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?
Research Context

Mean agricultural area in three global regions.

>380 million farming households
70% of food calories produced
>50% staple crops worldwide

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

- 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

CNN: April, 2016
Research Context

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

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

Map produced using India Water Tool
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?
Methods: **PIXEL to PEOPLE**

- **Satellite-derived Crop Phenology**
- **Climate Parameters**
  - Predictive models, independent variable
  - Coefficient
  - Linear predictor
- **Crop Types**
- **Irrigation**
- **Demography**

Mathematical Formula:

\[ Y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_p x_p + \epsilon \]

- 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

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Methods: Satellite data

Smoothed EVI phenology from sample pixel.

Methods: **Satellite data**

Variability in winter cropped area during 2001-2016.


[https://doi.org/10.7927/H47D2S3W](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 $T_{\text{max}}$
- Monthly average of daily $T_{\text{min}}$
- 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*

**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.

Image courtesy: ArcGIS Pro
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

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.

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

**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)