Modeling Wheat Yields in India: Describing & Exploiting Spatio-Temporal Variability with Panel Regression

# Introduction

The ability to monitor and predict crop yields in developing countries is critical to the sucessful adaptation to changes in our climate. Increased temperatures and variability has already been linked to losses in maize and wheat yields (-3.8 and 5.5% respectively)and crop prices globally (Lobell, Schlenker, and Costa-Roberts 2011). Althought much effort has been placed on modeling the spatial distribution of these shifts, less effort has been placed on how yields vary across space and time (Ray et al. 2015). Advances in remote sensing provide new avenues to monitor agricultural crop health at high spatial and temporal resolution. However, our ability to monitor changes in plant productivity is still limited in the more complex environments common to many developing countries (Mann and Warner 2015).

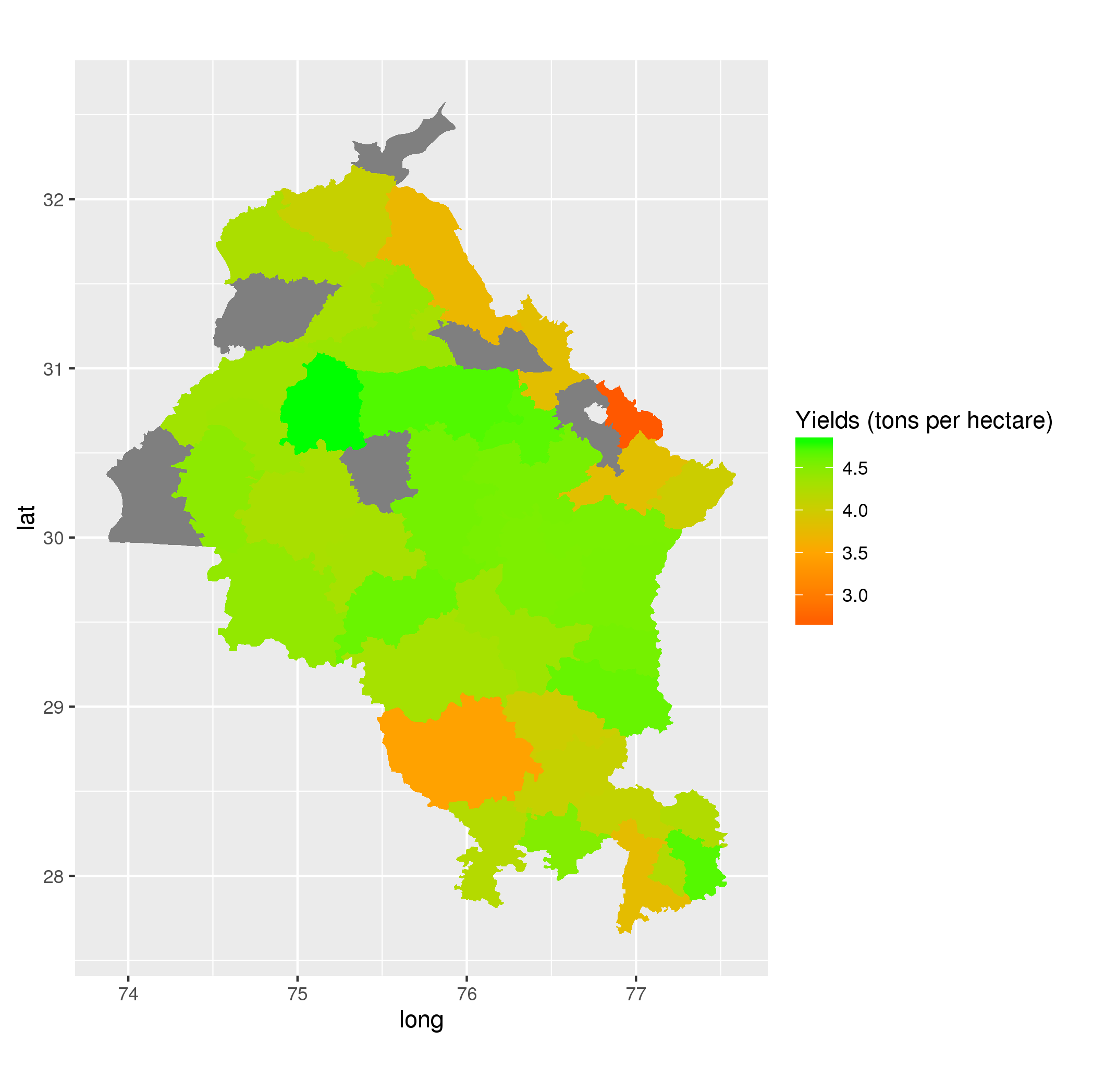
One primary thrust of these efforts has evolved out of the index insurance space. Index insurance is...

The main objectives of this project is to apply and compare statstical methods commonly applied these problems outside of the field of geography. In particular we will focus on the application of spatial panel regression to monitor spatio-temporal variability in wheat yields for Punjab and Haryana India.

# Methods

## Study Area and Period

We examine wheat yields at the district level for Punjab and Haryana India for Rabi season (roughly Nov-Apr) for the period of 2002 to 2012. Both Punjab and Haryana are extensively cropped but is comprised of a large number of smaller heterogenous plots. Both states are also extensively double-cropped with rice planting in the Kharif season (roughly May-Oct) and Wheat planted in the Rabi season. Rabi season wheat yeild range from 0.33 to 7.46 metric tons per hectare (Table 1, Figure 1).

*Figure 1: Mean Rabi Season Wheat Yields Metric Tons per Hectare by District*  

## Data

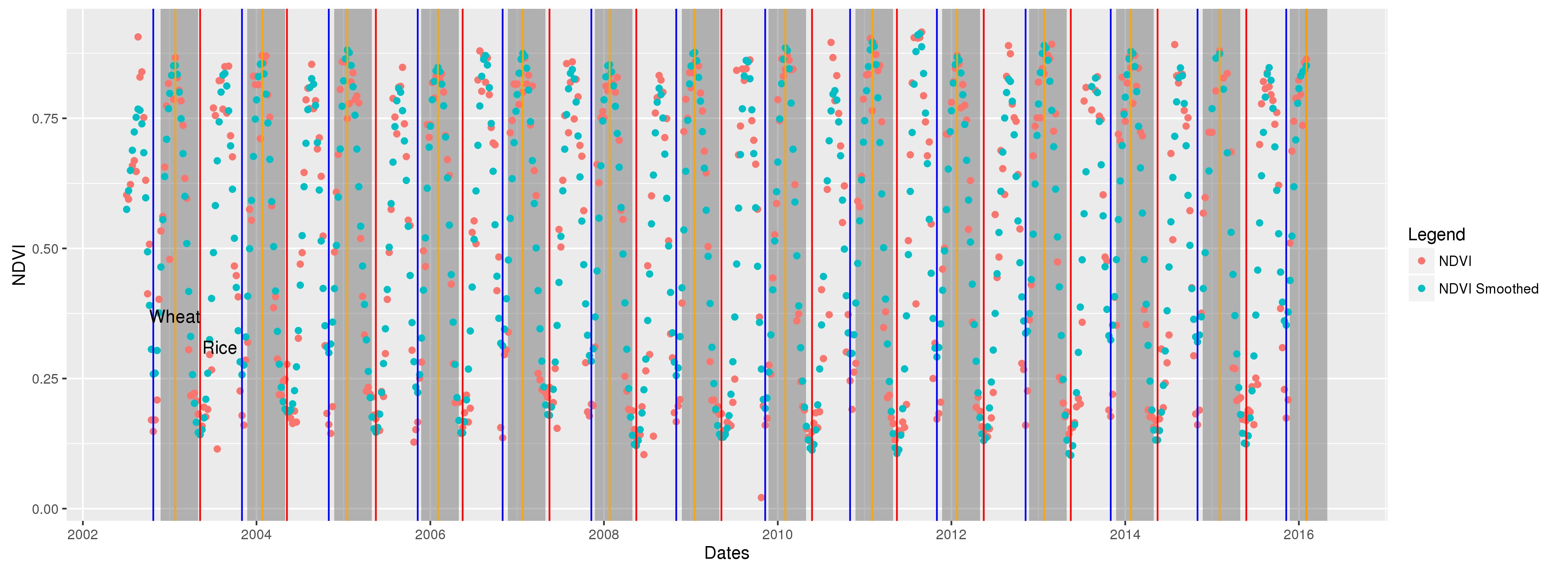
|  |  |  |
| --- | --- | --- |
|  | Mean | SD |
| **area** | 153.6 | 86.54 |
| **production\_tonnes** | 665,180 | 396,027 |
| **yield\_tn\_ha** | 4.247 | 0.6061 |
| **plant\_dates** | 314.7 | 9.28 |
| **harvest\_dates** | 128.3 | 27.13 |
| **season\_length** | 178.8 | 28.93 |
| **VEG\_annual\_mean** | 4,570 | 741.7 |
| **VEG\_annual\_min** | 2,369 | 1,117 |
| **VEG\_annual\_max** | 6,978 | 805.1 |
| **VEG\_annual\_AUC** | 1.26e+11 | 3.808e+10 |
| **VEG\_annual\_5th\_prct** | 2,454 | 1,097 |
| **VEG\_annual\_sd** | 1,516 | 479.1 |
| **VEG\_annual\_max\_5th\_prct** | 5,695 | 956.5 |
| **VEG\_annual\_AUC\_5th\_prct** | 2.192e+10 | 2.441e+09 |
| **VEG\_growing\_max\_date** | 43.75 | 21.84 |
| **VEG\_growing\_mean** | 4,523 | 500.8 |
| **VEG\_growing\_min** | 2,185 | 630.6 |
| **VEG\_growing\_max** | 6,826 | 791.4 |
| **VEG\_growing\_AUC** | 101,724 | 20,444 |
| **VEG\_growing\_5th\_prct** | 2,234 | 623.9 |
| **VEG\_growing\_max\_5th\_prct** | 6,309 | 822.8 |
| **VEG\_growing\_AUC\_5th\_prct** | 54,939 | 5,709 |
| **VEG\_growing\_AUC\_v2** | 101,716 | 20,442 |
| **VEG\_growing\_AUC\_leading** | 58,771 | 12,435 |
| **VEG\_growing\_AUC\_trailing** | 45,635 | 10,875 |
| **VEG\_growing\_AUC\_diff\_mn** | 17.47 | 16,825 |
| **VEG\_growing\_AUC\_diff\_90th** | -13,607 | 17,147 |
| **VEG\_all\_growing\_5th\_prct** | 2,149 | 509.3 |
| **VEG\_growing\_sd** | 1,679 | 462 |
| **Whe\_Yeild\_kgha** | 4,308 | 508.6 |
| **yield\_tn\_ha\_dual** | 4.232 | 0.6179 |

### Remote sensing

### Agricultural Surveys

## Compressing Time: Summarizing Remotely Sensed Data

### To smooth or not to smooth



Test

## Exploiting Time: (Spatial) Panel Regression Methods and Models

### Panel Regression

### Spatial Panel Regression

#### Defining the neighborhood

# Results

# Discussion

# Conclusions

# Appendix A

## Yield Data

*Table A1: Rabi Season Wheat Yields Metric Tons per Hectare by State*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| State | district | Min | Mean | Max |
| Haryana | AMBALA | 3.24 | 3.817 | 4.86 |
| Haryana | BHIWANI | 0.33 | 3.465 | 4.47 |
| Haryana | FARIDABAD | 3.66 | 4.22 | 4.92 |
| Haryana | FATEHABAD | 4.08 | 4.616 | 5.46 |
| Haryana | GURGAON | 3.52 | 4.094 | 4.92 |
| Haryana | HISAR | 3.7 | 4.301 | 5.1 |
| Haryana | JHAJJAR | 3.59 | 4.067 | 4.89 |
| Haryana | JIND | 3.96 | 4.355 | 5.24 |
| Haryana | KAITHAL | 4.11 | 4.533 | 5.45 |
| Haryana | KARNAL | 4.13 | 4.548 | 5.68 |
| Haryana | KURUKSHETRA | 4.03 | 4.545 | 5.44 |
| Haryana | MAHENDRAGARH | 3.73 | 4.202 | 4.78 |
| Haryana | MEWAT | 3.07 | 3.78 | 4.37 |
| Haryana | PALWAL | 4.15 | 4.688 | 5.09 |
| Haryana | PANCHKULA | 1.88 | 2.625 | 3.57 |
| Haryana | PANIPAT | 4.22 | 4.572 | 5.56 |
| Haryana | REWARI | 4.01 | 4.506 | 4.97 |
| Haryana | ROHTAK | 3.45 | 4.01 | 5 |
| Haryana | SIRSA | 3.43 | 4.425 | 5.36 |
| Haryana | SONIPAT | 4.28 | 4.626 | 5.51 |
| Haryana | YAMUNANAGAR | 3.39 | 4.013 | 5.38 |
| Punjab | AMRITSAR | 4.05 | 4.266 | 4.43 |
| Punjab | BARNALA | Inf | NA | -Inf |
| Punjab | BATHINDA | 3.89 | 4.281 | 4.79 |
| Punjab | FARIDKOT | 4.04 | 4.35 | 4.81 |
| Punjab | FATEHGARH SAHIB | 4.09 | 4.614 | 5.18 |
| Punjab | FAZILKA | Inf | NA | -Inf |
| Punjab | FIROZPUR | 3.98 | 4.332 | 4.92 |
| Punjab | GURDASPUR | 3.57 | 4.056 | 4.48 |
| Punjab | HOSHIARPUR | 3.4 | 3.715 | 4.29 |
| Punjab | JALANDHAR | 4.14 | 4.376 | 4.69 |
| Punjab | KAPURTHALA | 3.97 | 4.283 | 4.64 |
| Punjab | LUDHIANA | 4.39 | 4.7 | 4.96 |
| Punjab | MANSA | 3.75 | 4.293 | 4.88 |
| Punjab | MOGA | 4.14 | 4.81 | 7.46 |
| Punjab | MUKTSAR | 3.94 | 4.45 | 4.98 |
| Punjab | PATHANKOT | Inf | NA | -Inf |
| Punjab | PATIALA | 4.12 | 4.55 | 4.83 |
| Punjab | RUPNAGAR | 3.31 | 3.807 | 4.51 |
| Punjab | SAHIBZADA AJIT SINGH NAGAR | Inf | NA | -Inf |
| Punjab | SANGRUR | 4.23 | 4.574 | 5.13 |
| Punjab | SHAHID BHAGAT SINGH NAGAR | Inf | NA | -Inf |
| Punjab | TARN TARAN | Inf | NA | -Inf |

# References

Lobell, David B., Wolfram Schlenker, and Justin Costa-Roberts. 2011. “Climate Trends and Global Crop Production Since 1980.” *Science* 333 (6042). American Association for the Advancement of Science: 616–20. doi:[10.1126/science.1204531](https://doi.org/10.1126/science.1204531).

Mann, ML L, and J Warner. 2015. “Ethiopian Wheat Yield and Yield Gap Estimation: A Small Area Integrated Data Approach.” Addis Ababa, Ethiopia: International Food Policy Research Institute.

Ray, Deepak K, James S Gerber, Graham K MacDonald, and Paul C West. 2015. “Climate variation explains a third of global crop yield variability.” *Nature Communications* 6 (January). The Author(s): 5989. <http://dx.doi.org/10.1038/ncomms6989 http://10.1038/ncomms6989 http://www.nature.com/articles/ncomms6989{\#}supplementary-information>.