The Future of Food Security in India: Can Farmers Adapt to Environmental Change?

Meha Jain
Assistant Professor
School for Environment and Sustainability
University of Michigan
Co-PIs David Lobell, Ram Fishman. Collaborators: Balwinder Singh, Ashwini Chhatre


Cropped Area LCLUC team: Ruth DeFries, Pinki Mondal, Gillian Galford
Temperatures are warming

Chaturvedi et al. 2012
Monsoon rainfall has increasing break periods & intense events

Modified from Singh et al. 2014
Water tables are falling

54% of India’s groundwater wells are decreasing
Main Research Questions

• How are farmers adapting to multiple environmental changes?
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• How effective are these adaptation strategies in reducing long-term negative impacts?
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• Which socio-economic & biophysical factors constrain or enhance adaptation?
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• How are farmers adapting to multiple environmental changes?
• How effective are these adaptation strategies in reducing long-term negative impacts?
• Which socio-economic & biophysical factors constrain or enhance adaptation?
• Can satellite data be used to prioritize adaptation interventions?
Approach 1. Examine adaptation at large spatio-temporal scales using coarse scale census data.
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Approach 1. Examine adaptation at large spatio-temporal scales using coarse scale census data + empirical estimates of adaptation + examine adaptation at large spatiotemporal scales
Approach 1. Examine adaptation at large spatio-temporal scales using coarse scale census data + empirical estimates of adaptation + examine adaptation at large spatiotemporal scales - actual adaptation decisions and drivers of decision-making are unclear
Approach 2. Examine adaptation using household surveys and ask farmers how they have adapted.
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+ identify adaptation decisions and drivers of decision-making
Approach 2. Examine adaptation using household surveys and ask farmers how they have adapted
+ identify adaptation decisions and drivers of decision-making
- challenging to do across large spatio-temporal scales
- challenging to quantify adaptation
empirical estimates of adaptation
examine adaptation at large spatiotemporal scales
identify adaptation decisions and drivers of decision-making
Wheat Yield

Environmental Drivers
- Temperature
- Rainfall
- Groundwater Depth

Adaptation

Outcome
- Wheat Yield (Landsat & MODIS)

Cropping Decisions:
- Cropped area
- Sow date
- Crop variety
- Irrigation
Environmental Drivers

- Temperature
- Rainfall
- Groundwater Depth

Adaptation

- Cropping Decisions:
  - Cropped area
  - Sow date
  - Crop variety
  - Irrigation

Outcome

Wheat Yield (Landsat & MODIS)

*Will extend these methods to the monsoon season (rice)
Jain et al. 2017 using methods from Lobell et al. 2015
Mean annual Evapotranspiration (2001-2016)

Bhattarai et al. in prep.
Water tables are falling

54% of India’s groundwater wells are decreasing.
Main Research Questions

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• Is current groundwater depletion associated with yield declines or have farmers been able to adapt?
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• Is switching to canal irrigation a viable long-term adaptation strategy?
Main Research Questions

• Is groundwater depletion leading to decreased irrigation use or are farmers able to ‘chase’ the water table?
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground water Level (m)</td>
<td>-9.134*** (0.858)</td>
</tr>
<tr>
<td>Precipitation (mm)</td>
<td>0.007* (0.004)</td>
</tr>
<tr>
<td>District FE</td>
<td>Yes</td>
</tr>
<tr>
<td>Year FE</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>3024</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.05</td>
</tr>
</tbody>
</table>

*Note: *$p<0.1; **p<0.05; ***p<0.01

Bhattarai et al. in prep.
Main Research Questions

• Is current groundwater depletion associated with yield declines or have farmers been able to adapt?
<table>
<thead>
<tr>
<th>Regression/Subset</th>
<th>Change in Yield (kg/ha) per Standard Deviation in Groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>National</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Winter Wheat</td>
</tr>
<tr>
<td></td>
<td>Winter Rice</td>
</tr>
<tr>
<td></td>
<td>Winter Maize</td>
</tr>
<tr>
<td></td>
<td>Monsoon Rice</td>
</tr>
<tr>
<td></td>
<td>Monsoon Maize</td>
</tr>
<tr>
<td></td>
<td>Monsoon Pearl Millet</td>
</tr>
</tbody>
</table>

Pollack et al. in prep.
Main Research Questions

• Is switching to canal irrigation a viable long-term adaptation strategy?
Conclusions

• Groundwater depletion is already reducing irrigation capacity and the yields of some crops (e.g., wheat)

• Switching to canal irrigation when wells run dry will only be able to ameliorate production losses by ~ 50%

• This suggests that additional adaptation strategies that more efficiently use groundwater are needed (e.g., drip irrigation)
Conclusions

• Satellite data allow us to
  – map decision making in response to environmental change at fine spatial resolutions
  – link adaptation with drivers and outcomes at large spatio-temporal scales
  – examine heterogeneity in adaptation efficacy at fine spatial resolution
Informing Interventions & Capacity Building

- Partnering with CIMMYT and IWMI to identify ways our results and satellite data products can be used to target appropriate interventions regionally

- Conducting remote sensing trainings with scientists from CIMMYT and the Mahalanobis National Crop Forecast Centre on using Google Earth Engine
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New Investigator Program (NIP)