Agricultural sensitivity to inter-annual climate variability

Implications for smallholder farmers in India

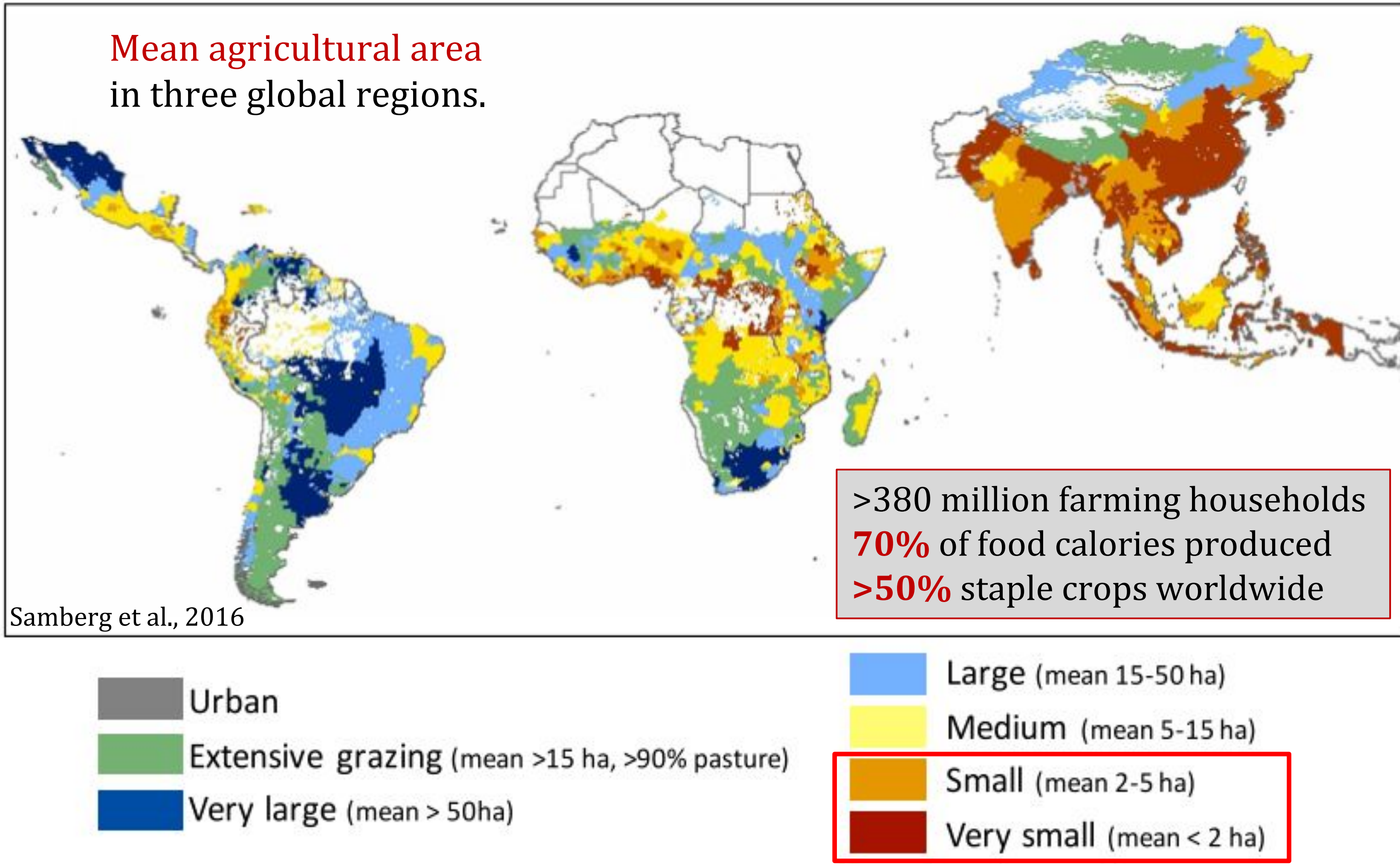
Pinki Mondal, University of Delaware

E-mail: mondalp@udel.edu Twitter: @environmondal

Who is a smallholder?

Photo: P. Mondal

Research Context



Samberg, Gerber, Ramankutty, Herrero & West, 2016. Subnational distribution of average farm size and smallholder contributions to global food production. *Environmental Research Letters* 11: 124010

Overall Research Focus

Smallholder Agricultural System

Spatial distribution of human-environmental interactions
(GIS and big data)

Weather variability

Socio-economic

Well-being (food & nutrition security)

Adaptation strategies

- Land Change Science (Land Use/Land Cover Change)
- Environmental/Societal Effects of Climate Change/Extreme Events
- Sustainability

Research Context

INDIA

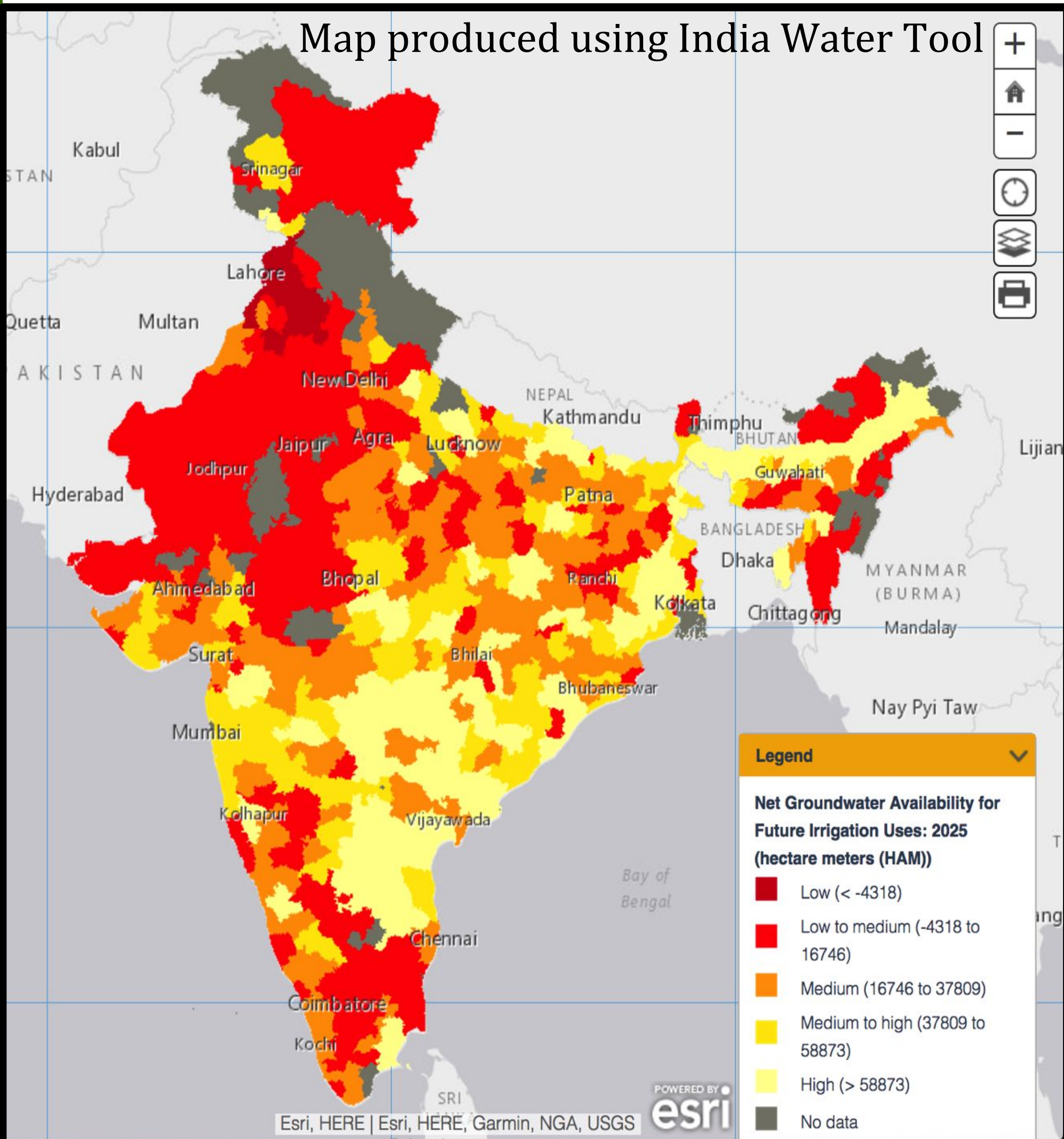

CNN: April, 2016

- **78%** of Indian farmers are smallholders
- 263 million (**10%** of global total) depend on agriculture
- **210 million** are hungry


H. Times: September, 2017

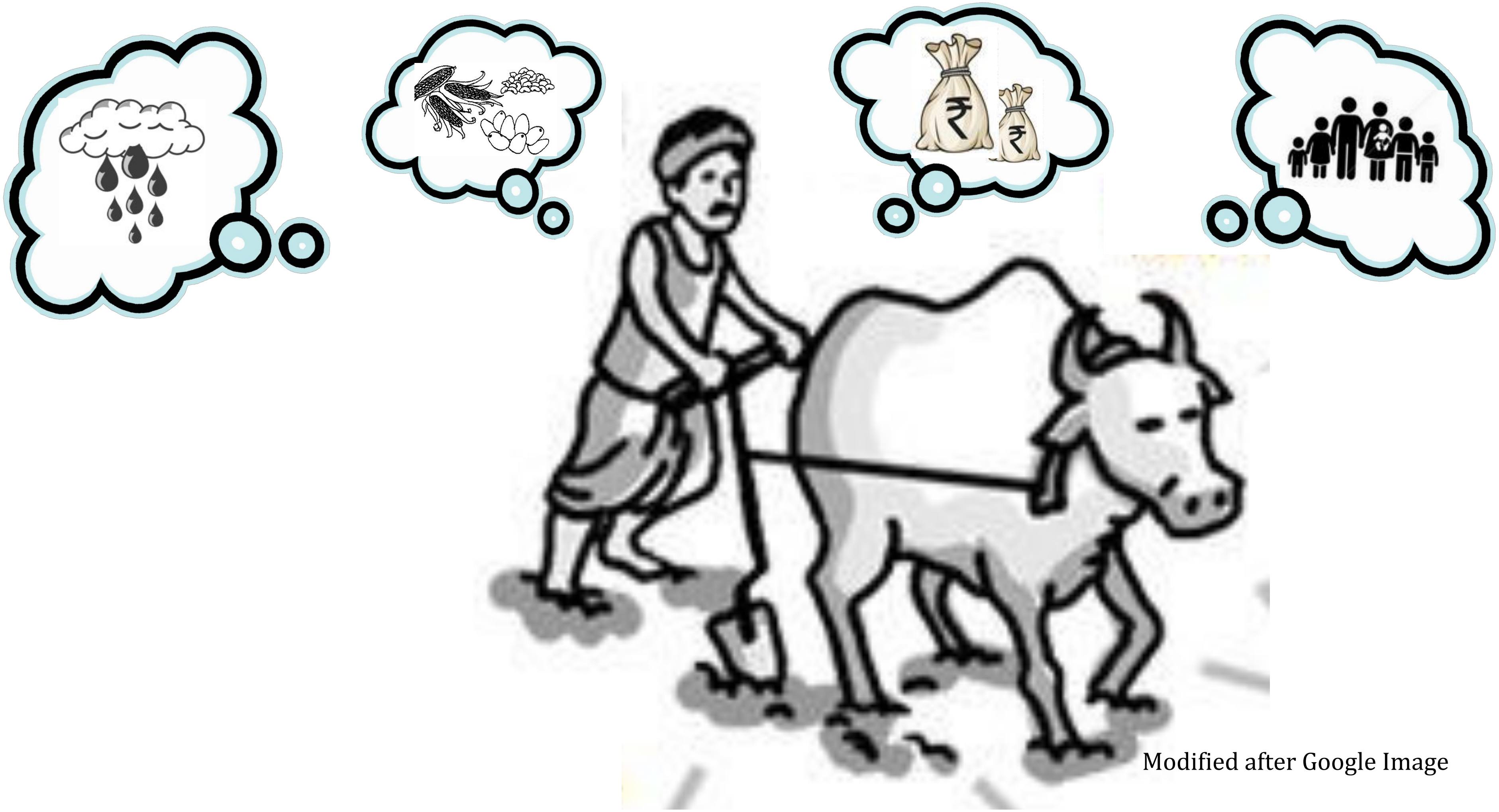

Photo: P. Mondal

Research Context



- **37%** of agricultural land is irrigated
- **60%** of irrigation is provided by groundwater
- **29%** less winter cropped area in regions with low groundwater availability

Jain, Fishman, **Mondal**, Galford, Bhattaarai, Naeem & DeFries. Groundwater Depletion Will Reduce Cropping Intensity in India. *Under review.*



Modified after Google Image

Rapidly changing weather patterns is one of the biggest challenges facing smallholder farmers

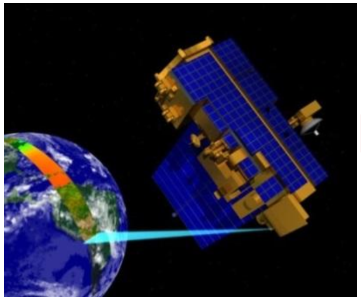
Questions

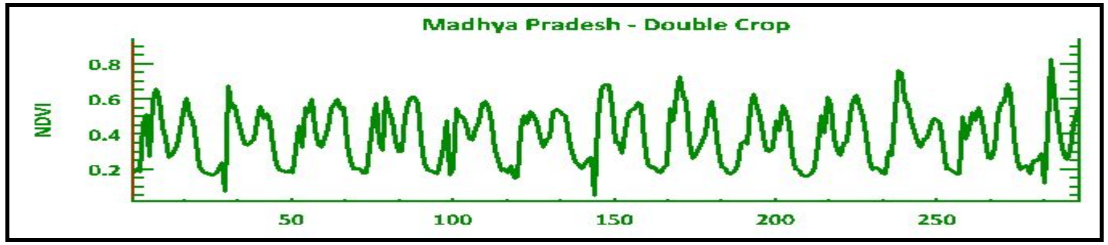
- How does weather variability affect smallholder agricultural systems?
- What are the potential adaptation strategies under future scenarios?
- Can these strategies secure food and nutrition security?



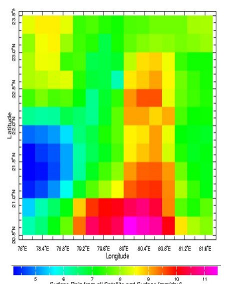
Photo courtesy: Google Image

Methods: ***PIXEL to PEOPLE***





Satellite-derived Crop Phenology



Climate Parameters

Crop Types

Irrigation

Demography

predictor, independent variable, 'x-variable'

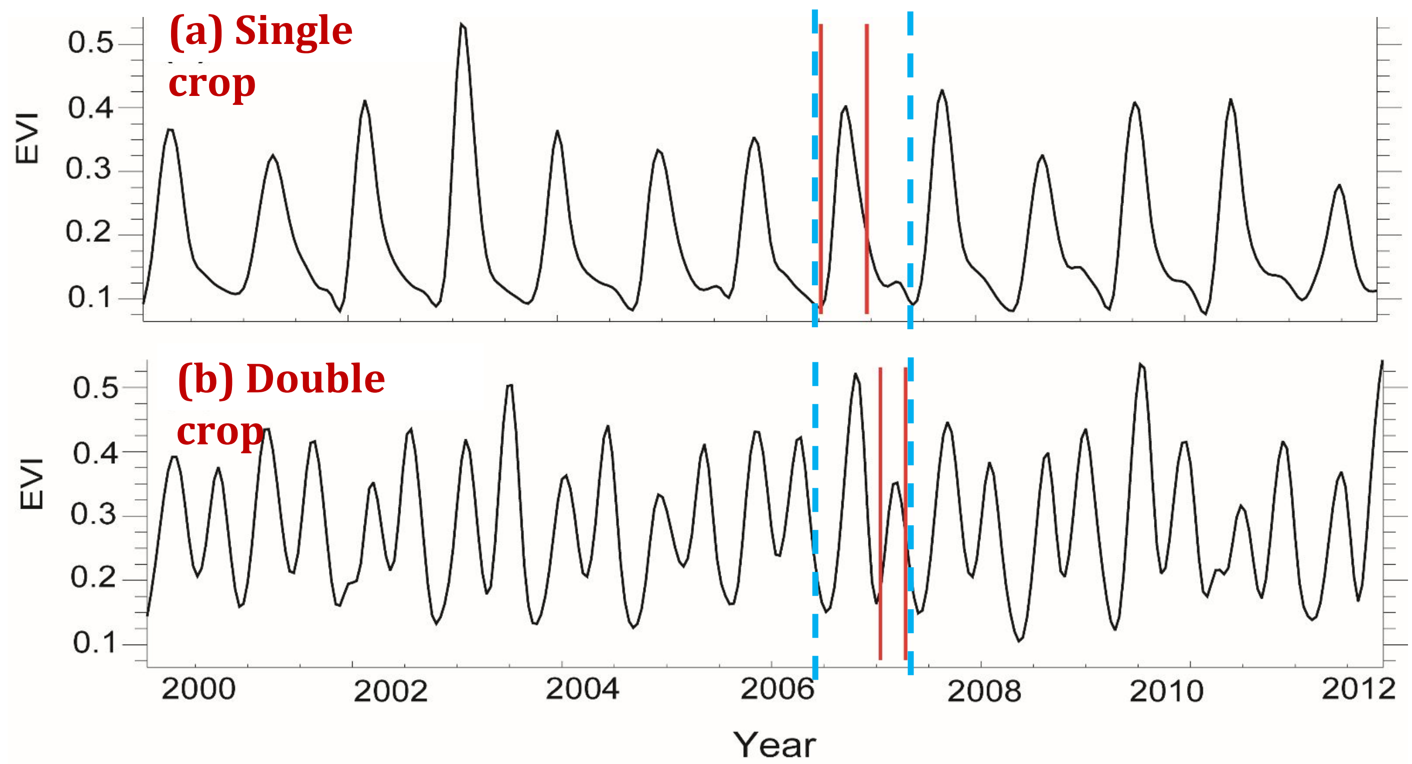
coefficient

$$Y = \underbrace{\beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_p x_p}_{\text{linear predictor}} + \varepsilon$$

response, dependent variable, observation, 'y-variable'

random error, "noise"

Methods: *Satellite data*



Enhanced Vegetation Index (EVI)

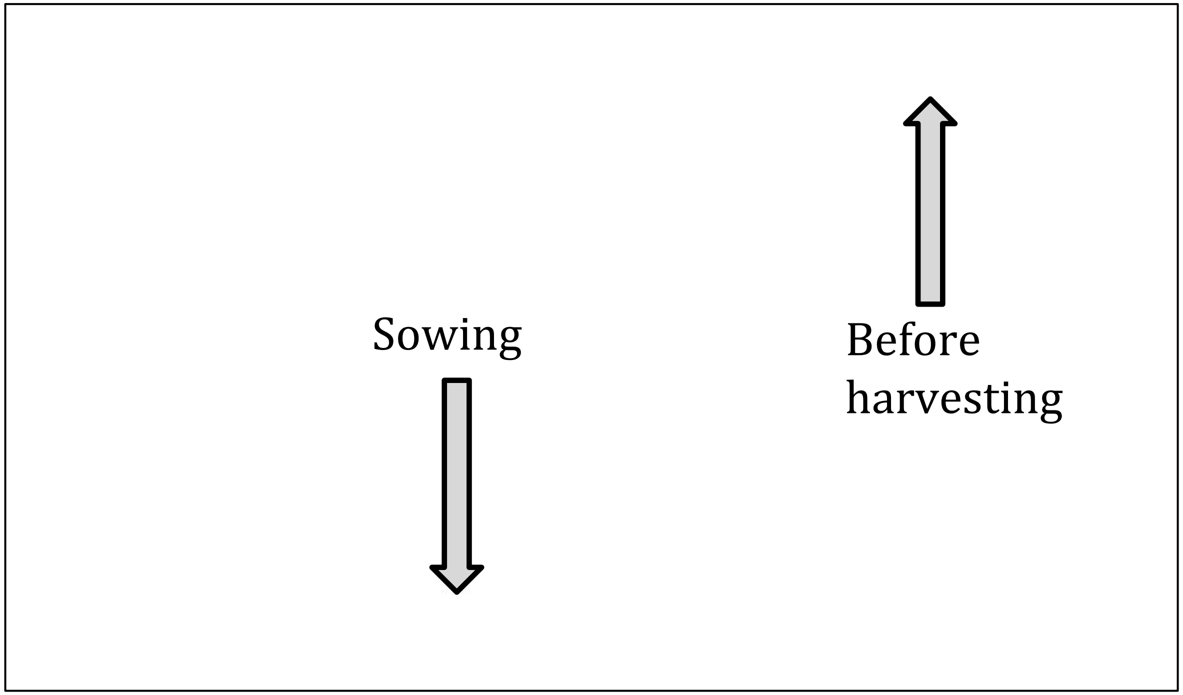
Source: MODIS

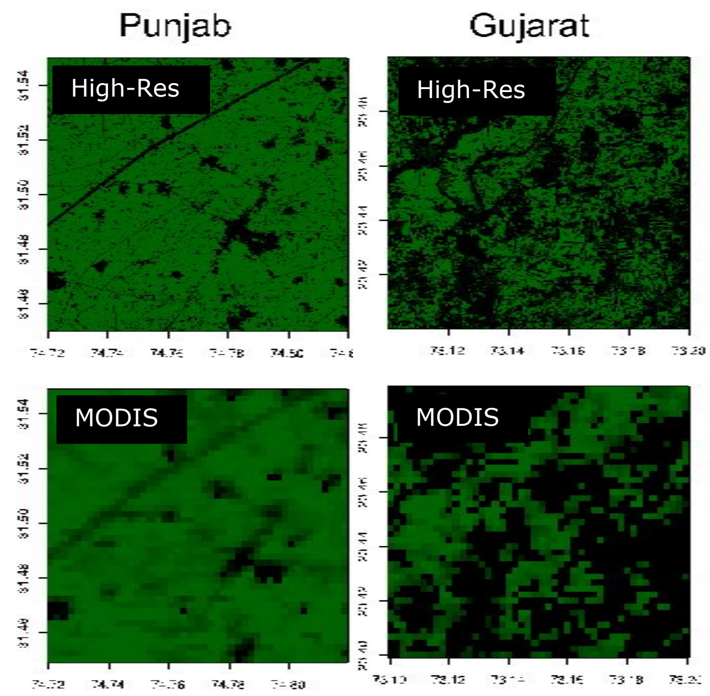
Spatial resolution: 250m

Temporal resolution: 16 days

Mondal, Jain, DeFries, Galford & Small, 2015. Sensitivity of crop cover to climate variability: Insights from two Indian agro-ecoregions. *Journal of Environmental Management* 148: 21-30

Methods: ***Satellite data***



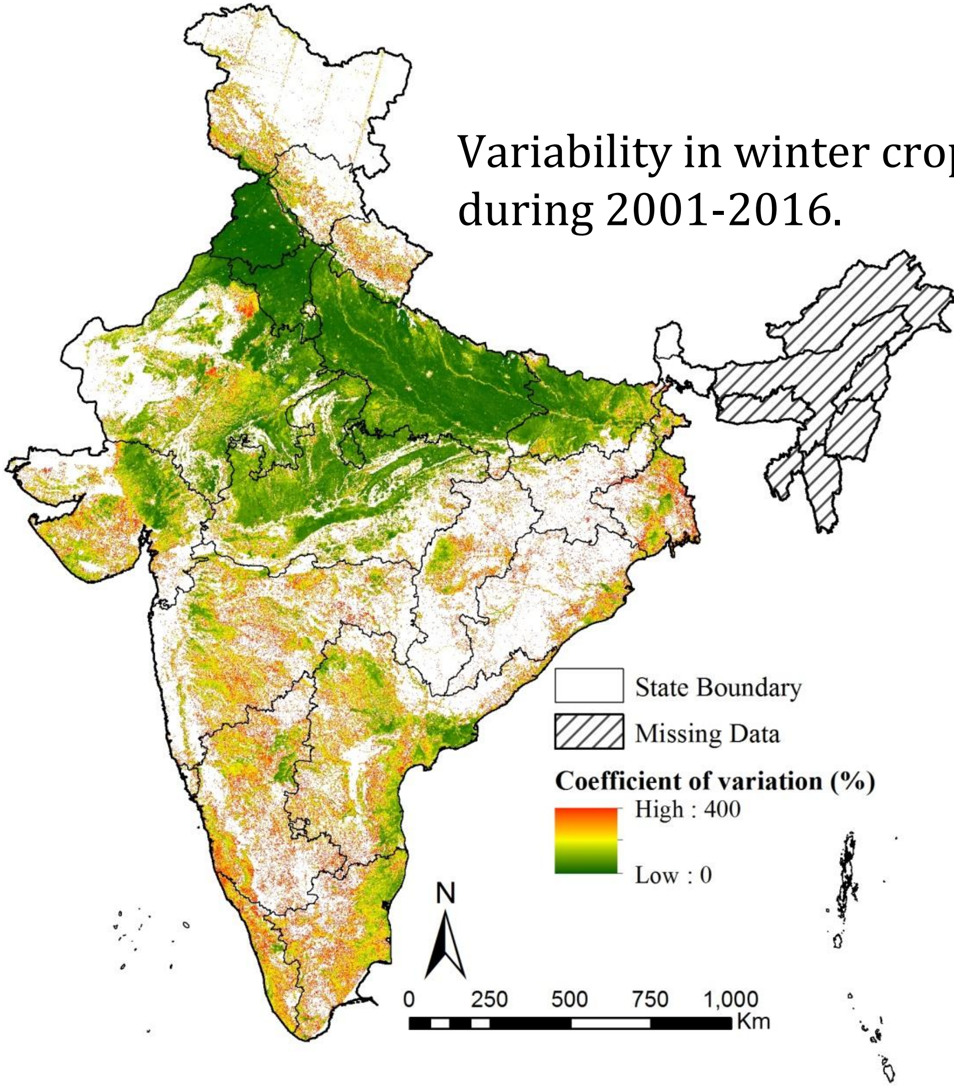


Smoothed EVI phenology from sample pixel.

Jain, **Mondal,** Galford, Fiske & DeFries, 2017. An Automated Approach to Map Winter Cropped Area of Smallholder Farms across Large Scales Using MODIS Imagery. *Remote Sensing* 9: 566

Methods: *Satellite data*

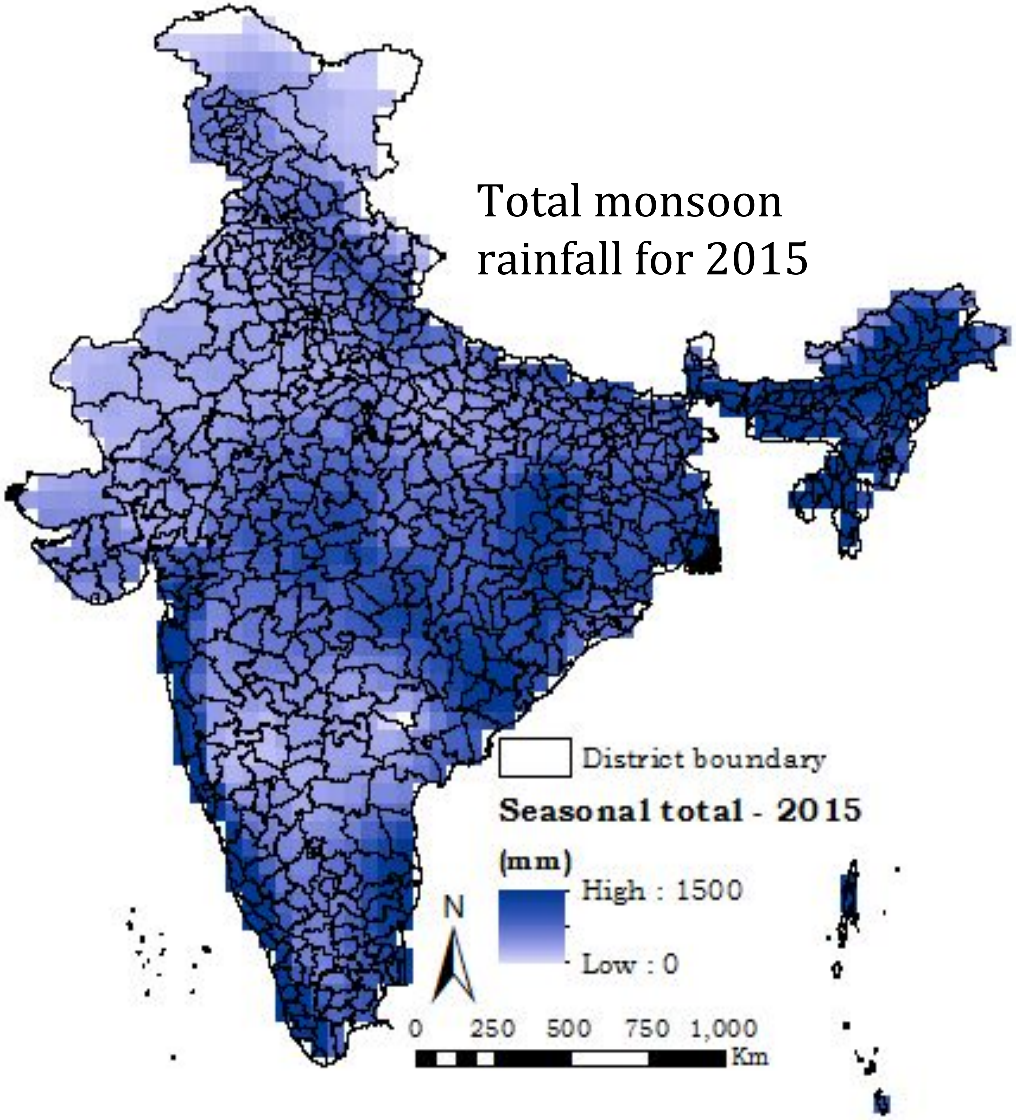
Variability in winter cropped area during 2001-2016.



Annual winter cropped area

Jain, **Mondal,** Galford, Fiske & DeFries, 2017. India Annual Winter Cropped Area, 2001-2016. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/H47D2S3W.

Methods: ***Satellite data***

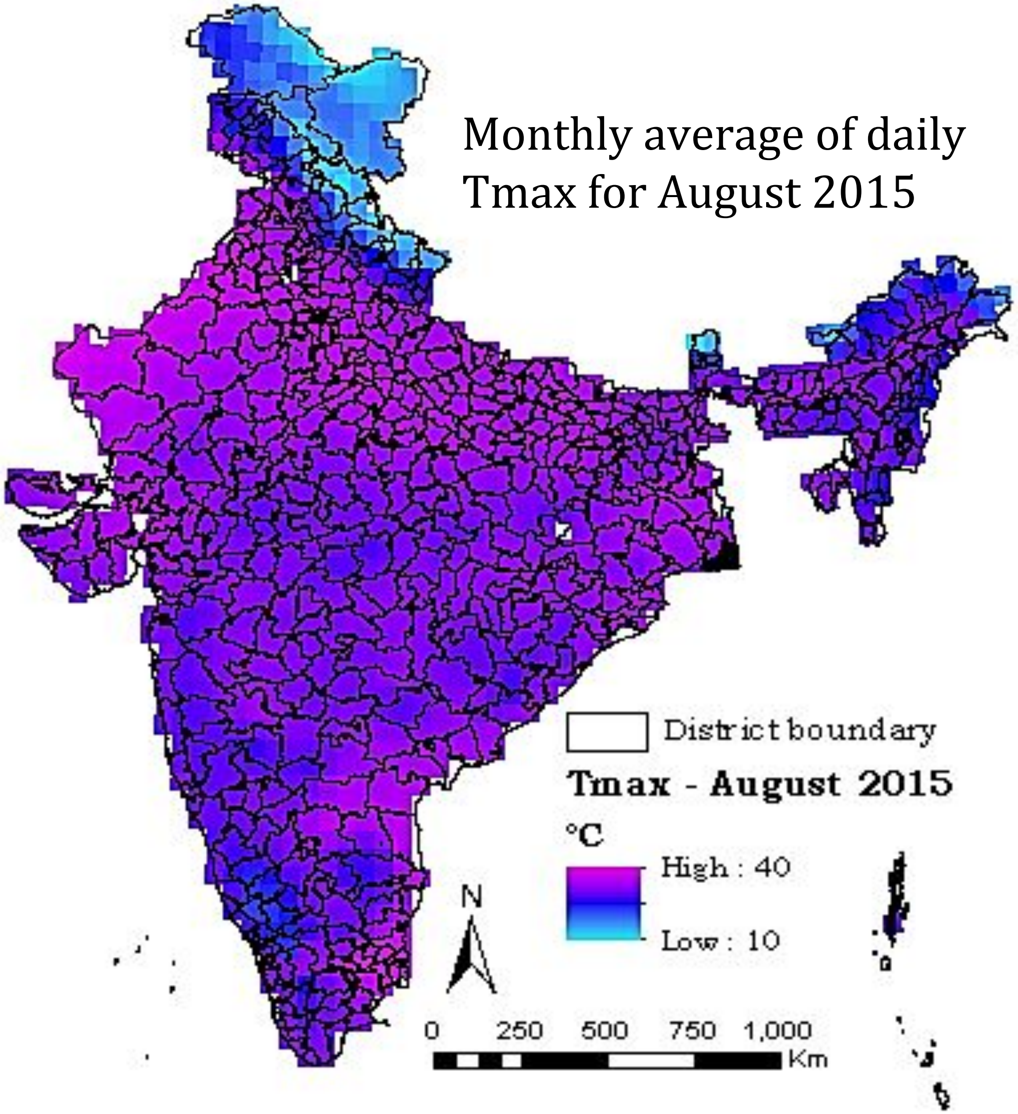


Precipitation

- Monsoon start date
- Monsoon end date
- Seasonal total
- Season length
- Monsoon dry days
- Days with low rain
- Days with heavy rain

Mondal, Jain, Singh, Galford, & DeFries.
Relative importance of climatic and
non-climatic factors in Indian winter crop.
In prep.

Methods: *Satellite data*



Monthly average of daily Tmax for August 2015

Temperature

- Monthly average of daily Tmax
- Monthly average of daily Tmin
- Daily temperature range (DTR)

Mondal, Jain, Singh, Galford, & DeFries. Relative importance of climatic and non-climatic factors in Indian winter crop. *In prep*.

Methods: *Space time cube*

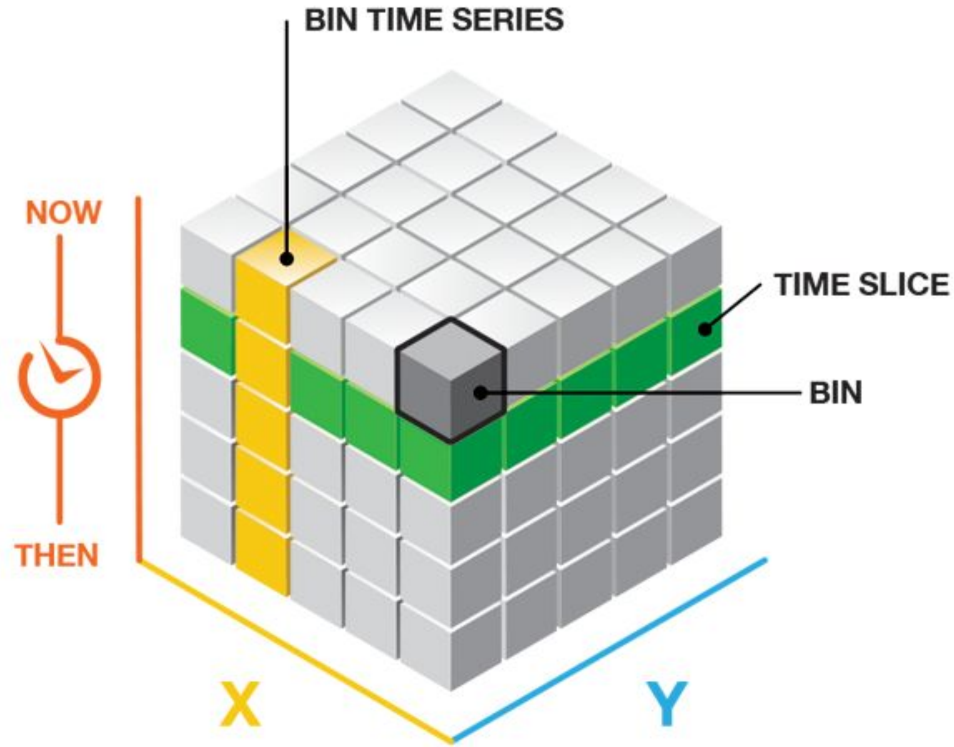


Image courtesy: ArcGIS Pro

Time: 16 years (2001 - 2016)

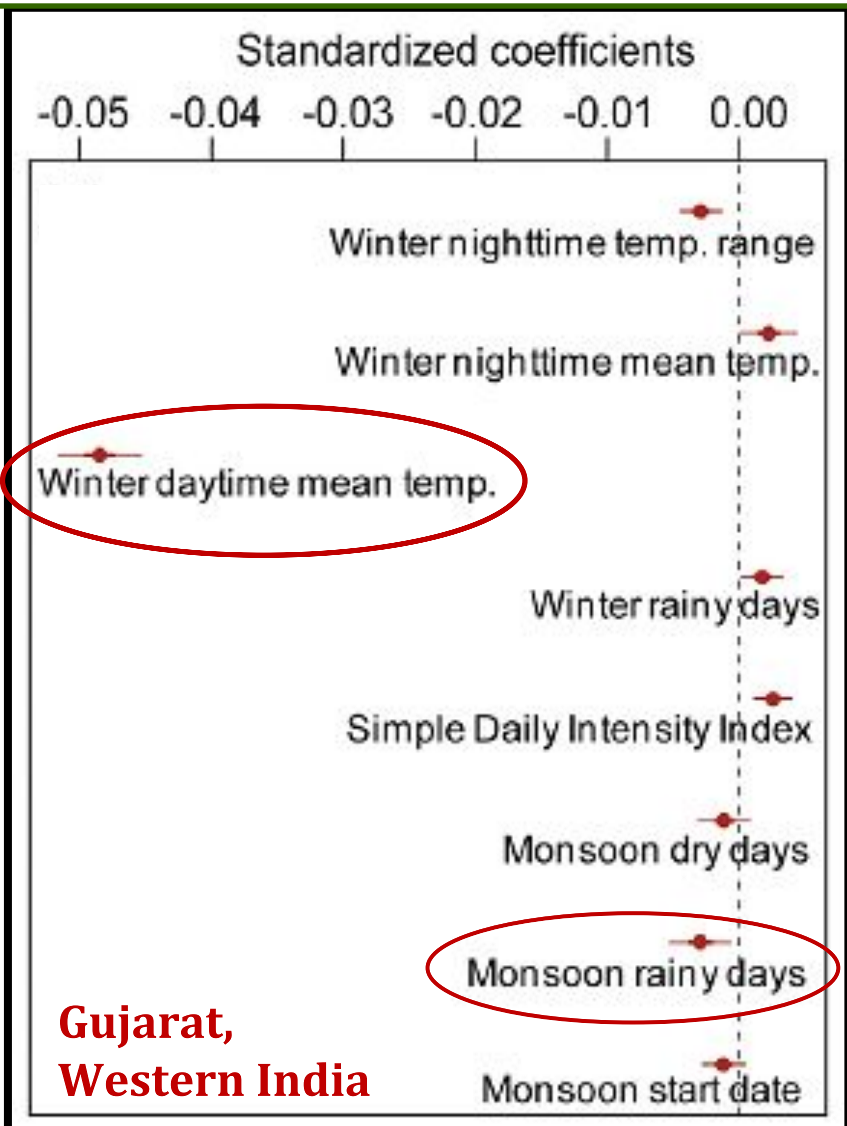
Space:

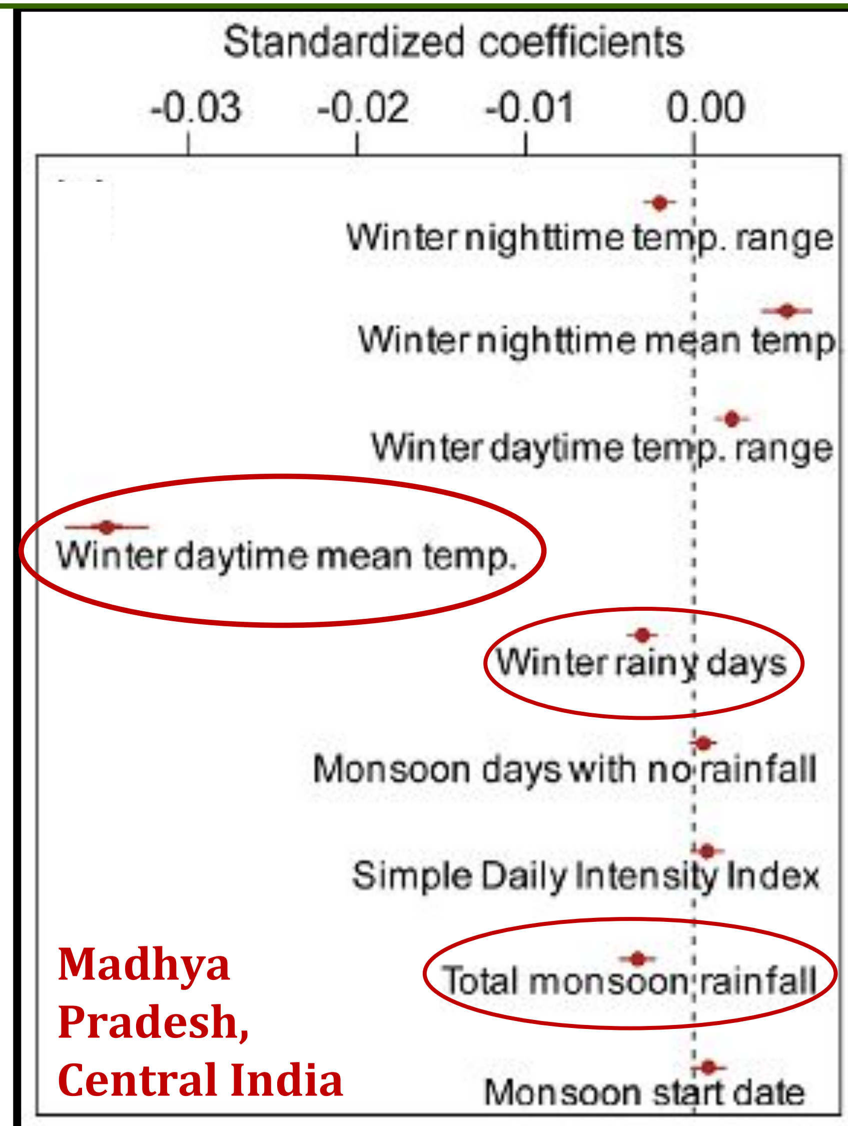
- 3,660 pixels (NOAA CPC)
- 14,157 pixels (TRMM)
- 355,116 pixels (CHIRPS)
- 1,787,433 pixels (MODIS)

Variables:

- Response: *winter cropped area*
- Predictors: *precip., temp.*

Location-specific Vulnerability





Mondal, Jain, DeFries, Galford & Small, 2015. Sensitivity of crop cover to climate variability: Insights from two Indian agro-ecoregions. *Journal of Environmental Management* 148: 21-30

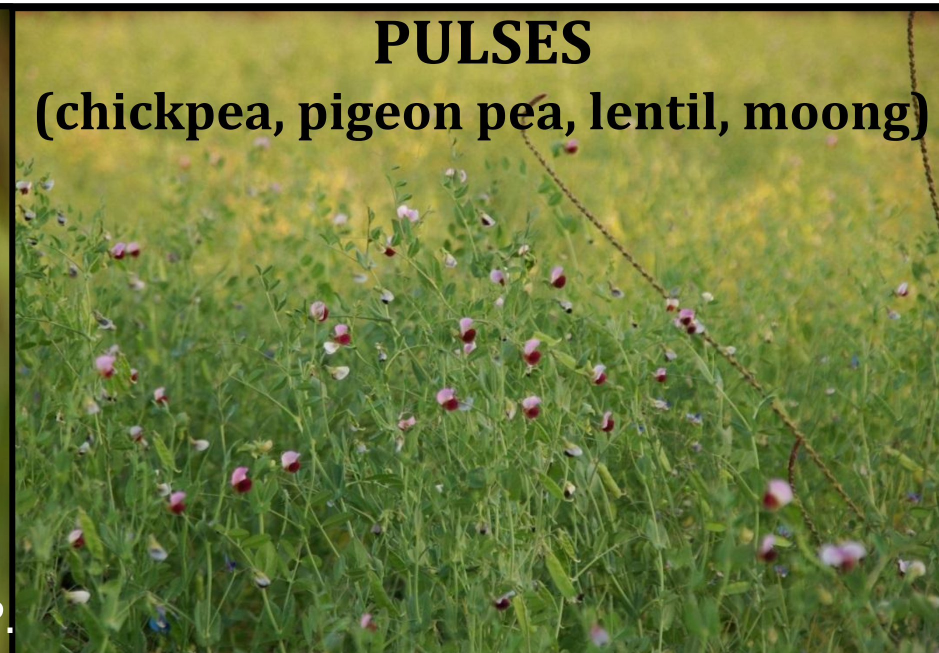
Location-specific Vulnerability

- Sensitivity of crop productivity to climate variability is location specific – mostly due to **different cropping practices** and **irrigation** access

- **Temperature** is critically important for winter crops

- Sensitivity of crop productivity to precipitation depends on **irrigation source**

Crop-specific Vulnerability

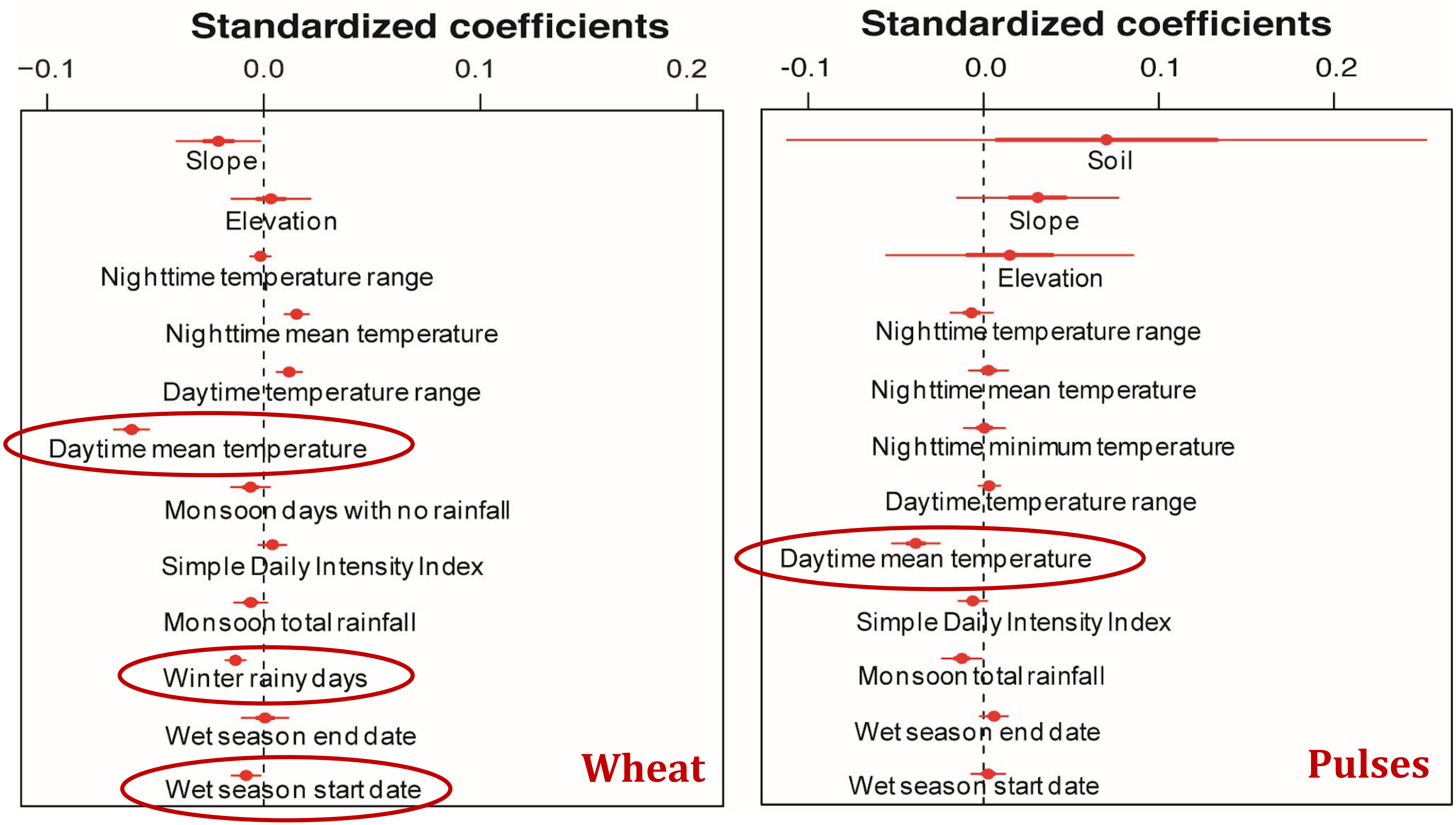


Irrigated field → wheat

Non-irrigated field → pulses

Mondal, Jain, Robertson, Galford, Small & DeFries, 2014. Winter crop sensitivity to inter-annual climate variability in central India. *Climatic Change* 126: 61-76

Crop-specific Vulnerability



Mondal, Jain, Robertson, Galford, Small & DeFries, 2014. Winter crop sensitivity to inter-annual climate variability in central India. *Climatic Change* 126: 61-76

Crop-specific Vulnerability

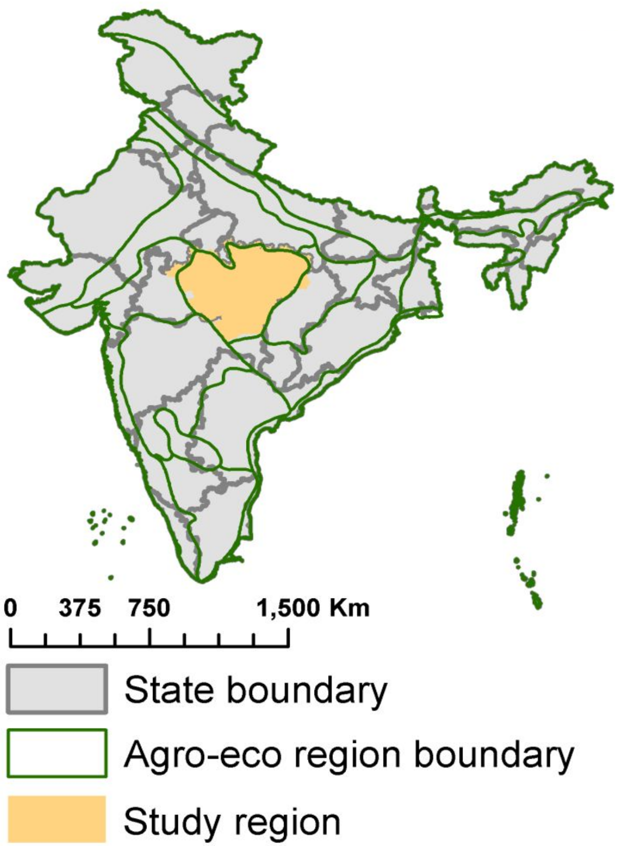
- A *longer wet season followed by higher winter temperatures* OR a *late and dry monsoon* → limited water availability through surface irrigation

- Pulses can be grown on *residual moisture in rainfed rice fallow* lands → potential candidate for alternate winter crop

- Some possible adaptation strategies:
  - Switching to crops *less sensitive to heat*
  - shifting *planting date*
  - new *early maturing* crop varieties

DeFries, **Mondal,** Singh, Agrawal, Fanzo, Remans & Wood, 2016. Synergies and trade-offs for sustainable agriculture: Nutritional yields and climate-resilience for cereal crops in Central India. *Global Food Security* 11: 44-53

Fluctuations – where & why?



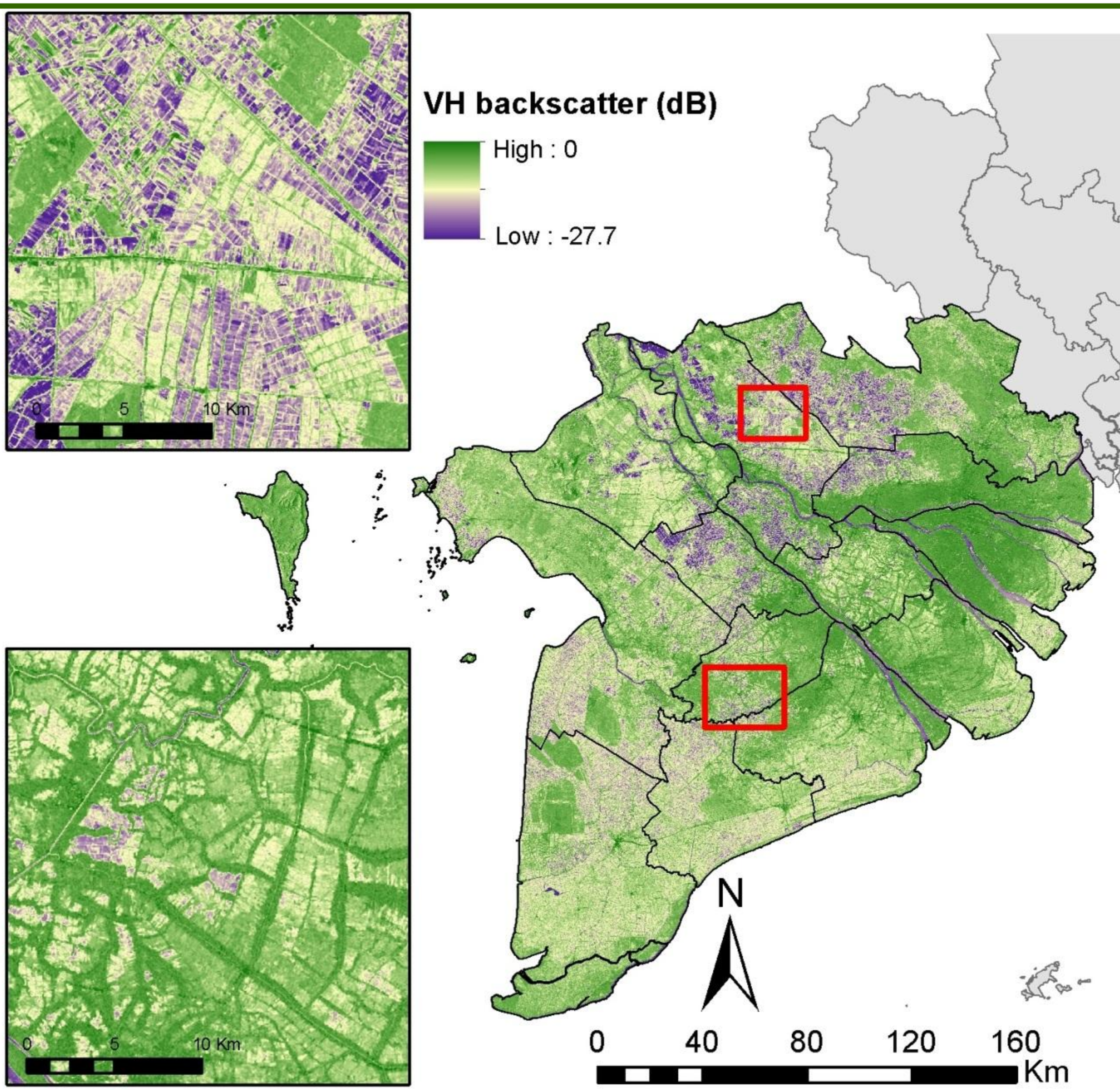
Mondal, Jain, Zukowski, Galford & DeFries, 2016. Quantifying fluctuations in winter cropped area in the Central Indian Highland landscape. *Regional Environmental Change* 16: 69-82

- Findings indicate a **fluctuating** landscape – 2.11 million ha to 3.73 million ha of winter cropped area.
- **Seasonal labor migration** to nearby towns was found to be associated with **less winter crop**.
- Increasing irrigation coverage will eventually result in more agricultural intensification.

Overall findings

- More irrigation accessibility → more winter crop
- Current winter crops might not be climate resilient
- Potential for coarse cereals, along with pulses, needs to be examined under projected conditions
    - Ongoing and planned collaborative work with crop-climate modelers

Machine Learning for Crop Phenology



Issues:

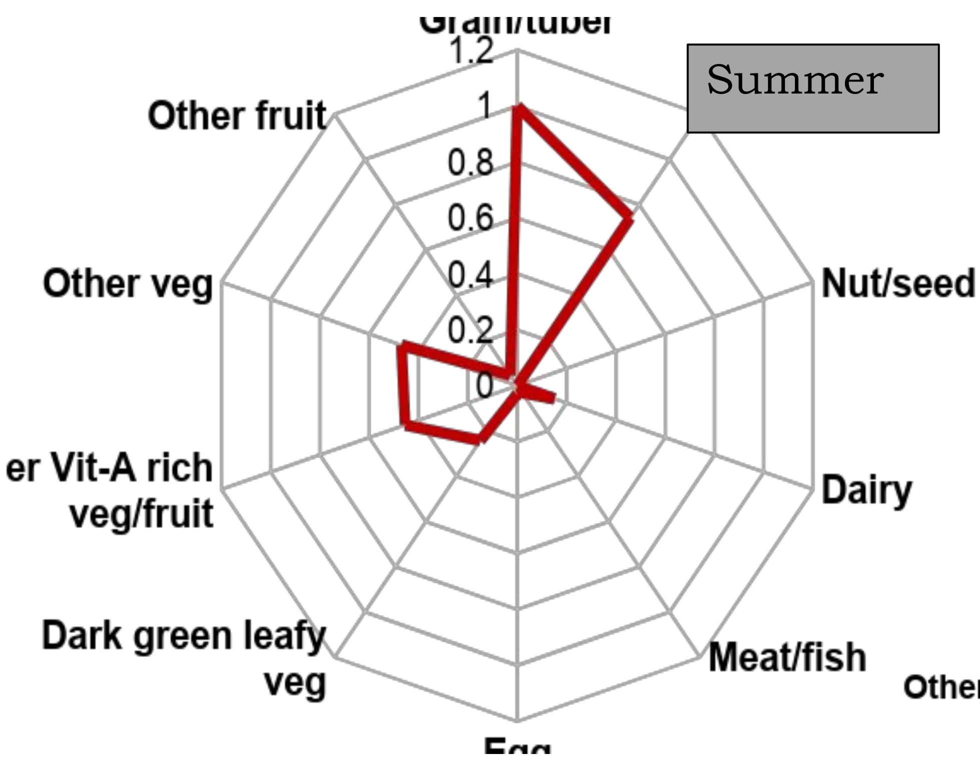
- Dense time-series data required
- Lack of cloud-free data
- Fine spatial resolution suitable for small farms

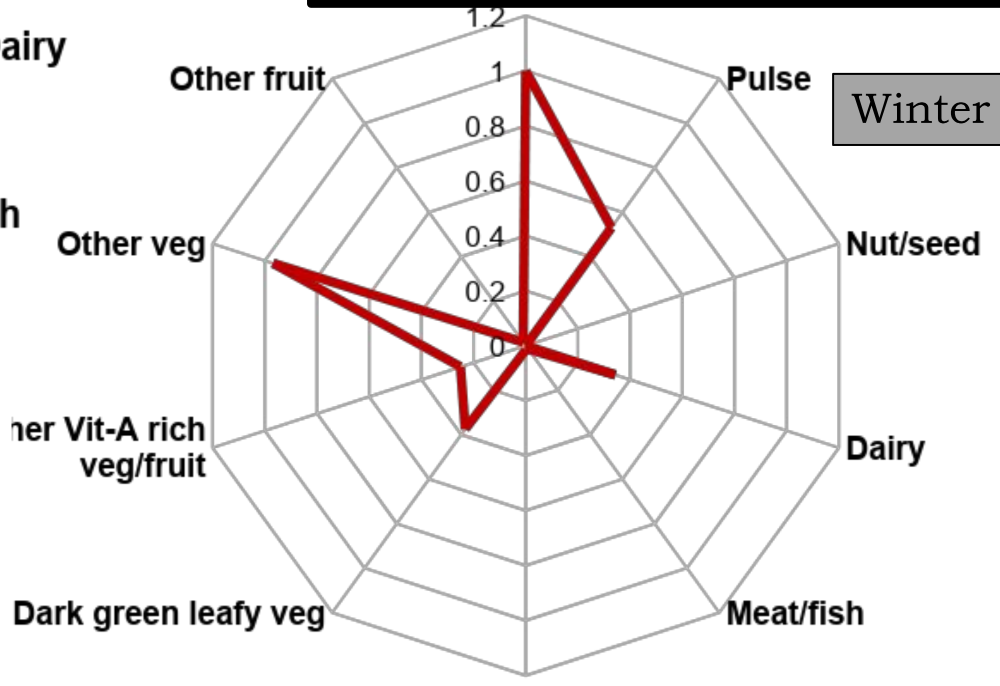
Synthetic Aperture Radar (SAR):

- Freely available SAR data
- Advancement of machine learning algorithms

Mondal. Drought and rice intensification in Vietnam: Mapping small farms using time-series of Sentinel-1radar data. *In prep.*

Food & Nutrition Security





Mondal, DeFries, Harou, Downs, Md. Arif, Gallant, & Fanzo. Implications of Agricultural Intensification for Diet and Nutrition in Rural India. *In prep.*

Collaborators: Nutritionist, Agricultural economist

THANK YOU!!!

Meha Jain (Michigan Ann Arbor)
Ruth DeFries (CU)
Chris Small (LDEO)
Gillian Galford (Vermont)
Deepti Singh (LDEO)
Andrew Robertson (IRI)
Harini Nagendra (APU, India)
Md. Arif (FES, India)
Sonali McDermid (NYU)
Shauna Downs (Rutgers)
Aurelie Harou (McGill)
Jessica Fanzo (Johns Hopkins)