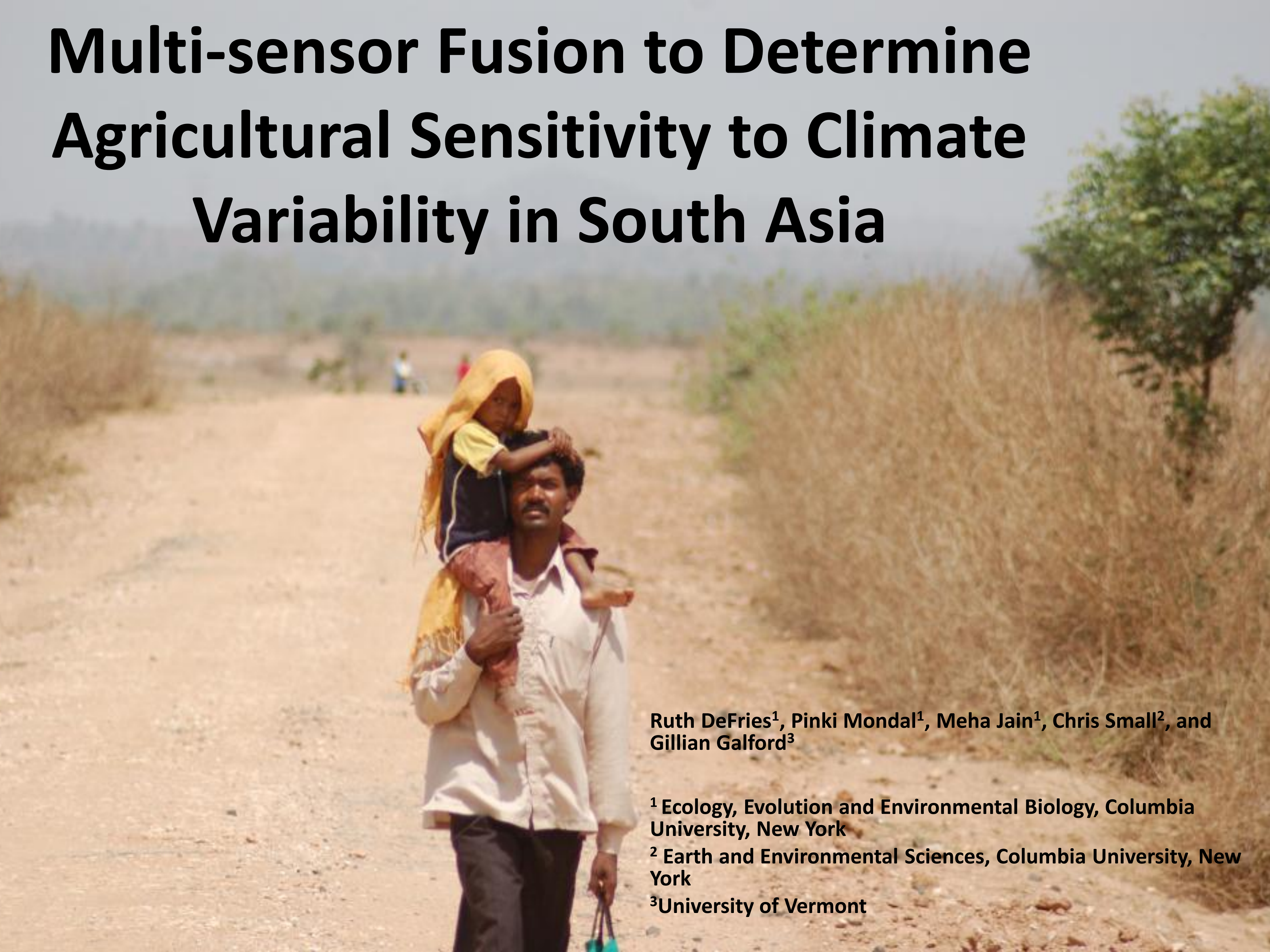
Multi-sensor Fusion to Determine Agricultural Sensitivity to Climate Variability in South Asia



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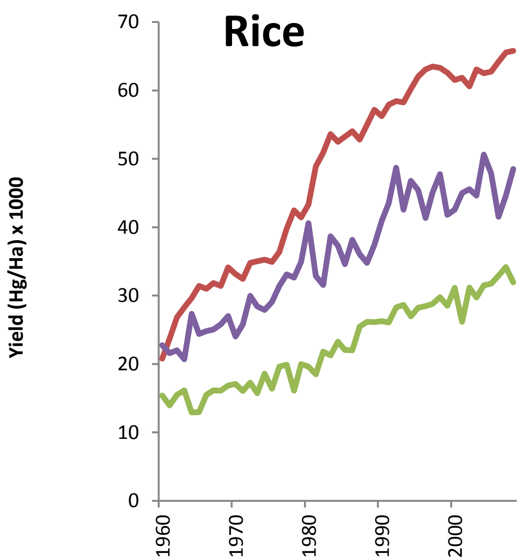
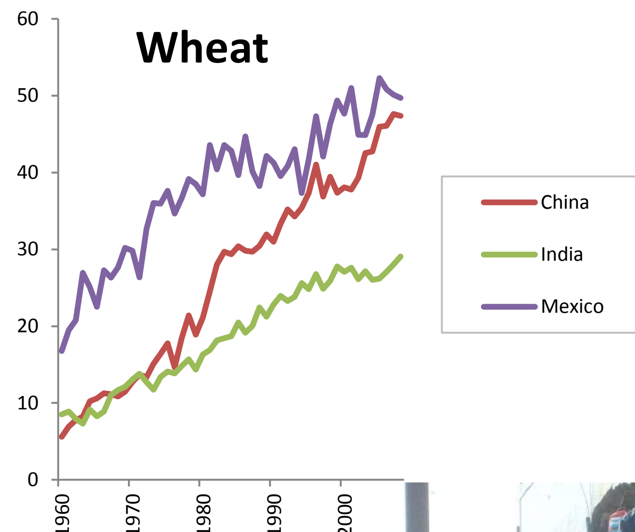
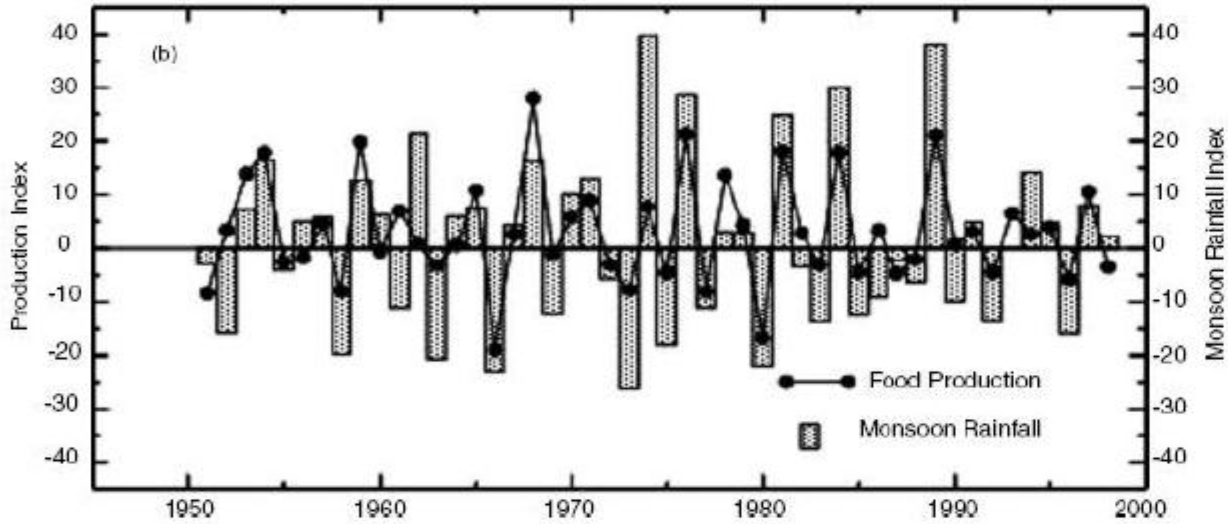
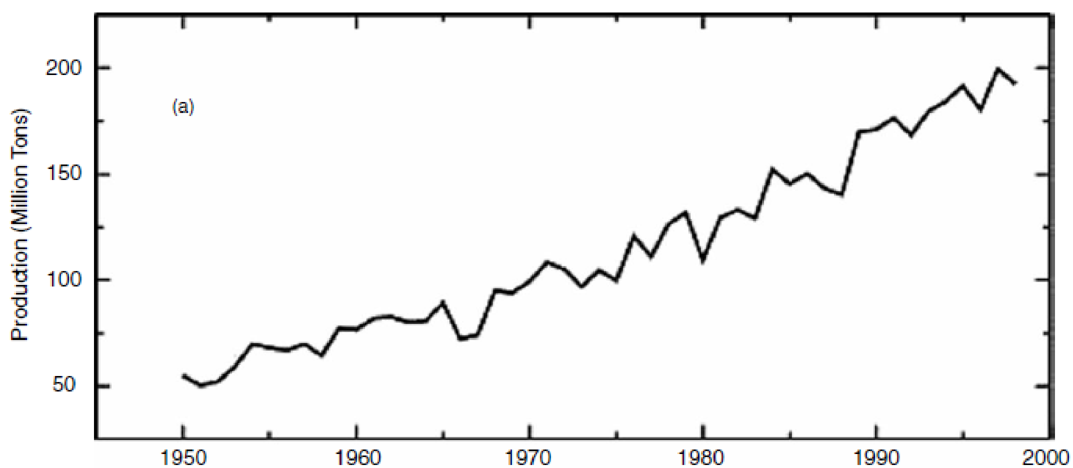
Cropping intensity: a major component of food security



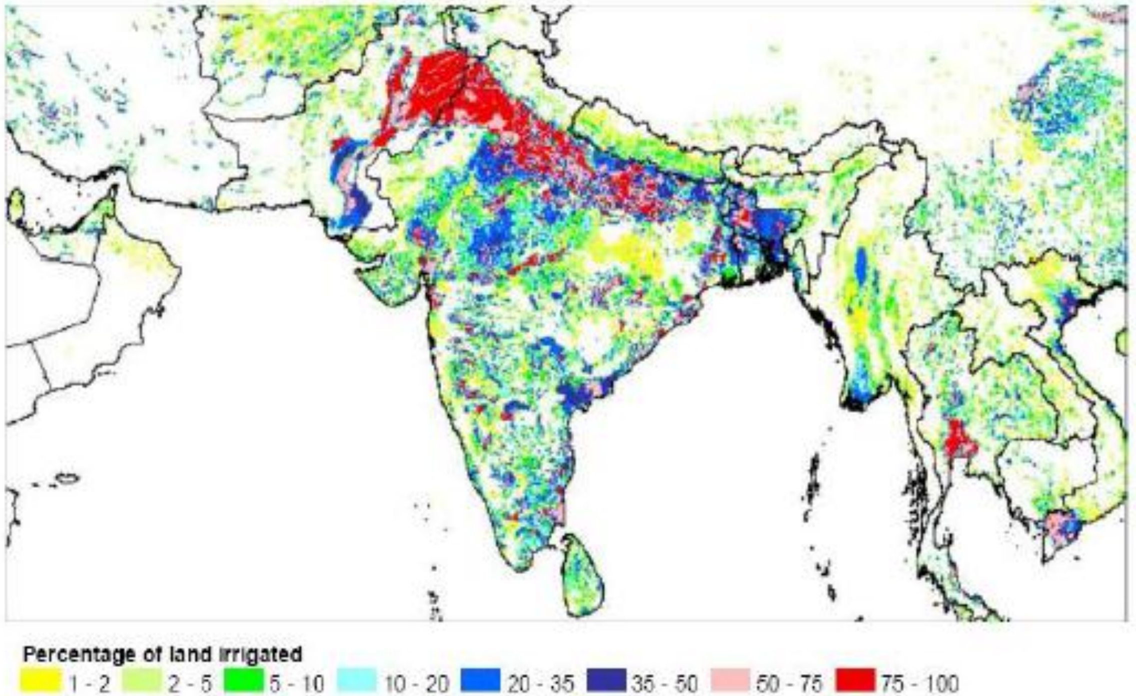


Data: FAOSTAT





All-India total food grain production and monsoon rainfall (from Kumar et al 2004)



Percent of land area irrigated at 1km resolution based on multiple remote sensing data sets (from Thenkabail, 2008)

OBJECTIVES

- What are the spatial patterns and temporal variability in cropping intensity throughout India since 2000?
- How are the patterns and variability in cropping intensity related to climate variability in India?
- What data sets and analytical methods provide a baseline and methodology for monitoring vulnerability of multiple cropping to climate variability?

MODIS PHENOLOGY TO DETERMINE CROPPING INTENSITY

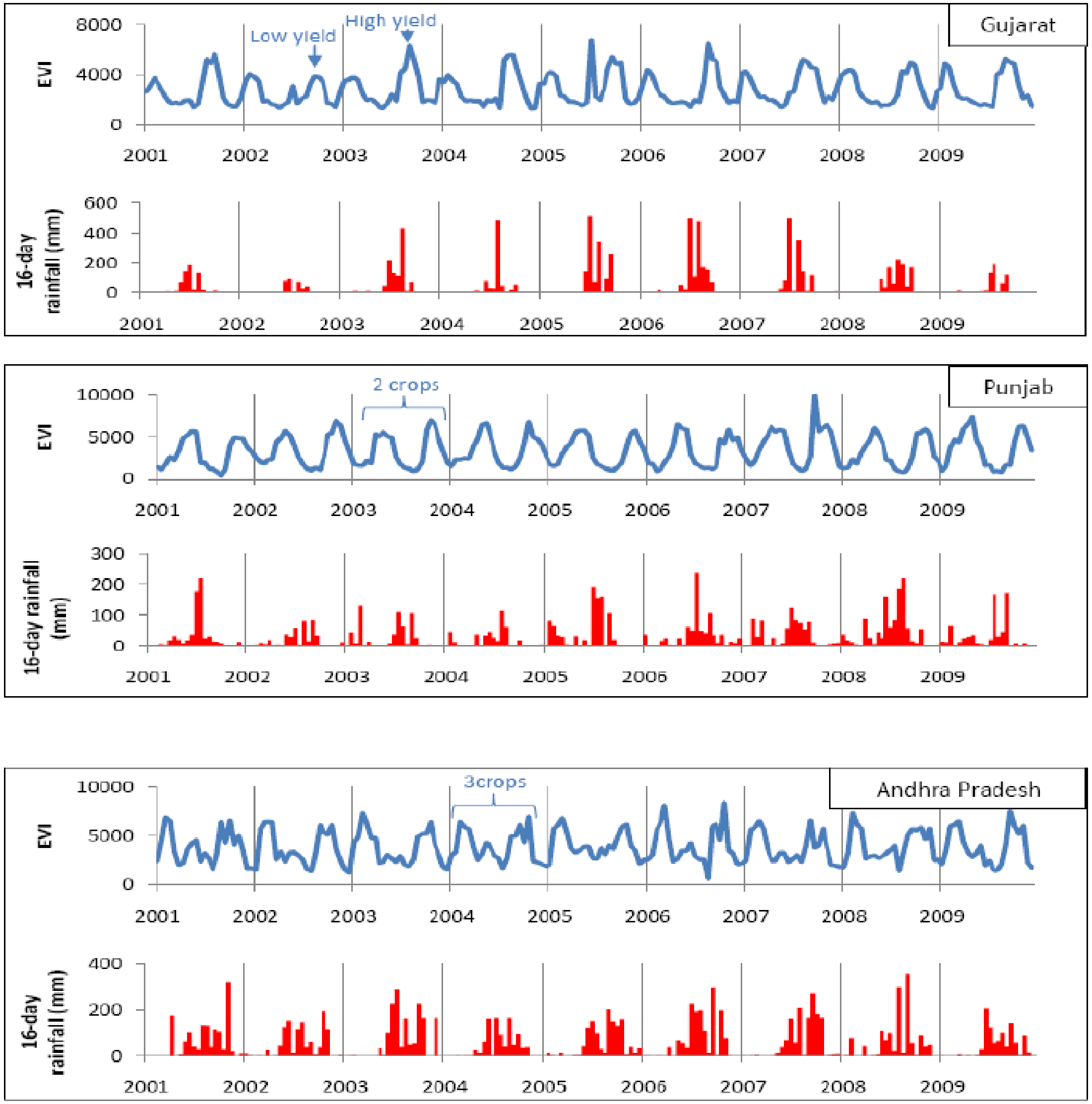


Fig. 3. Three examples of EVI time series from Gujarat where rainfall is variable (top), Punjab which is heavily irrigated (middle) and Andhra Pradesh in southern India (bottom). EVI (x10000) 16-day profiles indicate multiple crops per year and interannual variability. Data have not been smoothed. Rainfall data is from daily TRMM aggregated to 16 days.

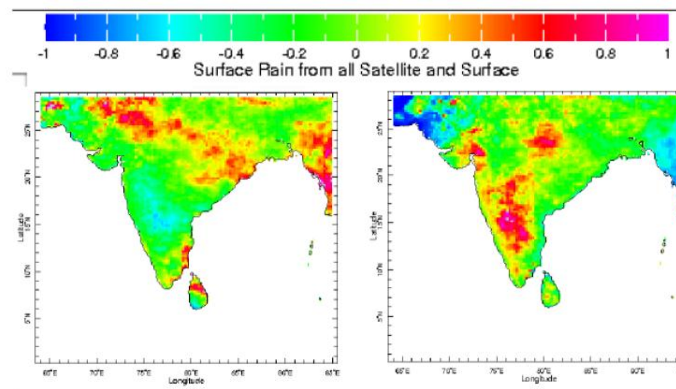


Figure 6. Rainfall anomalies for 2001, a dry year (left) and 2005, a wet year (right) from TRMM. Data are anomalies relative to 1998-2009 mean normalized by mean precipitation.

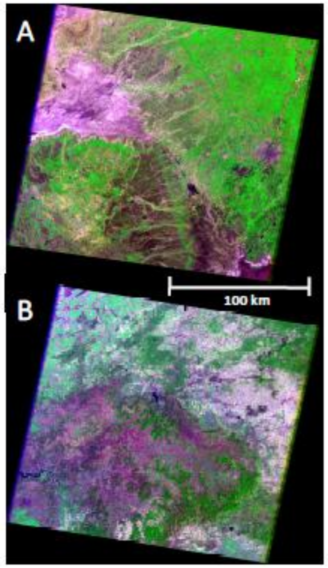
TRMM FOR PRECIPITATION

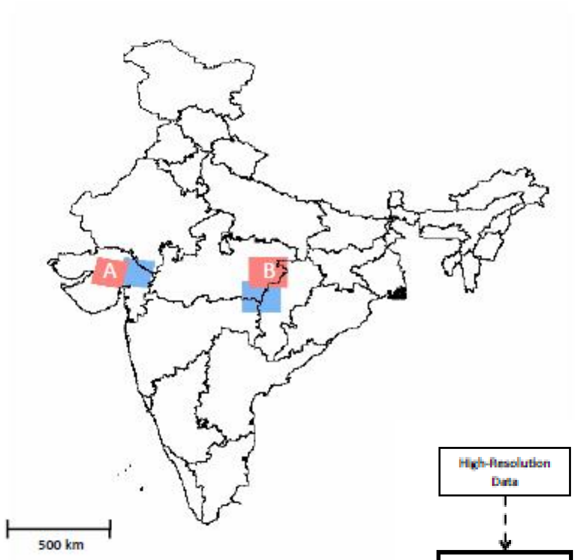
METHODS FOR MAPPING CROPPING INTENSITYFOR SMALL HOLDER FARMING

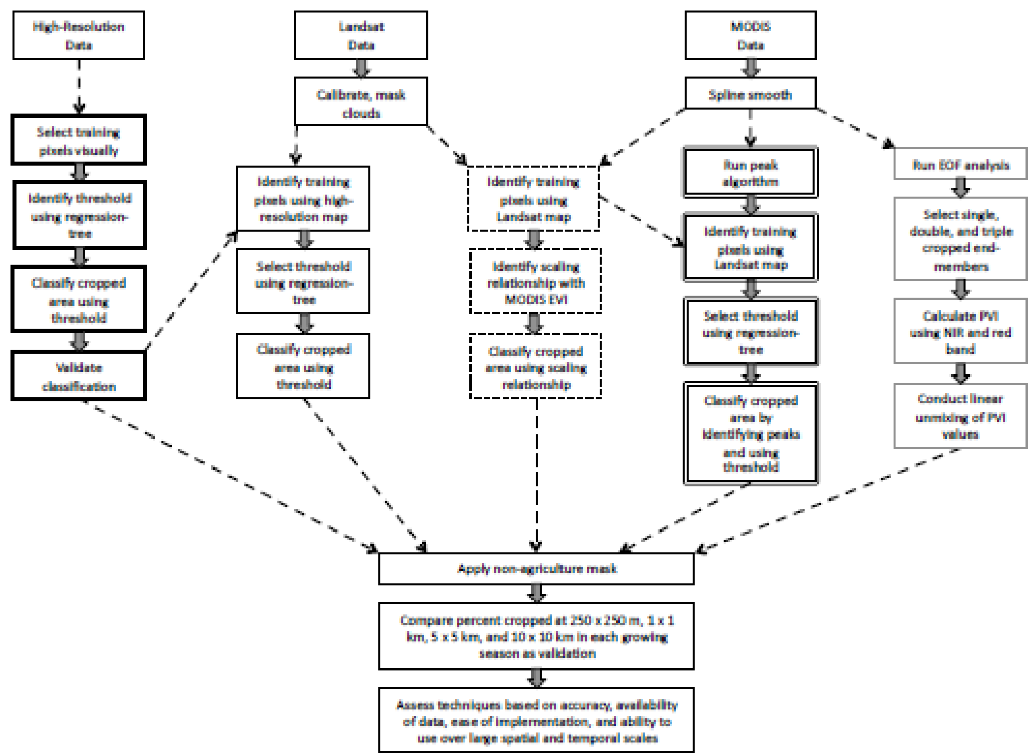
METHOD	DESCRIPTION	SCALE OF RESULT
Landsat Threshold	Regression tree to distinguish NDVI for crop/non-crop by visual interpretation of HR	30 m
MODIS Peak	EVI peak above threshold for crop/non-crop by visual interpretation of Landsat	250 m
Temporal mixture analysis	Endmembers from PCA of MODIS PVI time series	Fraction of 250m
Hierarchical Training Technique	Calibrate % cropped from HR with MODIS EVI from visual interpretation of random sample	Fraction of 250 m

(Biradar and Xiao, 2011; Lobell and Asner, 2004; Morton et al, 2006; Macedo et al., 2011; Brawell, 2003)

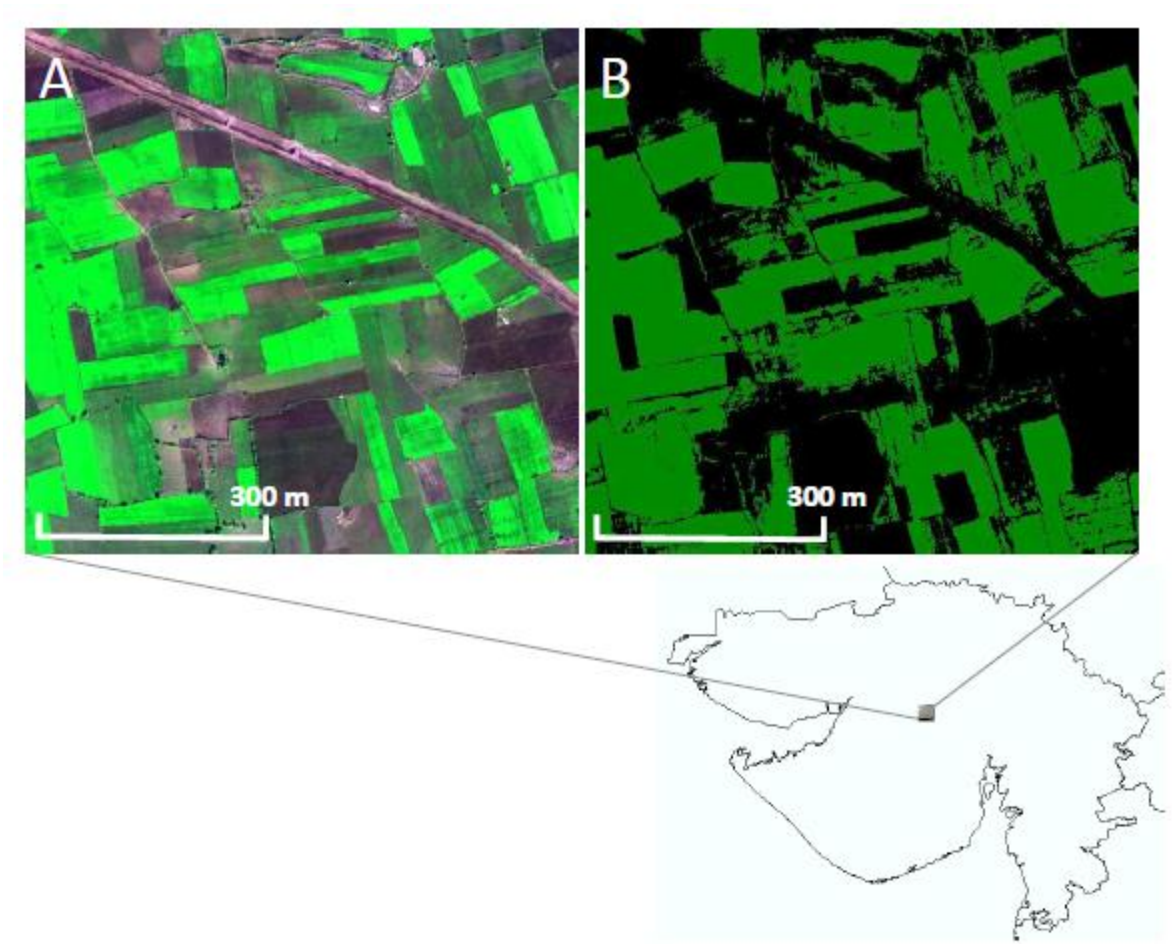
STUDY REGIONS



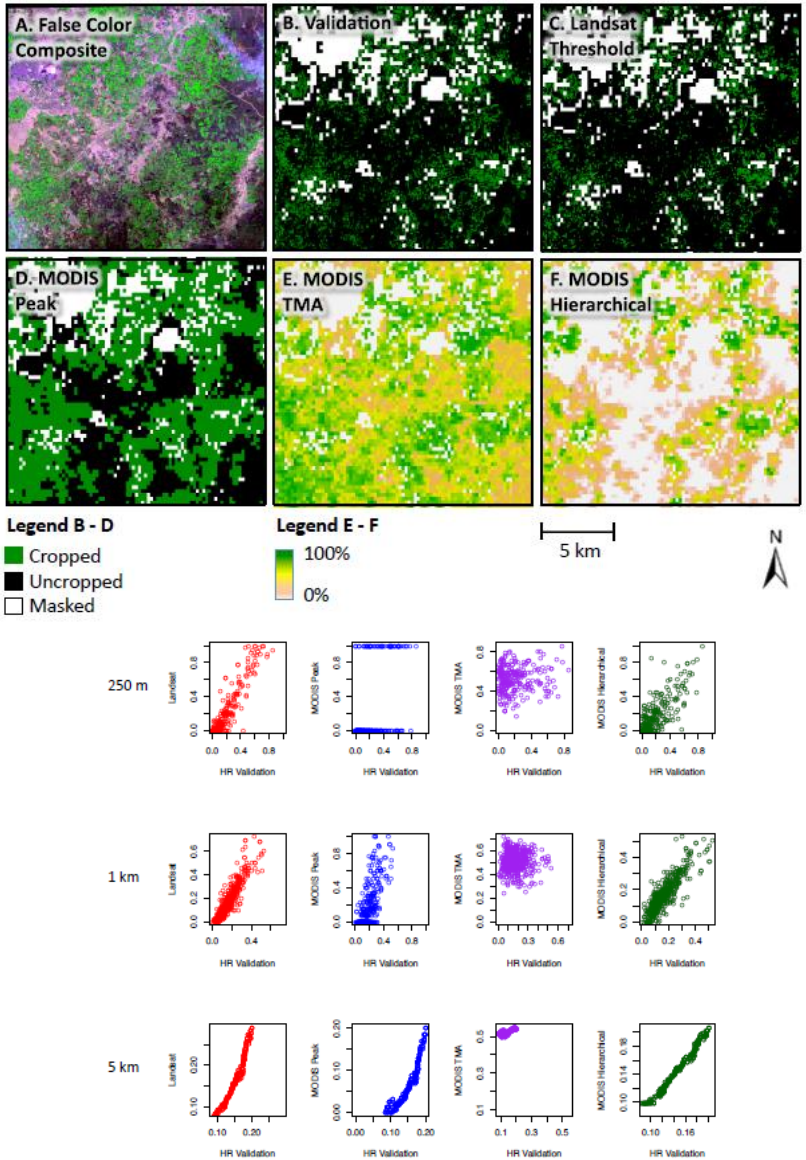




HIGH RESOLUTION FOR CALIBRATION AND VALIDATION



Gujarat site winter 2009-10



Madhya Pradesh site winter 2009-10

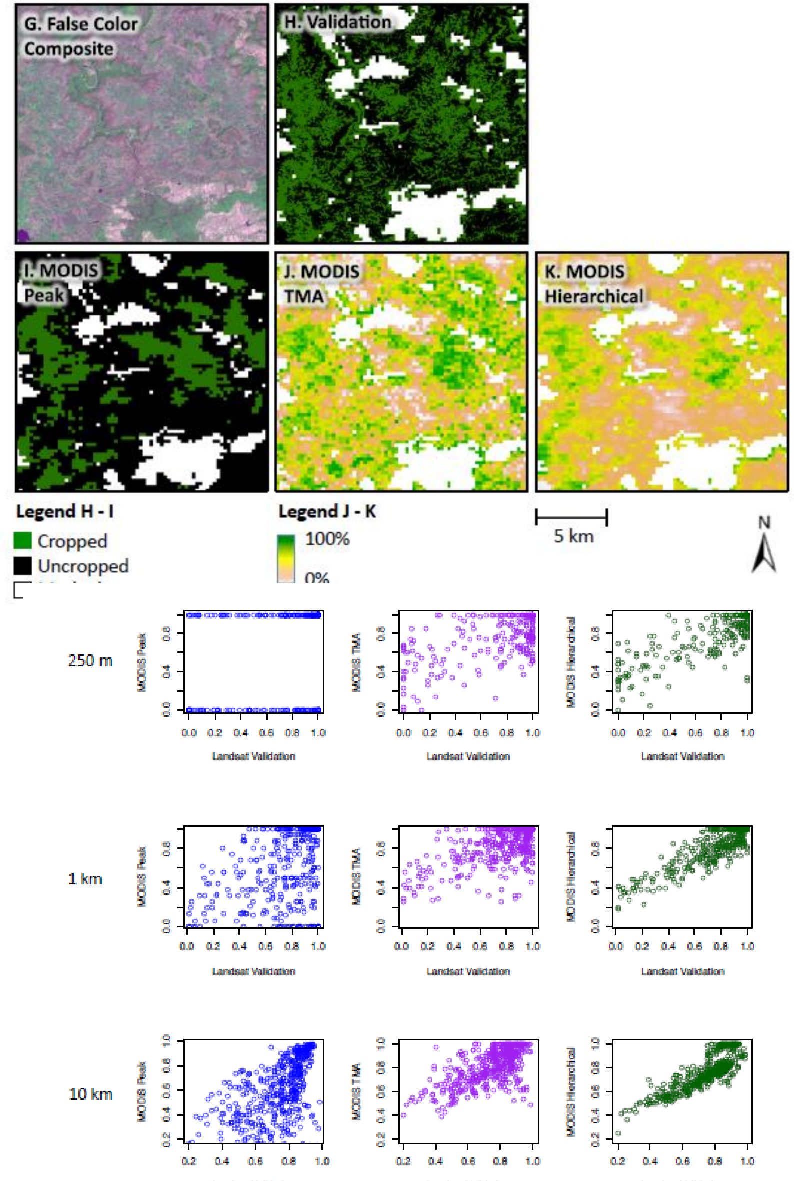
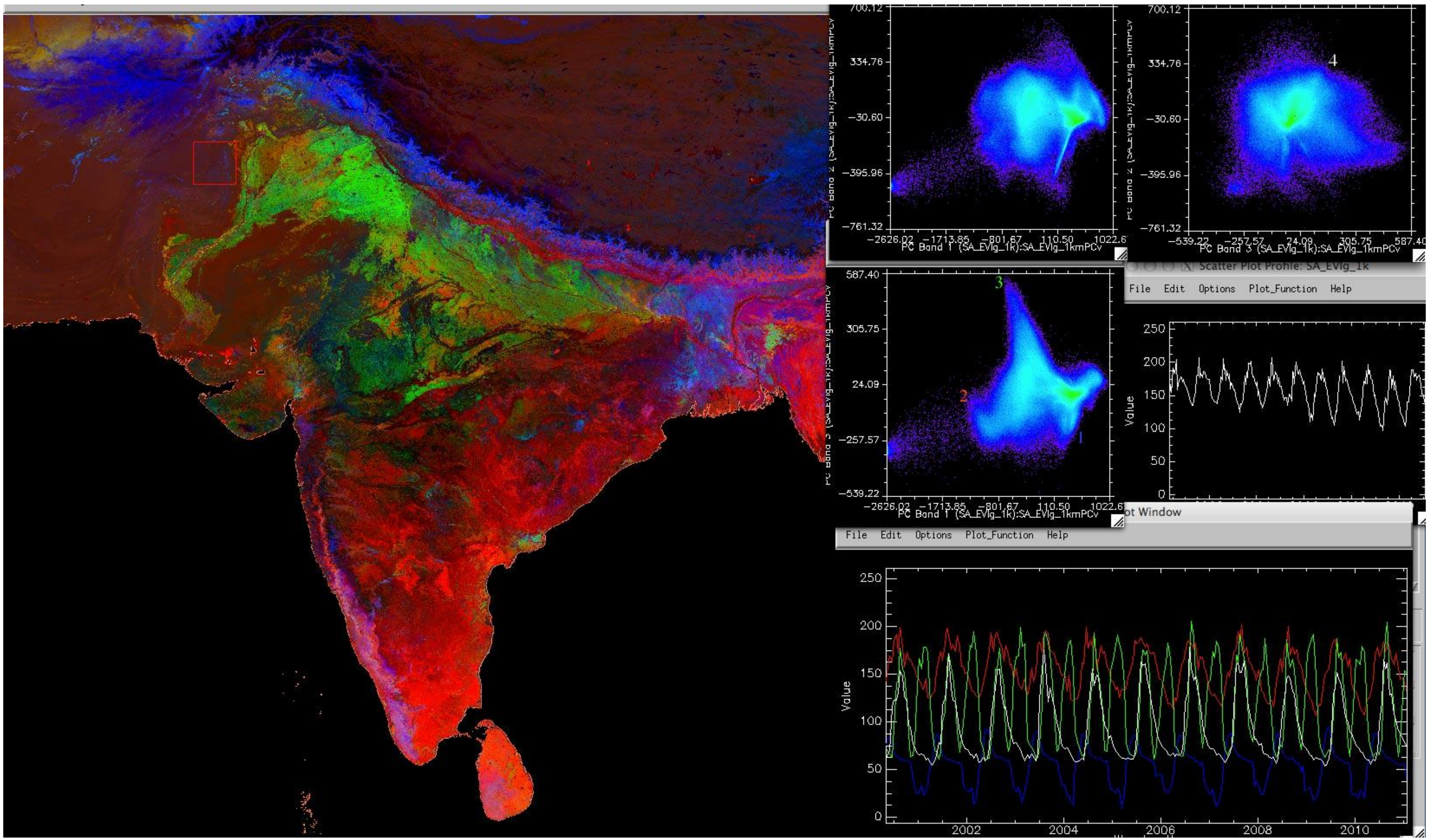


Table 5. The performance of each of our four methods based on the four criteria we use to assess our models: accuracy of method, data availability, ease of use, and ability to use over large spatial scales. Each method is ranked as *high* (highest rank), *moderate, or low* (lowest rank) for each of these four criteria. Calibration data refer to Quickbird, Worldview-2, or Landsat imagery. Considering the ability to use the method over large areas, mosaic is defined as whether Landsat mosaics are required for analysis and calibration data required suggests that some high resolution or Landsat data must be available to calibrate the model

Method	Accuracy		Data Availability		Ease of use		Ability to use over large areas	
	R^2 Range	Rank	Data Required	Rank	Technique	Rank	Mosaic/ Calibration data required	Rank
Landsat	0.71 – 0.97	High	Landsat	Low	Threshold	High	Yes/Yes	Low
MODIS Peak	0.00 – 0.95	Low	Calibration data, MODIS	Moderate	Count peaks, Threshold	Moderate	No/Yes	Moderate
TMA	0.01 – 0.60	Low	MODIS	High	Temporal mixture analysis	Low	No/No	High
Hierarchical	0.16 – 0.97	Moderate	Calibration data, MODIS	Moderate	Calibrate EVI value	Moderate	No/Yes	Moderate

(Jain et al., submitted)

Scale up to continent with Temporal Mixture Analysis



How are the patterns and variability in cropping intensity related to climate variability in India?

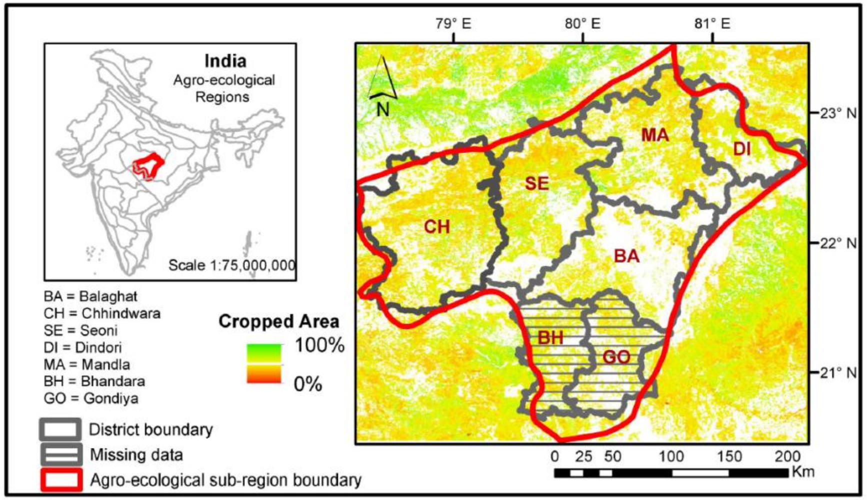


Figure 1. Study region covering five districts in central India. Two districts from Maharashtra (Bhandara and Gondiya) were excluded from final analyses due to missing irrigation data.

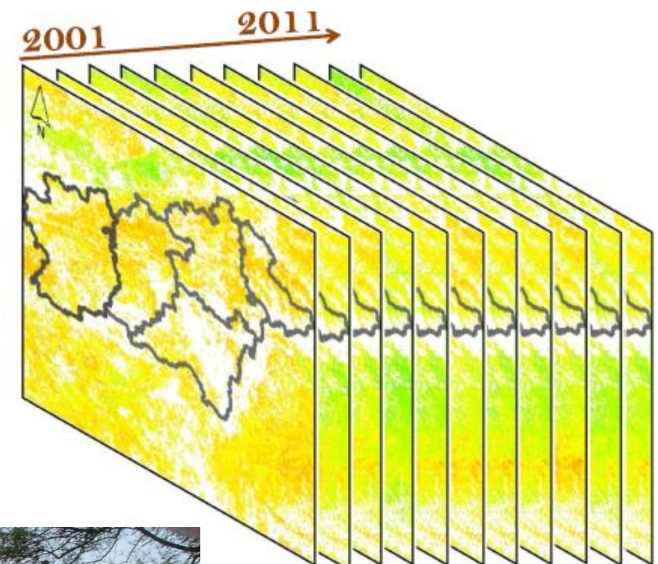
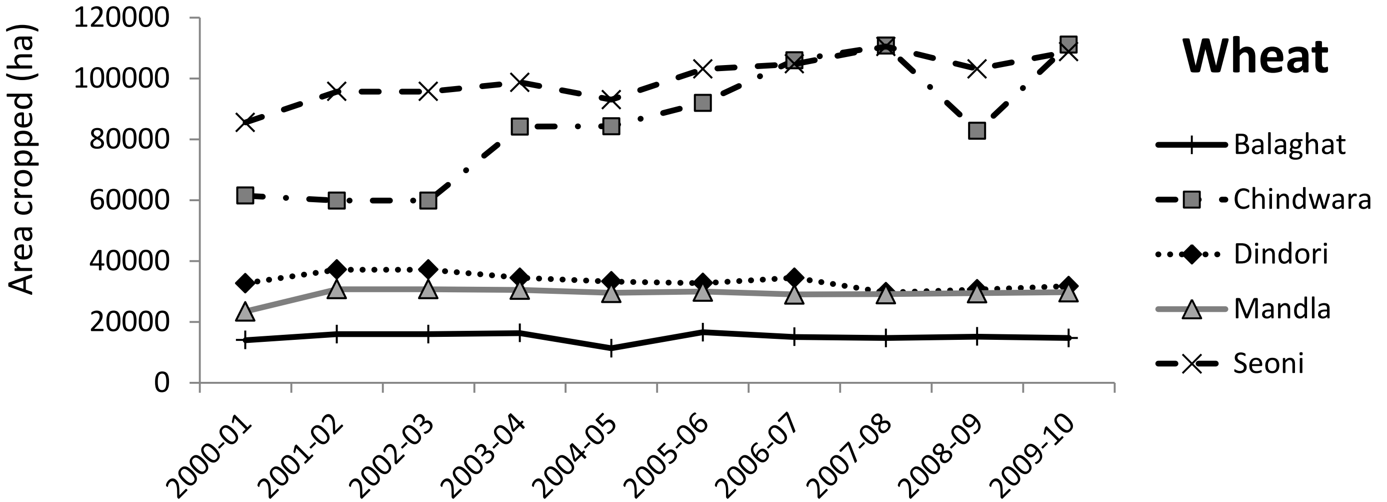
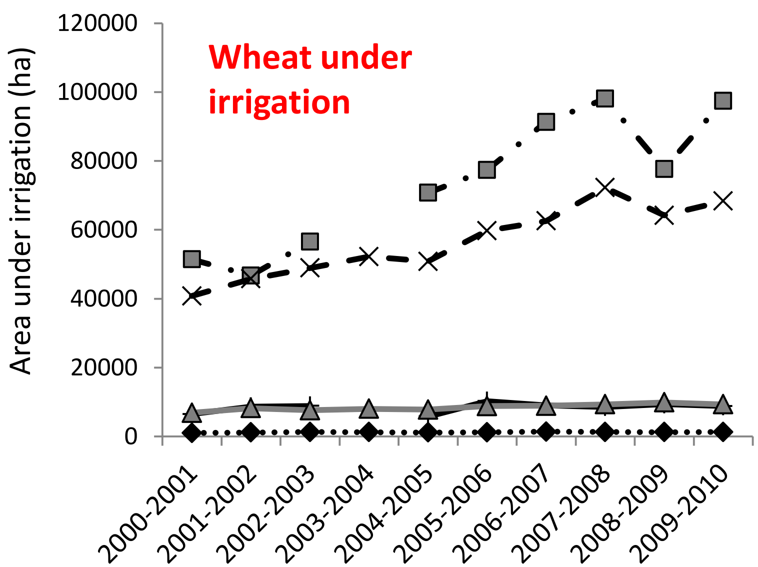


Figure 3. Time-series of winter crop (fraction area cropped) as response variable.

(Mondal et al., in prep)

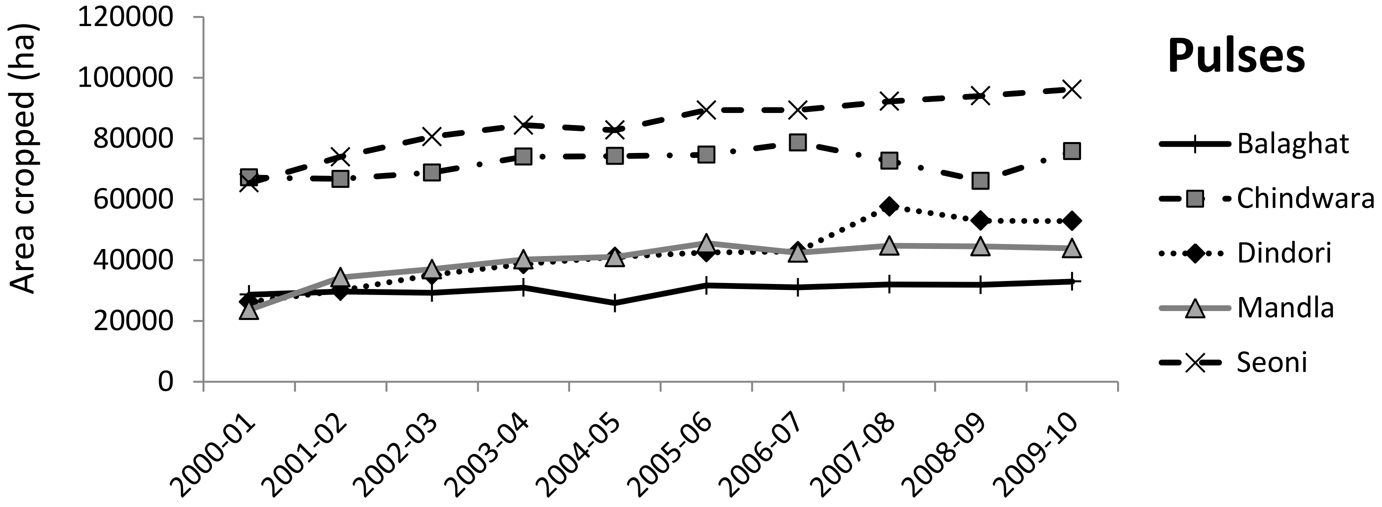
Wheat area

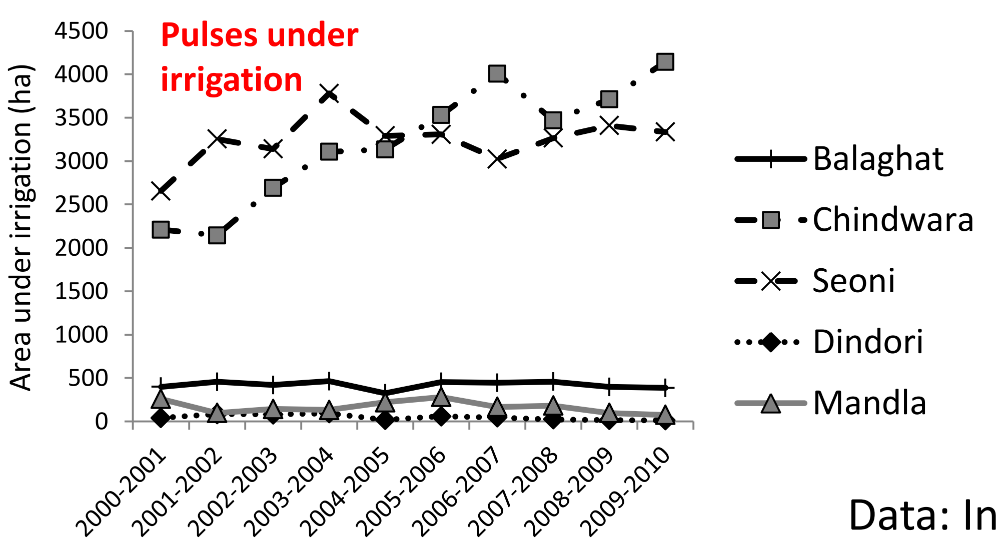




Data: Indian agricultural census

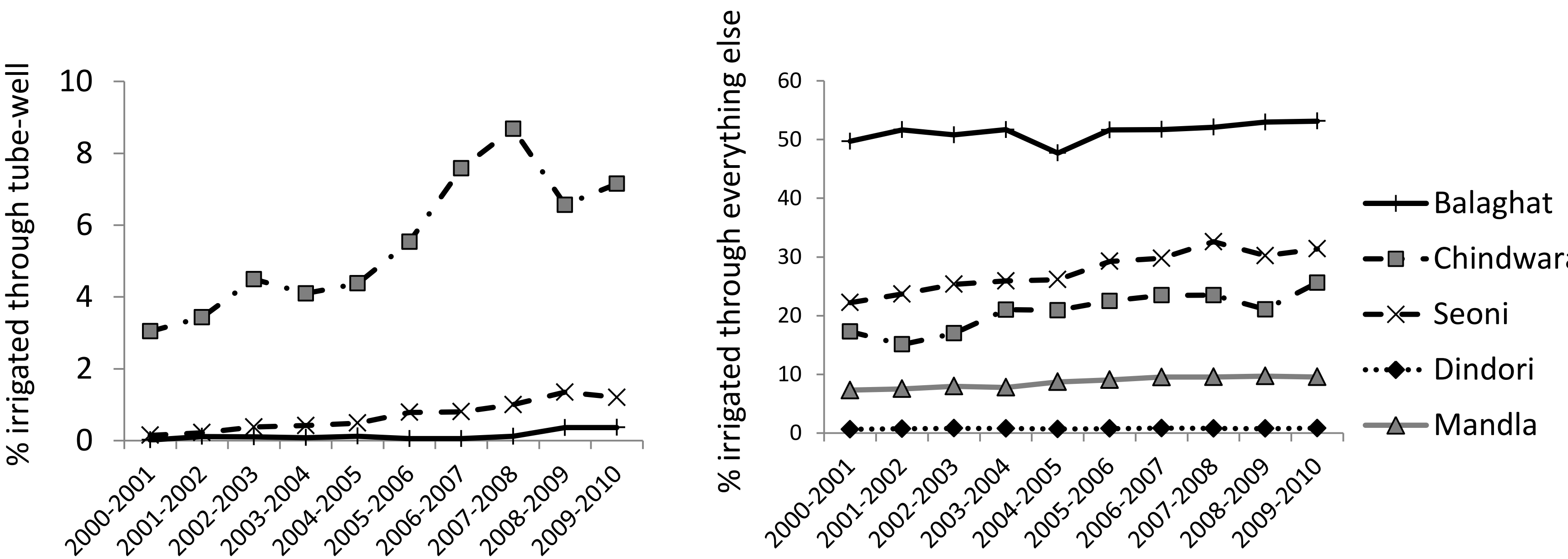
Pulse area





Data: Indian agricultural census

Irrigation sources



Data: Indian agricultural census

Model results for predicting winter crop from climate variables

Coefficients:

	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	0.491028	0.005507	89.167	< 2e-16 ***
Monsoon end date	0.037966	0.012216	3.108	0.003612 **
Winter rainy days	0.051737	0.011985	4.317	0.000114 ***
Monsoon intensity	0.018233	0.011244	1.622	0.113391
Monsoon dry days	-0.018749	0.012156	-1.542	0.131487
Mean winter temp	-0.021877	0.012350	-1.771	0.084733 .
Tubes wells per area	0.025655	0.011344	2.262	0.029694 *

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.03544 on 37 degrees of freedom

Multiple R-squared: 0.6632, **Adjusted R-squared: 0.6086**

F-statistic: 12.14 on 6 and 37 DF, p-value: 1.671e-07

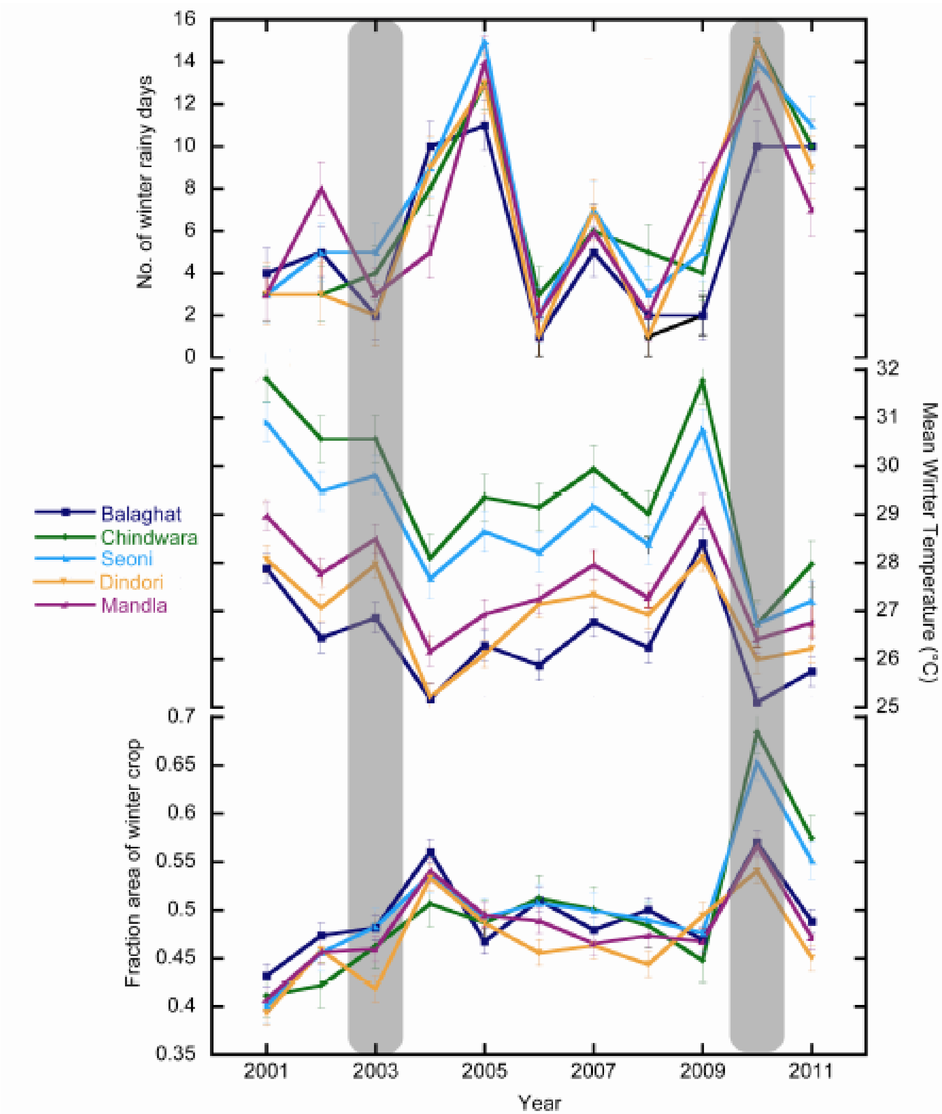
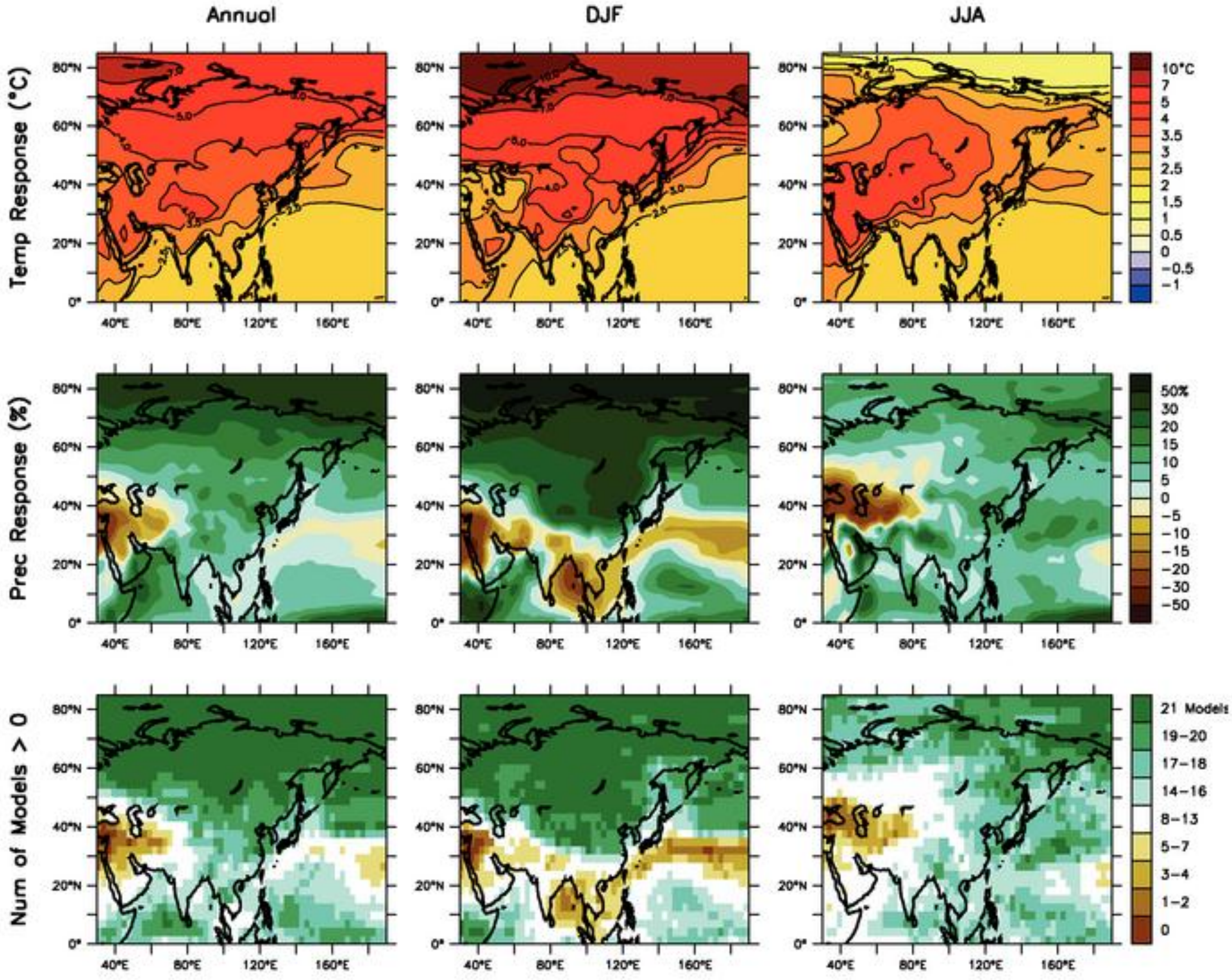


Figure 4. ***Relationship between time-series of response variable (fraction area of winter crop) and two of the predictor variables with high variable importance values (no. of winter rainy days and mean winter temperature). Two contrasting years in terms of winter crop prevalence are highlighted.***

❖ Approximately 60% variance in winter crop prevalence can be explained by the coupled effects of number of winter rainy days, monsoon withdrawal, tube-well irrigation, mean winter temperature, and monsoon intensity.

(Mondal et al., in prep)

Vulnerability to future climate in 21st century



IPCC, 2007

Preliminary Conclusions

- “Best” method to map cropping intensity depends on scale of results required
- Climate variables correlated with winter crop suggest future vulnerability
- Climate-dependent irrigation vulnerable
- Next steps scale to continent and incorporate agriculture and socioeconomic census data to assess vulnerability of winter crop to climate change


THANKS

END MEMBER PHENOLOGIES FROM MODIS