

# Trends and Drivers of Land Use/Cover Change in India

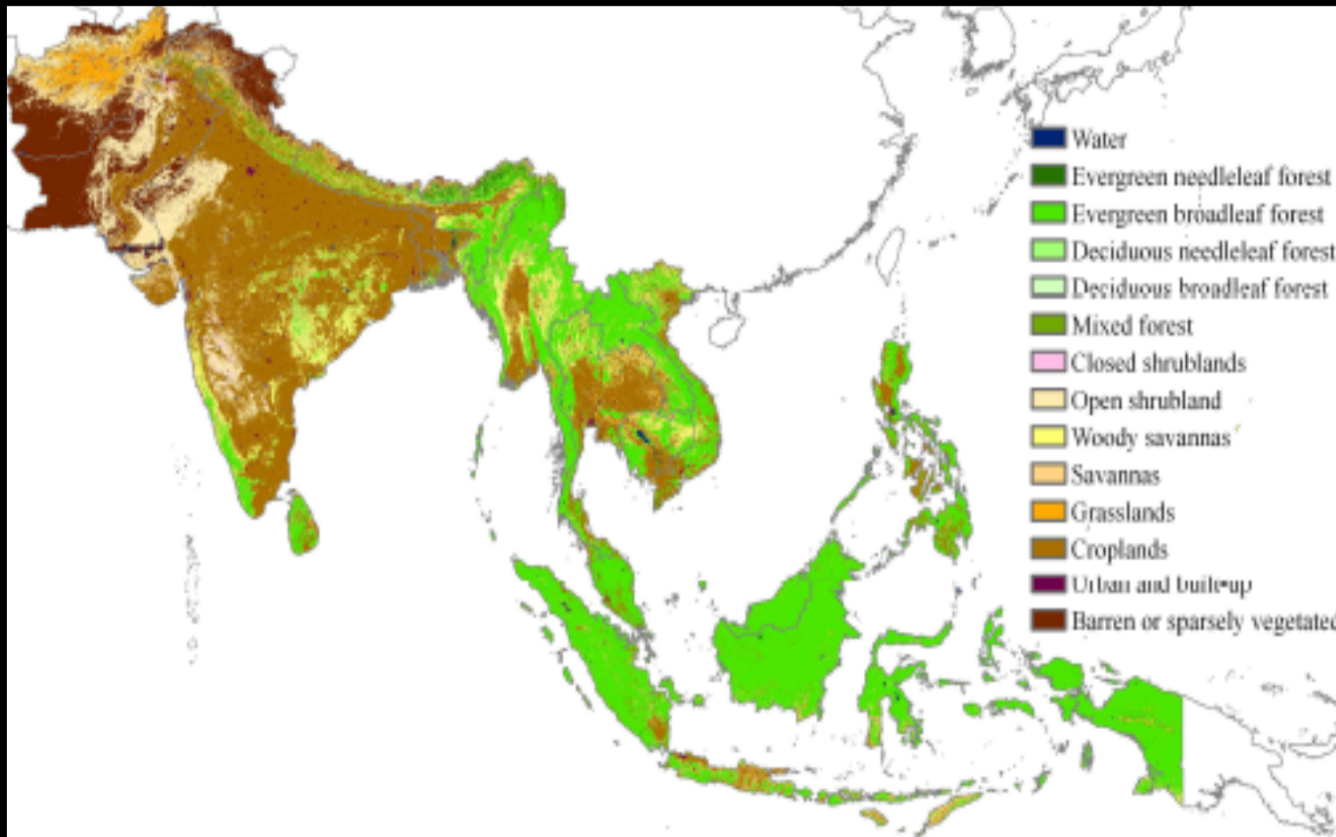
Atul Jain

Department of Atmospheric Sciences  
University of Illinois, USA

# Background

- Three principal objectives
  - *To understand the major LCLUC transition activities in the study region.*
  - *To advance our understanding of the causes of LCLUC.*
  - *To improve our understanding of the historical effects of LCLUC dynamics on the quantities and pathways of terrestrial carbon and nitrogen fluxes.*

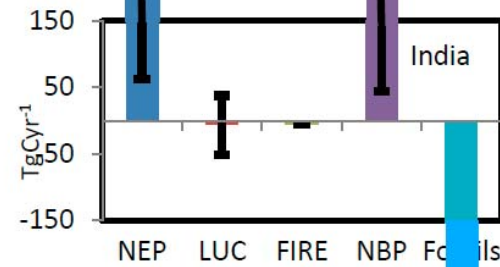
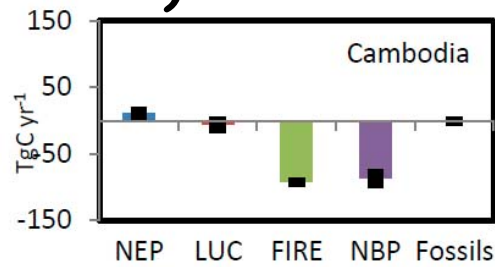
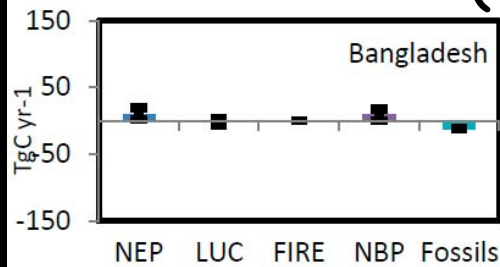
# SSEA Region



*LCLUC  
distribution  
in the study  
region*

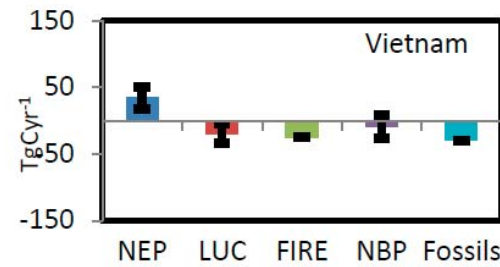
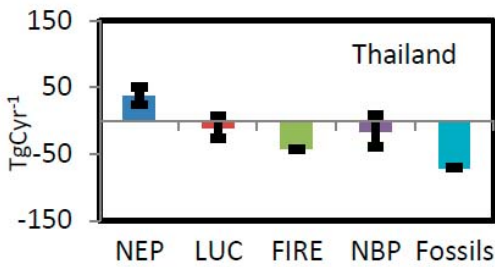
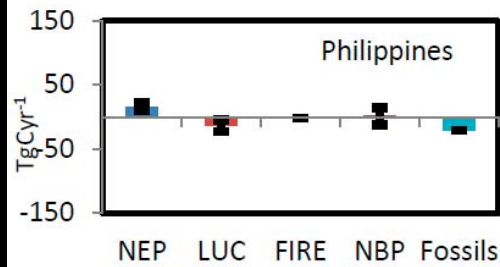
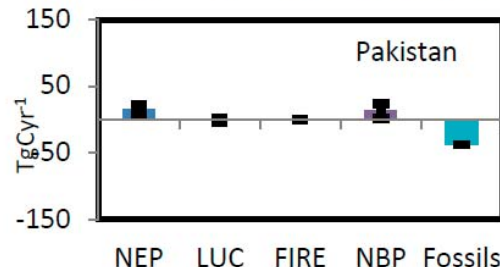
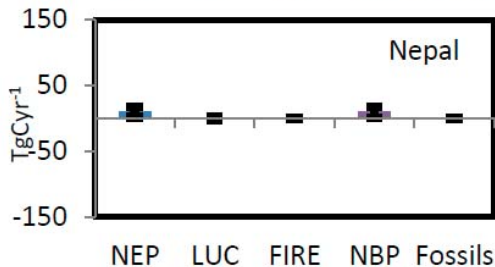
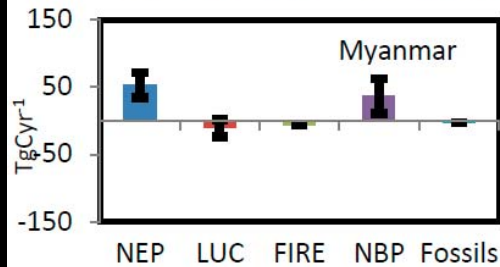
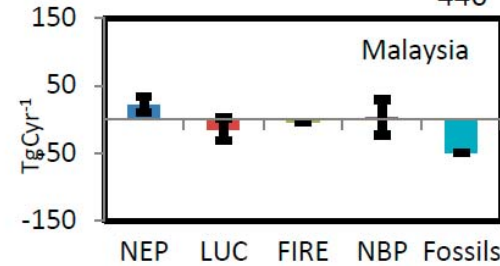
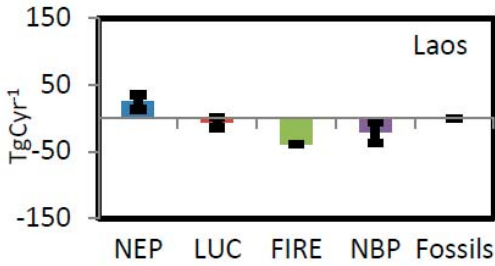
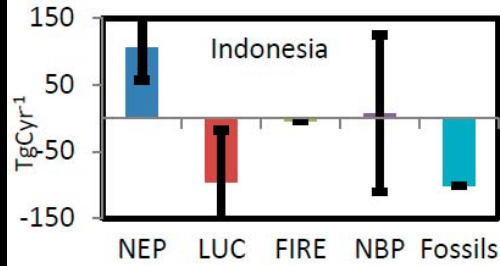
- Covers about 16% of earth's land surface
- Characterized by a long history of LCLUC activities
- the home for over 50% of the world's population
- *Study LCLUC dynamics country-by-country basis*

# Carbon Budget for SSEA countries (2000s)



**NBP = NEP - FIRE - LUC**

**-ve is C Source  
+ve is C Sink**





# Quantification of LCLUC in India - Reviewed Literature

- We reviewed literature for LCLUC studies covering India published between 1980 and May 2015.
- Overall, the literature review resulted in more than 630 articles that we studied in detail.
  - About 72% of all articles focused on LCLUC processes and rest on causes of LCLUC

# Quantification of LCLUC

## Dynamics & Causes - Reviewed Literature

### Dynamics

- Studies are carried out small regions
- Studies are carried out using coarse resolution remote-sensing products
  - tend to mask highly fragmented land
- Data is not available at regular time interval

### Causes of LCLUC

- No geospatial socioeconomic data available at national scale
- Data collection efforts (e.g., social surveys) are focused on small regions
- Biophysical variables are compiled based on courser resolution global scale data sets

# Quantification of LCLUC

## Dynamics & Causes - Synthesis

### Dynamics

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*All these constraints are hindering effective national level planning and policy-making.*

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# Dynamics & Causes of LCLUC in India - Our Approach

- Quantified land-cover conversion (~30m resolution) at national scales using Landsat-MSS/TM imageries (30m) at decadal time interval (1985, 1995, and 2005)
- Quantified the causes by estimating spatial logistic regressions between land-cover conversion estimates and socioeconomic and biophysical factors
  - used village level (>630,000 administrative units) socioeconomic data (>200 variables) at national scale
  - evaluated our regression results through collective evidence from synthesis of 102 case studies

## Studied Causes for Three LCLUC Types

- We studied the causes (spatial determinants as opposed to aggregate) of three broad LCLUC that are central to land use planning in India
  - Underutilization of land area (non-productive land specifically fallow land and wasteland)
  - Deforestation and forest degradation, and
  - Increase in forest area.

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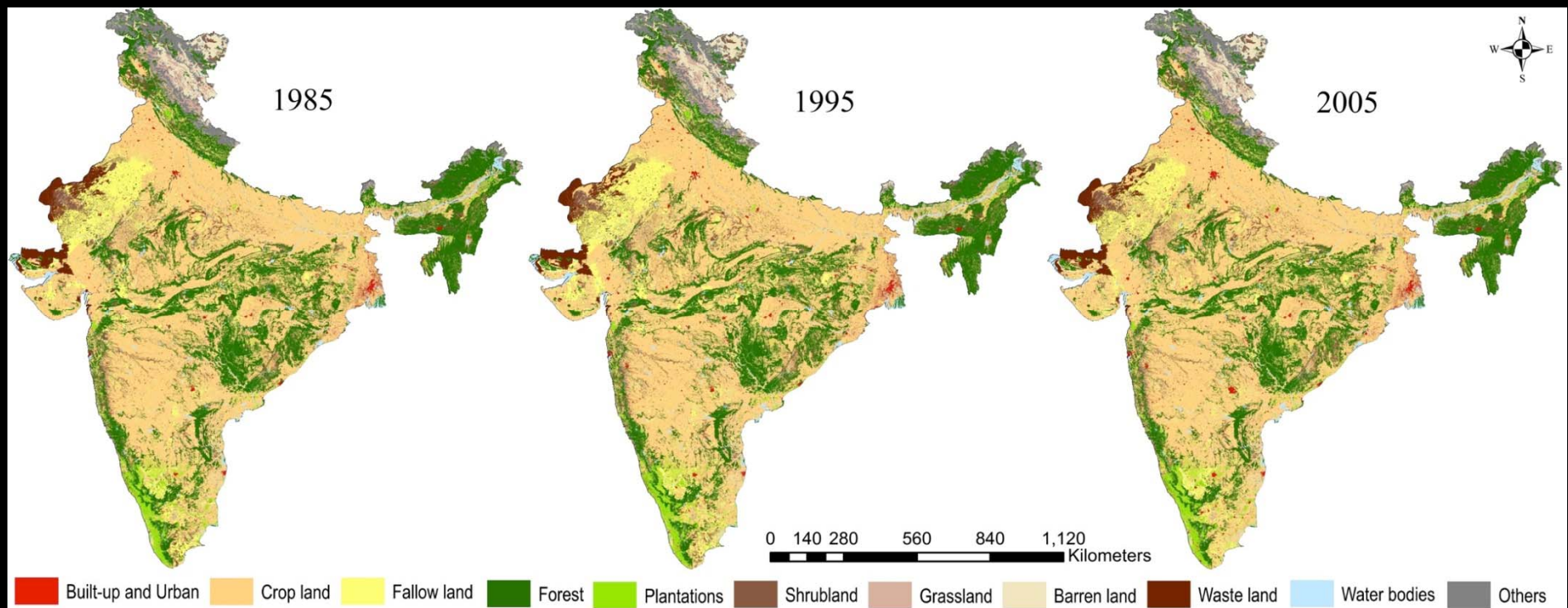
Decadal national Land use and Land Cover change  
for Land dynamics and Climate Change studies  
(1975-1985-1995-2005-2015)

Approach for LULUC change mapping



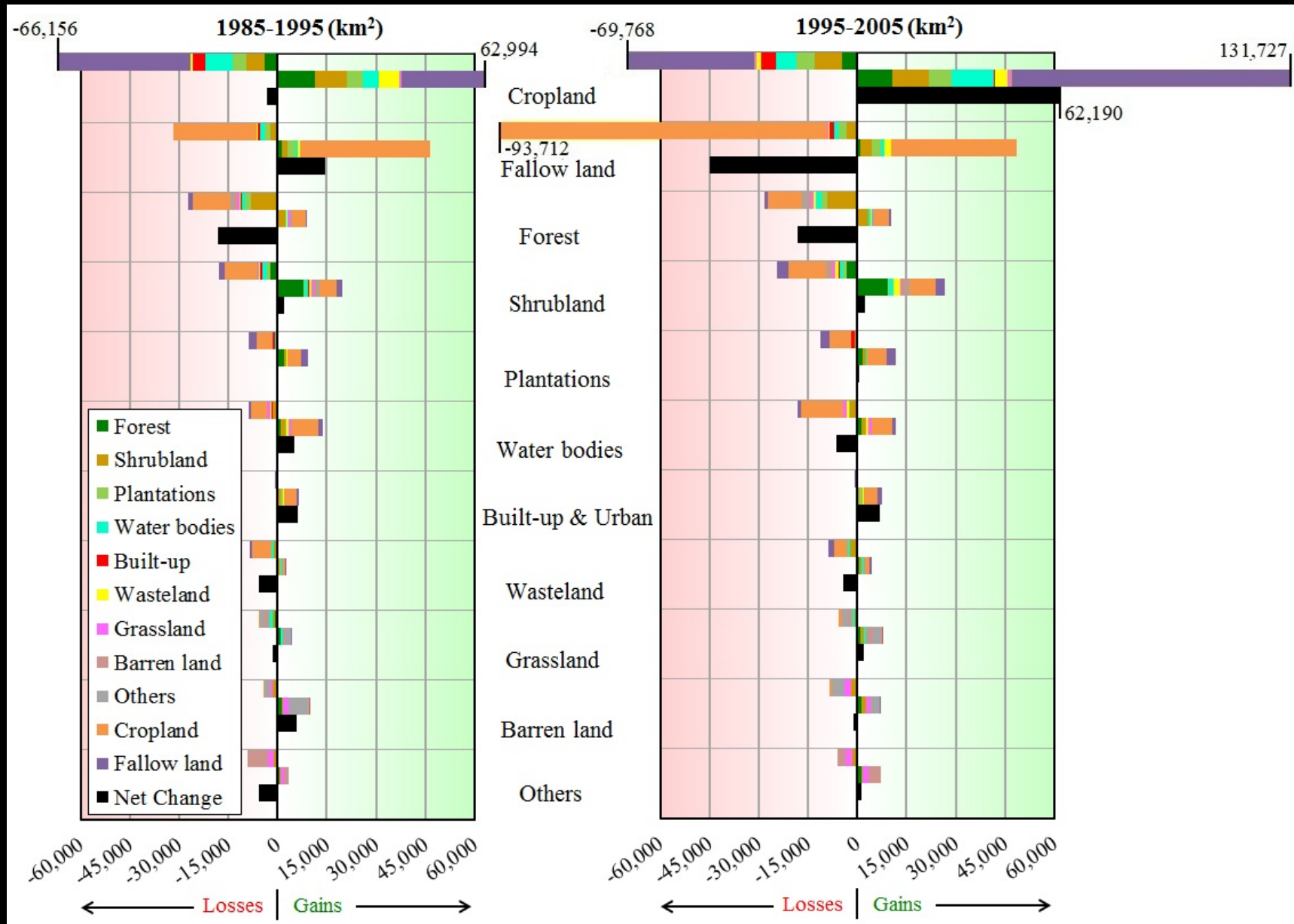
# Wall-to-wall Landsat Analysis (30m)

- Covers Longer Time Period: Decadal (1985-1995-2005)
- Uniform Classification Scheme: IGBP
- Patch to Patch Land Dynamics
- Ground Validation (>12000 points)

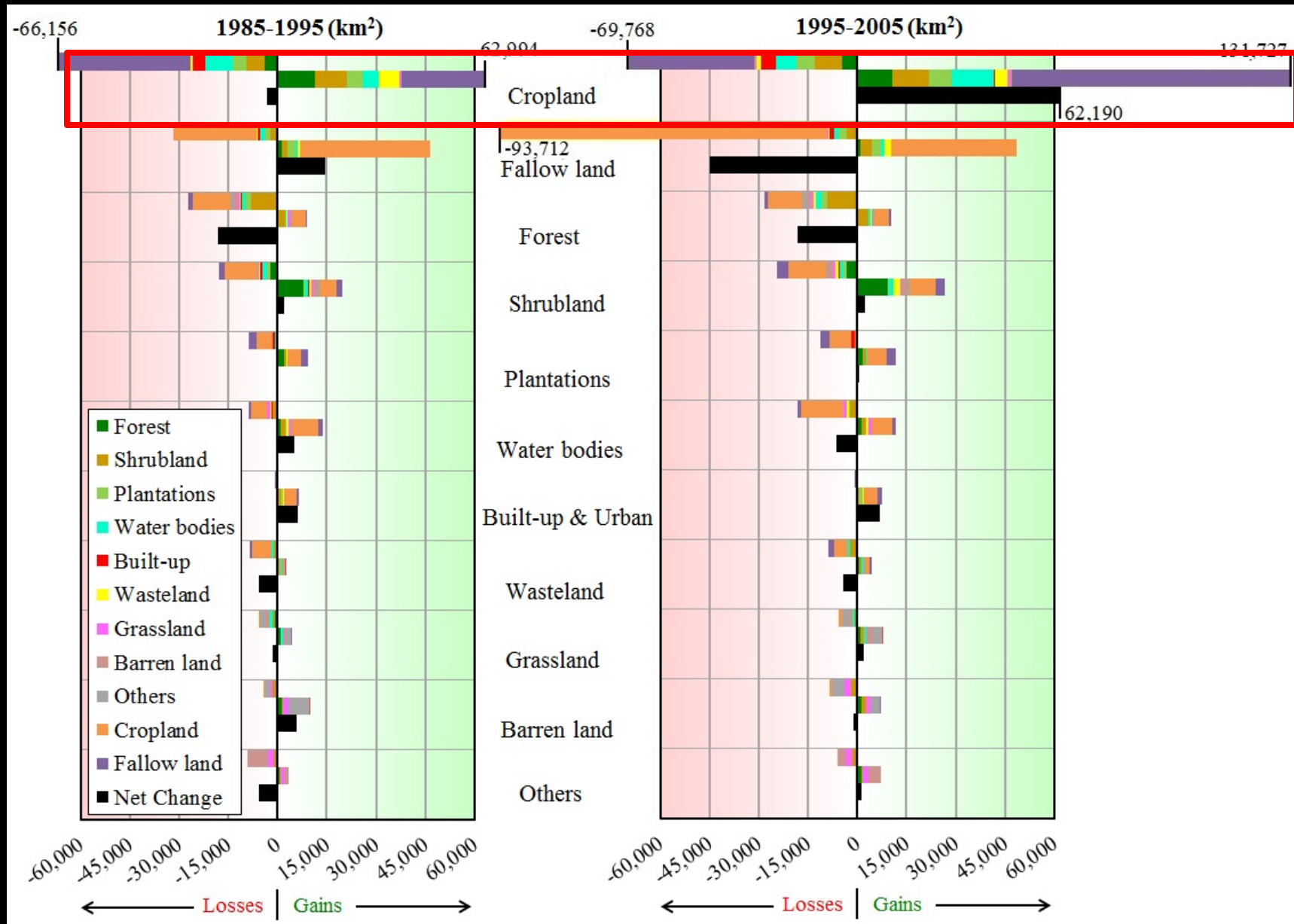


Roy et al. (*Remote Sensing*, 2015)

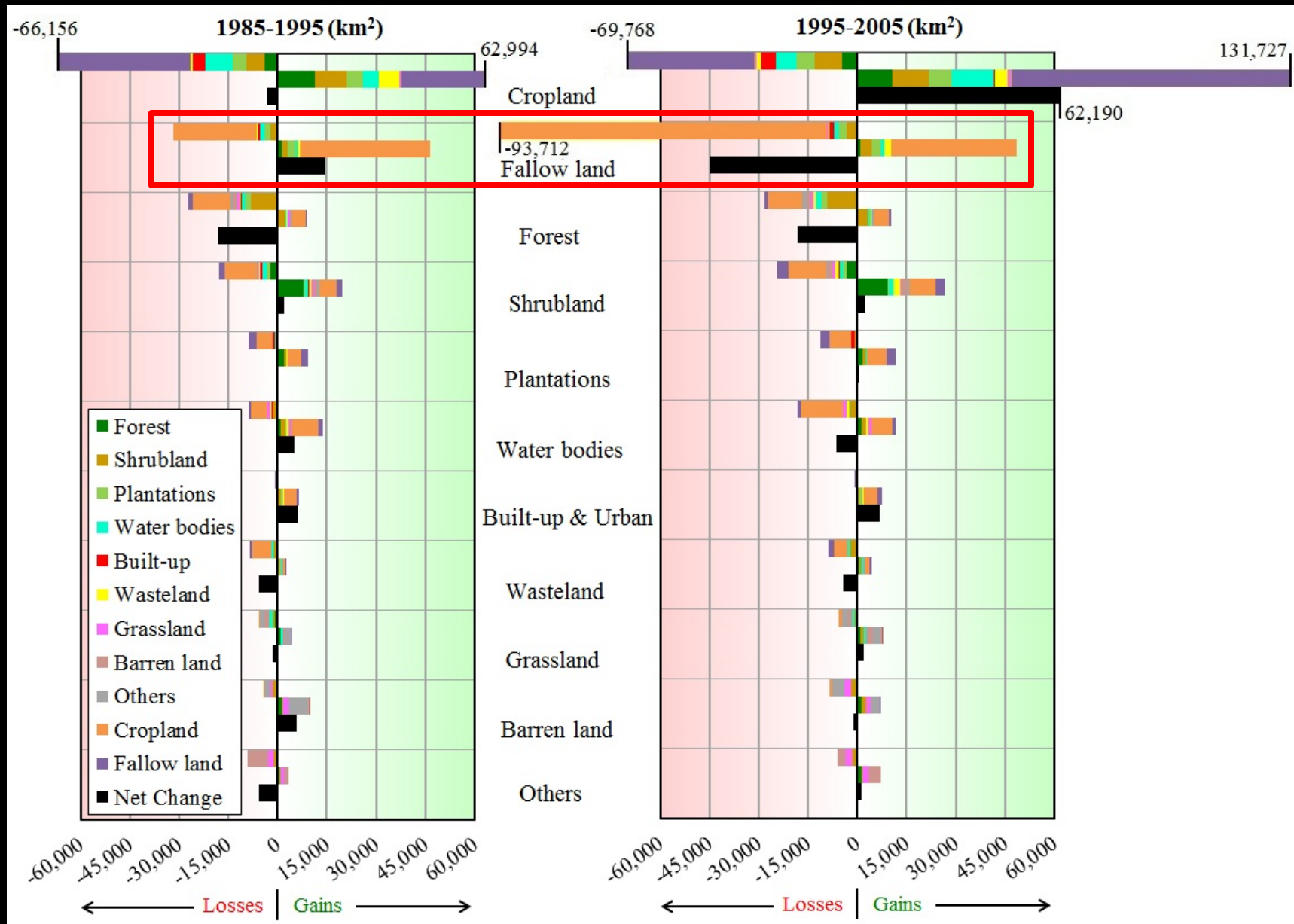
# LCLUC Dynamics at National Scale



# LCLUC Dynamics at National Scale

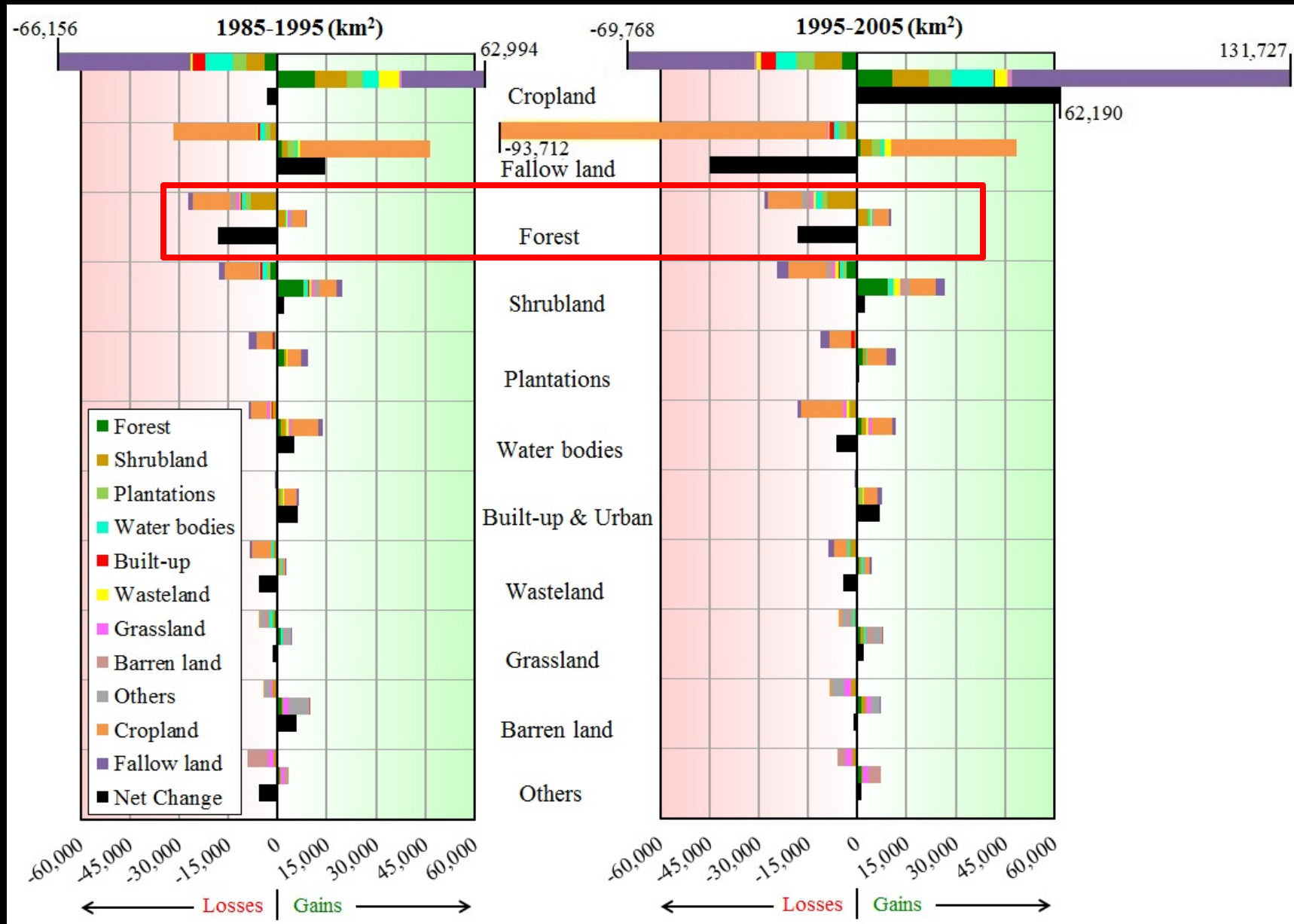


# LCLUC Dynamics at National Scale

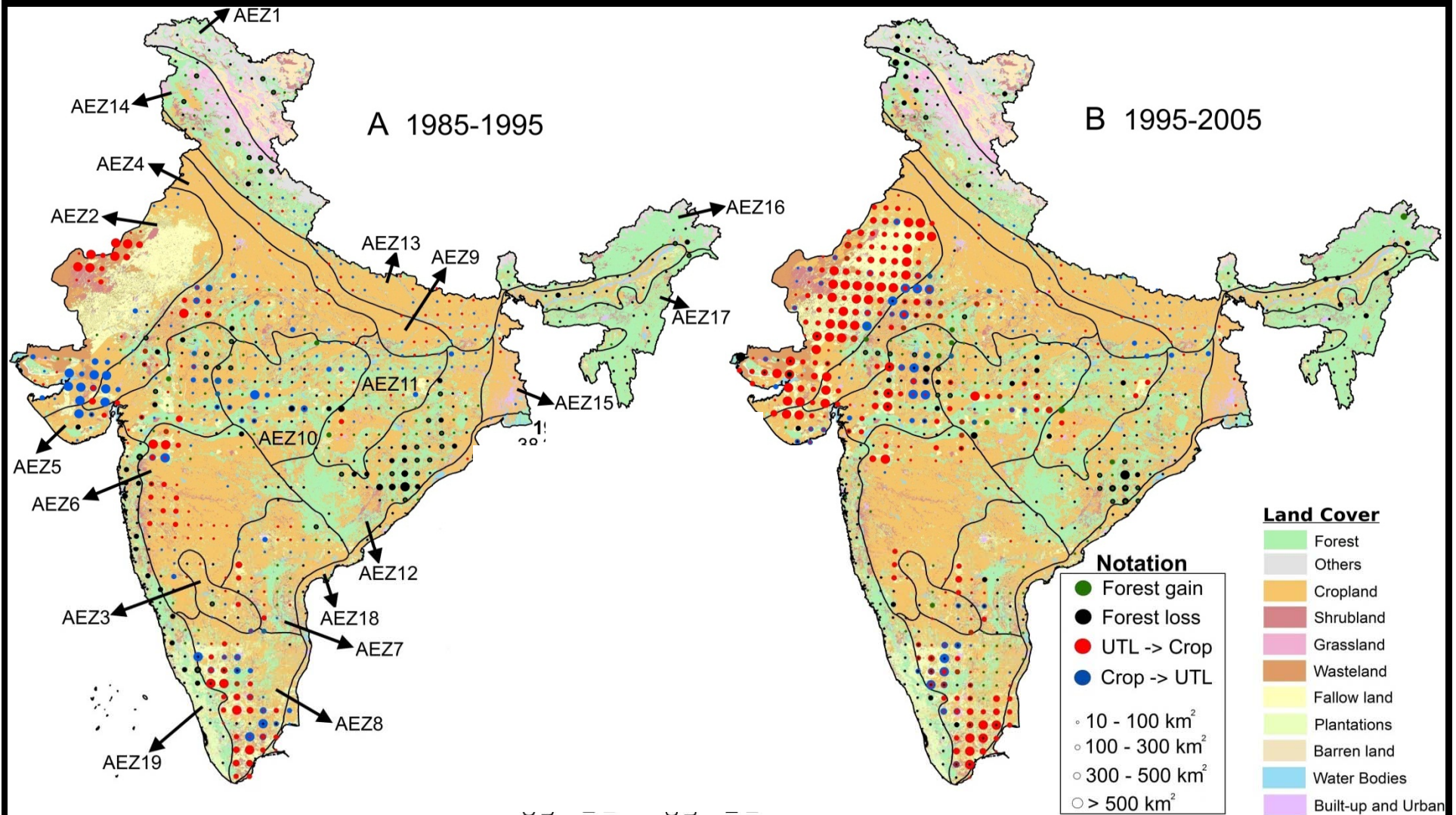




# LCLUC Dynamics at National Scale



# Regional LCLUC Dynamics



# Socioeconomic Causes of LCLUC

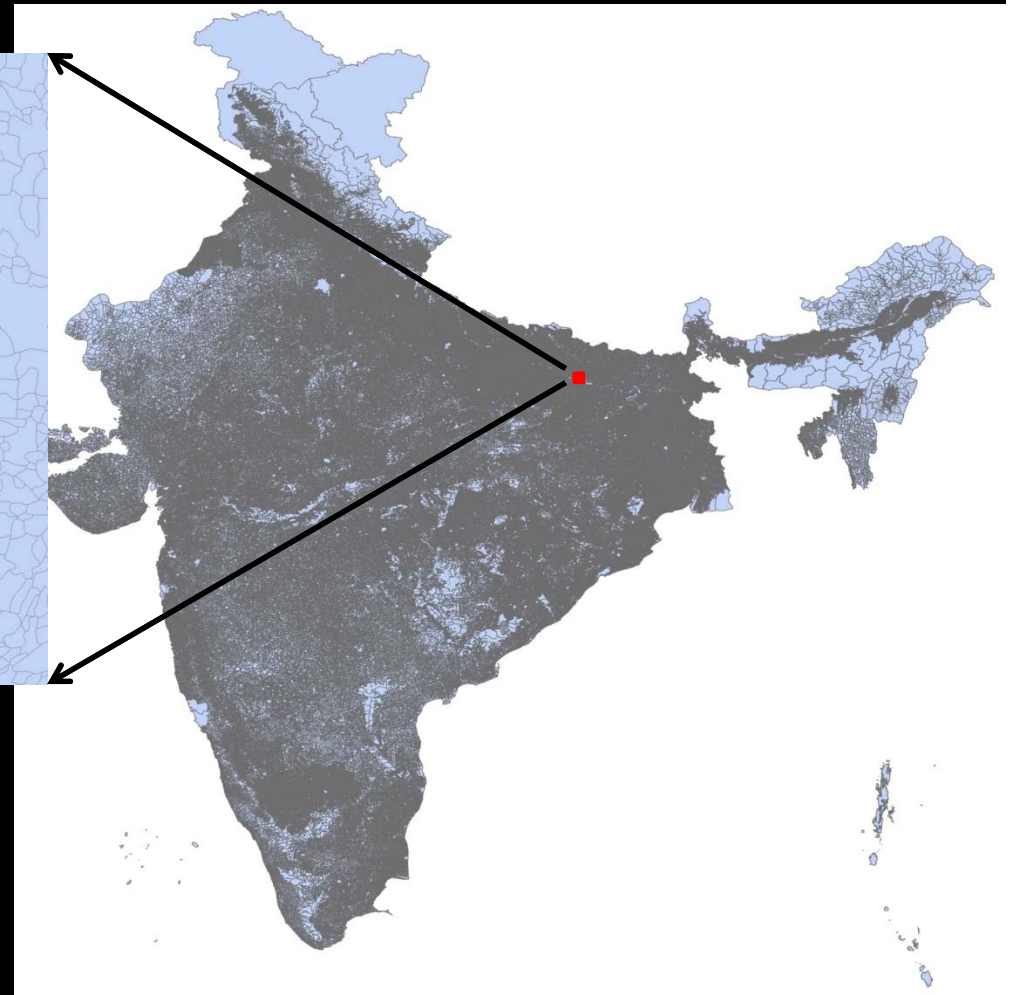
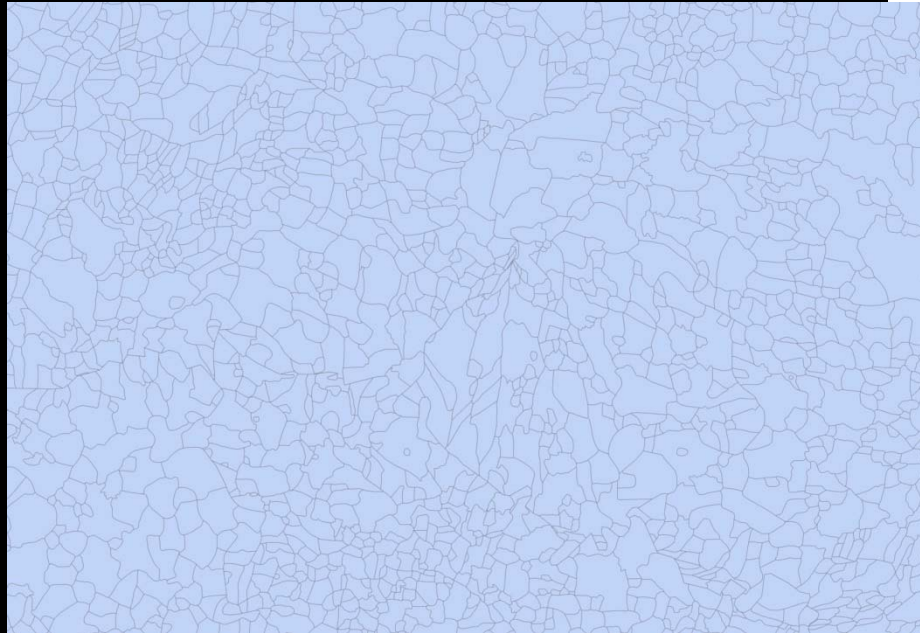
- A key aspect of our study is the compilation and usage of the most detailed, national level spatial database
  - over 80 socioeconomic factors at village/town level (~630,000 administrative units) for two consecutive census years (1991 and 2001).



# Data - Administrative Hierarchy

Village (~630,000 units)

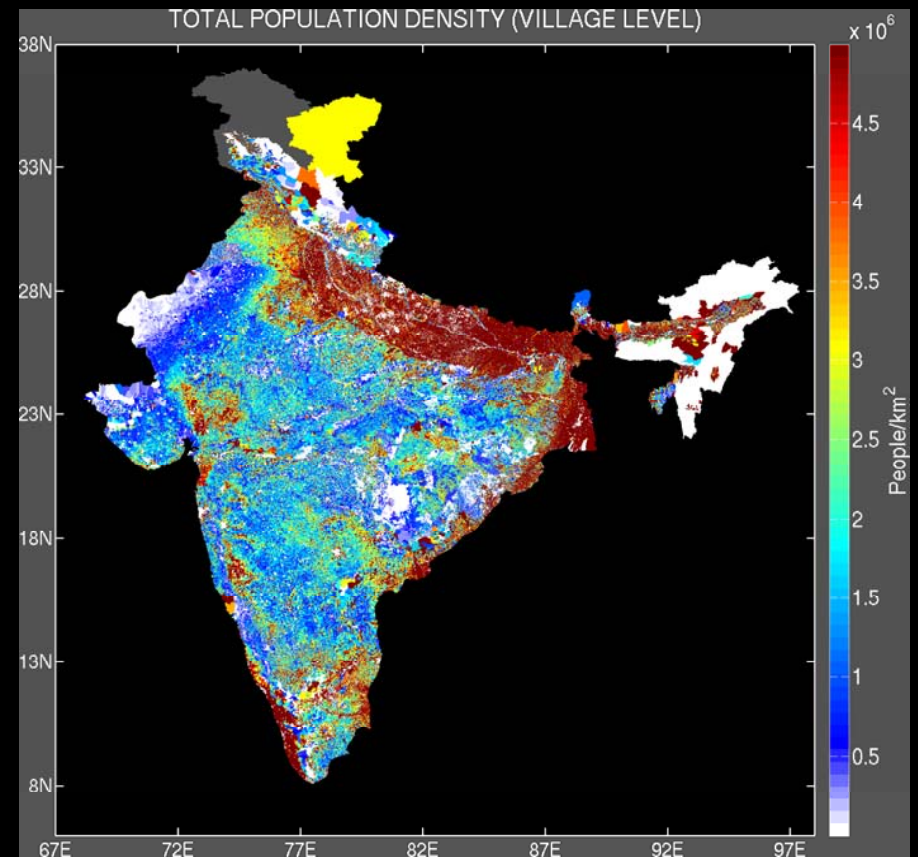
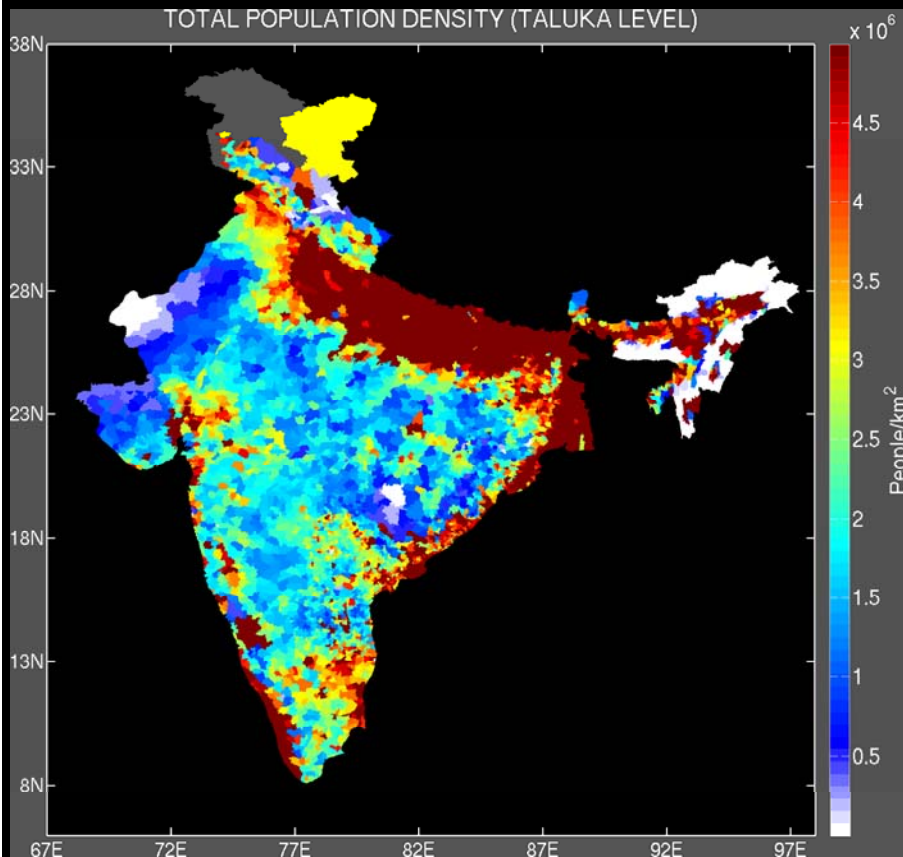
Zoomed-in View



- Captures the high granularity in socioeconomics
- Used village specific qualitative variables that reflects the base of the socio-economic culture prevalent in rural parts of India

# Socioeconomics: Illustration with example

Best Res. Data (Currently Available)  $\xrightarrow{> 100x \text{ improvement}}$  Our Database

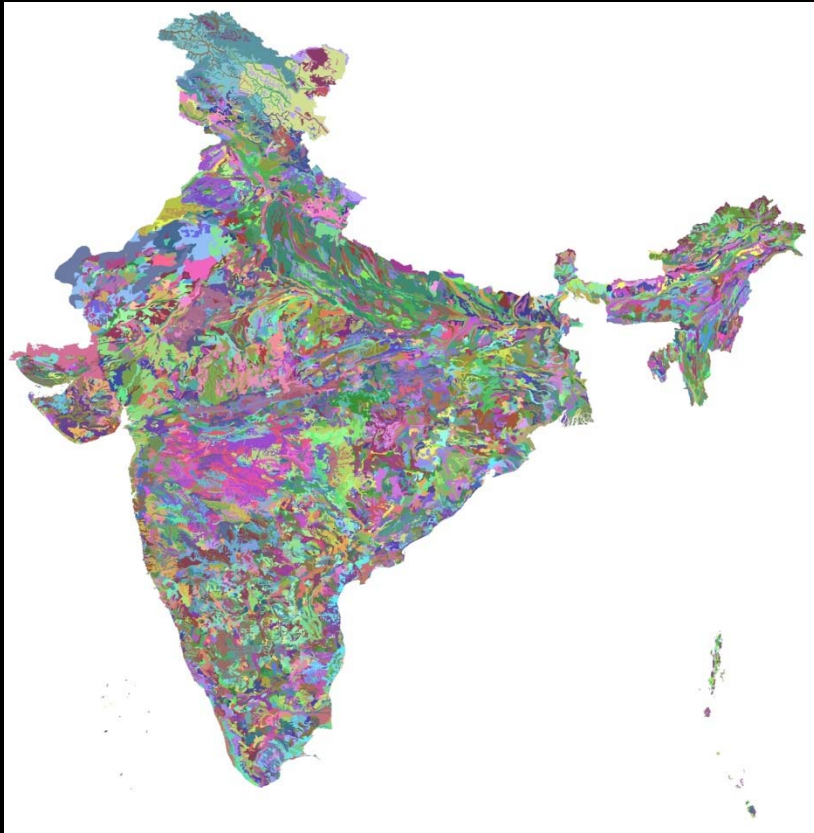


# Broder Cluster and Explanatory Factors - Examples

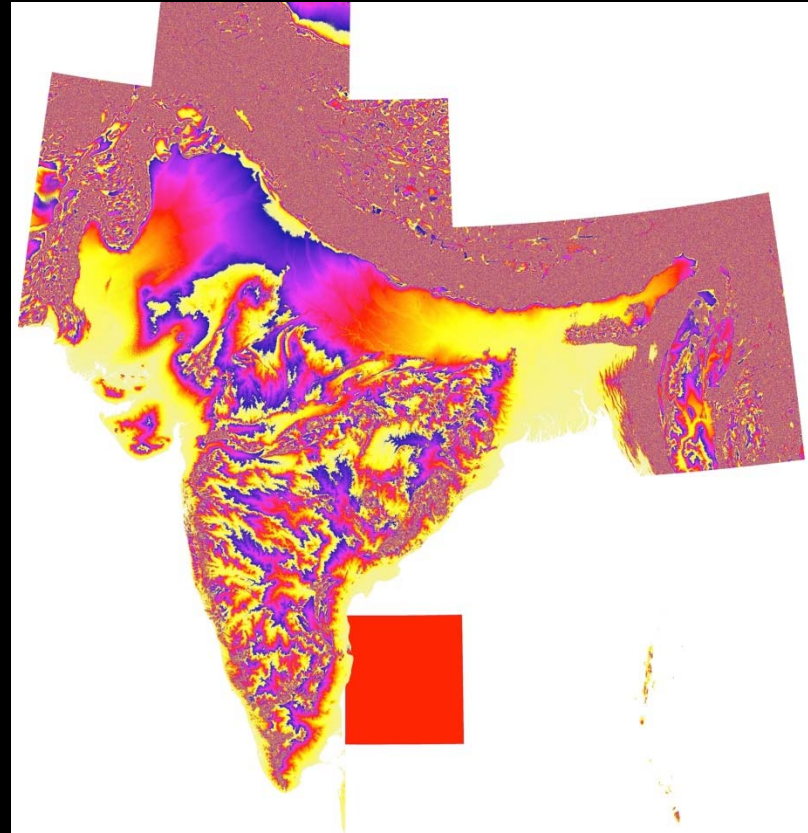
Irrigation Infrastructure	Proportion of cropland irrigated	Income dependency: Binary variables coded to indicate primary occupations of each village.	Building/mining Materials
	Proportion of area irrigated by government canal		Dairy/cattle/leather
	Proportion of area irrigated by private canal		Wool/Woolen Blankets
	Proportion of area irrigated by well without electricity		Poultry
	Proportion of area irrigated by well with electricity		Coffee Production
	Proportion of area irrigated by tube well without electricity		Tea production
	Proportion of area irrigated by tube well with electricity		Coconut Production
	Proportion of area irrigated by tanks		Rubber production
	Proportion of area irrigated by rivers		Forestry-related Products
	Proportion of area irrigated by lakes		Making of Wooden Furniture's/timber
	Proportion of crop area irrigated by other means		Manufacturing of wooden agricultural implements
	Availability of well irrigation with electricity		Prawn harvesting
	Availability of tube well irrigation with electricity		80+ other binary-coded variables to capture the other common primary occupations in India relevant to the three land-cover conversions investigated in this analysis.
	Availability of irrigation facility		
	Availability of well irrigation without electricity		
	Availability of tube well irrigation without electricity		
	Availability of tank irrigation		



# Underlying Causes: Examples of Biophysical Data



Soil data (NBSS - ~30 variables)



Terrain (SRTM)

# Statistical Estimation: Causes of LCLUC

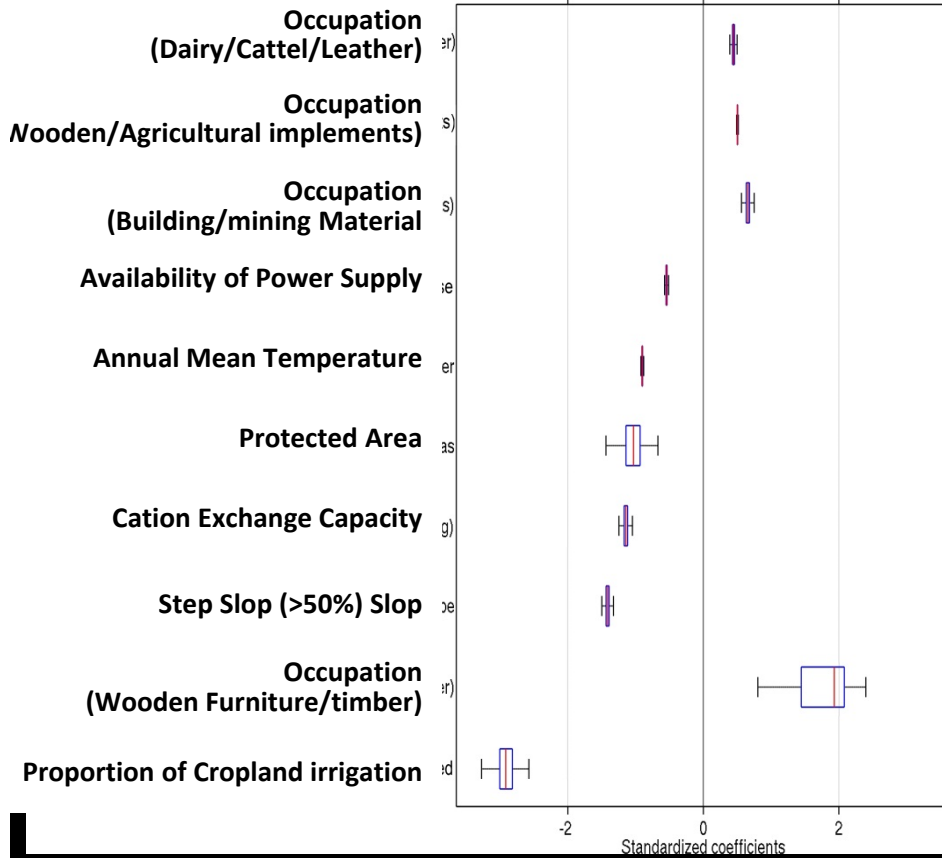
## Example: Forest loss

### Key Points

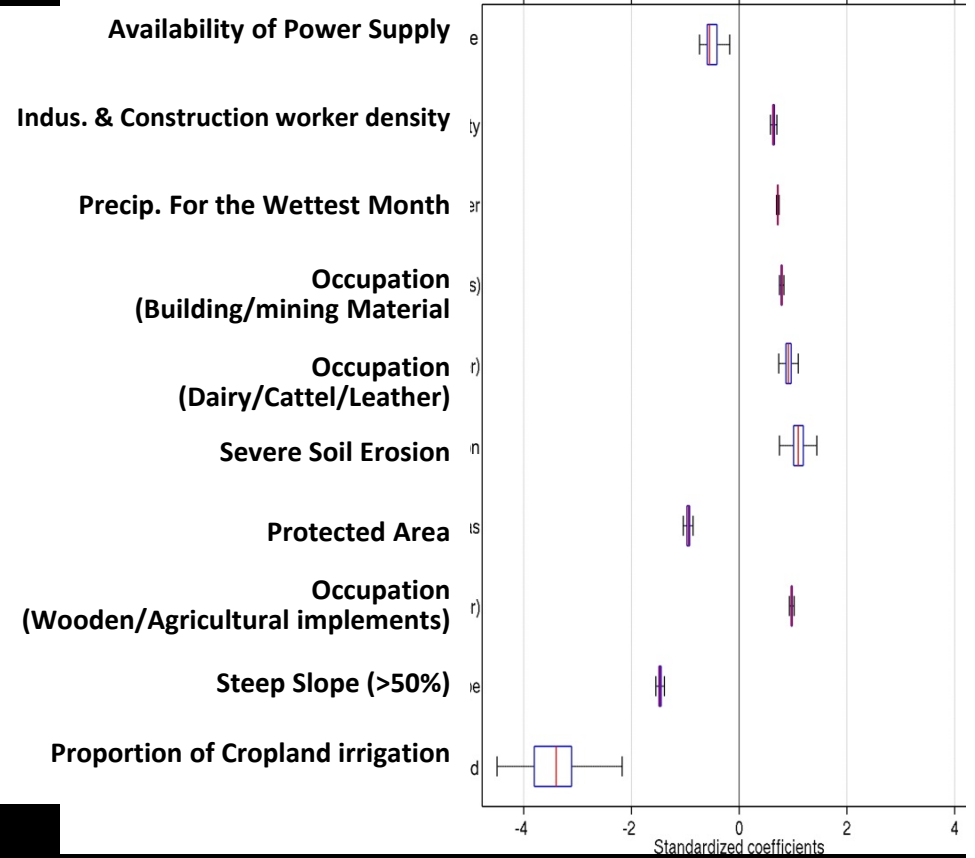
- **Model Technique** Fractional Binomial Logit Model
- **Modeling Resolution** 1km x 1km lat/long
- **Spatial Domain** National & by regional hotspots
- **Temporal Domain** Separate estimation by decade (1985-95, 1995-05)
- **Scaling of predictors** Z-score standardization
- **Multicollinearity** Elastic-net regularization
- **Parameter selection** k-fold cross validation
- **Confidence Intervals & Spatial autocorrelation** Bootstrap with 500 replicates

# Causes of Forest loss: National Scale

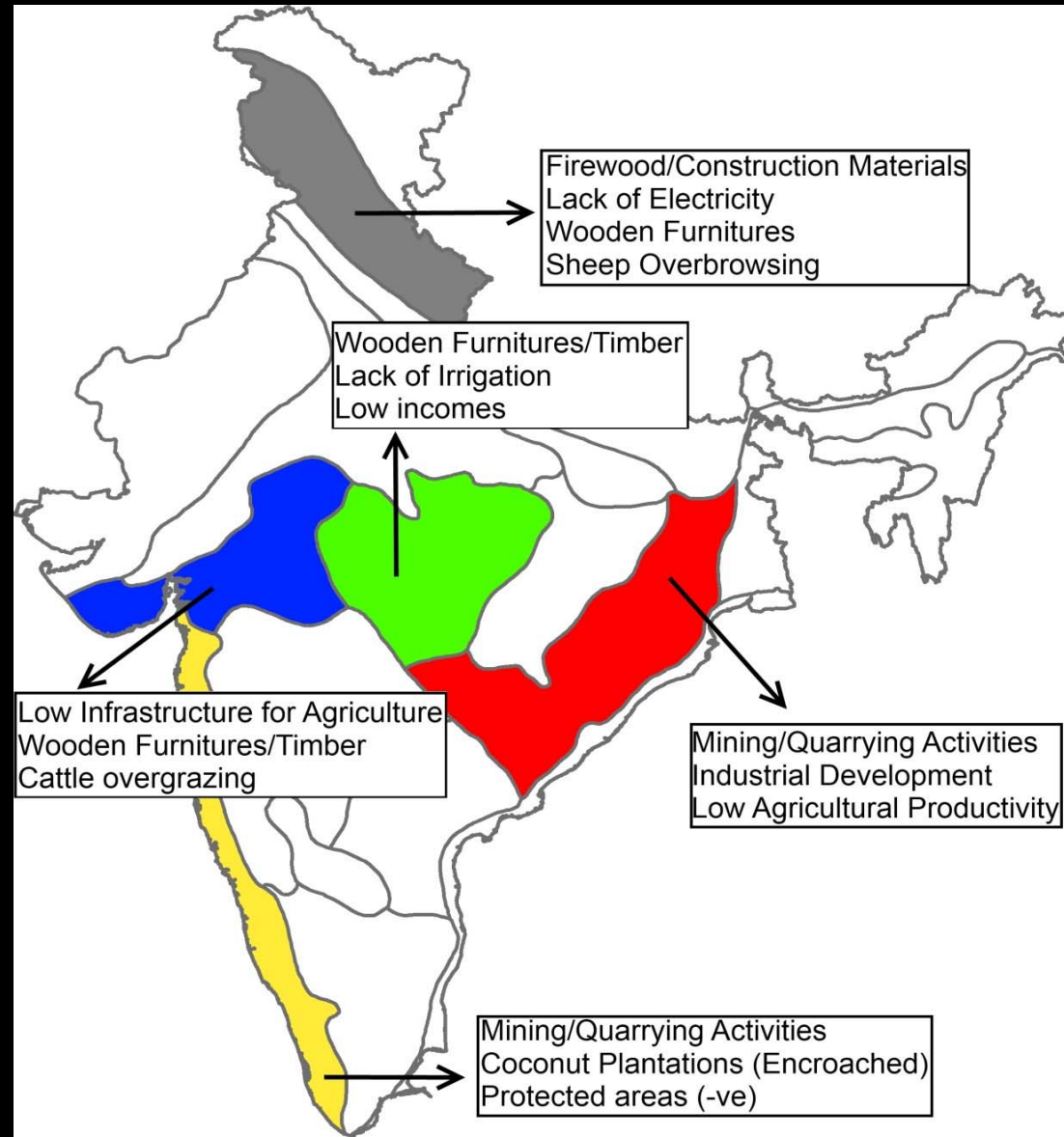
1985-1995



1995-2005

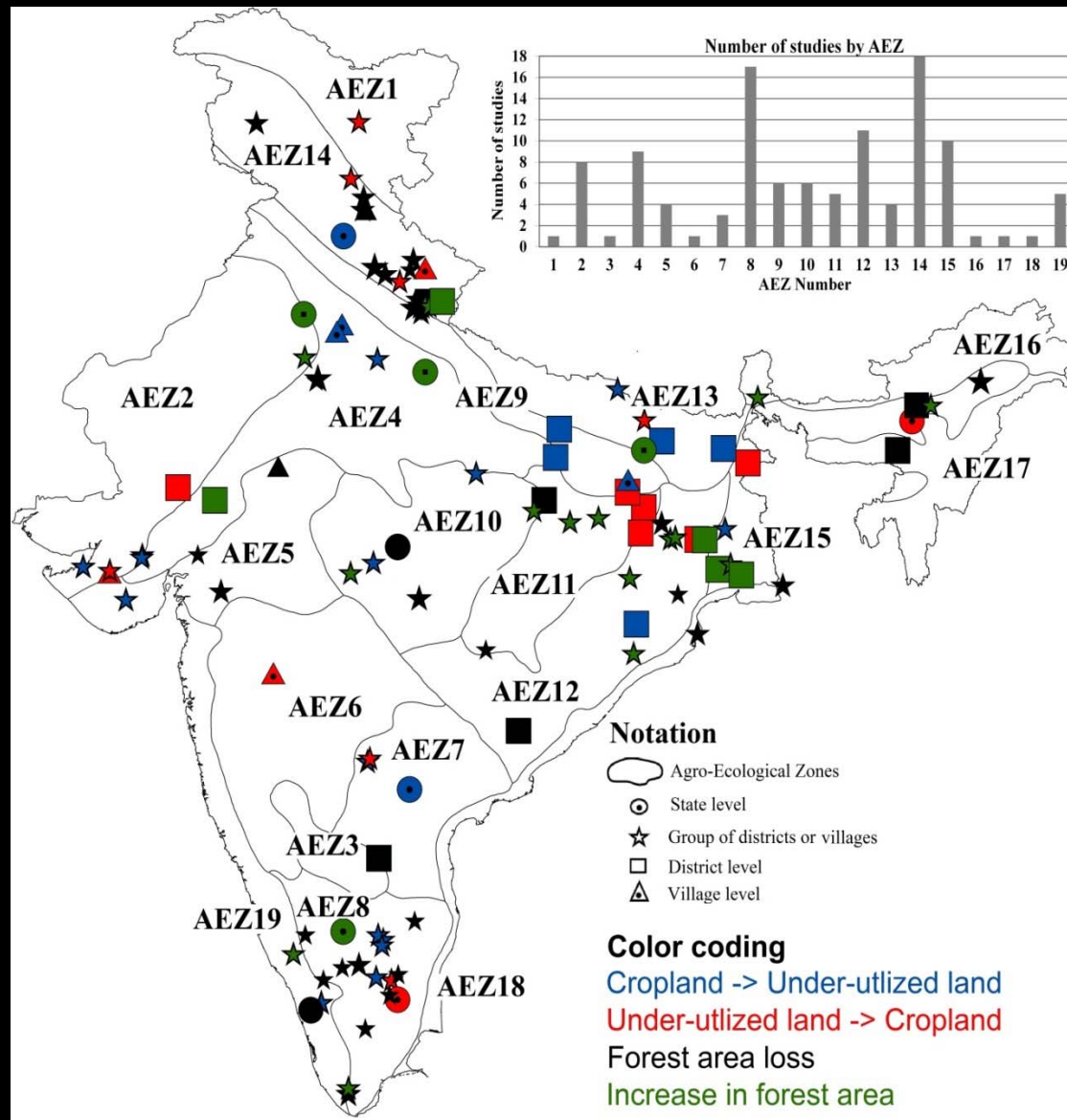


# Summary of model findings (regional hotspots)

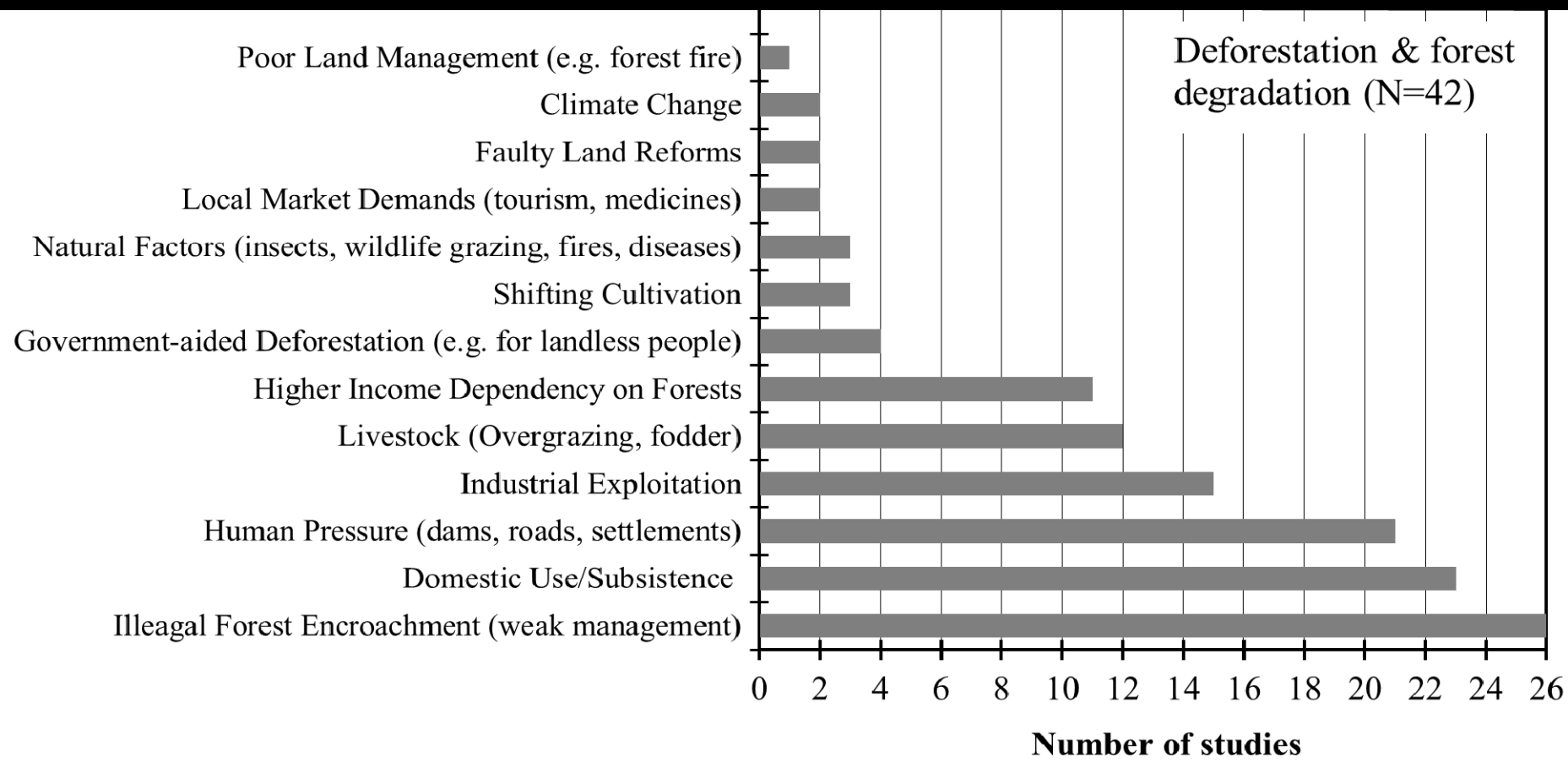




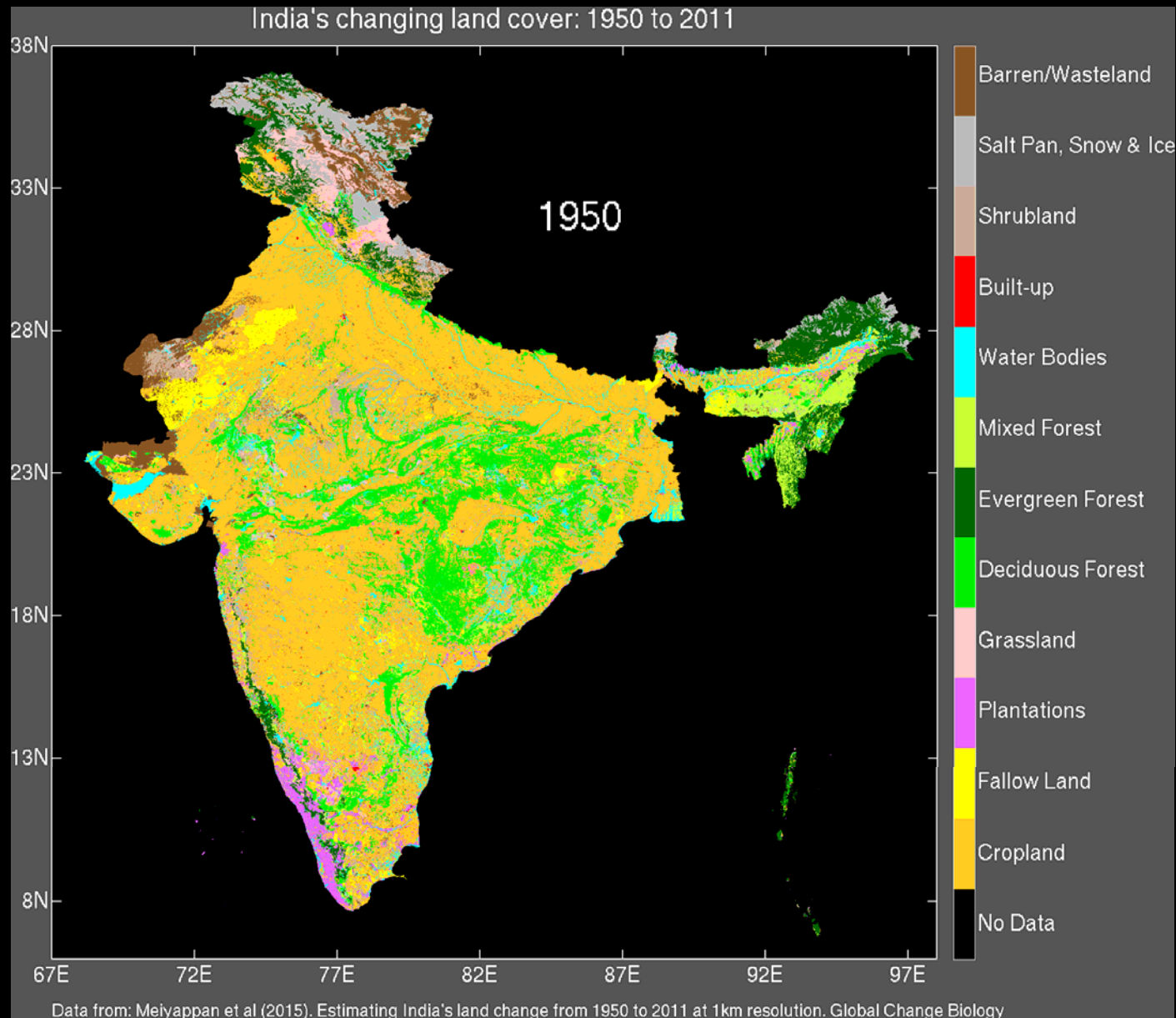
# Evaluation: Meta-synthesis of 102 case studies



# Evaluation: Case-study results (national aggregates)



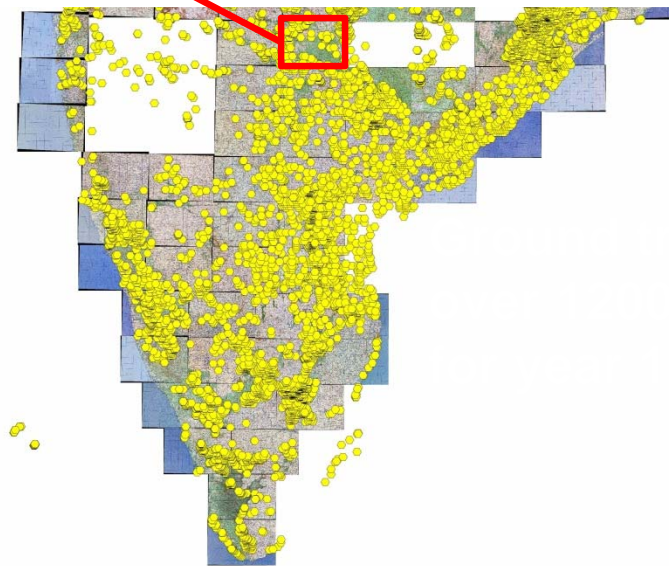
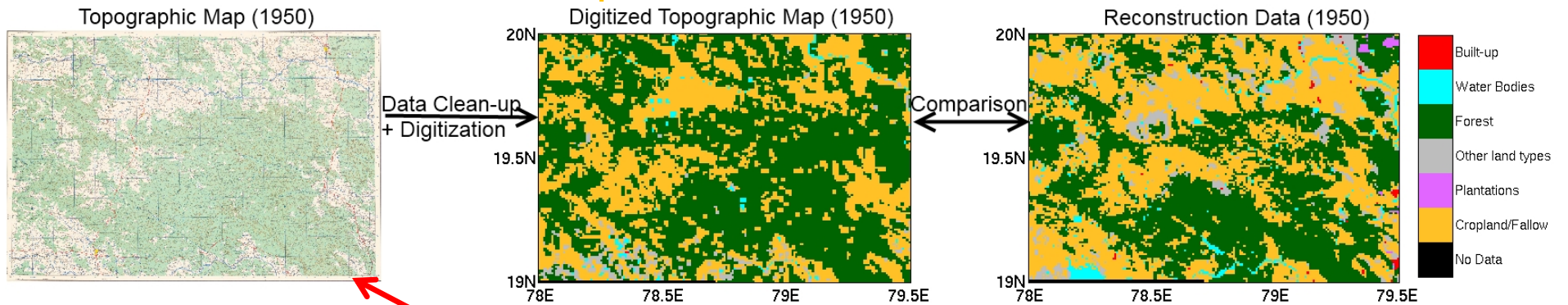
# Extended efforts: 1km reconstruction (1950-2011)



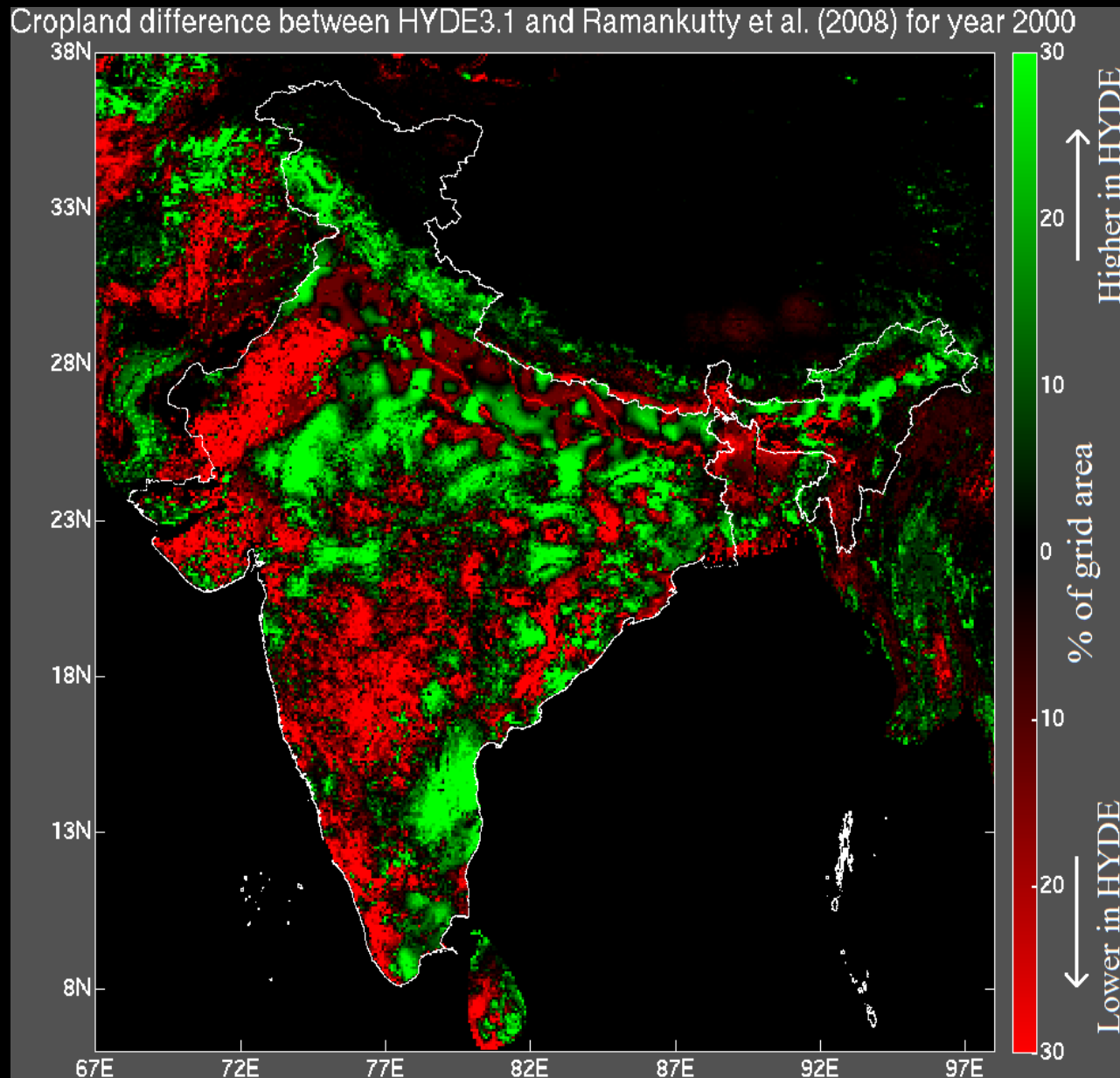
# Validation: How good are the reconstructed maps?



## Pattern validation: an example



# Prevailing uncertainties in LULCC over India





# References

Front. Earth Sci., 6(2): 122–139  
DOI 10.1007/s11707-012-0314-2

RESEARCH ARTICLE

## Three distinct global estimates of historical land-cover change and land-use conversions for over 200 years

Prasanth MEIYAPPAN, Atul K. JAIN (✉)

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*Remote Sens.* 2015, 7, 2401-2430; doi:10.3390/rs70302401

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*remote sensing*

ISSN 2072-4292

www.mdpi.com/journal/remotesensing

Article

### Development of Decadal (1985–1995–2005) Land Use and Land Cover Database for India

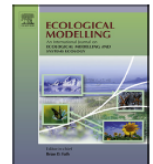
Ecological Modelling 291 (2014) 152–174

Full text lists available at ScienceDirect



Ecological Modelling

journal homepage: [www.elsevier.com/locate/ecolmodel](http://www.elsevier.com/locate/ecolmodel)



Spatial modeling of agricultural land use change at global scale

Prasanth Meiyappan<sup>a,\*</sup>, Michael Dalton<sup>b</sup>, Brian C. O'Neill<sup>c</sup>, Atul K. Jain<sup>a,\*\*</sup>



## Global Change Biology

*Global Change Biology* (2013) 19, 2893–2906, doi: 10.1111/gcb.12207

## CO<sub>2</sub> emissions from land-use change affected more by nitrogen cycle, than by the choice of land-cover data

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 AGU PUBLICATIONS



## Global Biogeochemical Cycles

RESEARCH ARTICLE

10.1002/2015GB005086

### Increased influence of nitrogen limitation on CO<sub>2</sub> emissions from future land use and land use change

Special Section:

Prasanth Meiyappan<sup>1</sup>, Atul K. Jain<sup>1</sup>, and Joanna I. House<sup>2</sup>

Spatial modeling of agricultural land use change at global scale

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# Data Product: Historical LULCC Reconstruction



**National Oceanic and Atmospheric Administration, Department of Commerce**

 Dataset

## Historical Land-Cover Change and Land-Use Conversions Global Dataset

 Updated: Feb 02, 2015

A set of three estimates of land-cover types and annual transformations of land use are provided on a global 0.5 x 0.5 degree lat/lon grid at annual time steps. The longest of the three estimates spans 1770-2010. The dataset presented here takes into account land-cover change due to four major land-use/management activities: (1) cropland expansion and abandonment, (2) pastureland expansion and abandonment, (3) urbanization, and (4) secondary forest regrowth due to wood harvest. Due to uncertainties associated with estimating historical agricultural (crops and pastures) land use, the study uses three widely accepted global reconstruction of cropland and pastureland in combination with common wood harvest and urban land data set to provide three distinct estimates of historical land-cover change and underlying land-use

# Data Product: Village level socioeconomic database for India

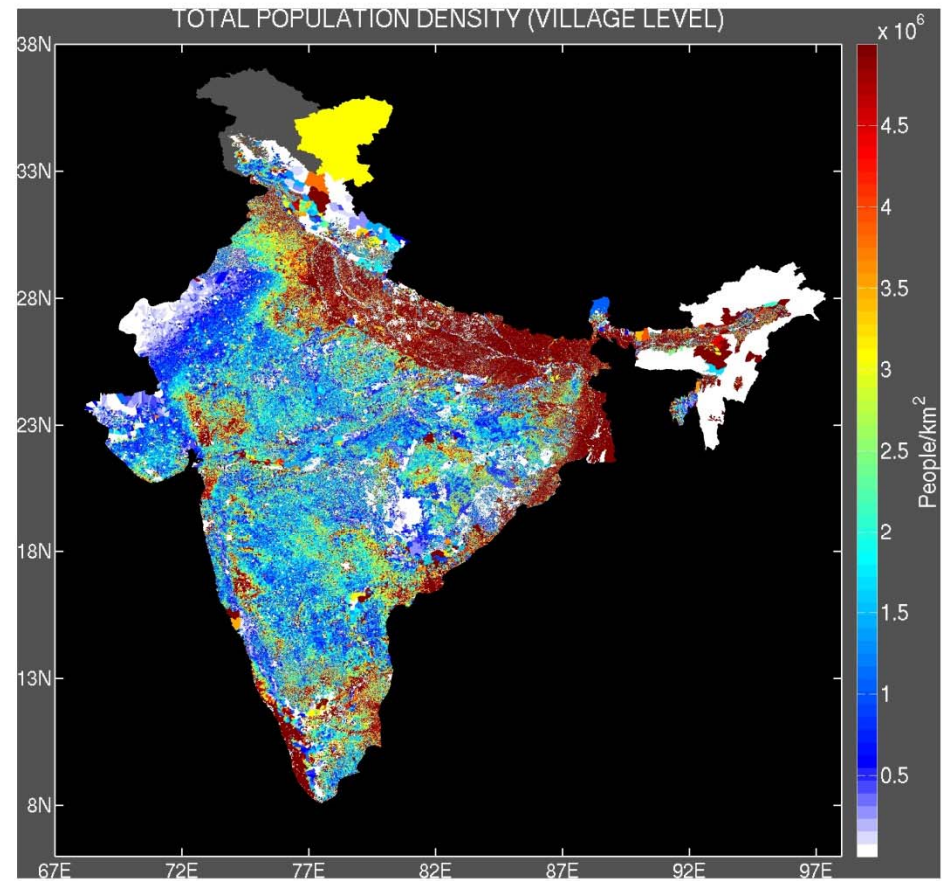
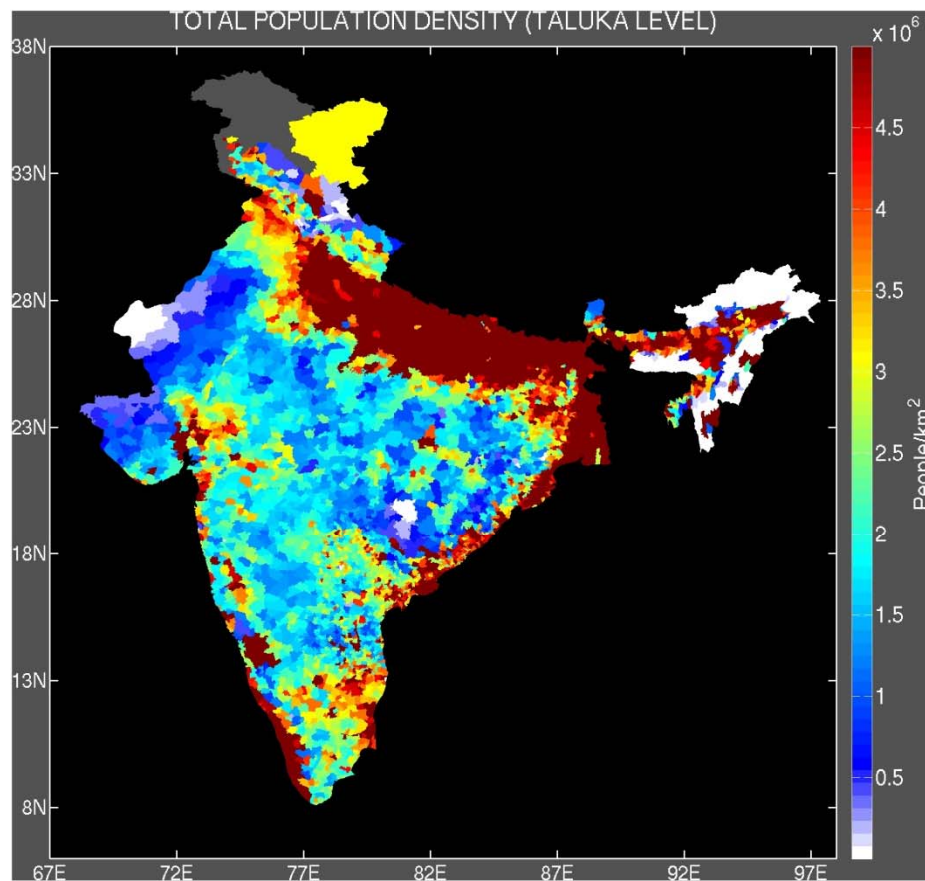


## SOCIOECONOMIC DATA AND APPLICATIONS CENTER (SEDAC)

A Data Center in NASA's Earth Observing System Data and Information System (EOSDIS) — Hosted by CIRES at Columbia University

Illustrating the new data product with population density as example (notice the high granularity captured in the new data)

Data currently available  $\xrightarrow{>100x \text{ improvement in resolution}}$  My new data product



# Key collaborators

Yeshu Sharma



Prasanth Meiyappan



Parth Roy



Jing Gao



Pawan Joshi

**Acknowledgement:** NASA LCLUC Program

Thank You

## LCLUC Dynamics and Causes - Overall Challenges

- Spatiotemporal dynamics and causes of LCLUC over larger regions of India are limited
- It is hard to generalize and quantify the causes of LCLUC by studying small regions (e.g., few villages)
  - Note that India has 630,000 villages with diverse agro-ecological and socio-cultural environment.

*All these constraints are hindering effective national level planning and policy-making.*