Landscapes in flux: the influence of demographic change and institutional mechanisms on land cover change, climate adaptability and food security in rural India

Aditya Singh, Sarika Mittra, Phil Townsend, Jacob van Etten
Sidhanand Kukrety, Shrawan Acharya

Bioversity International

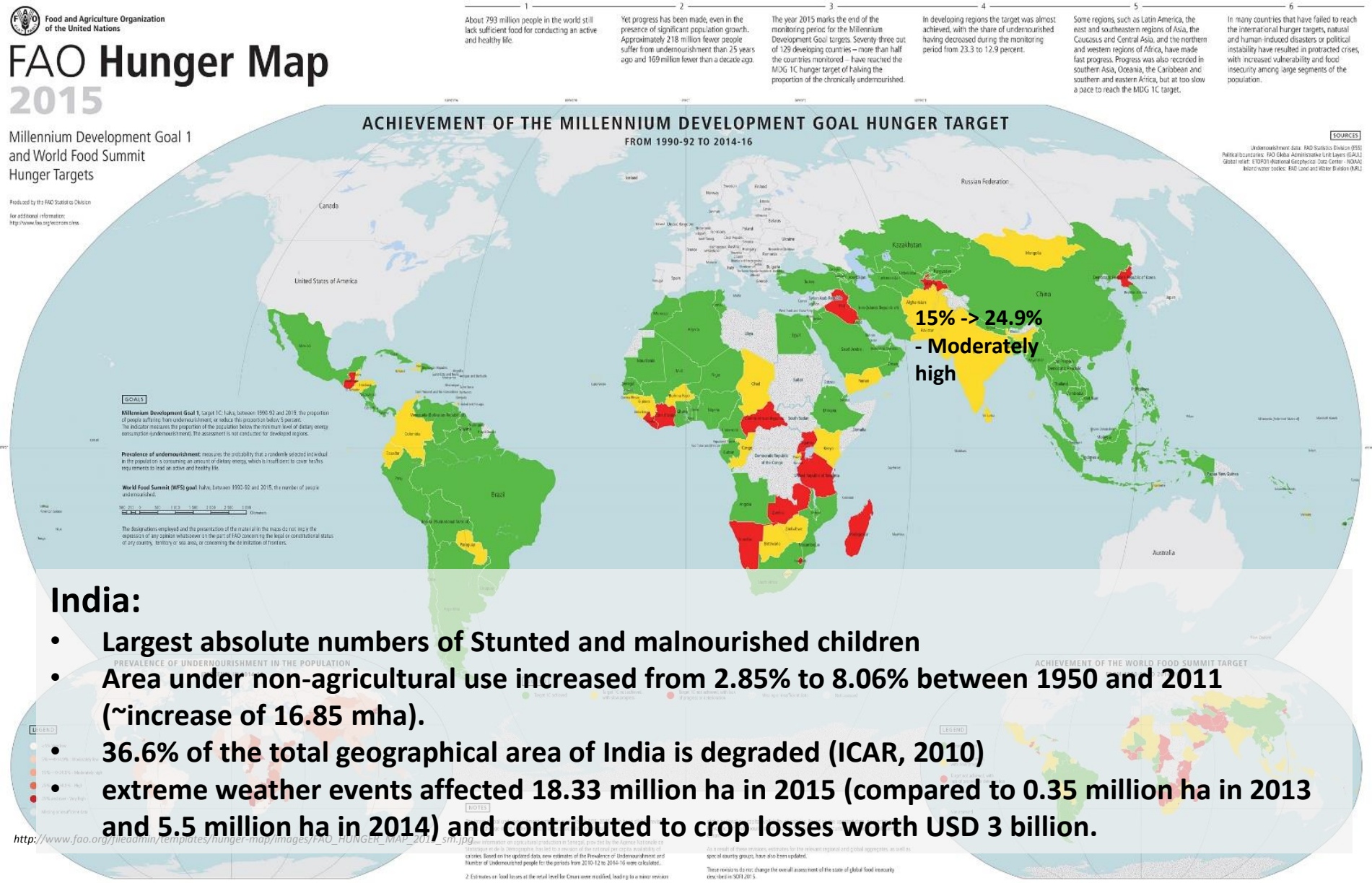
UF IFAS UNIVERSITY of FLORIDA

NASA

WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

The Ecosystem Dynamics Laboratory
University of Florida, Gainesville

Motivation



India:

- **Largest absolute numbers of Stunted and malnourished children**
- **Area under non-agricultural use increased from 2.85% to 8.06% between 1950 and 2011 (~increase of 16.85 mha).**
- **36.6% of the total geographical area of India is degraded (ICAR, 2010)**
- **extreme weather events affected 18.33 million ha in 2015 (compared to 0.35 million ha in 2013 and 5.5 million ha in 2014) and contributed to crop losses worth USD 3 billion.**

http://www.fao.org/fileadmin/templates/hunger-map/images/FAO_HUNGER_MAP_2015_sm.jpg

Motivation

Investigating regional variations in key indicators of food security as proximal causes of land use/land cover change

Recognizing that:

- Food security is a manifestation of several extant factors rather than a small set of indicators,
- Land use/cover change is a multidimensional concept (…yet a ‘zero-sum’ game.)

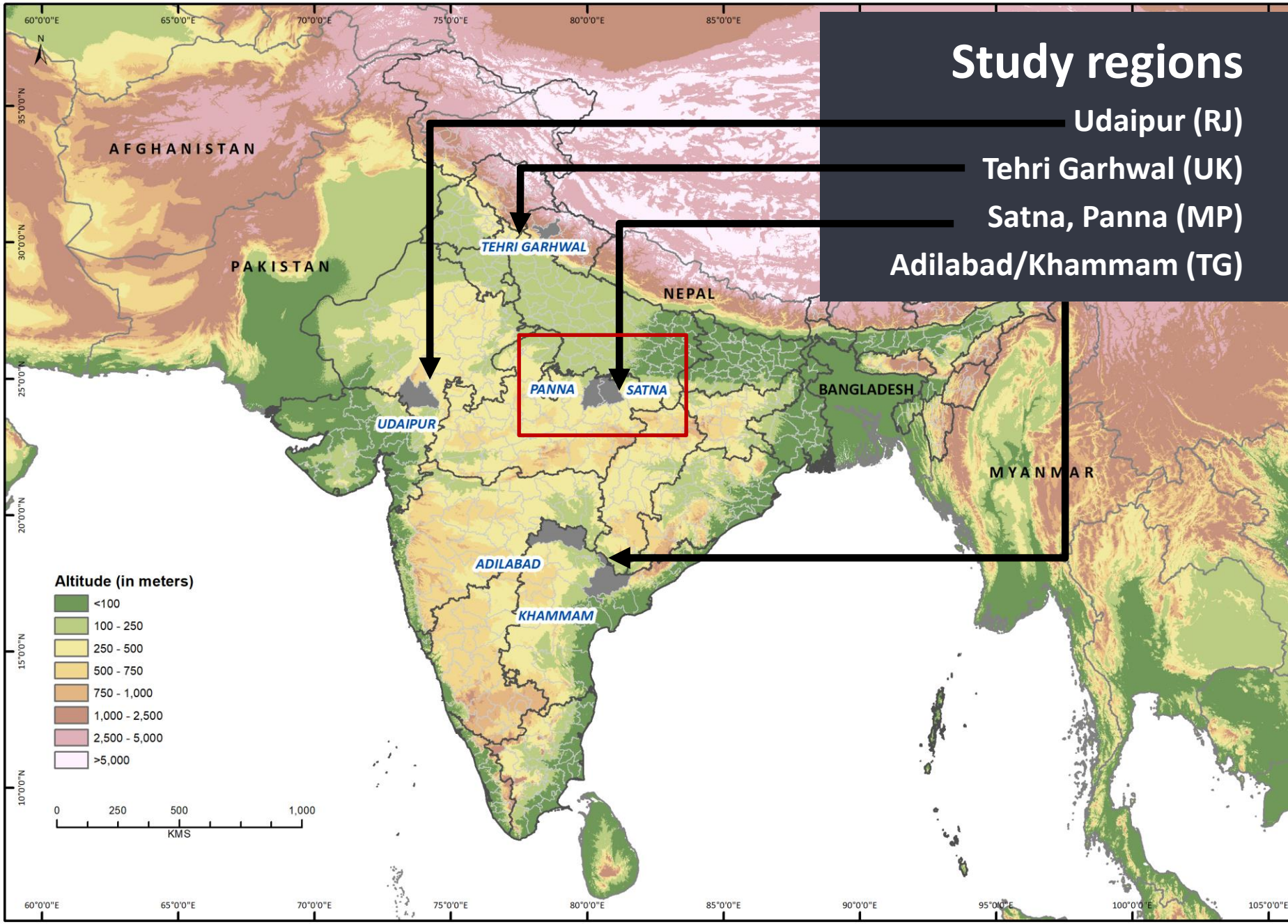
Proposed activities

01
Downscaling socioeconomic data to the unit level using small area estimation methods

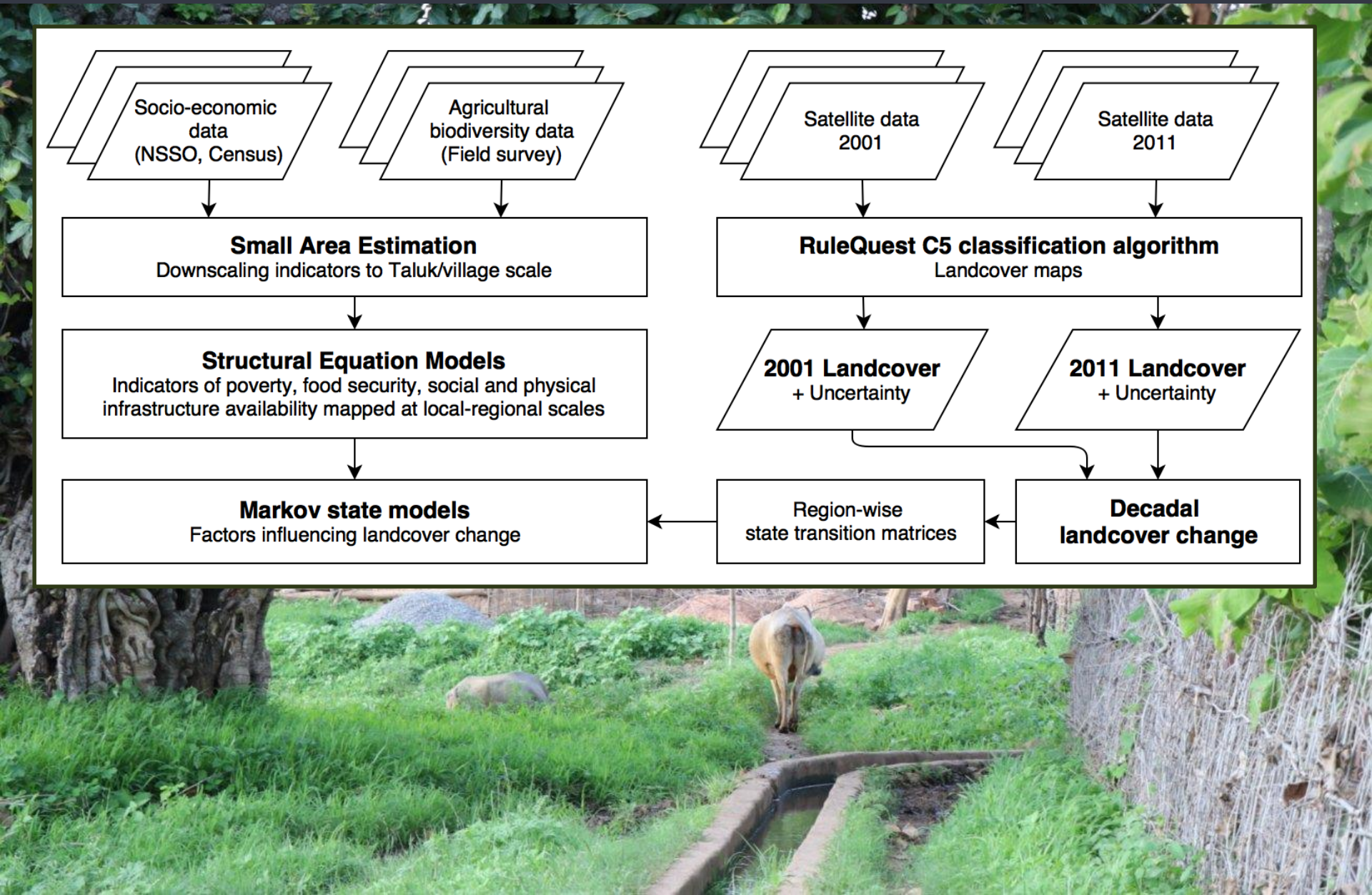
02
Combining downscaled socio-economic data to produce localized indicators of food security using a structural equation modeling approach

03
Mapping land cover and assessing land cover change at the local (village or taluk) scale across one decade

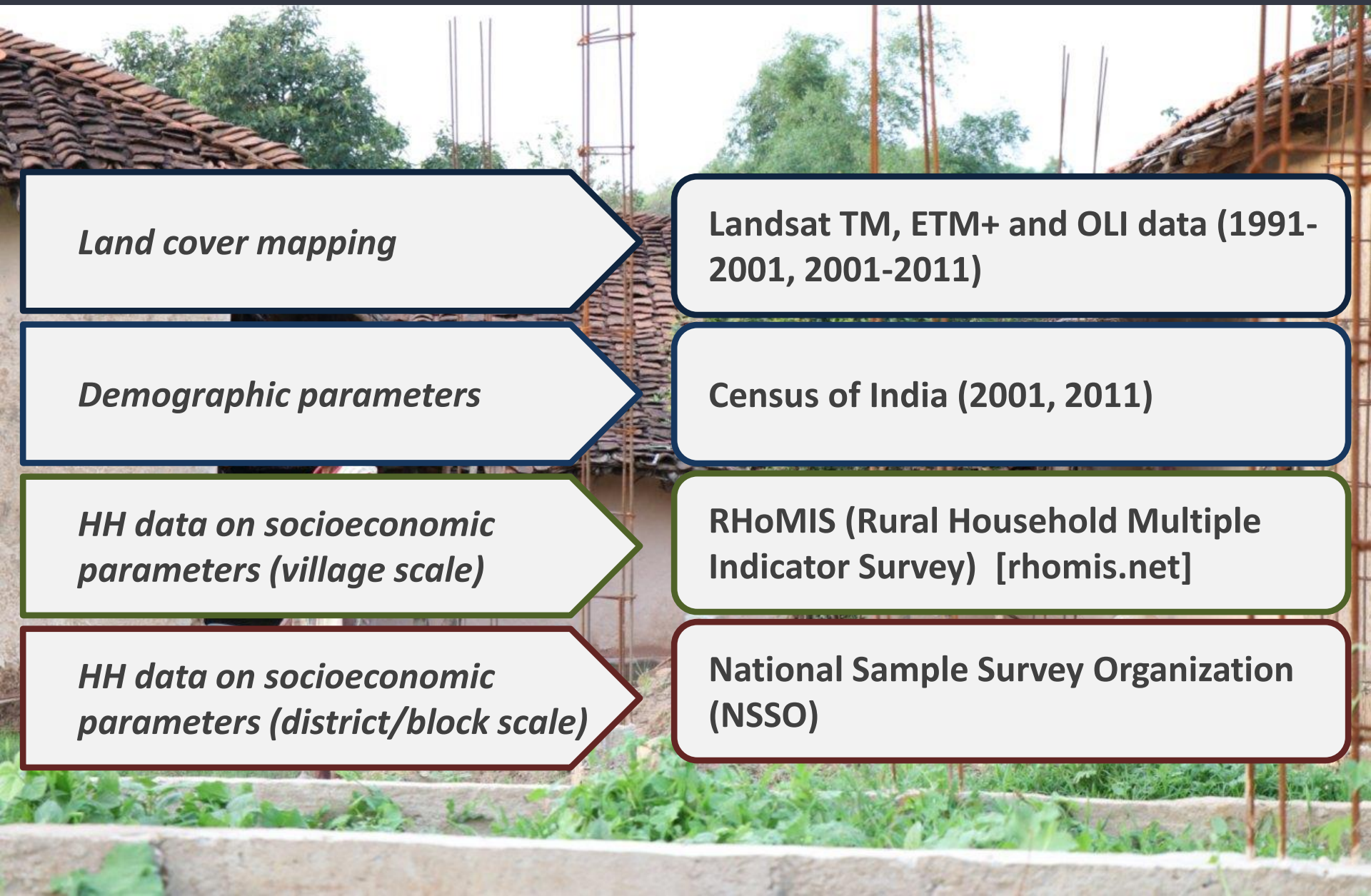
04
Assessing localized drivers of land cover change as functions of food security and extant socio-economic indicators in a probabilistic framework


Study regions
Udaipur (RJ)
Tehri Garhwal (UK)
Satna, Panna (MP)
Adilabad/Khammam (TG)
AFGHANISTAN
PAKISTAN
NEPAL
BANGLADESH
MYANMAR
TEHRI GARHWAL
PANNA
SATNA
UDAIPUR
ADILABAD
KHAMMAM
Altitude (in meters)
<100
100 - 250
250 - 500
500 - 750
750 - 1,000
1,000 - 2,500
2,500 - 5,000
>5,000
0 250 500 1,000
KMS

Proposed activities: Methods

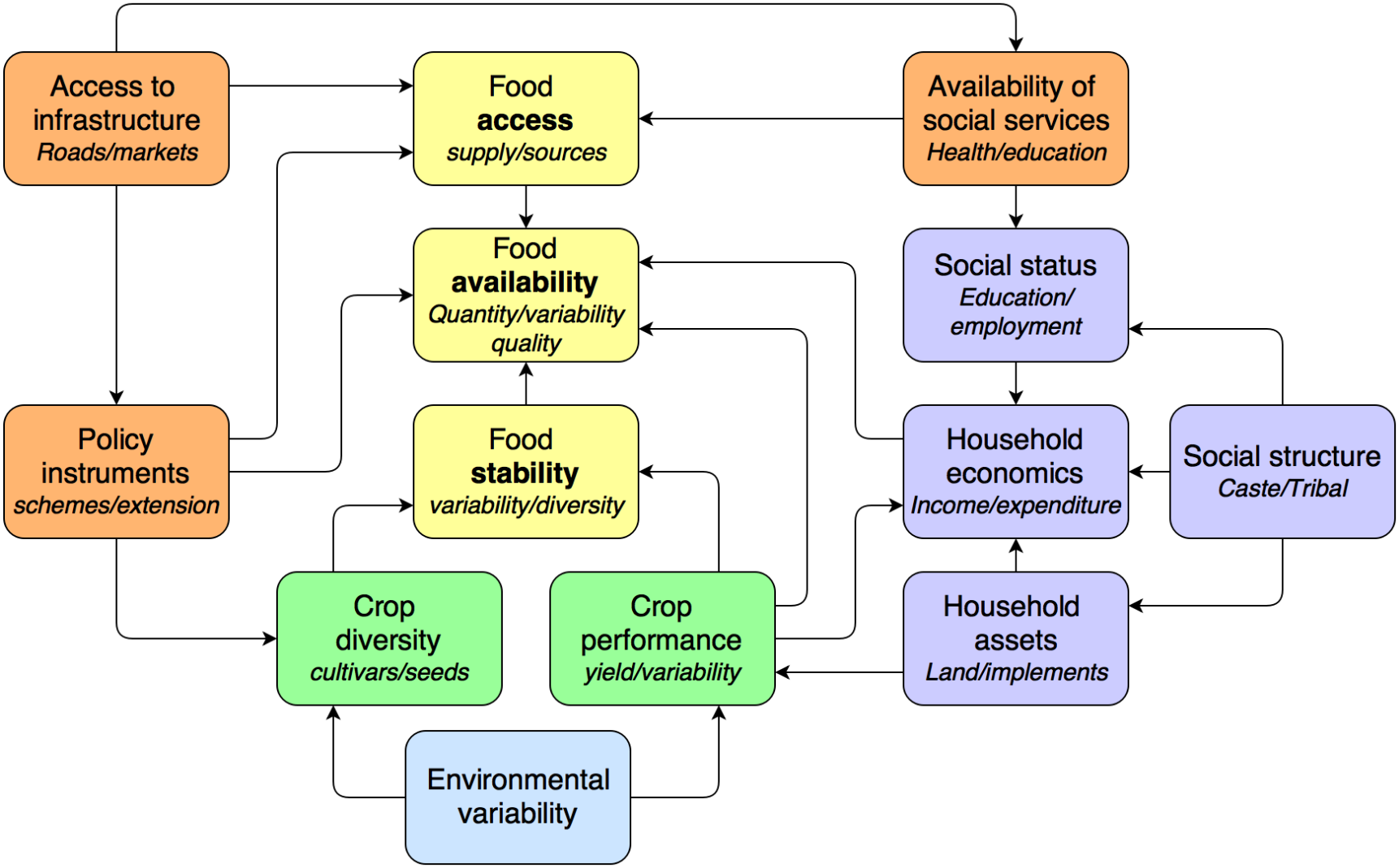


Data sources

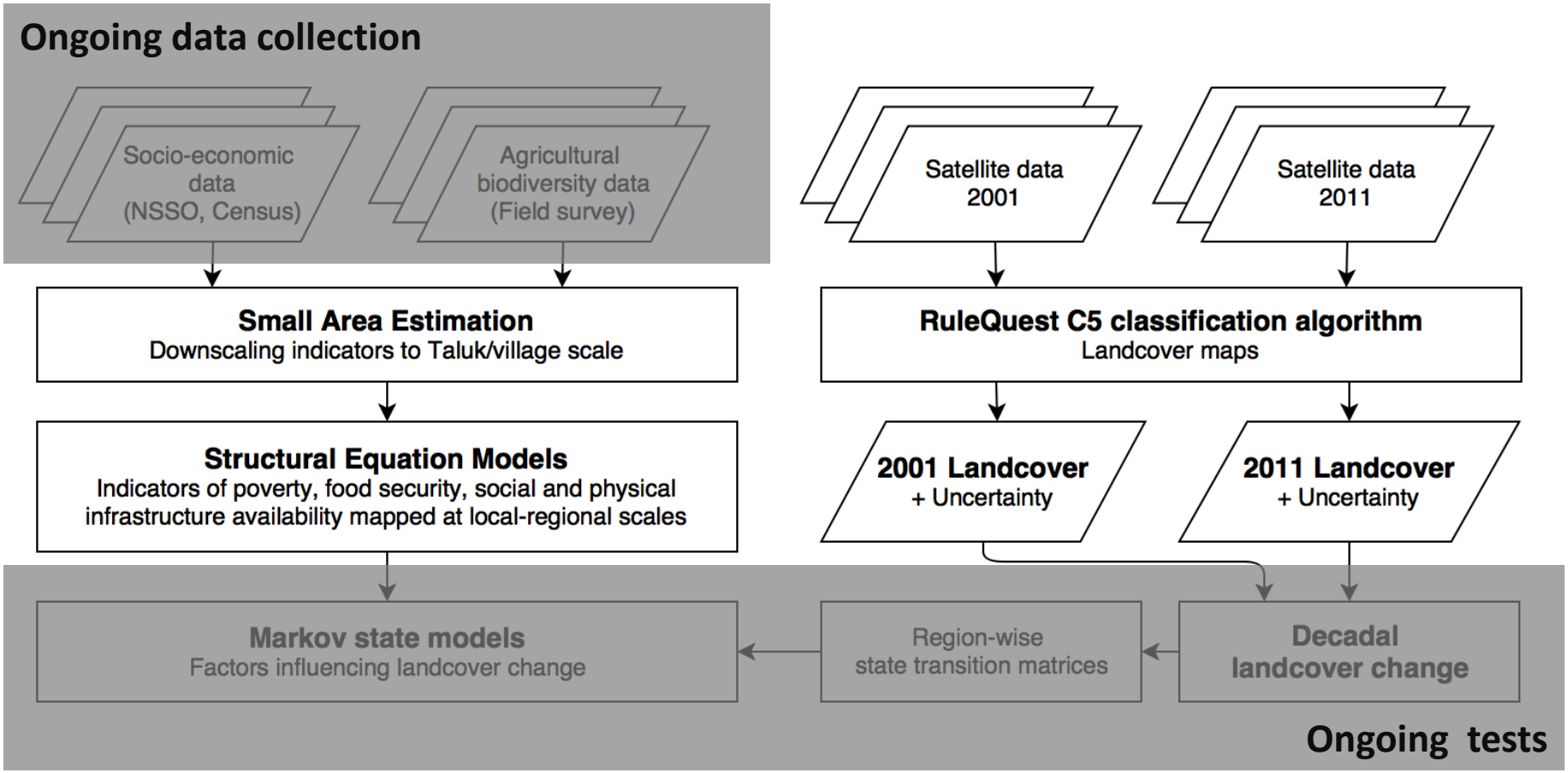


Land cover mapping	Landsat TM, ETM+ and OLI data (1991-2001, 2001-2011)
Demographic parameters	Census of India (2001, 2011)
HH data on socioeconomic parameters (village scale)	RHoMIS (Rural Household Multiple Indicator Survey) [rhomis.net]
HH data on socioeconomic parameters (district/block scale)	National Sample Survey Organization (NSSO)

Overall idea

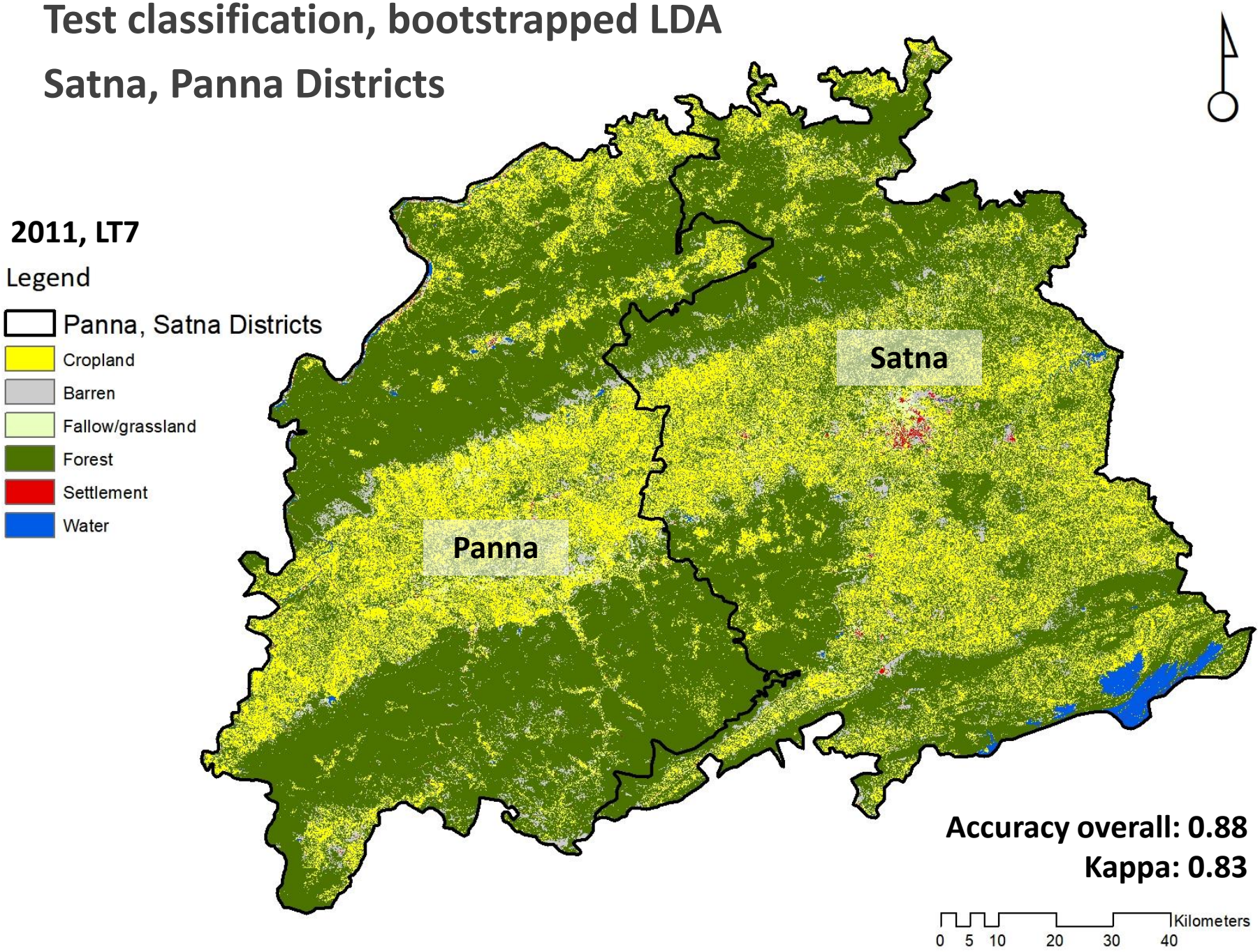


Proposed activities: Methods

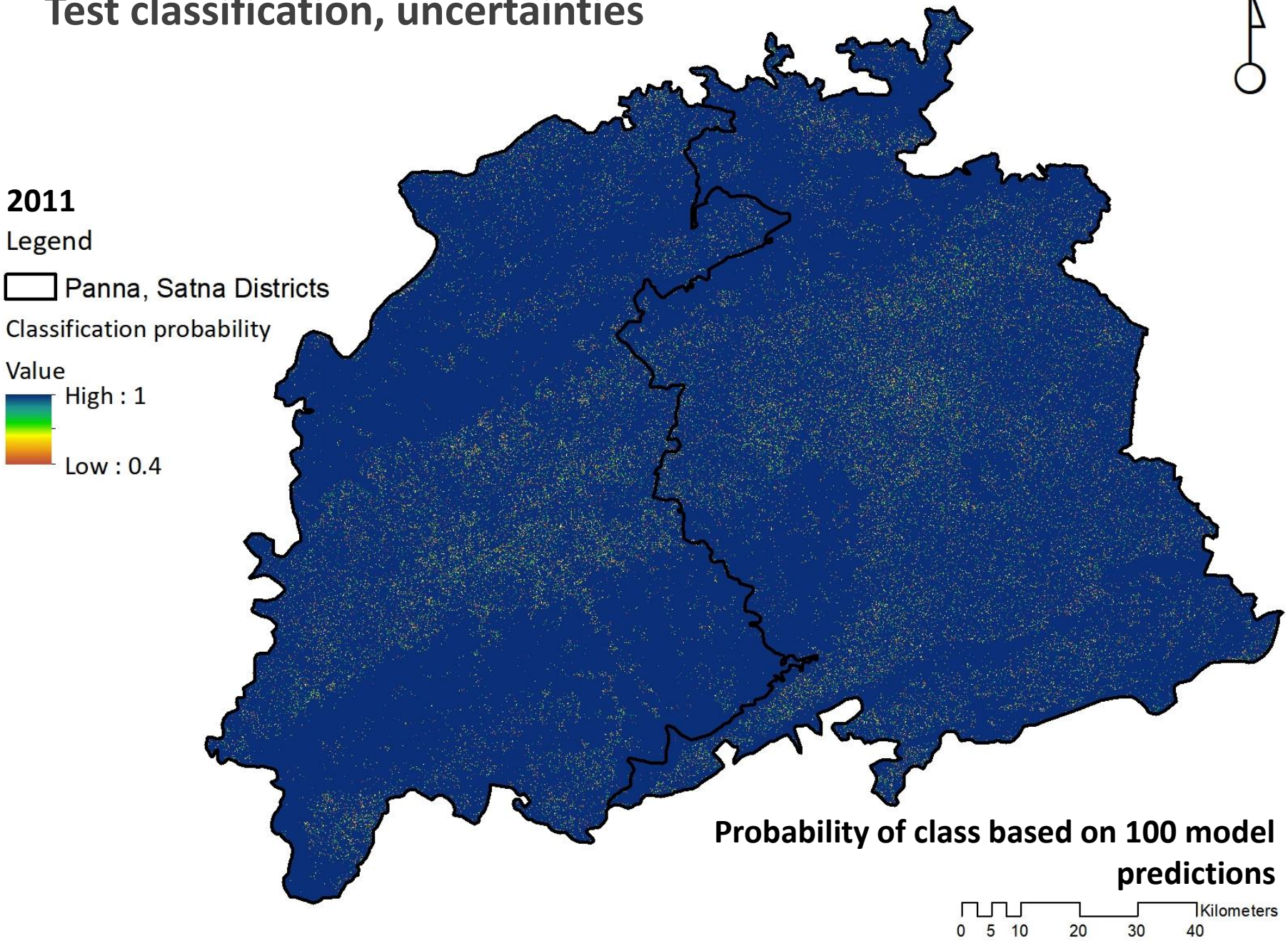


Test classification, bootstrapped LDA

Satna, Panna Districts



Test classification, uncertainties



Modeling land cover transitions

How to:

1. Model attribution of the process of land cover changes, potentially via multiple factors/covariates,
2. Recognize that land cover transitions are essentially bounded (the ‘zero-sum’ idea),

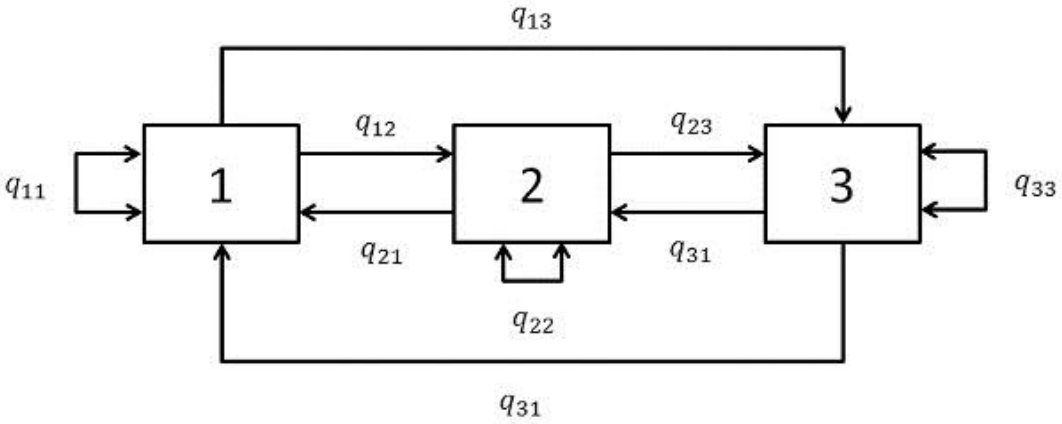
Latent Markov models for longitudinal data

1. Estimate transition probabilities using land cover maps from two time periods,
2. Condition transition probabilities on covariates from existing census data,
3. Eventually, covariates will be latent vectors obtained from SEM.

Modeling land cover transitions

Assumptions

1. All pixels comprise of a population that can be at several different states in a given time period.
2. Pixel '*i*' move from state '*r*' to the state '*s*' at time *'t'* with a probability 'q_{irs}',
3. The probability of moving from state *'r'* to state *'s'* can be modeled as a function of covariates *'x_i'*,
4. …by maximizing:



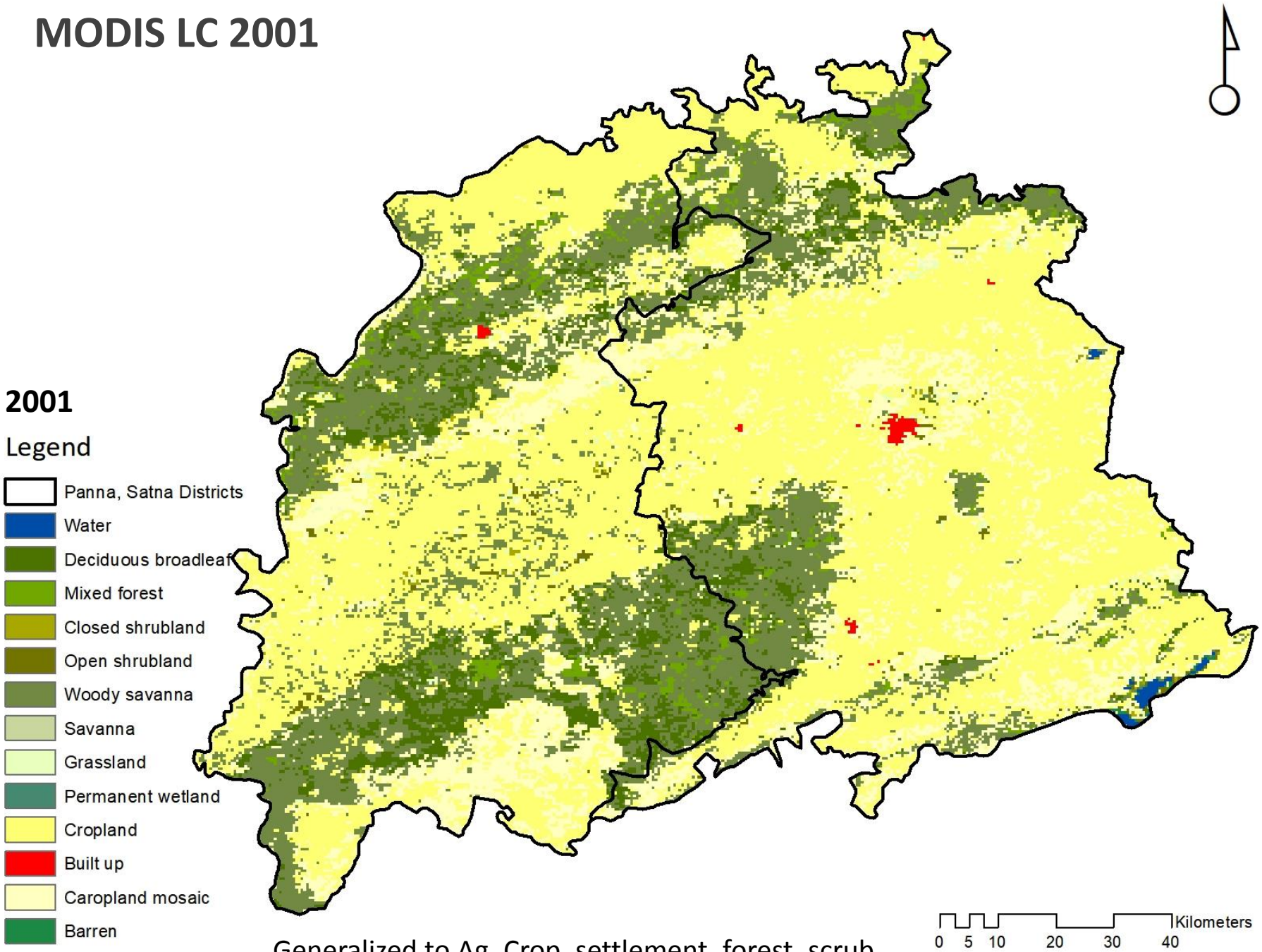
$$Q = \begin{pmatrix} q_{11} & q_{12} & q_{13} \\ q_{21} & q_{22} & q_{23} \\ q_{31} & q_{32} & q_{33} \end{pmatrix}$$

$$q_{irs}(t) = \lim_{\Delta t \to 0} \frac{P(E_i(t+\Delta t) = s | E_i(t) = r)}{\Delta t}$$

$$q_{irs}(x_i(t)) = q_{rs}^{(0)} \exp(\beta_{rs}^T x_i(t))$$

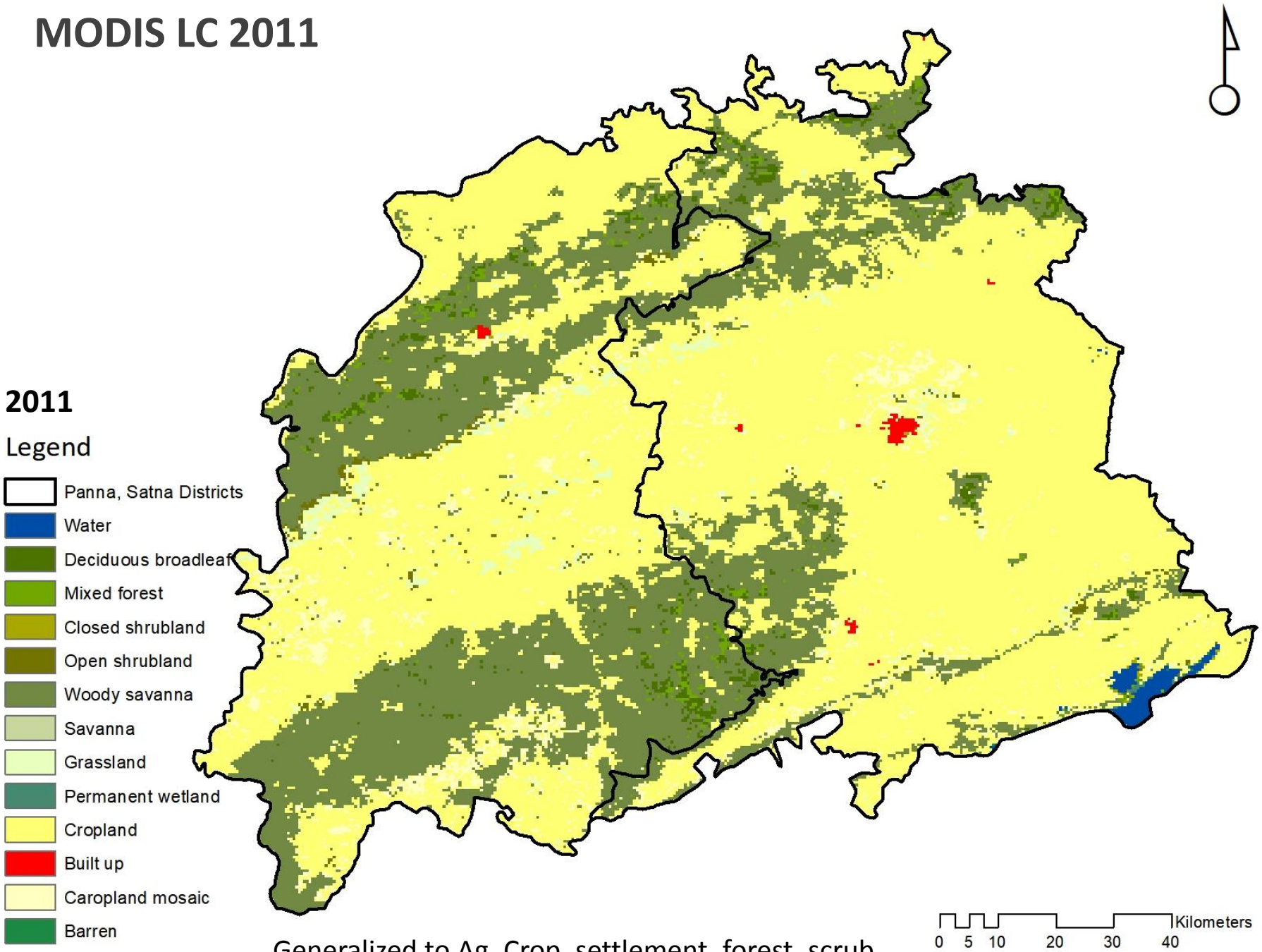
$$L = \prod_{i=1}^{n} \prod_{k=1}^{\tau-1} p_{E_i(t_k) E_i(t_{k+1})}$$

MODIS LC 2001



Generalized to Ag, Crop, settlement, forest, scrub

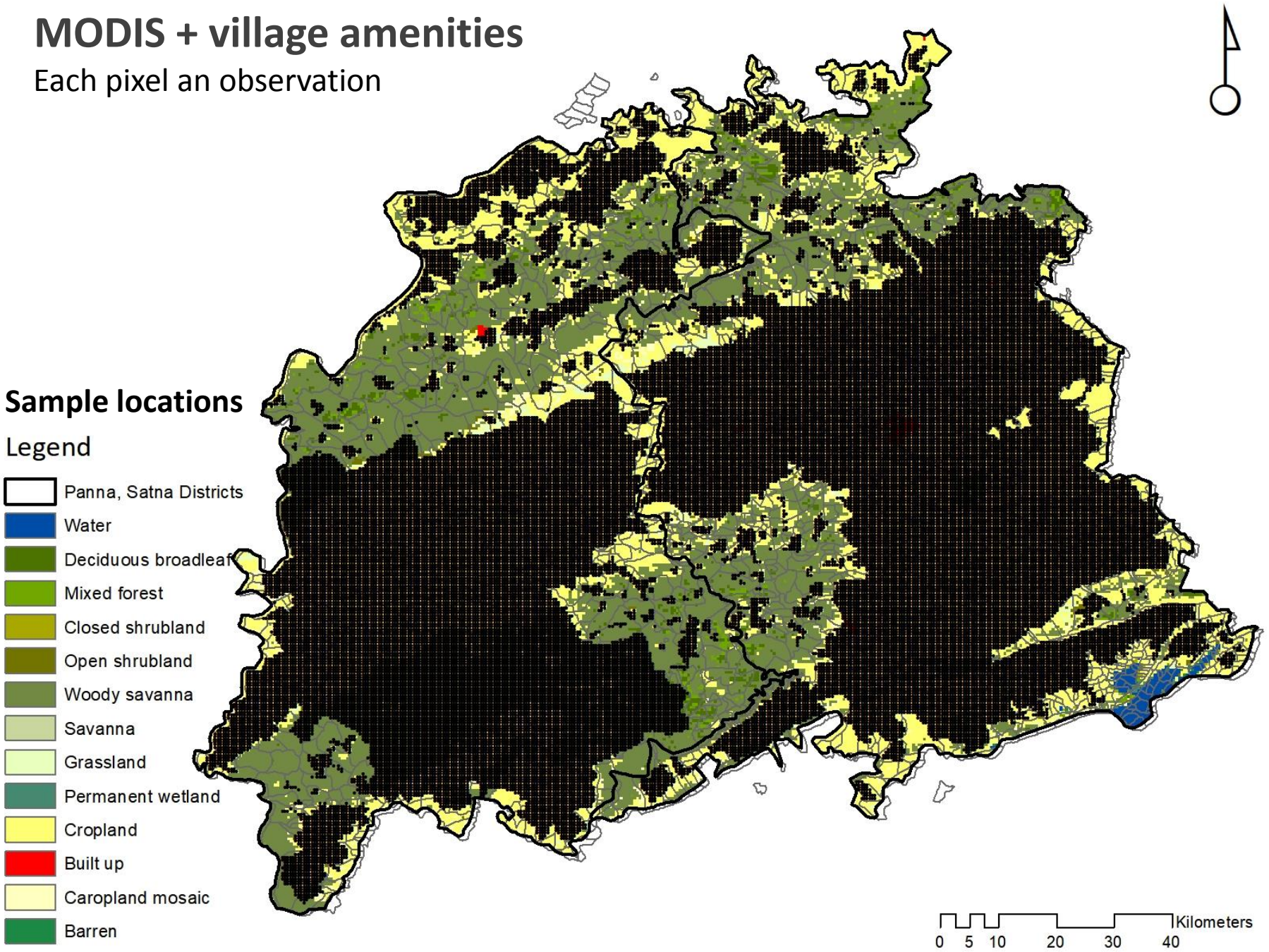
MODIS LC 2011



Generalized to Ag, Crop, settlement, forest, scrub

MODIS + village amenities

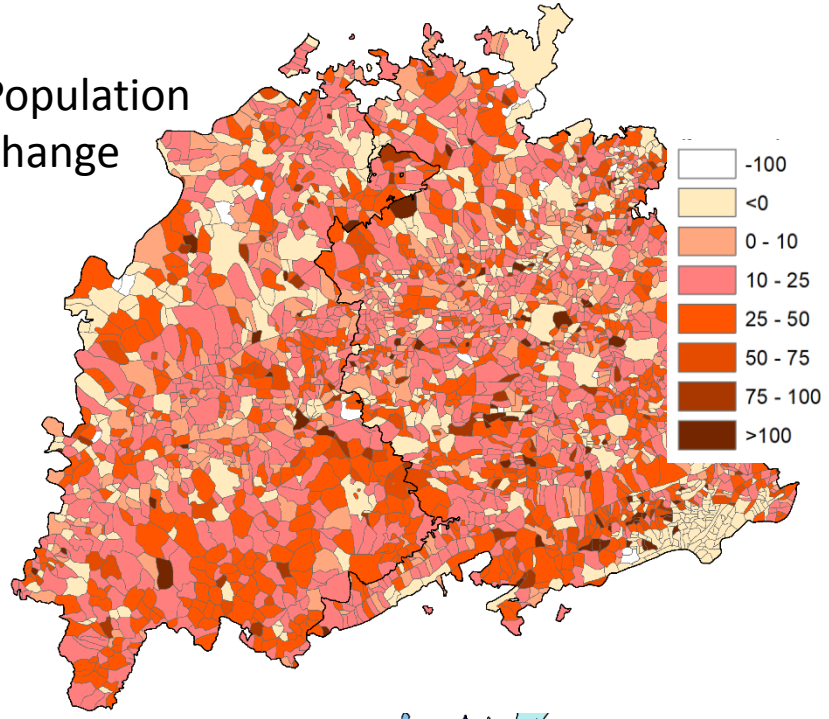
Each pixel an observation



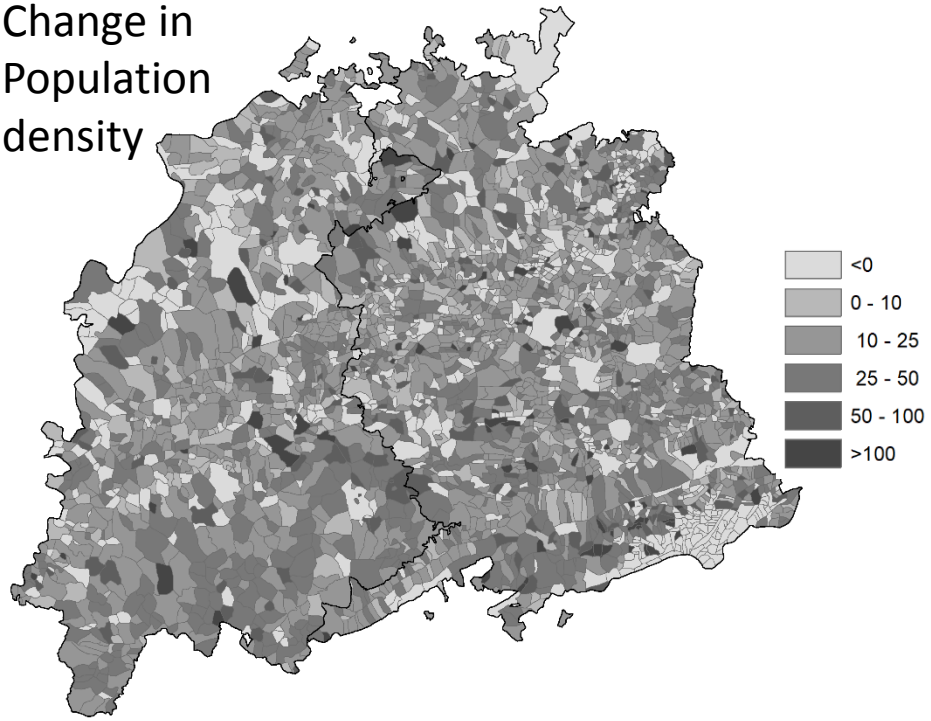
Covariates

- Simple indicators of population growth
- Change in density,
- Change in irrigated land,
- …

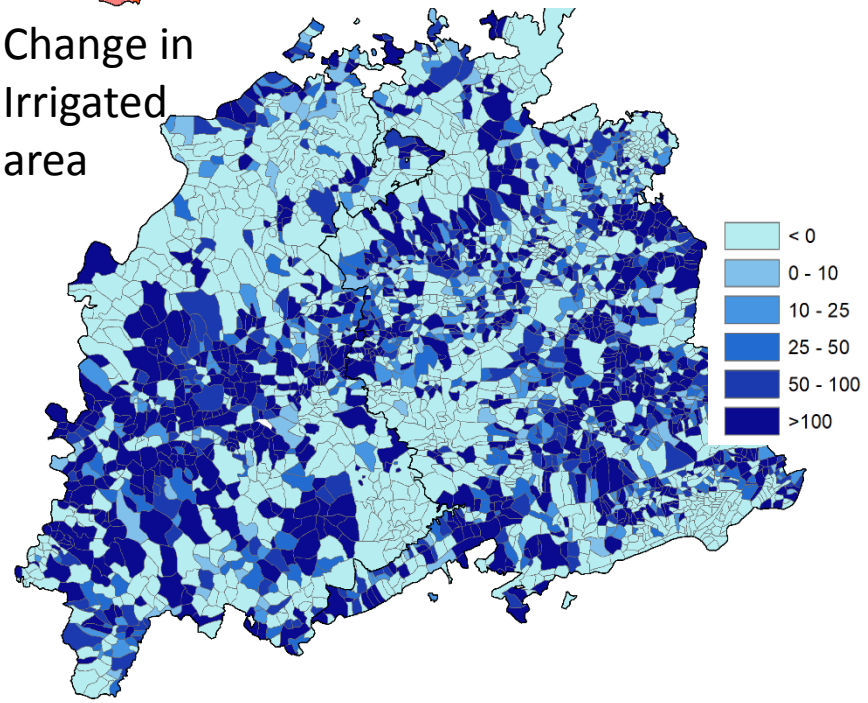
Population change



Change in Population density



Change in Irrigated area



Results

Estimated transition probabilities:

2001/2011	Forest	Shrub	Grassland	Cropland	Settlement
Forest	0.002	0.170	0.315	0.293	0.220
Shrub	0.000	0.392	0.158	0.244	0.207
Grassland	0.002	0.056	0.810	0.074	0.059
Cropland	0.002	0.149	0.108	0.689	0.052
Settlement	0.002	0.193	0.133	0.080	0.592

Log-odds of covariates (trunc.):

Forests->	Shrub	Grassland	Cropland	Settlement
Intercept	0.850	1.547	1.292	0.903
Population	0.011	0.011	0.011	0.010
Irrigation intensity	0.107	0.098	0.090	0.087
Population density	0.474	0.649	0.931	1.041

Preliminary conclusions

Estimated transition probabilities:

1. Significant loss of forests inside revenue villages,
2. Likelihood of conversion of shrubland/marginal land to cropland,
3. Cropland does not seem to change much, except likely going fallow,

4. Should settlements be considered an absorbing state?
5. What are the effects of misclassifications?

Effects of covariates:

- Forests seem to be changing as a factor of increasing population density (not size)
- Change in irrigation intensity does not seem to be having a significant effect on land cover transitions.

- Availability of socio-economic indicators will likely boost inferences.

Thank you! Questions?

Team:
Aditya Singh, Sarika Mittra, Phil Townsend, Jacob van Etten, Sidhanand Kukrety, Shrawan Acharya

Local collaborators:
Satna/Panna: RS Negi
Tehri Garhwal: Avtar Negi
Udaipur: Rakesh Kumar
Adilabad/Khammam: Praveen Kumar

Logistics and management:
Anish Sadanandan

Bioversity International

UF IFAS UNIVERSITY of FLORIDA

NASA

WISCONSIN UNIVERSITY OF WISCONSIN–MADISON

The Ecosystem Dynamics Laboratory
University of Florida, Gainesville