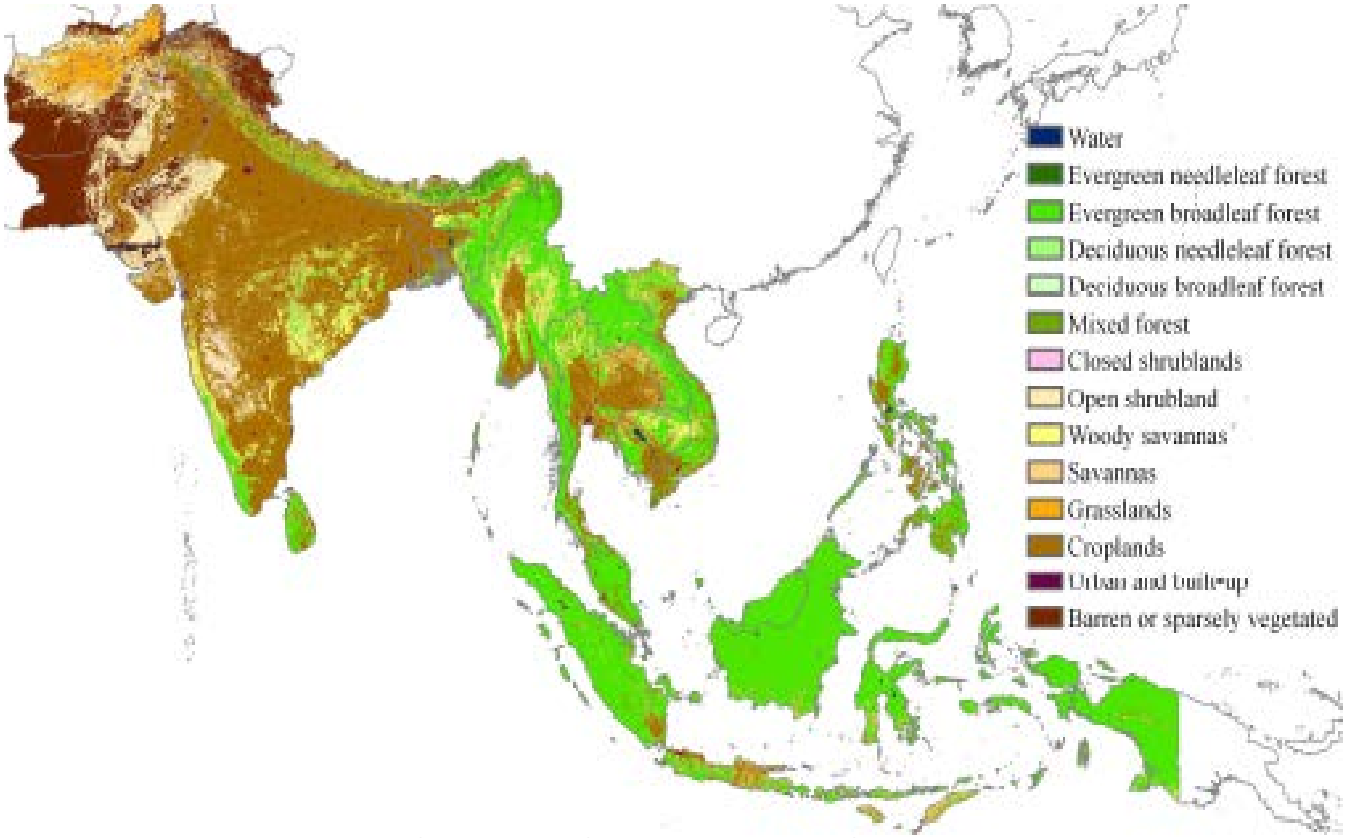


Global Scale

Regional Scale

Country Scale

Bottom-Up Approach: Regional Scale Study
LULCC Drivers for South and Southeast Asia (SSEA)

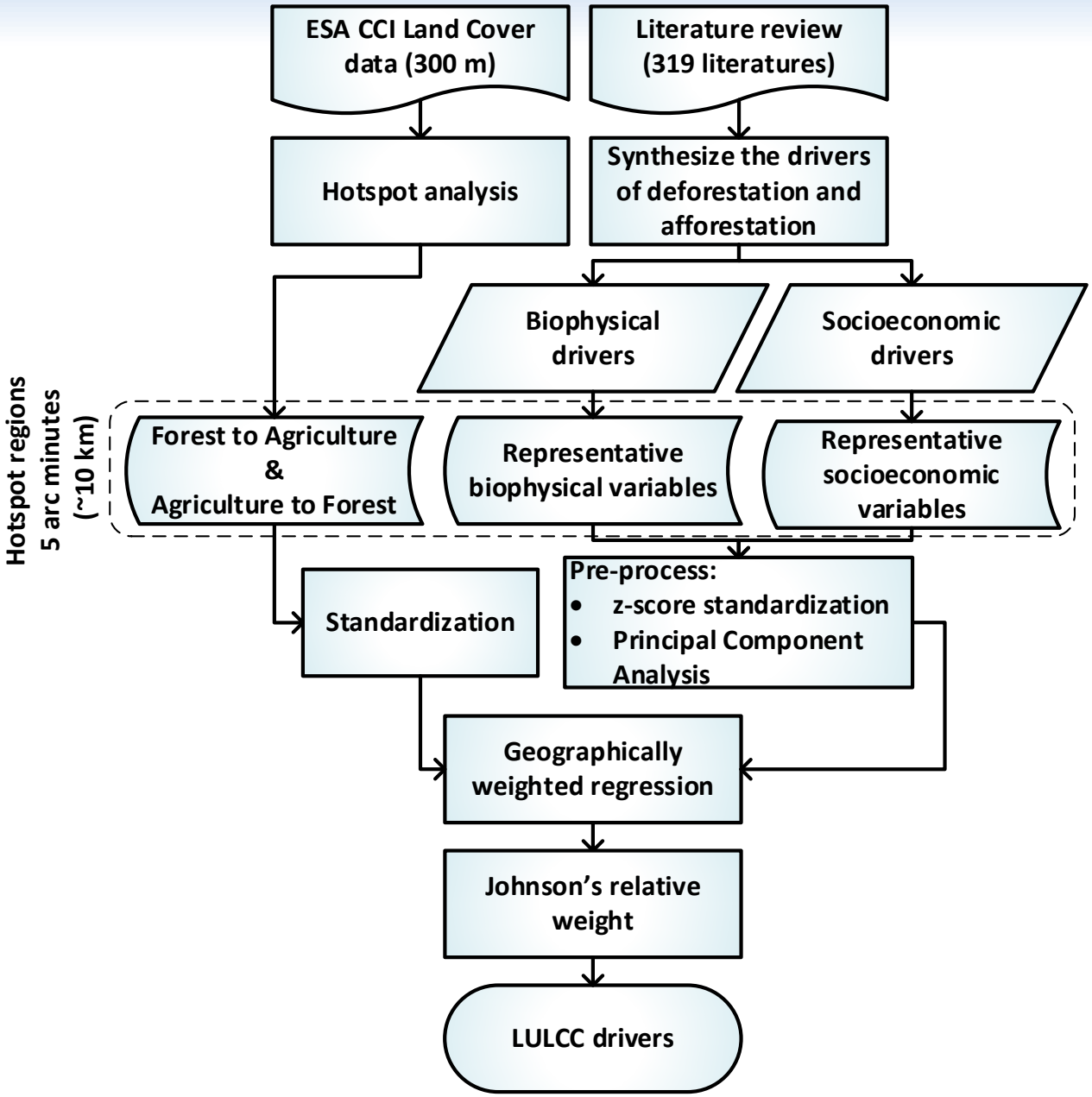


- Covers about 16% of earth's land surface.
- Characterized by a long history of LULCC activities.
- The home for over 25% of the world's population.
- ***Study LULCC drivers on a country-by-country basis.***

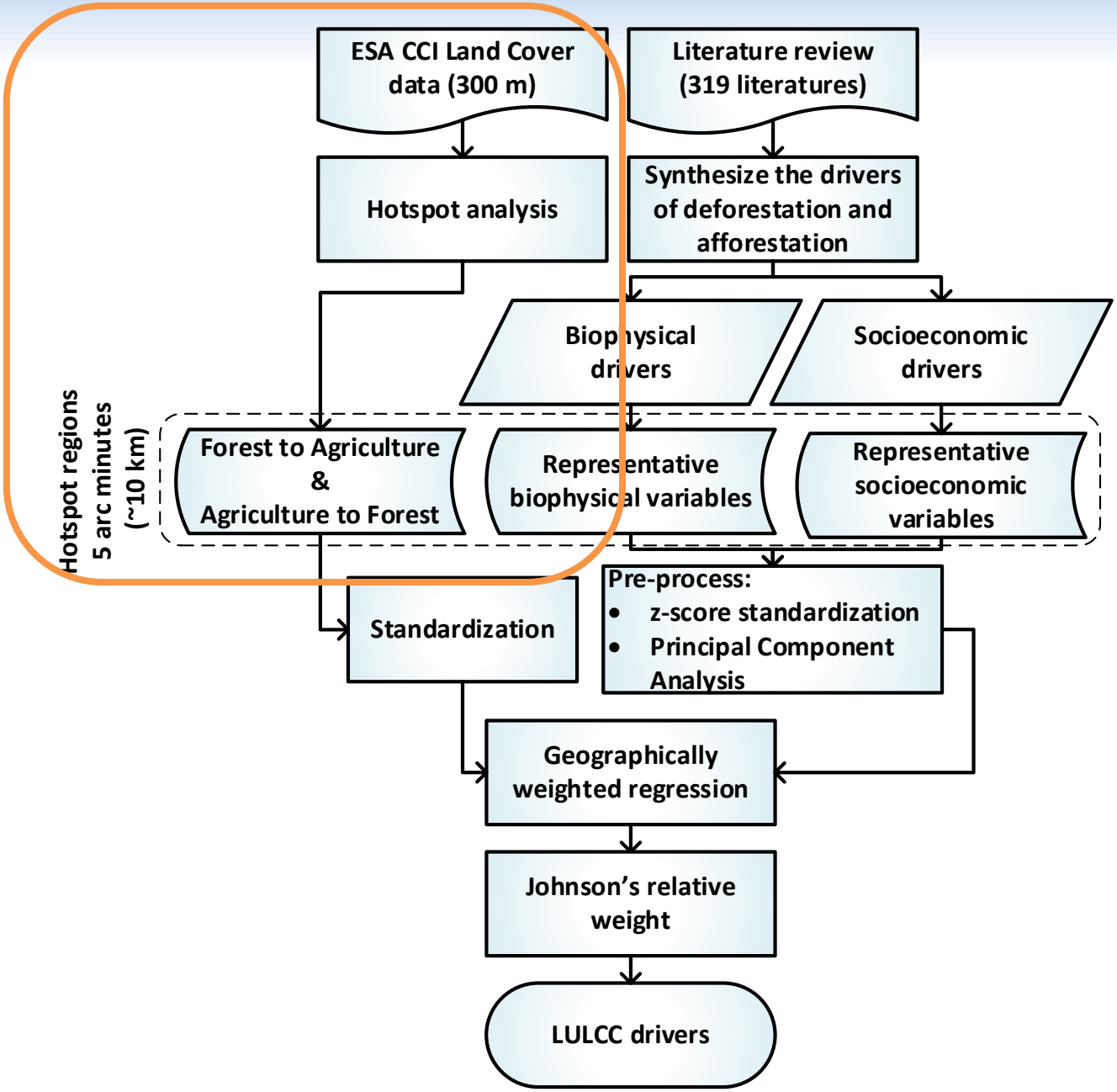
Objectives of this Study

- Advance our understanding of the causes of LULCC in SSEA region for the following two LULCC activities:
  - Forest to agricultural land.
  - Agricultural land to forest.
- Synthesize the literature to identify the socioeconomic and biophysical drivers.
- Quantify the relationships between drivers and the LULCCs.

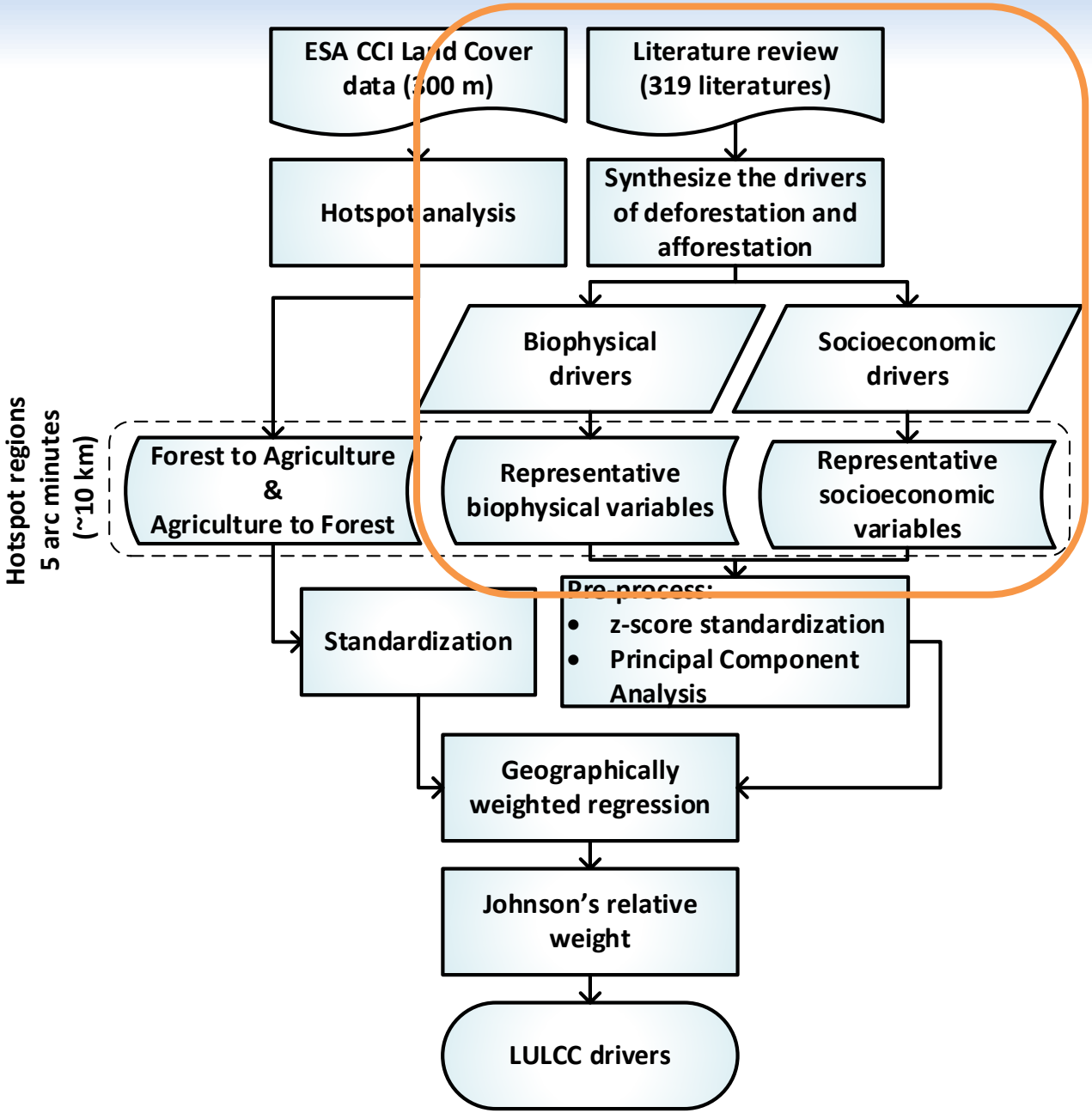
Material and Methods



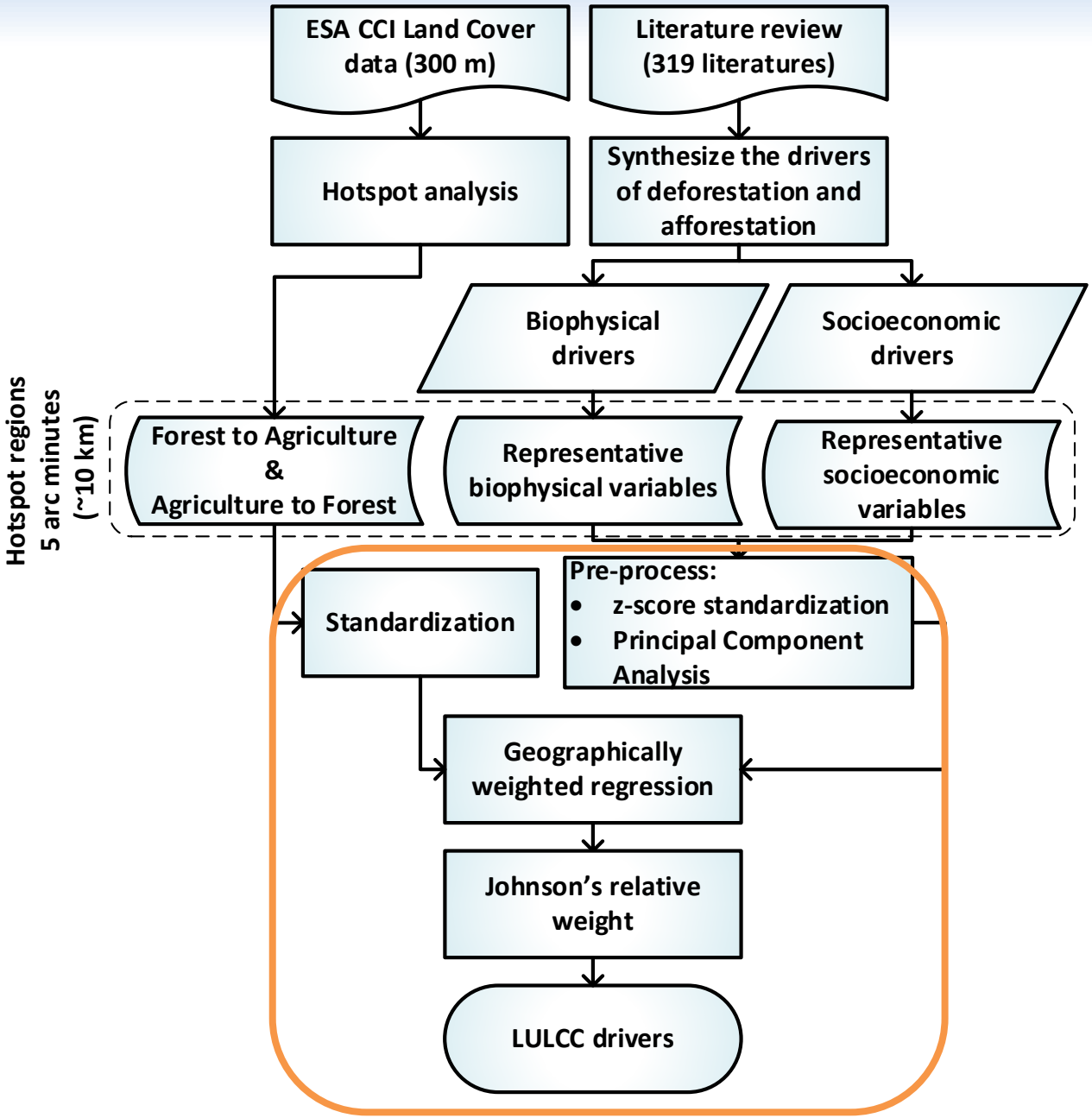
Material and Methods



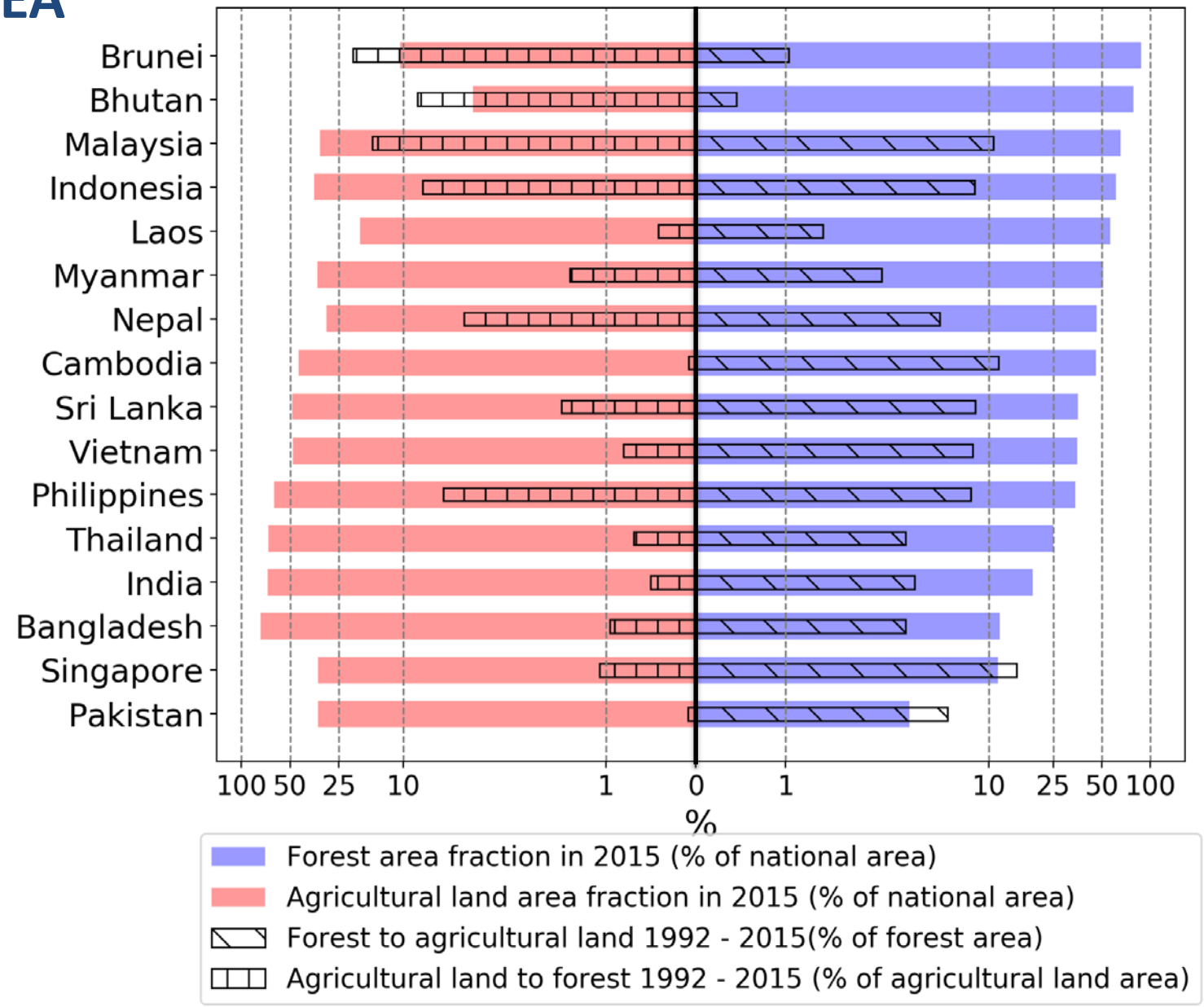
Material and Methods



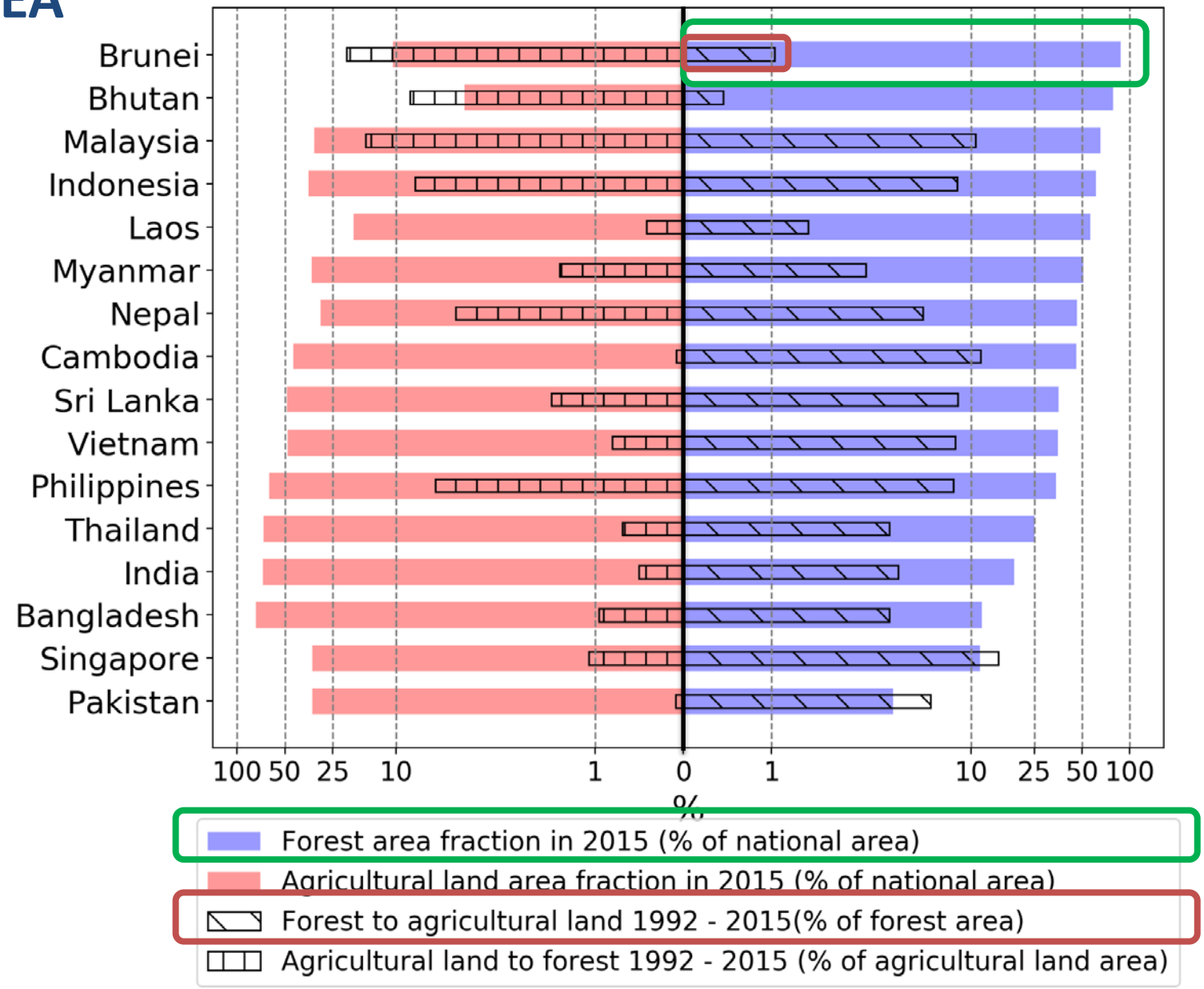
Material and Methods



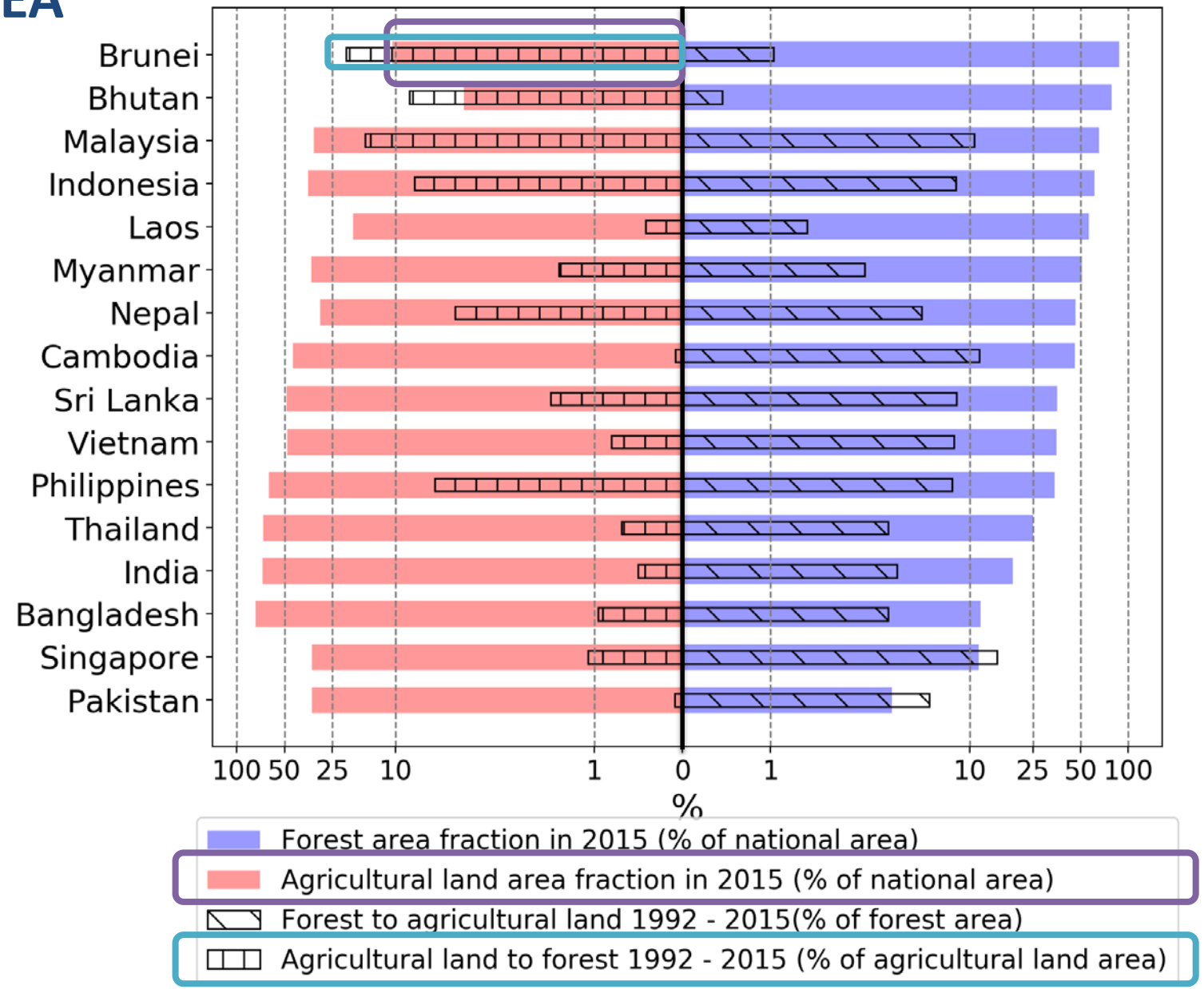
Country Specific Dynamics of Forest and Agricultural Land in SSEA



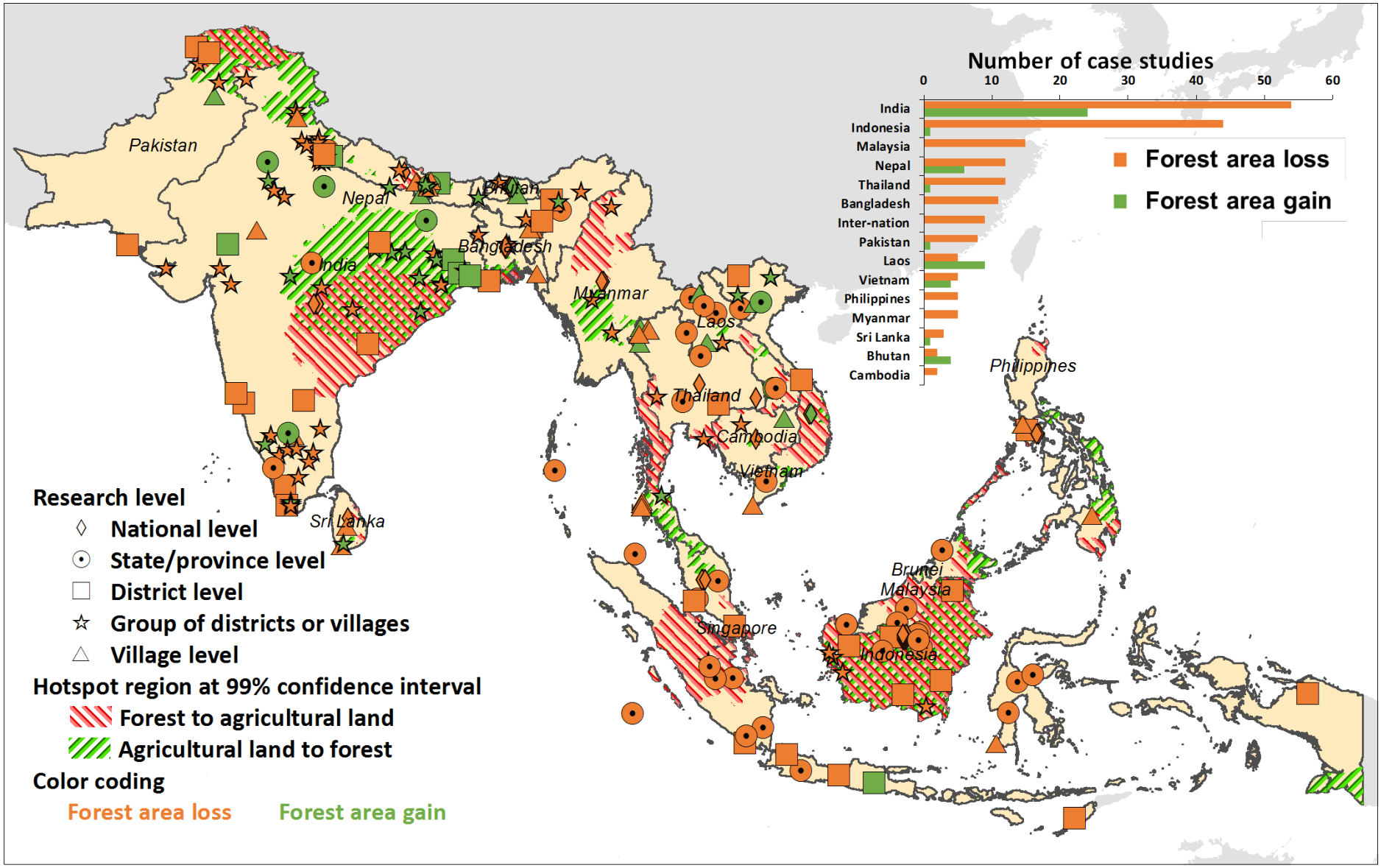
Country Specific Dynamics of Forest and Agricultural Land in SSEA



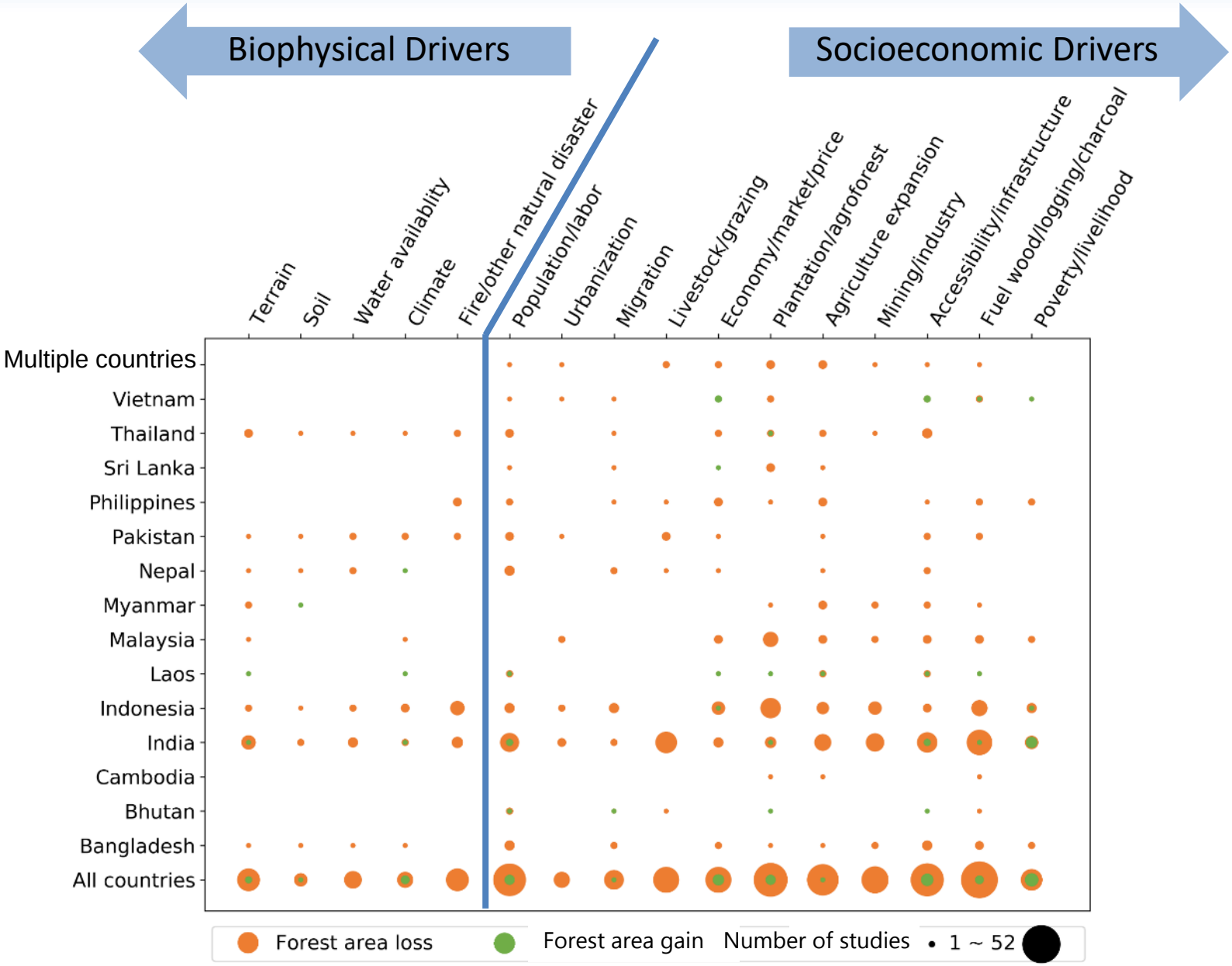
Country Specific Dynamics of Forest and Agricultural Land in SSEA



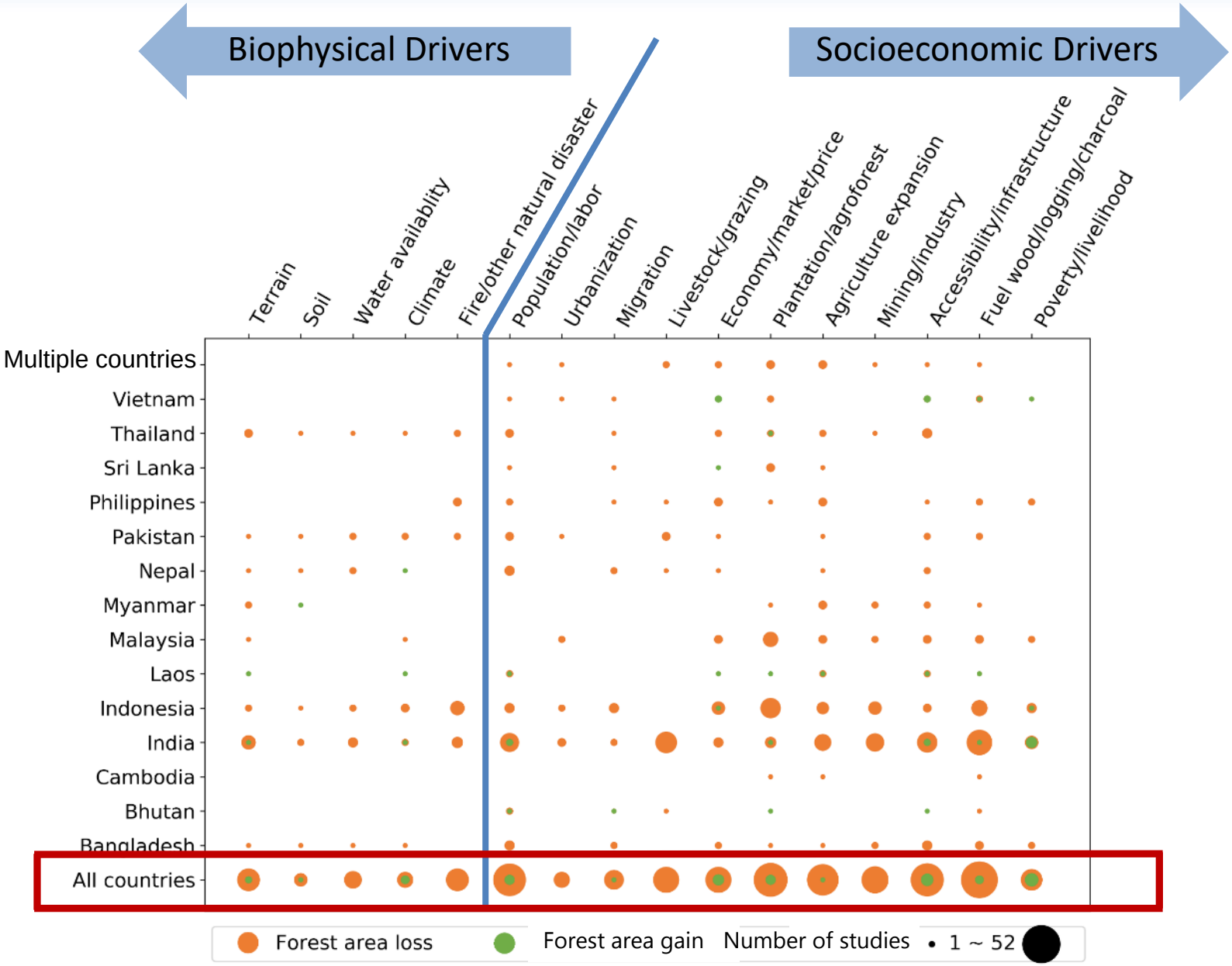
Synthesis of Case Studies and Hotspot Regions



Identified Drivers Based on the Synthesis of Case Studies



Identified Drivers Based on the Synthesis of Case Studies

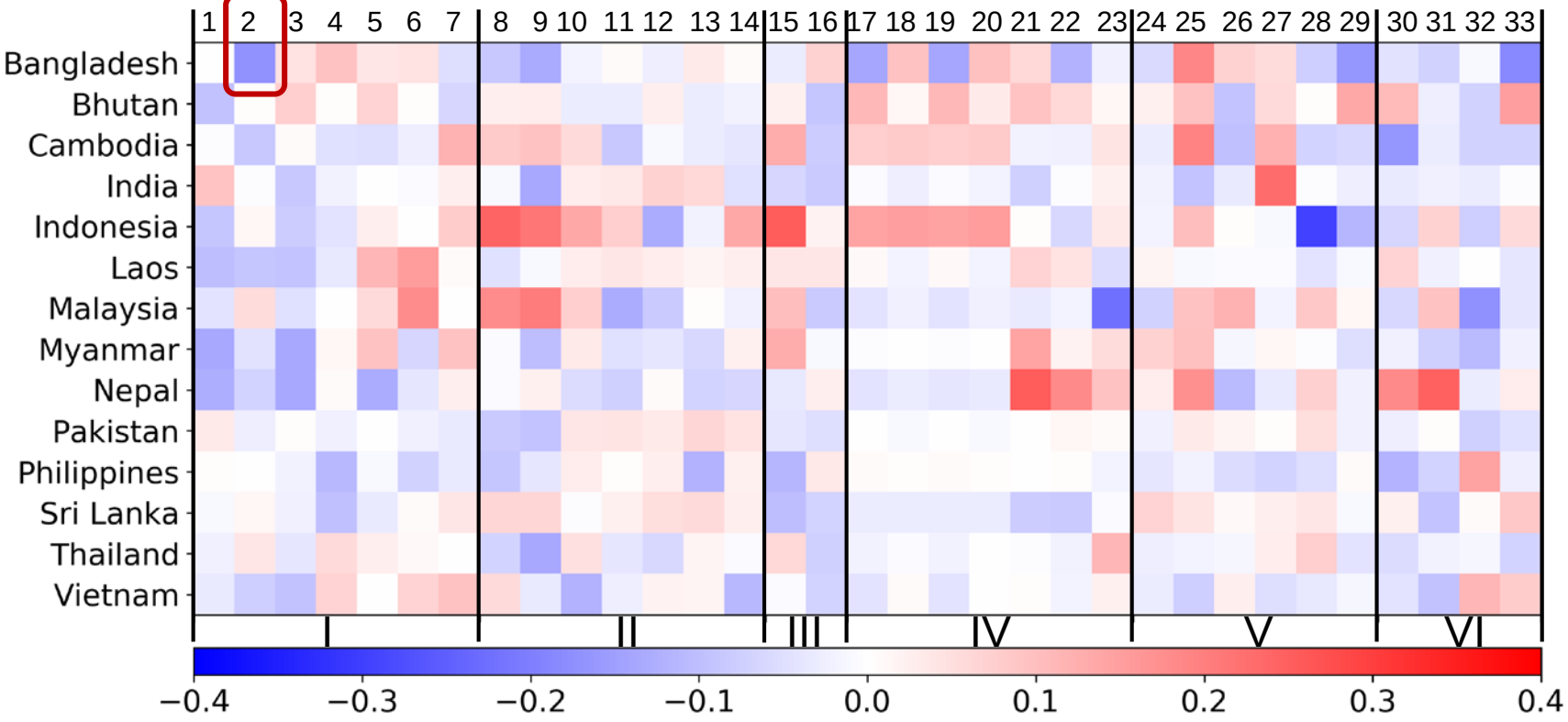


Combining Different Drivers into Categories (I – VI)

		Category		Variable	Resolution	Source
Biophysical variables	I	Terrain, soil and water	1.	Terrain	5' x 5' (~ 10 km x 10 km)	FAO/IIASA 2010. Global Agro-ecological Zones (GAEZ v3.0).
			2.- 6.	Soil chemical composition, depth, drainage, fertility, and texture		
			7.	Distance to waterbodies	5' x 5'	Calculated from Global Lakes and Wetlands Database (GLWD level 2 data)
	II	Climate	8. - 10.	Mean, rate of change, and standard deviation of annual precipitation	0.5° x 0.5°	Climatic Research Unit (CRU) TS 4.01
			11. - 13.	Mean, rate of change, and standard deviation of annual temperature		
			14.	Mean annual potential evapotranspiration		
	III	Natural disaster	15.	Burned area fraction	0.25° x 0.25°	Global Fire Emissions Database 4.1
			16.	Distance to landslide events	5' x 5'	Calculated from Global Landslide Catalog NASA
Socioeconomic variables	IV	Population and urbanization	17. - 18.	Mean and rate of change in urban population density	5' x 5'	HYDE 3.2
			19. - 20.	Mean and rate of change in rural population density		
			21. - 22.	Mean and rate of change in urban area fraction		
			23.	Migration	0.5° x 0.5°	Global Estimated Net Migration Grids By Decade v1
	V	Livestock	24. - 29.	Chicken, Cattle, Sheep, Pig, Goat and Duck counts	1 km x 1 km	Gridded Livestock of the World (GLW) version 2
	VI	Economy	30.	Market accessibility index	5' x 5'	Verburg et al. (2011)
			31.	GDP per capita	0.5° x 0.5°	Global dataset of gridded population and GDP scenarios (Murakami and Yamagata 2016)
			32.	Distance to mining facilities	5' x 5'	Calculated from Mineral Resources On-Line Spatial Data by USGS
			33.	Poverty index	5' x 5'	Calculated from population (HYDE 3.2) and Night time light (Version 4 DMSP-OLS Nighttime Lights Time Series) by following the method developed by Ghosh *et al.* (2013)

Impacts of Drivers by Variables

- Forest to agricultural land.

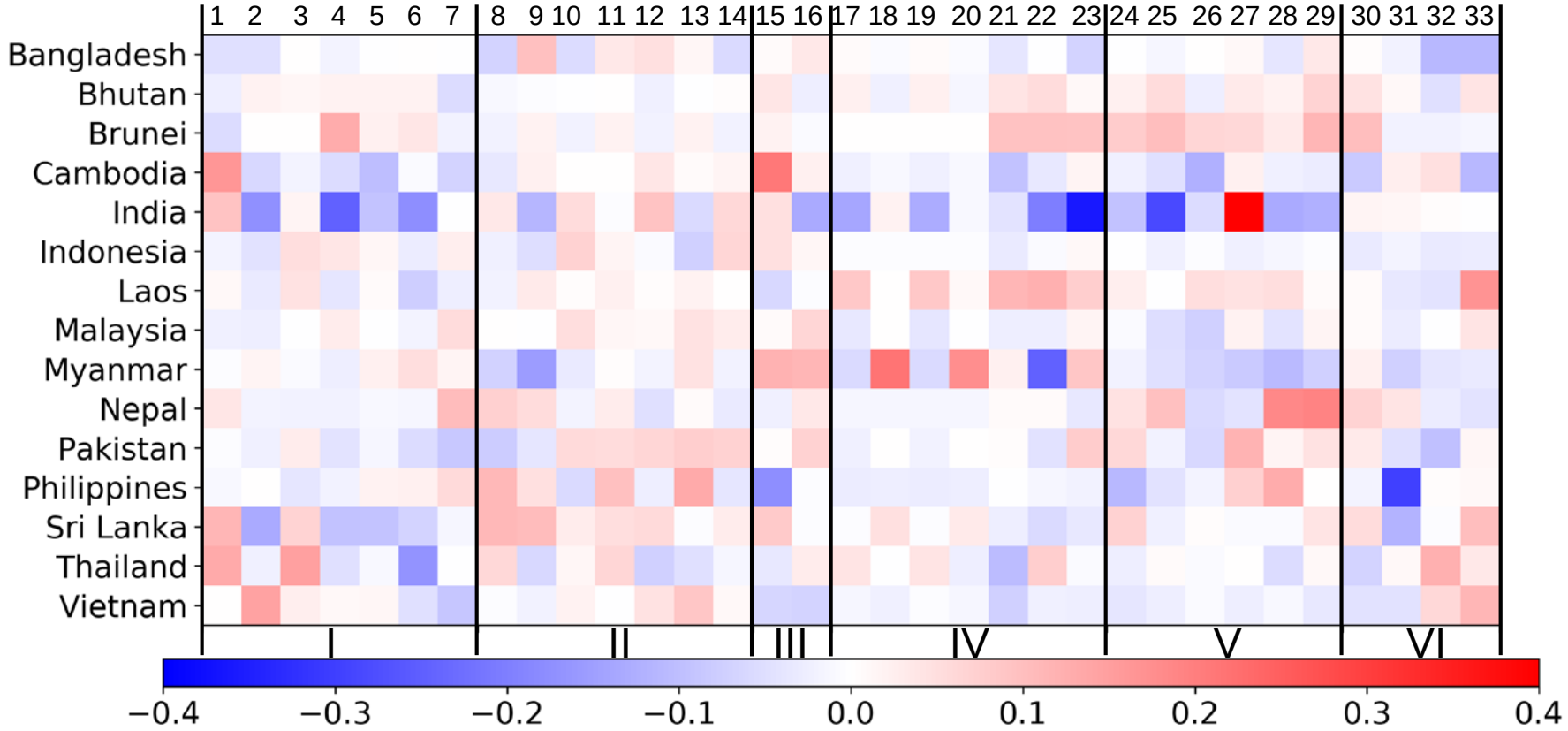


I.	Terrain, soil and water	IV.	Population and urbanization
II.	Climate	V.	Livestock
III.	Natural disaster	VI.	Economy

- The values refer to how many standard deviations the area of forest to agricultural land will change, per standard deviation increase in the driver variable.

Impacts of Drivers by Variables

- Agricultural land to forest.

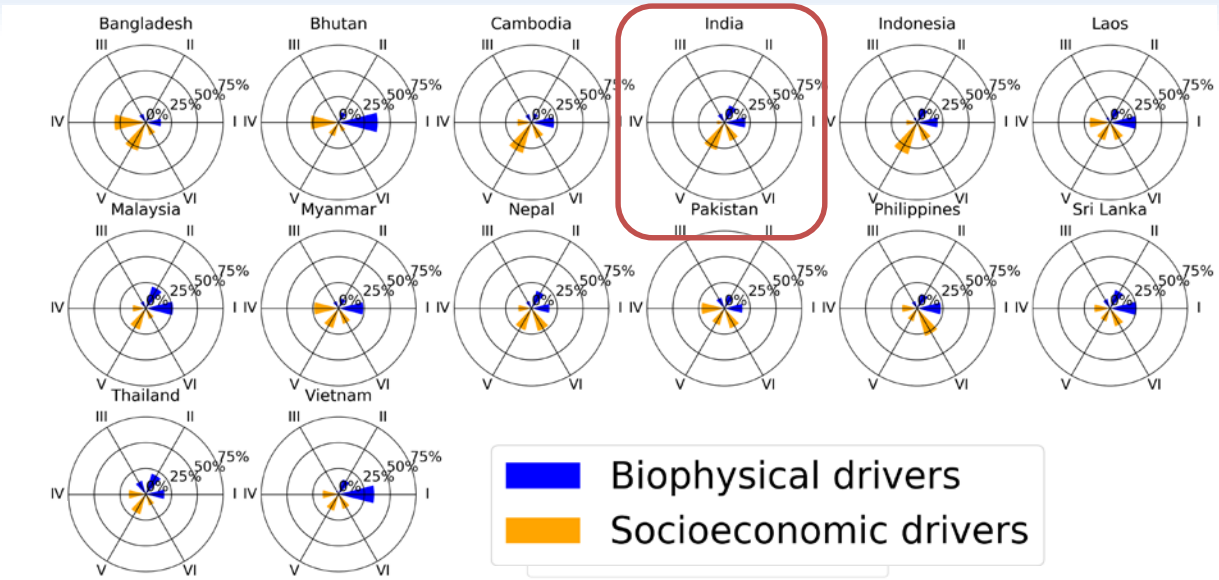


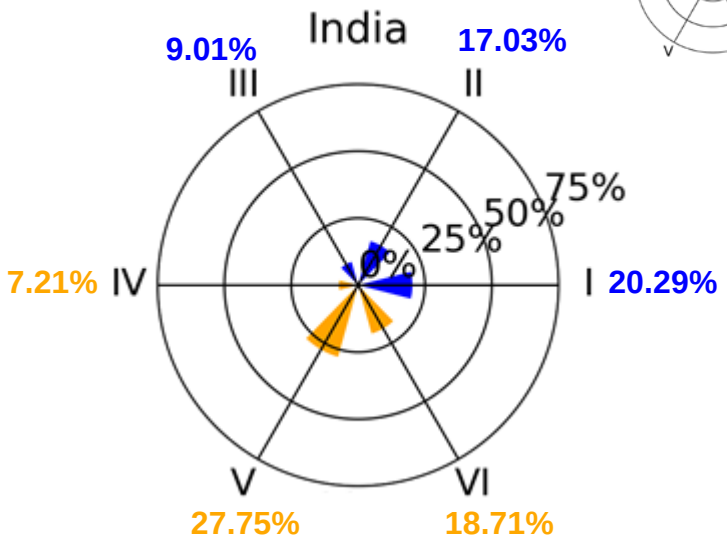
I.	Terrain, soil and water	IV.	Population and urbanization
II.	Climate	V.	Livestock
III.	Natural disaster	VI.	Economy

- The values refer to how many standard deviations the area of agricultural land to forest will change, per standard deviation increase in the driver variable.

Country-Specific Relative Importance of Driver Category

Forest ⟶ Agriculture





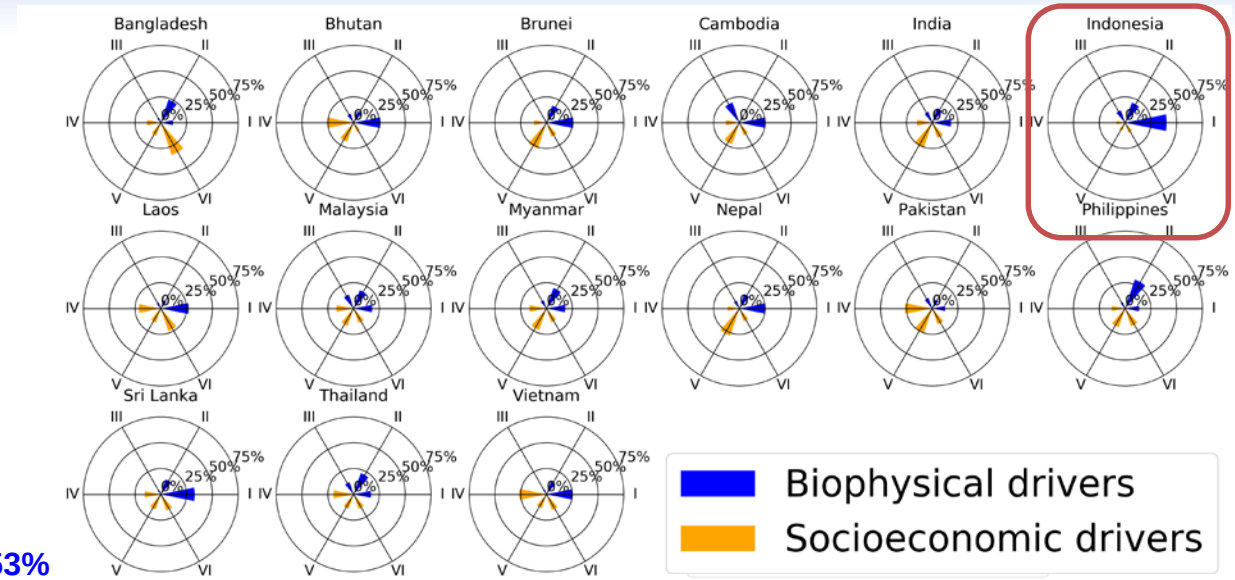
I.	Terrain, soil and water	IV.	Population and urbanization
II.	Climate	V.	Livestock
III.	Natural disaster	VI.	Economy

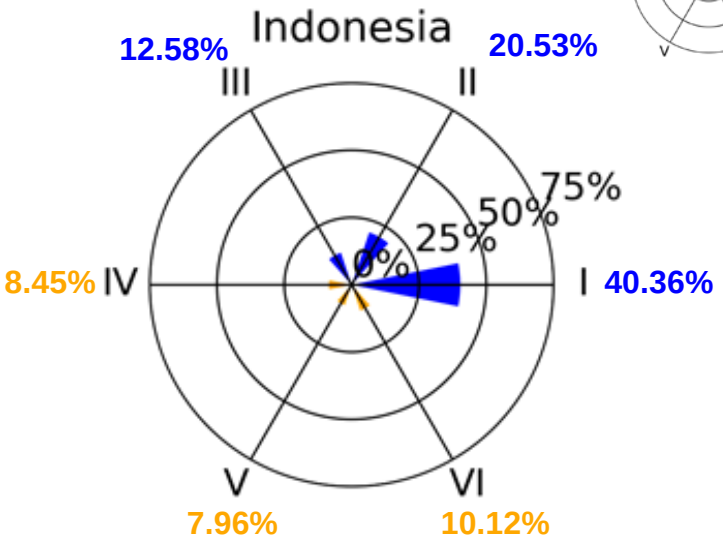
Biophysical drivers: 46.33%

Socioeconomic drivers: 53.67%

Country-Specific Relative Importance of Driver Category

Agriculture → Forest





I.	Terrain, soil and water	IV.	Population and urbanization
II.	Climate	V.	Livestock
III.	Natural disaster	VI.	Economy

Biophysical drivers: 73.47%

Socioeconomic drivers: 26.53%

Conclusions

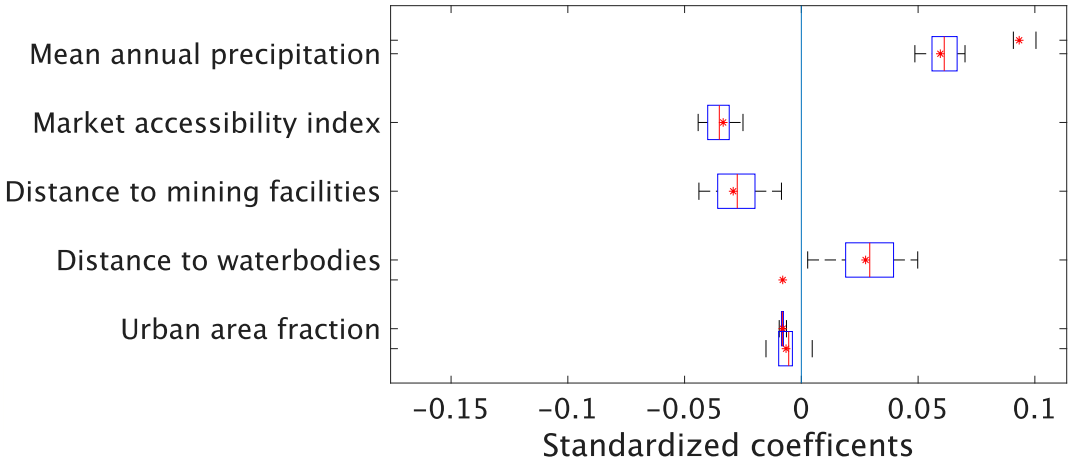
- Quantification of LULCC at spatial scale requires modeling tools to bridge scales between human dimension and earth climate system.
- The major challenges for developing such tools at global scale include:
  - heterogeneous LULCC dynamics at spatial scale,
  - diversity of socioeconomic drivers at country and regional scales.
- One way to address these challenges is to develop and apply modeling tools that can combine top-down and bottom-up approaches.
  - Bottom-up approach helps to improve the understanding of the LULCC drivers at local to regional scales.
  - Top-down approach helps to bridge the gaps between local-regional scale and global scale.
- Evaluating the performance of such tools over the historical time at local and regional scales can help to improve projections of LULCC on a longer time scale.

Future Plans

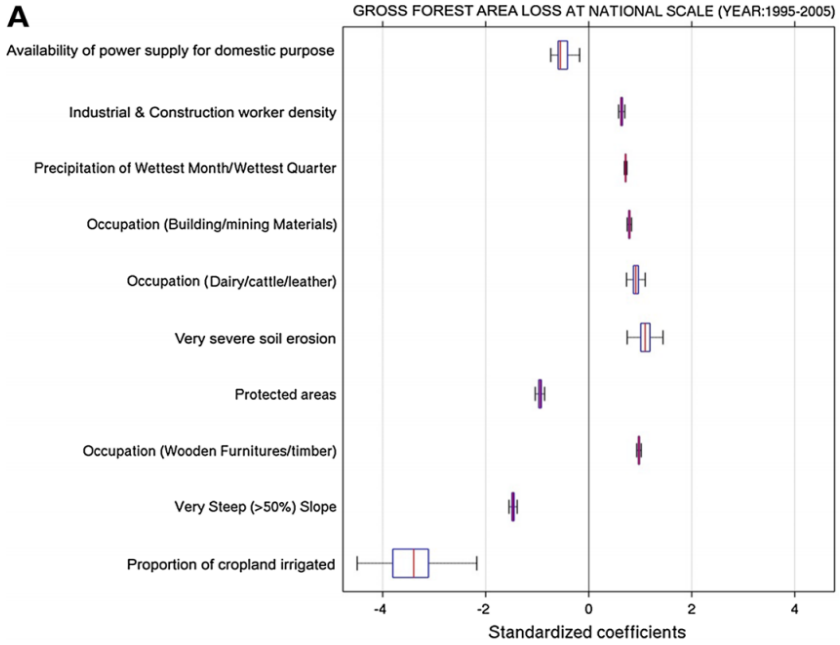
- Further validate the regional drivers with local-scale studies.
- Evaluate the SDAM for other regions.
- Implement SDAM into GCAM and E3SM.

Thank you!

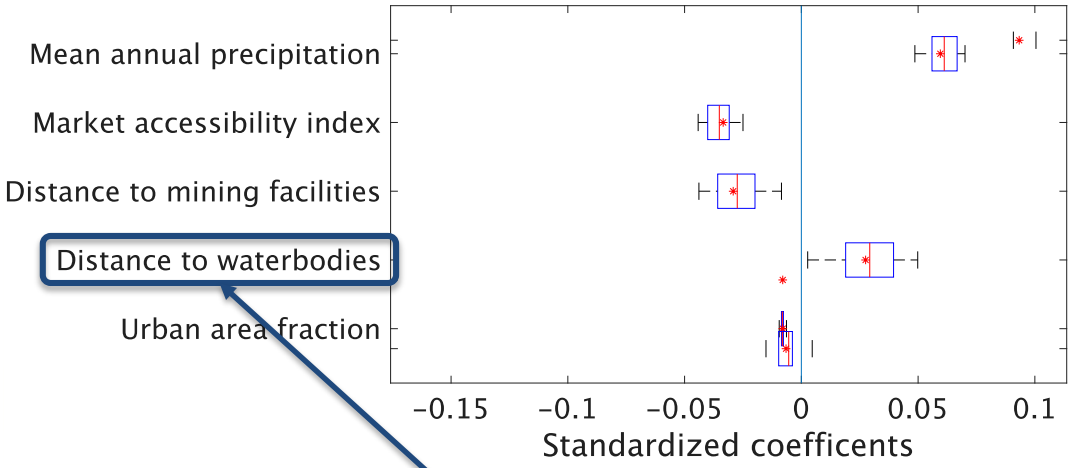
Results validation:
India (forest to agricultural land)



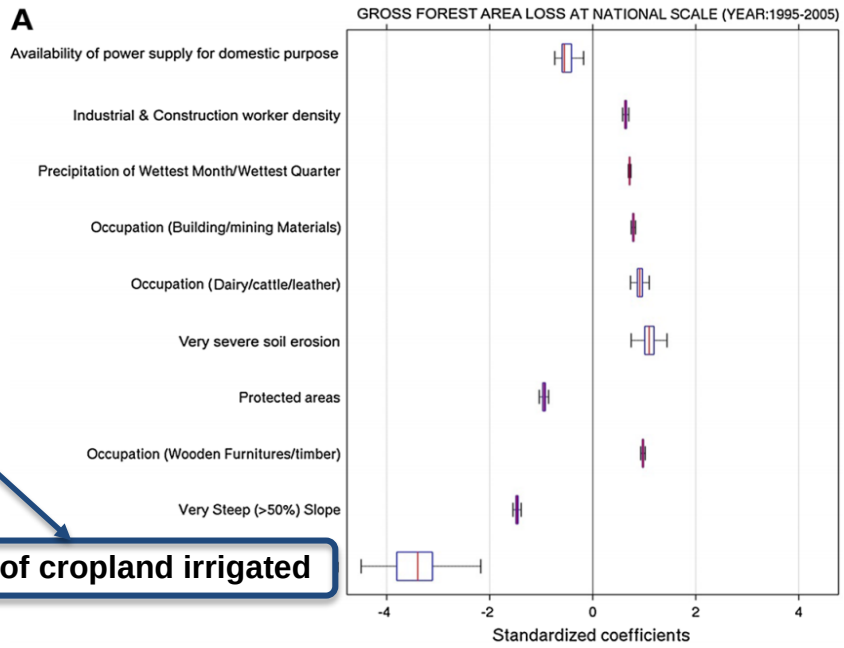
Forest area loss



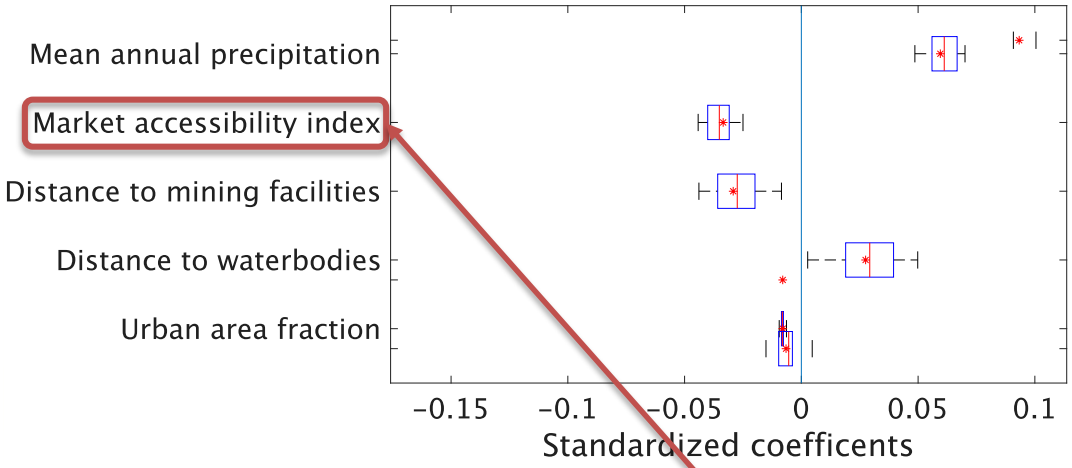
Results validation:
India (forest to agricultural land)



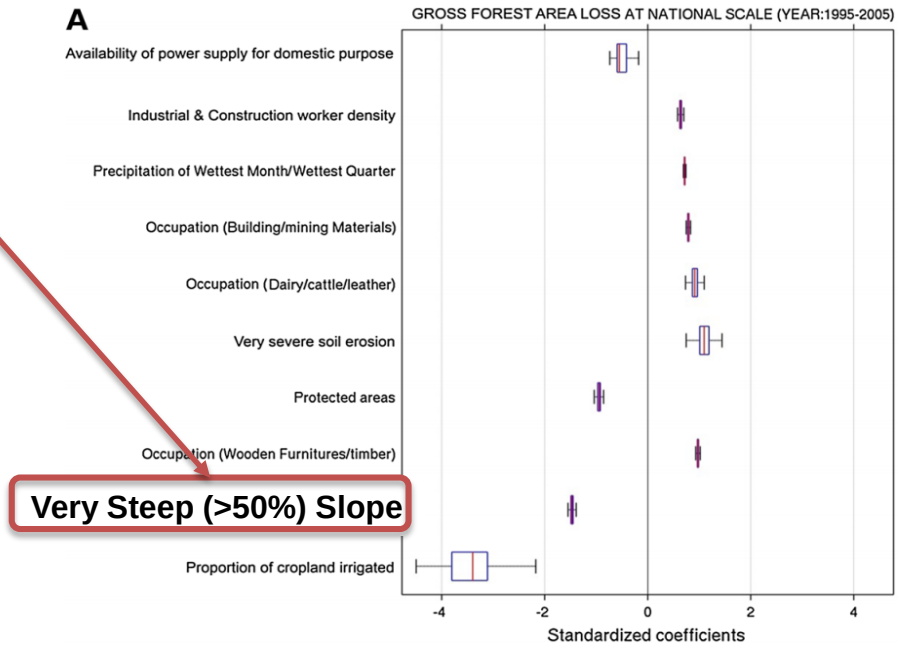
Forest area loss



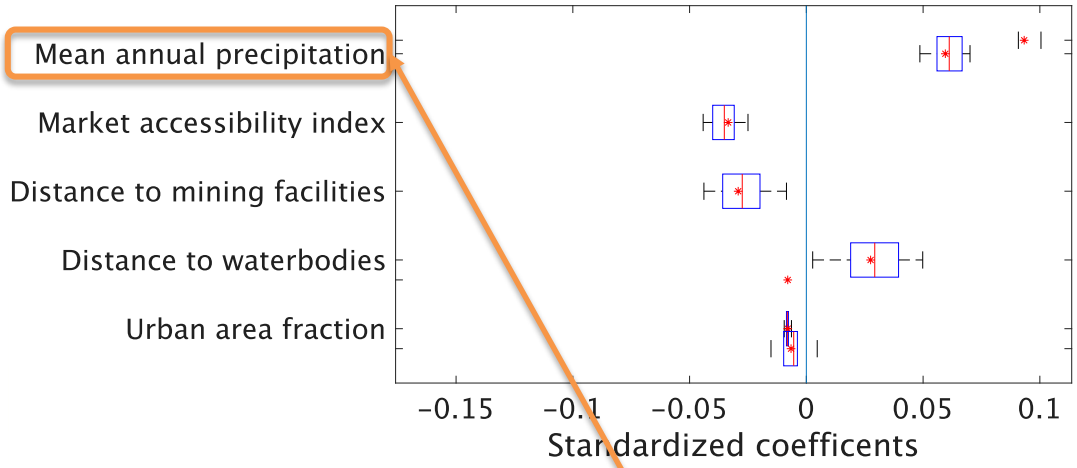
Results validation:
India (forest to agricultural land)



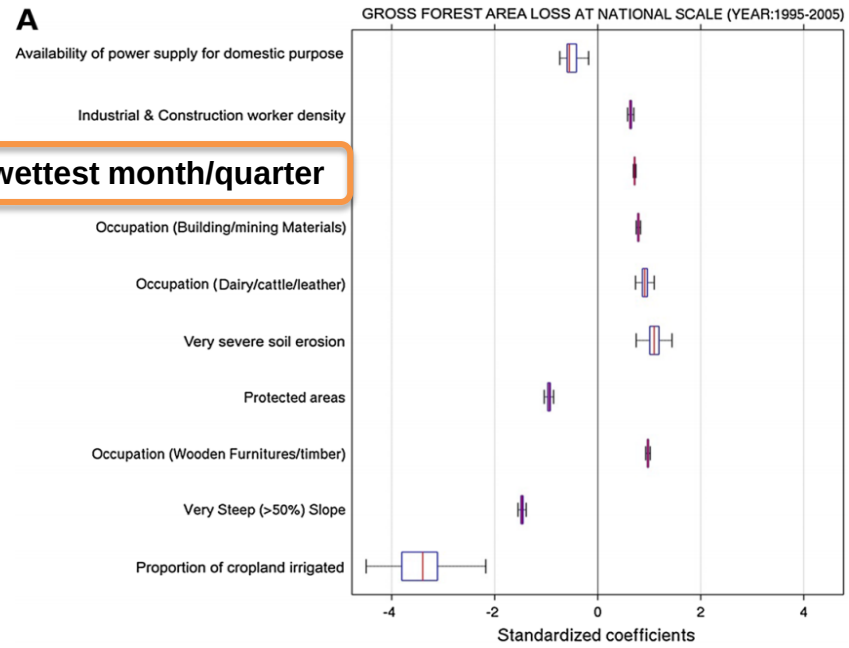
Forest area loss



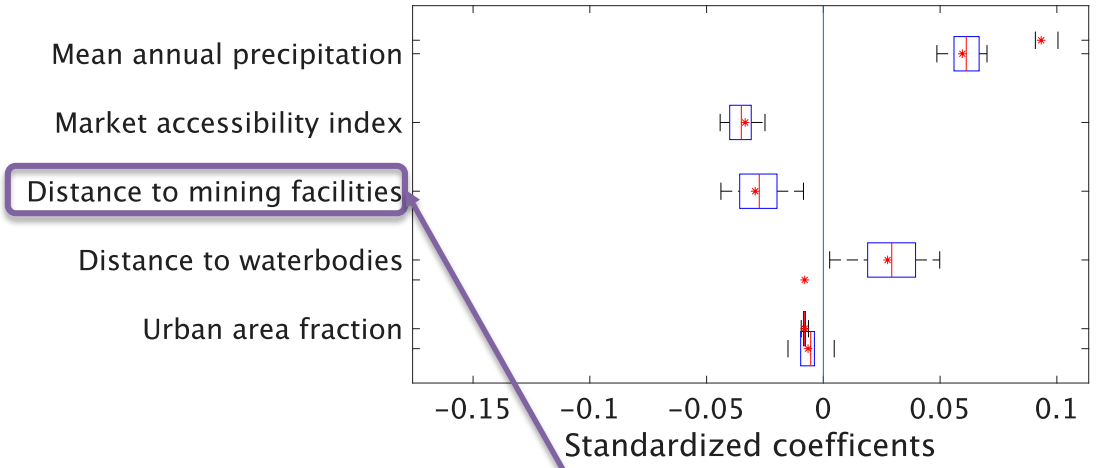
Results validation:
India (forest to agricultural land)



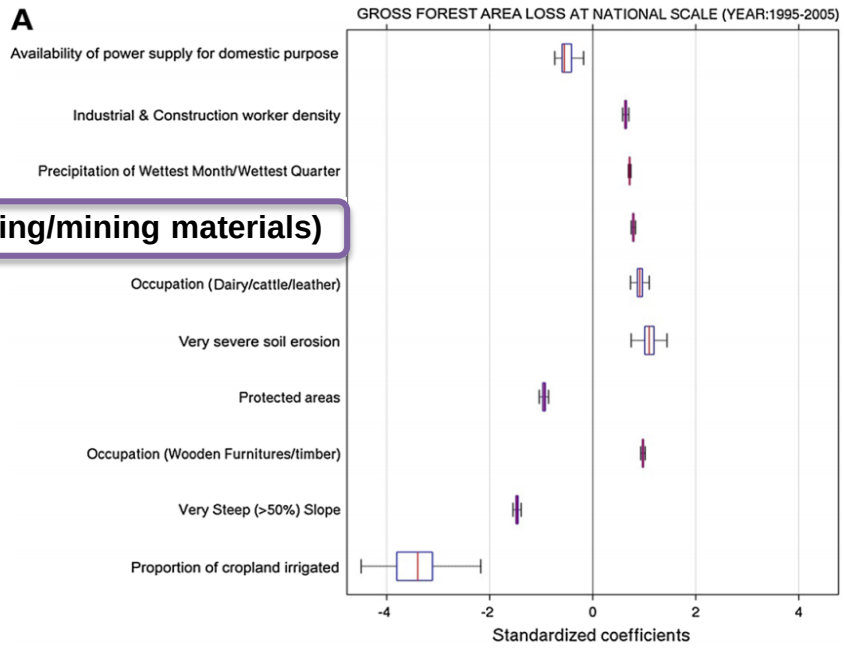
Forest area loss



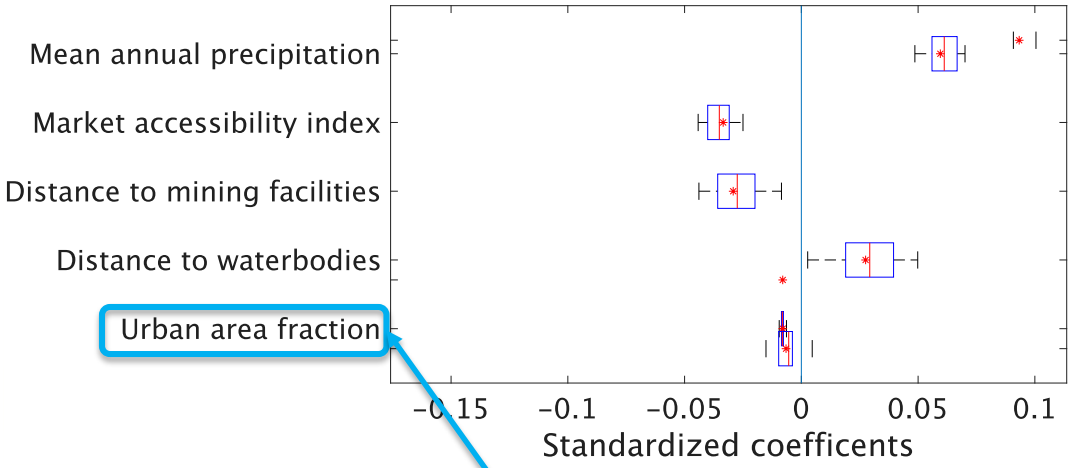
Results validation:
India (forest to agricultural land)



Forest area loss



Results validation:
India (forest to agricultural land)



Availability of power supply for domestic purpose

Forest area loss