50 Years of Remote Sensing in India

Wheat Yield Mapping and Prediction: Empirical to Simulation Modelling using RS

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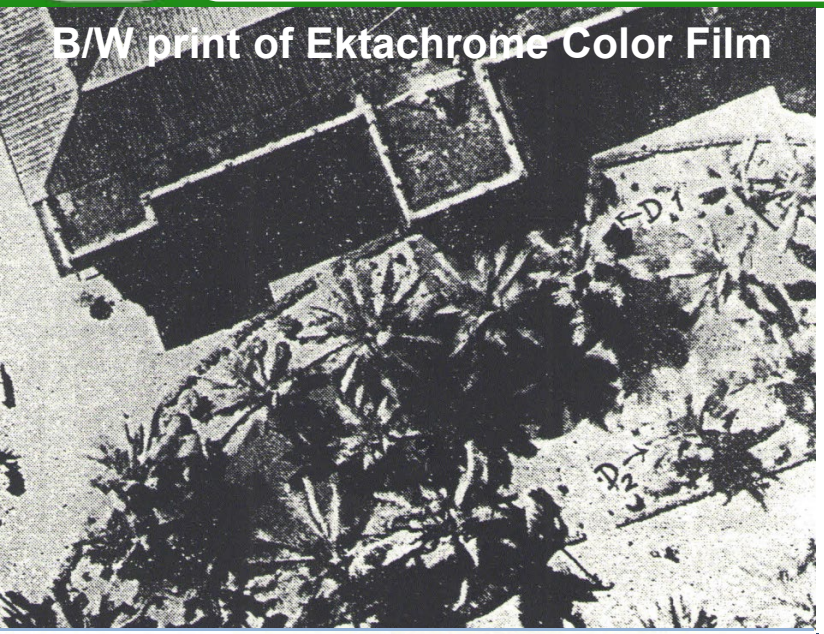
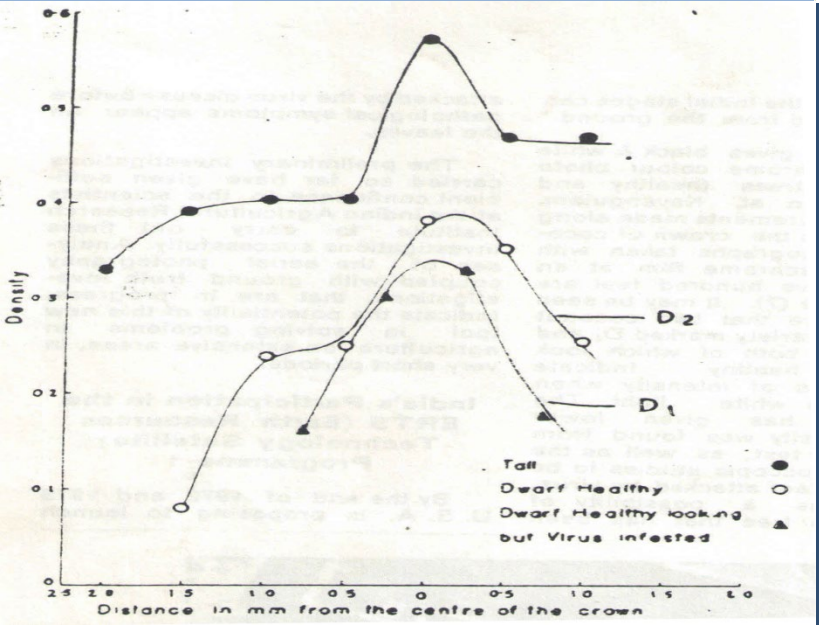
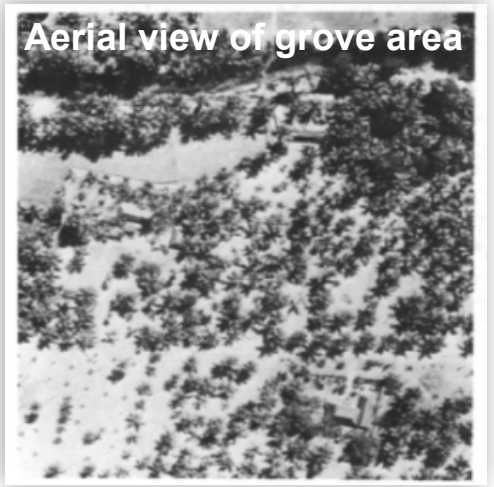
http://creams.iari.res.in

First RS Expt in India
Coconut Root Wilt Disease Detection







Experimental Details:

- NASA-ISRO-IARI-CCRS Collaboration
- 1969-70
- CRW disease caused by virus
- Aim to identify diseased pockets and intensity of disease to check its spread
- Multi-band images acquired at 500 & 1000 feet from an helicopter
- Distinguished diseased palms from healthy
- Distinguished one species from another
- **Possibility of identifying infected palms before pathological symptoms appear**

Contents

- Need for Yield Mapping and Prediction
  - For food security planning
  - For crop insurance payouts
- Approaches of yield modelling by Satellite Images
  - Historical Yields
    - Generate synthetic yield series
    - Spatial disaggregation of yield statistics
  - In-season Yields
    - Empirical : Single / Multi-date RS
    - Linking RS with Dynamic Crop Models
- Operational System – Convergence of Evidence

Why Remote Sensing for Crop Yield Modeling?

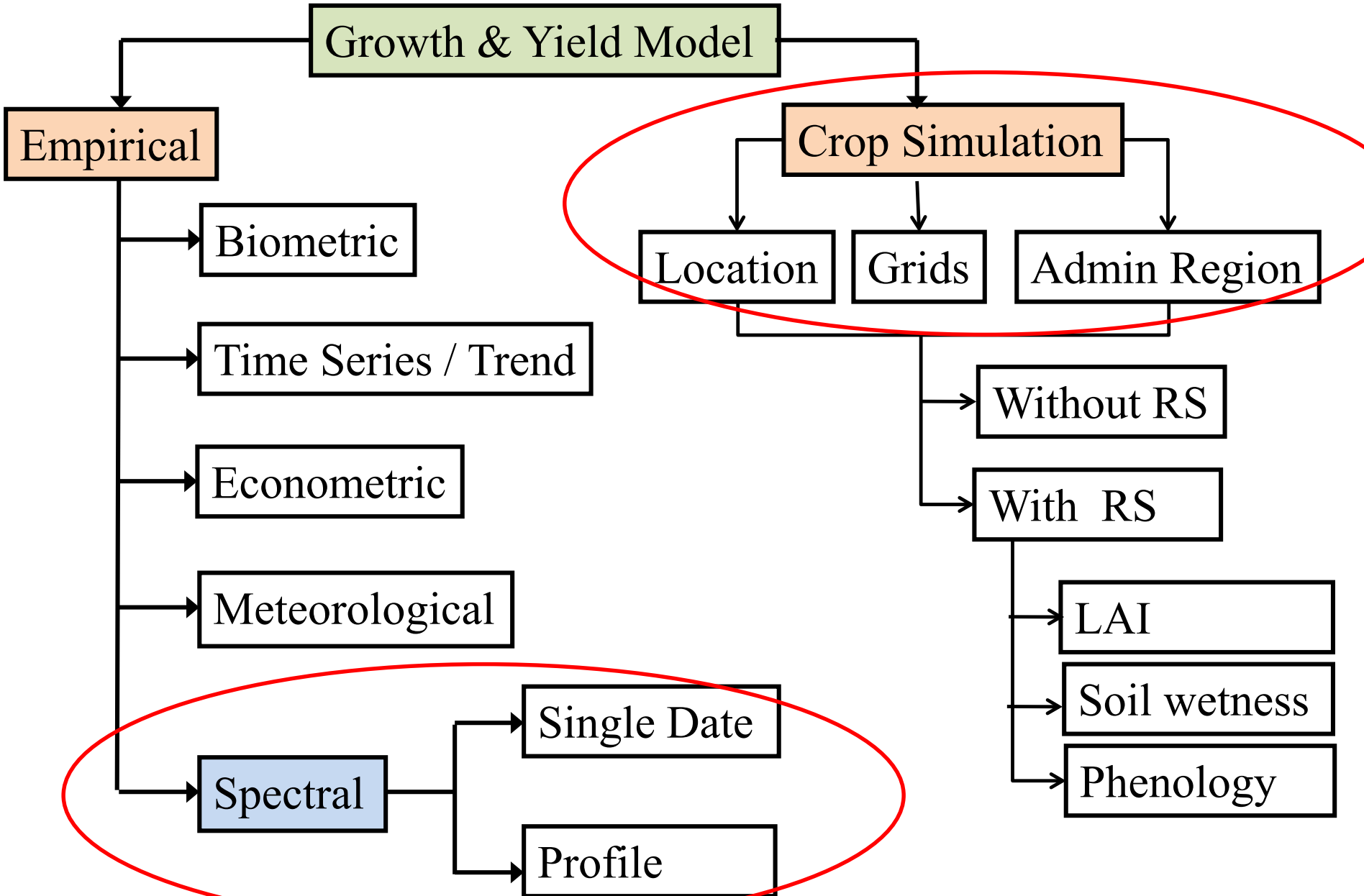
PROS

- Range of Spatial / Spectral Resolutions – field scale to regional scale
- Repetitive – for regular monitoring
- Indices directly observe crop vigour – sound scientific basis
- Observe crop environment – Rainfall, Temperature, Soil moisture, ...
- Digital – amenable to computer algorithms, objectivity, sharing, storage
- Low cost per unit area
- Multiple sources and historical standardized datasets

CONS

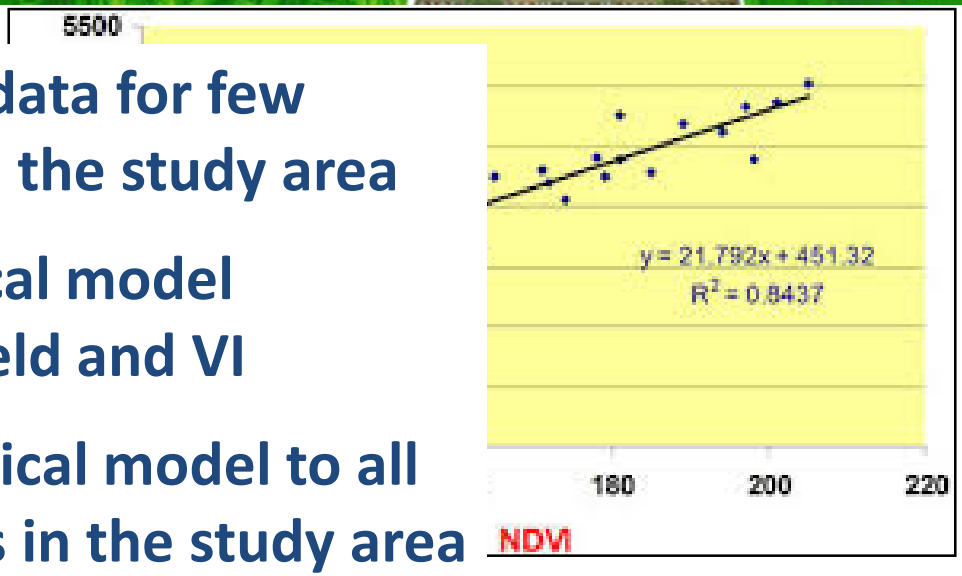
- Not directly measure crop yield
- Difficult to observe crop during early growth stages
- Greenness / vigour and yield may be poorly related for some crops
- Crop signatures are not unique - Heterogeneity
- Noise in data – viewing condition, cloud cover, haze
- Specialized software and analyst requirement

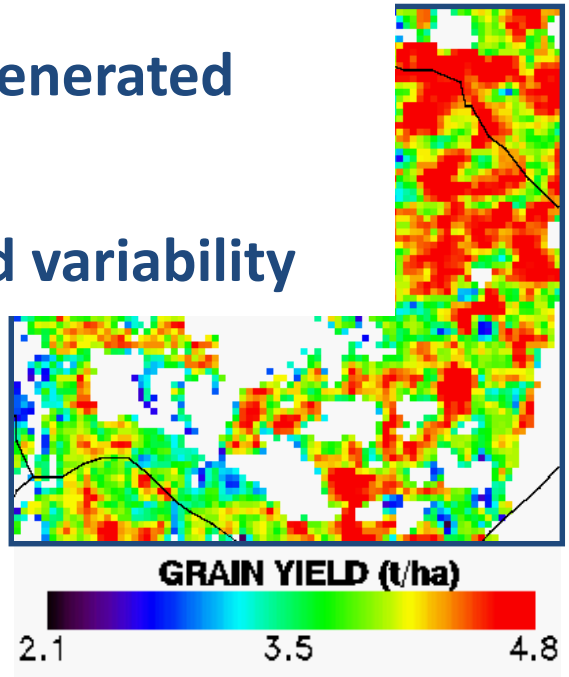
Broad Yield Modeling Approaches



Empirical Single Date Model Wheat

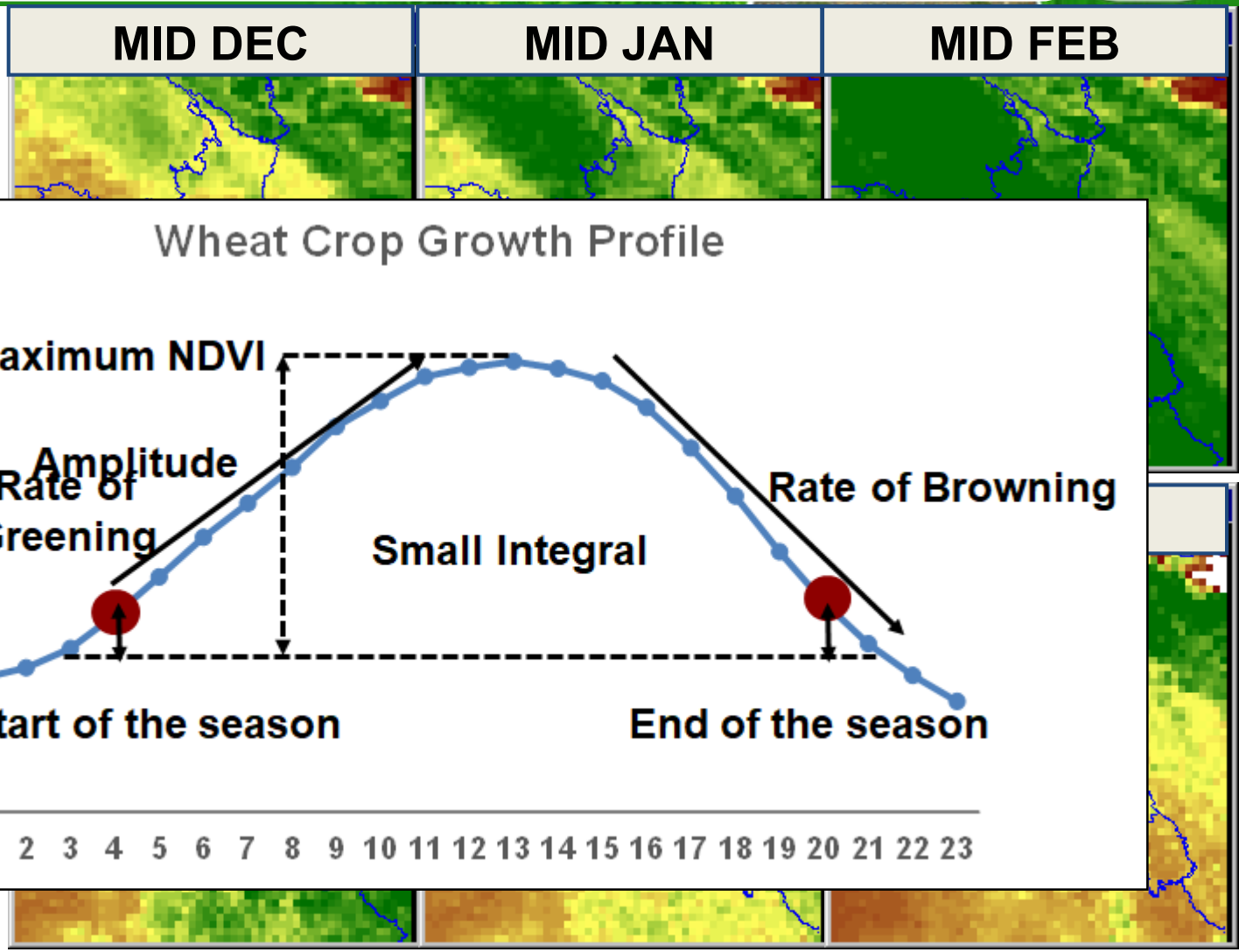
- Need CCE yield data for few selected plots in the study area
- Develop empirical model between CCE yield and VI
- Apply the empirical model to all other crop fields in the study area
- Model need to be generated every year
- 20-30% unexplained variability



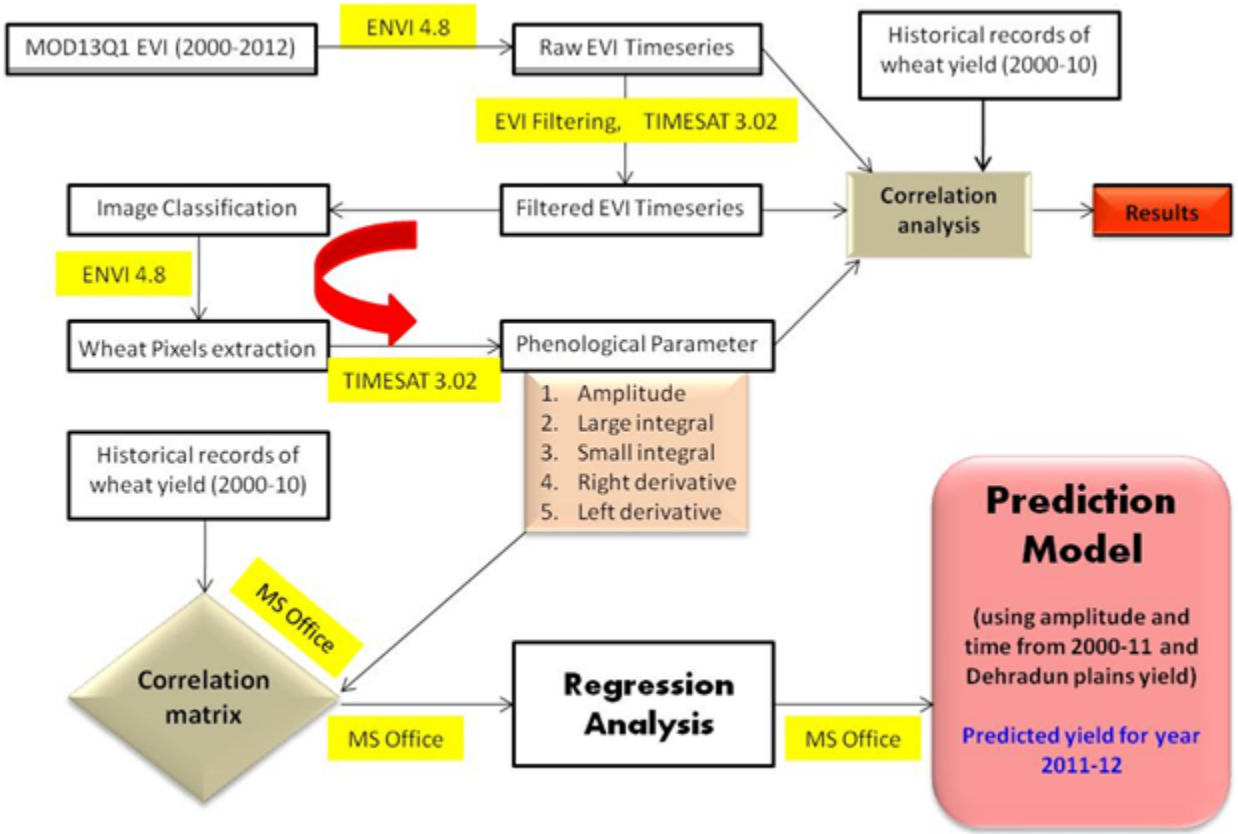


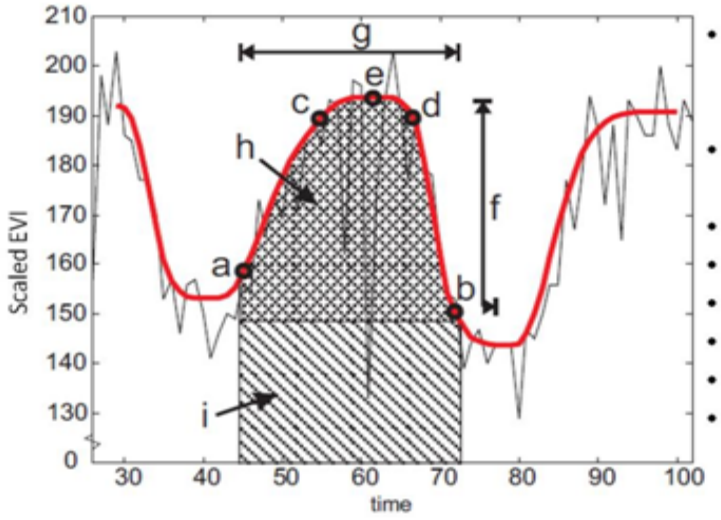
Empirical Multi Date Model : Wheat

- Use moderate to coarse resolution images
- Higher revisi satellite
- Need to filte RS data for r
- Fit a growth model
- Derive paran from profile
- The paramet shows integr seasonal growth
- Better relate to yield

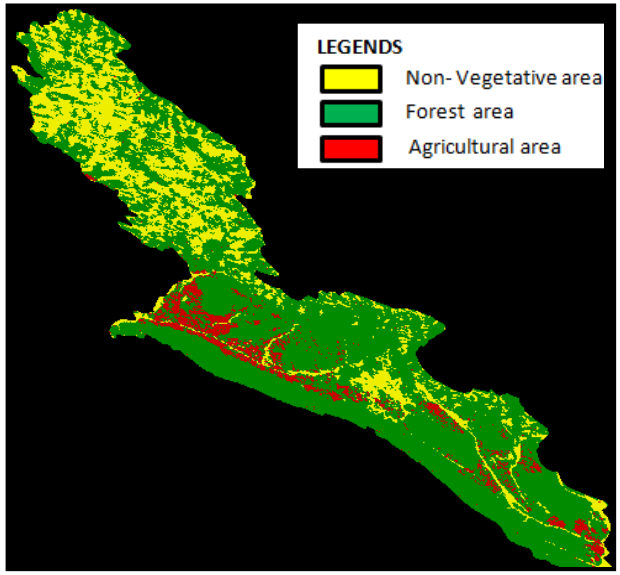


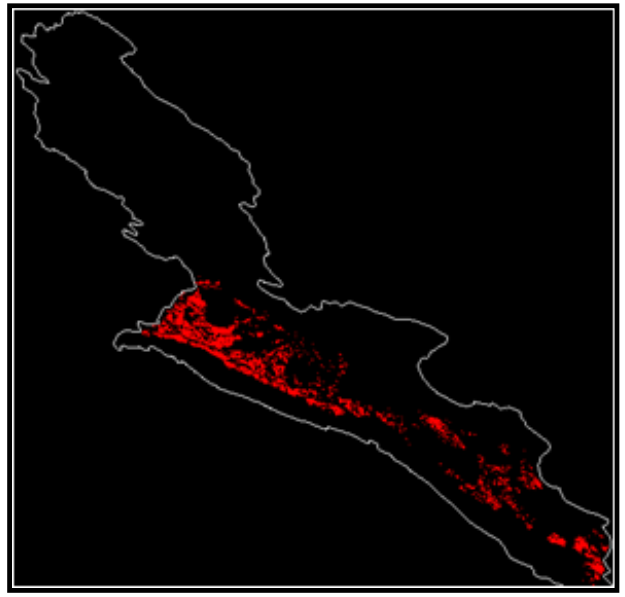
Wheat Crop Yield Modeling



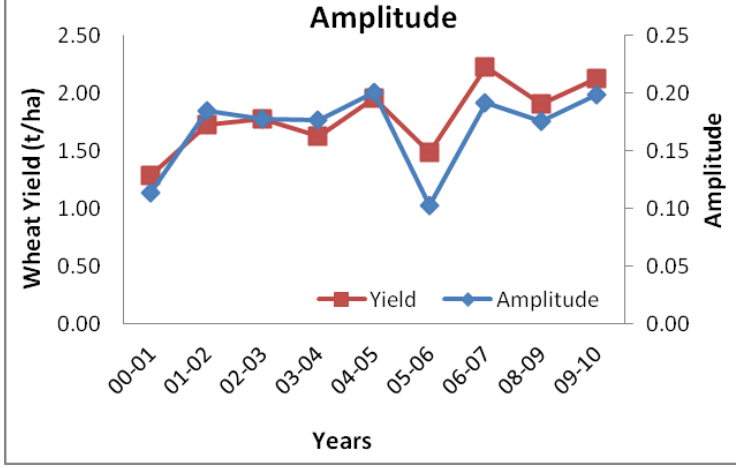


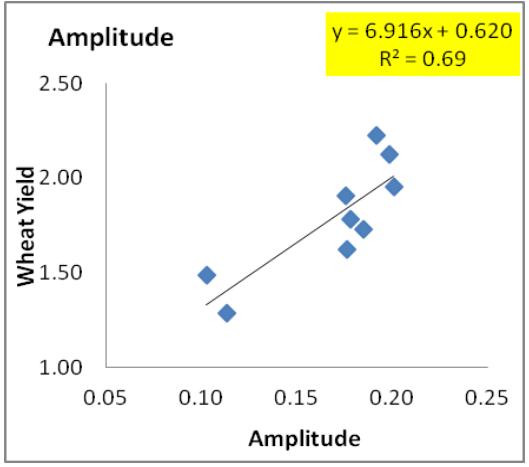
- Points (a) and (b) mark, respectively, start and end of crop season
- Point (e) shows the time of peak growth
- (f) shows the amplitude
- (g) shows the length of season
- slope of line ac is left derivative
- slope of line db is right derivative
- (h) is small integral
- (i) is large integral

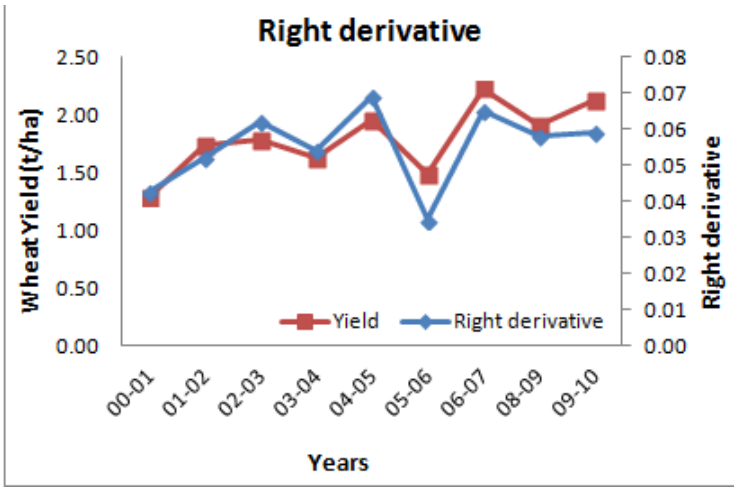


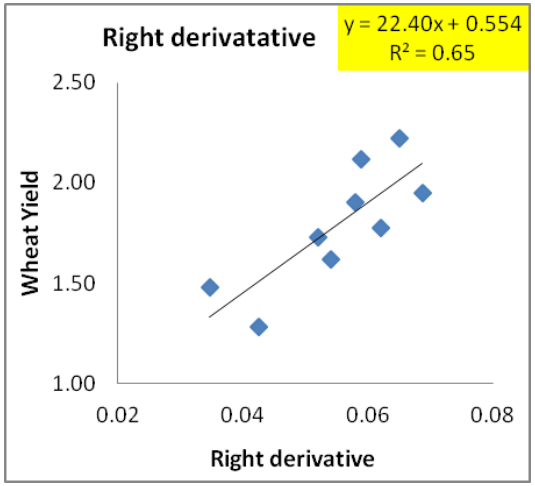


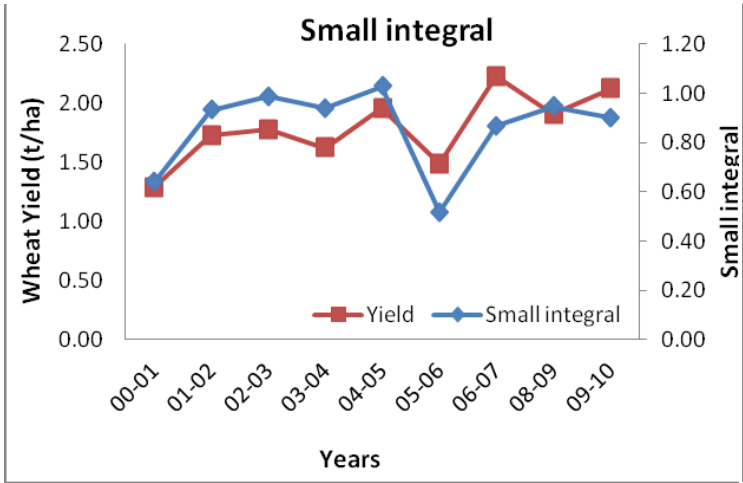
Dehradun District

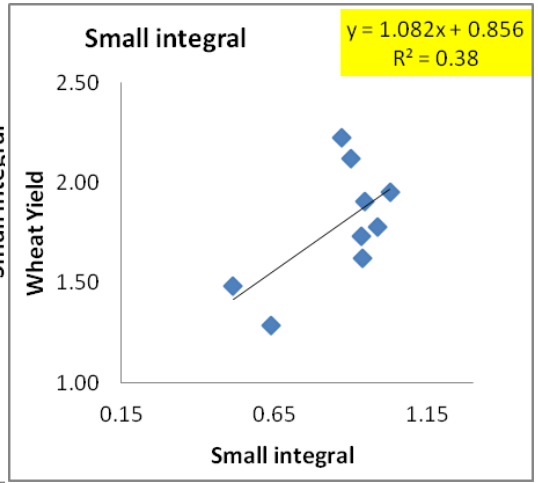

Amplitude
Wheat Yield (t/ha)
Amplitude
Yield
Amplitude
00-01
01-02
02-03
03-04
04-05
05-06
06-07
08-09
09-10
Years


Amplitude
y = 6.916x + 0.620
R² = 0.69
Wheat Yield
Amplitude

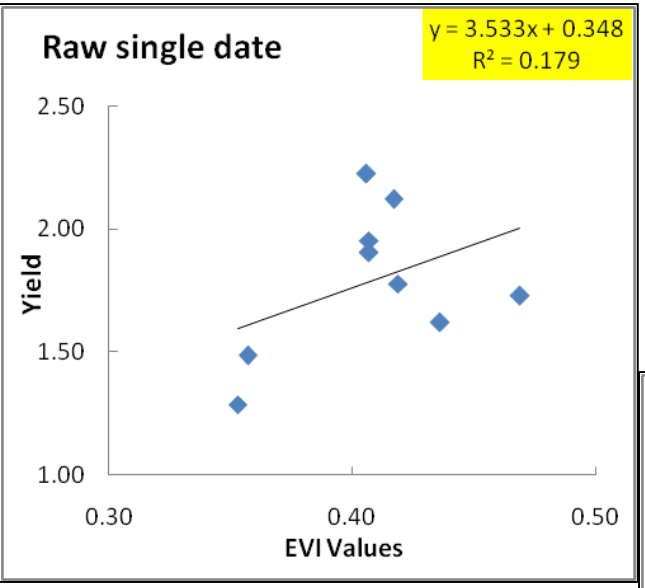

Right derivative
Wheat Yield(t/ha)
Right derivative
Yield
Right derivative
00-01
01-02
02-03
03-04
04-05
05-06
06-07
08-09
09-10
Years

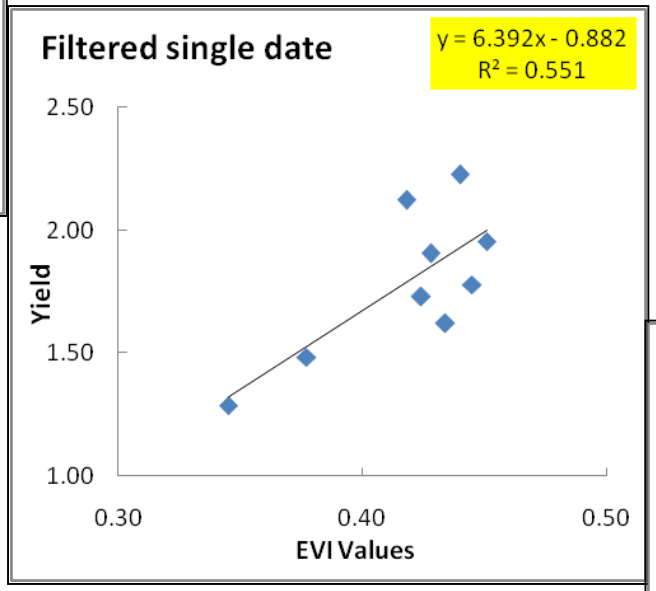

Right derivatative
y = 22.40x + 0.554
R² = 0.65
Wheat Yield
Right derivative

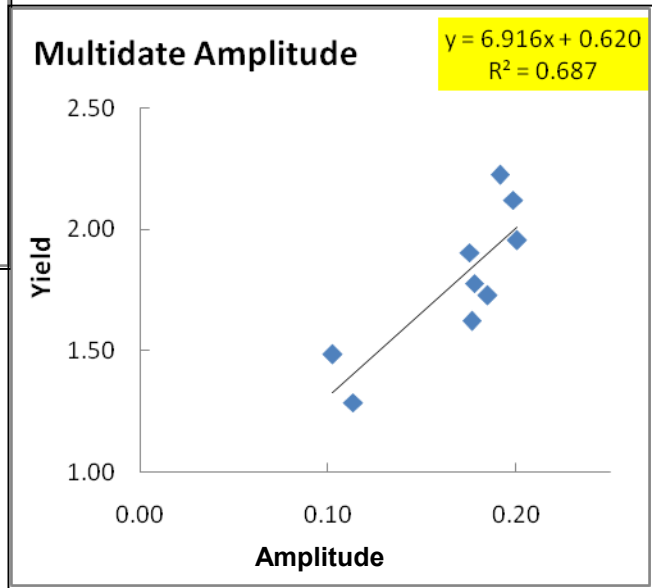

Small integral
Wheat Yield (t/ha)
Small integral
Yield
Small integral
00-01
01-02
02-03
03-04
04-05
05-06
06-07
08-09
09-10
Years


Small integral
y = 1.082x + 0.856
R² = 0.38
Wheat Yield
Small integral

Comparison between single date raw, filtered and multi-date phenology derived parameter

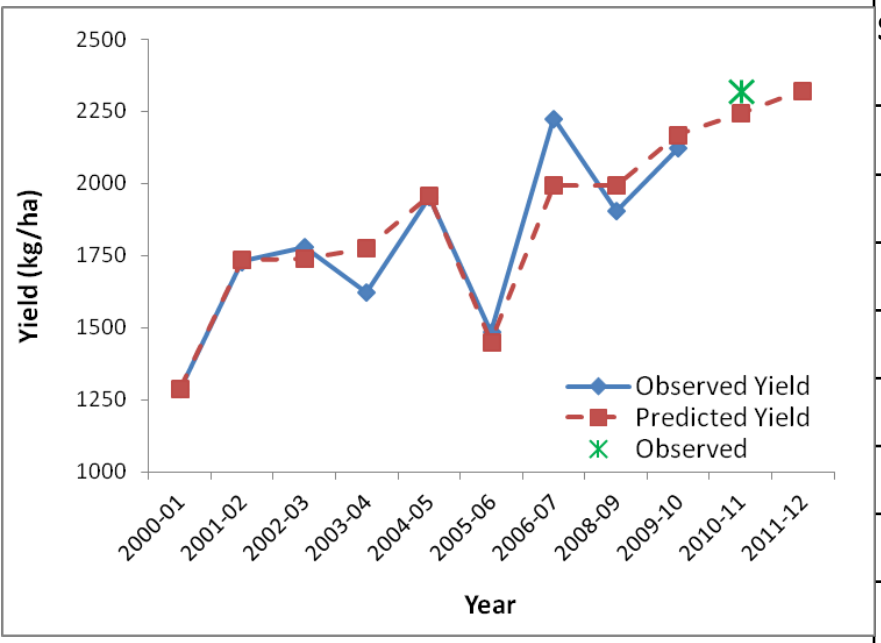






Performance of Crop Yield Model

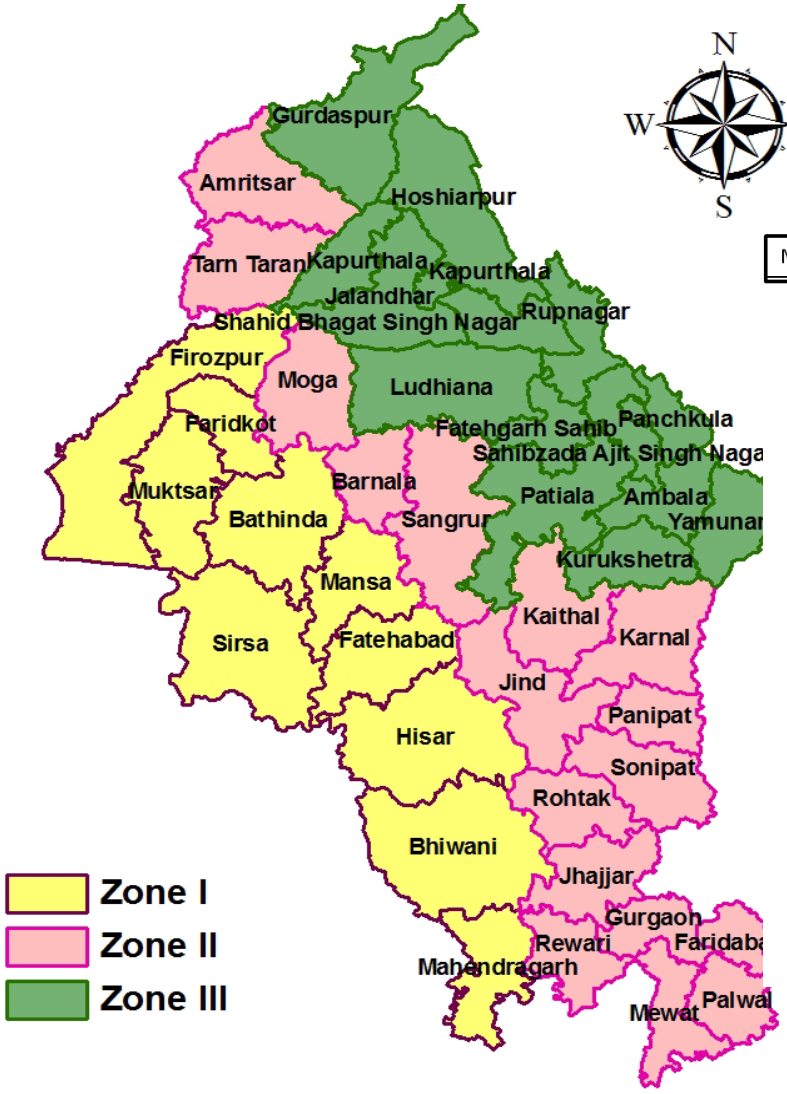
Yield = 607.23 + 5614.9*Amplitude + 44.72 * Time
(Adj R^2 = 0.83 (p=0.002), SE = 123.0)

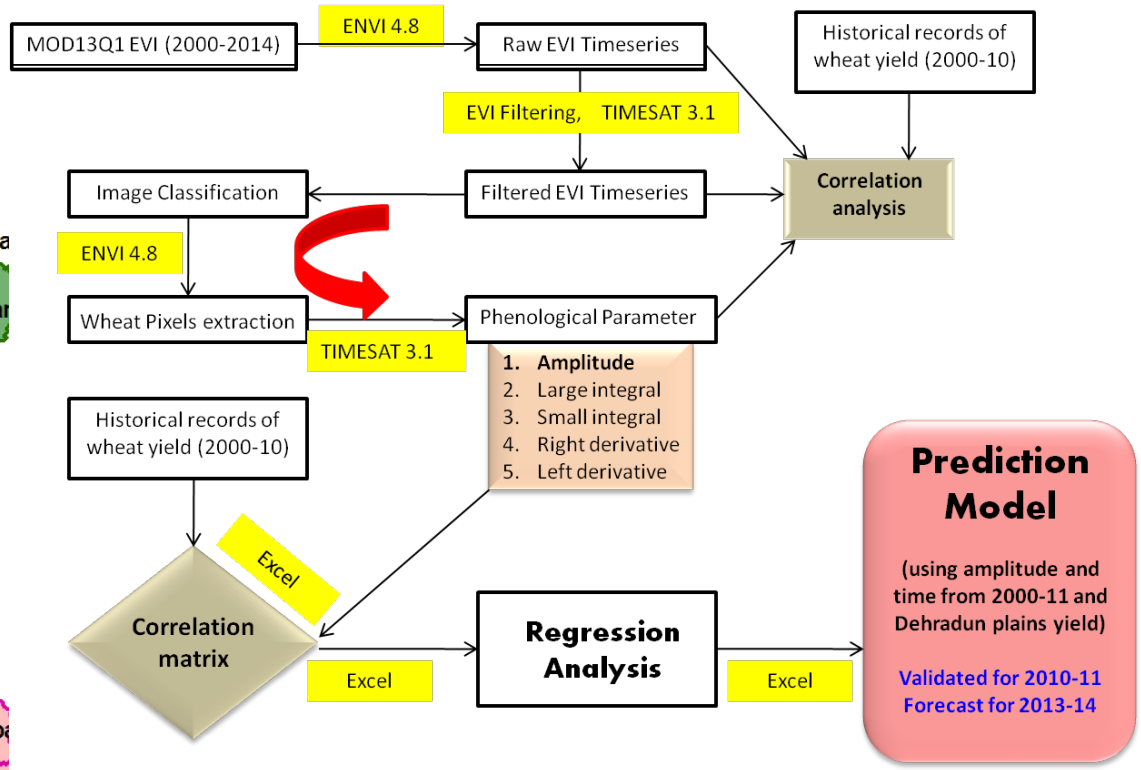


S. No.	Year	DAC Yield (kg/ha)	Amplitude	Time	Predicted Yield (kg/ha)	Relative Deviation (%)
1	2000-01	1287.1	0.11	1	1289.0	0.15
2	2001-02	1729.6	0.19	2	1735.4	0.34
3	2002-03	1779.2	0.18	3	1740.3	-2.19
4	2003-04	1621.4	0.18	4	1776.6	9.57
5	2004-05	1954.0	0.20	5	1957.8	0.19
6	2005-06	1484.8	0.10	6	1450.5	-2.31
7	2006-07	2226.4	0.19	7	1995.0	-10.39
9	2008-09	1904.4	0.18	9	1994.6	4.74
10	2009-10	2121.8	0.20	10	2169.6	2.25
11	2010-11	---	0.20	11	2244.7	---
12	2011-12	---	0.21	12	2323.1	---

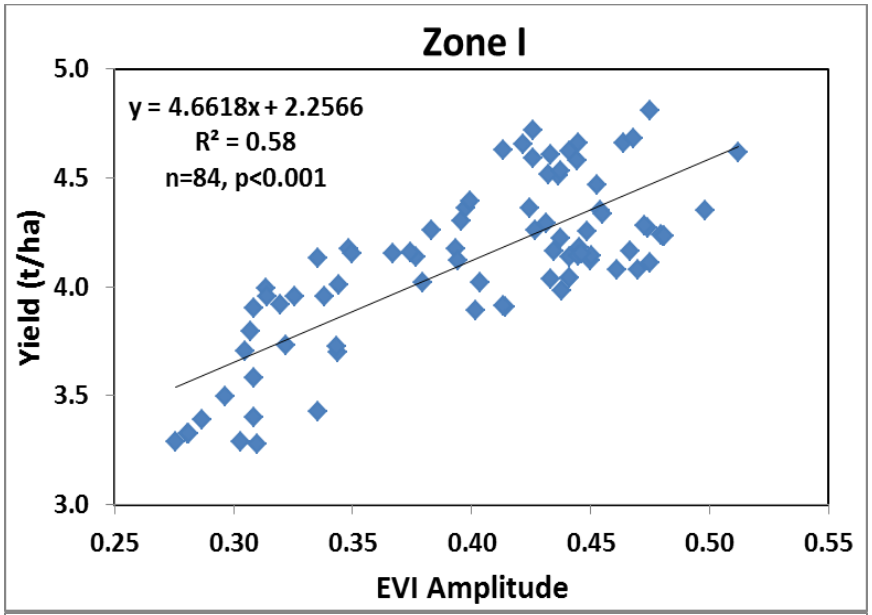
Wheat Yield Forecasting – Group of Districts

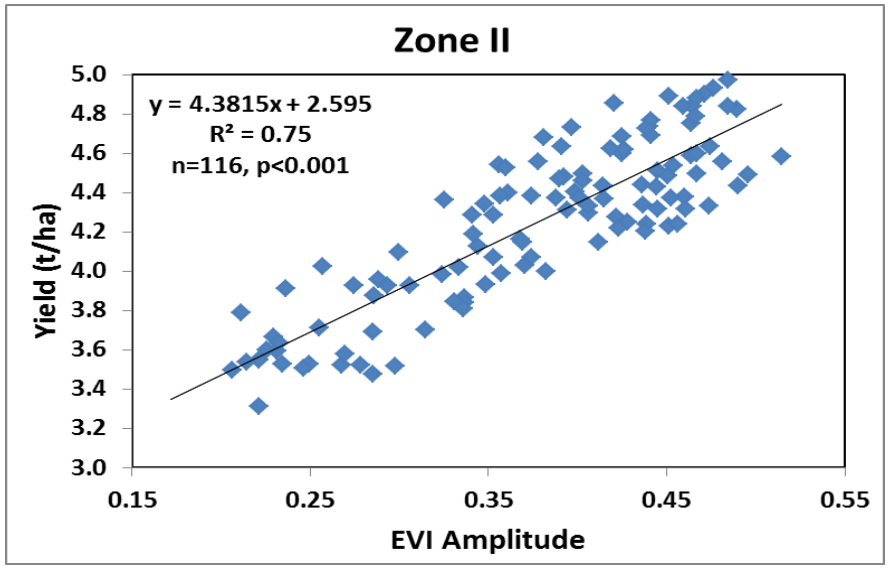
Punjab & Haryana Agro-ecoregions

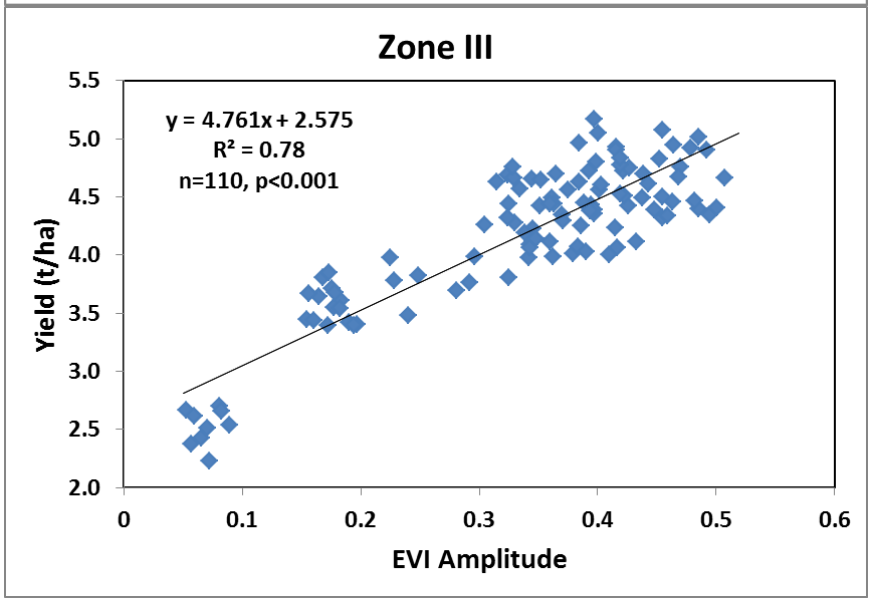




The Models and their Performance







Agro-ecological Sub region of Punjab & Haryana	Regression model developed from 2000-01 to 2009-10 yield data		Validation (with 2010-11 yield data)	
	R^2	No. of observations	RMSE (kg/ha)	Error as percentage of Zone (%)
Zone I	0.58	84	500	10.4
Zone II	0.75	116	510	11.0
Zone III	0.78	110	420	9.4

The Forecasts

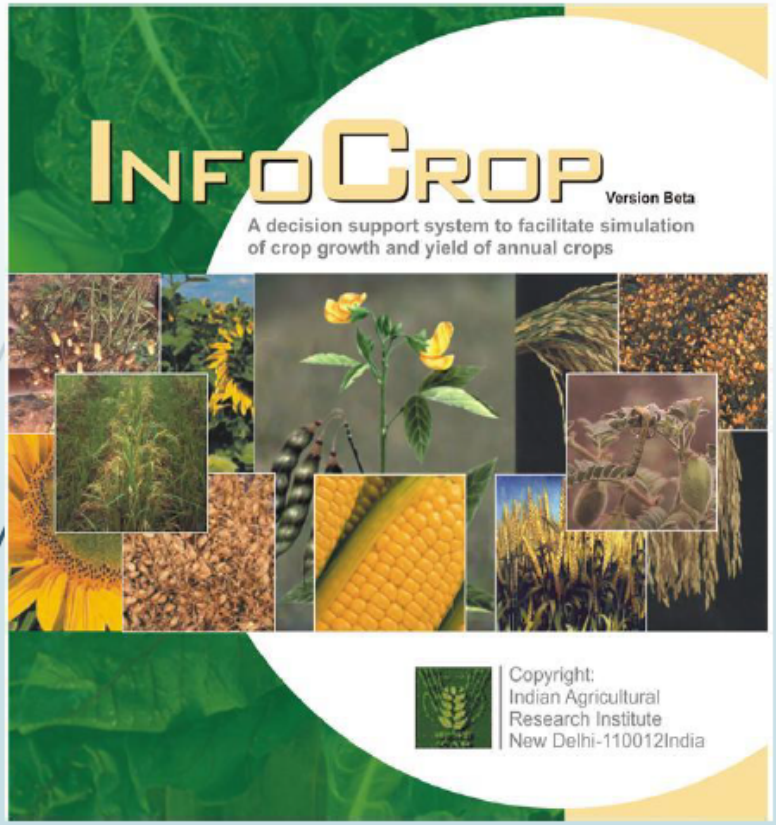
	Forecast for 2013-2014		Change over previous year		Estimates by State Dept		
	Production (M t)	Yield (t/ha)	Production (%)	Yield (%)	Production (M t)	Yield (t/ha)	**Error Yield (%)**
Punjab	16.97	4.84	+ 2.2	+ 2.3	17.62	5.01	**-3.4**
Haryana	11.48	4.59	+ 3.0	+ 2.9	11.80	4.72	**-2.75**

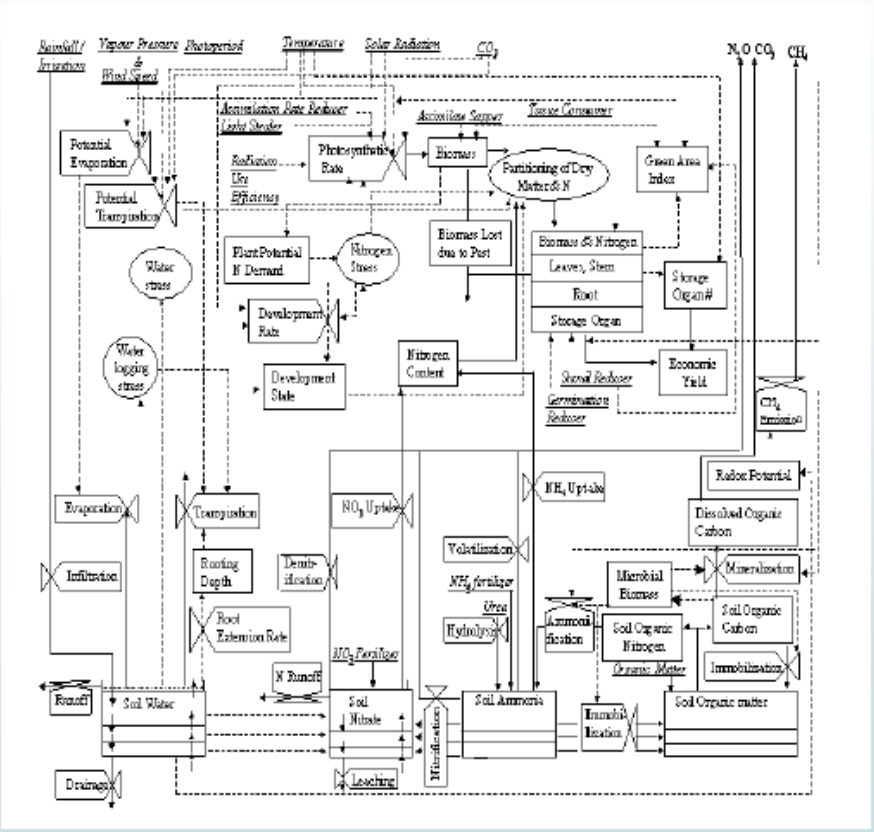
First Forecast

Used Satellite Data upto 20 March 2014.

Crop Simulation Model : InfoCrop

InfoCrop:
A User-friendly Crop Modelling System

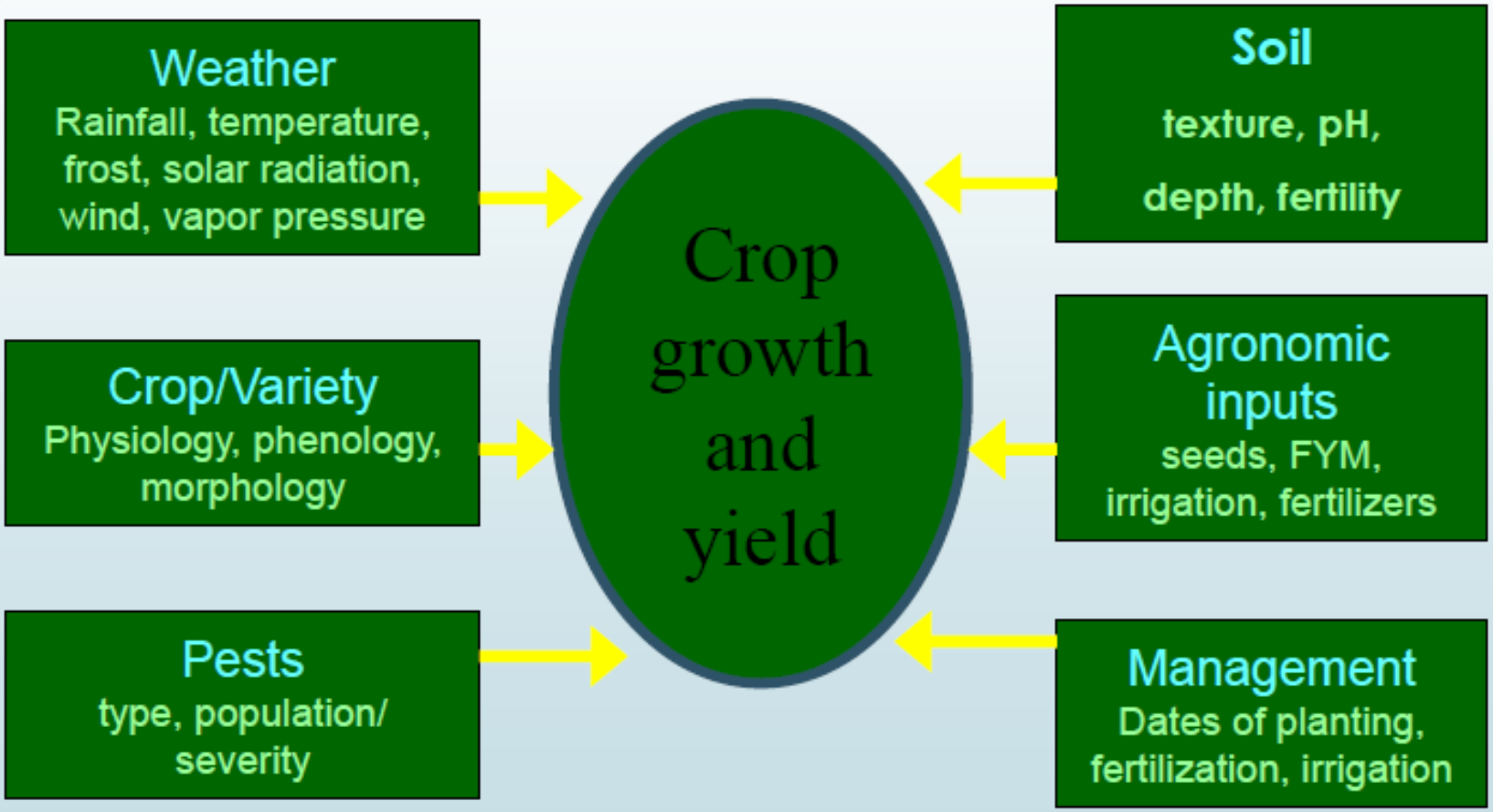




InfoCrop: Relational diagram

Crop Simulation Model : InfoCrop

InfoCrop: Simulates the Effect of Major Yield Regulating Factors



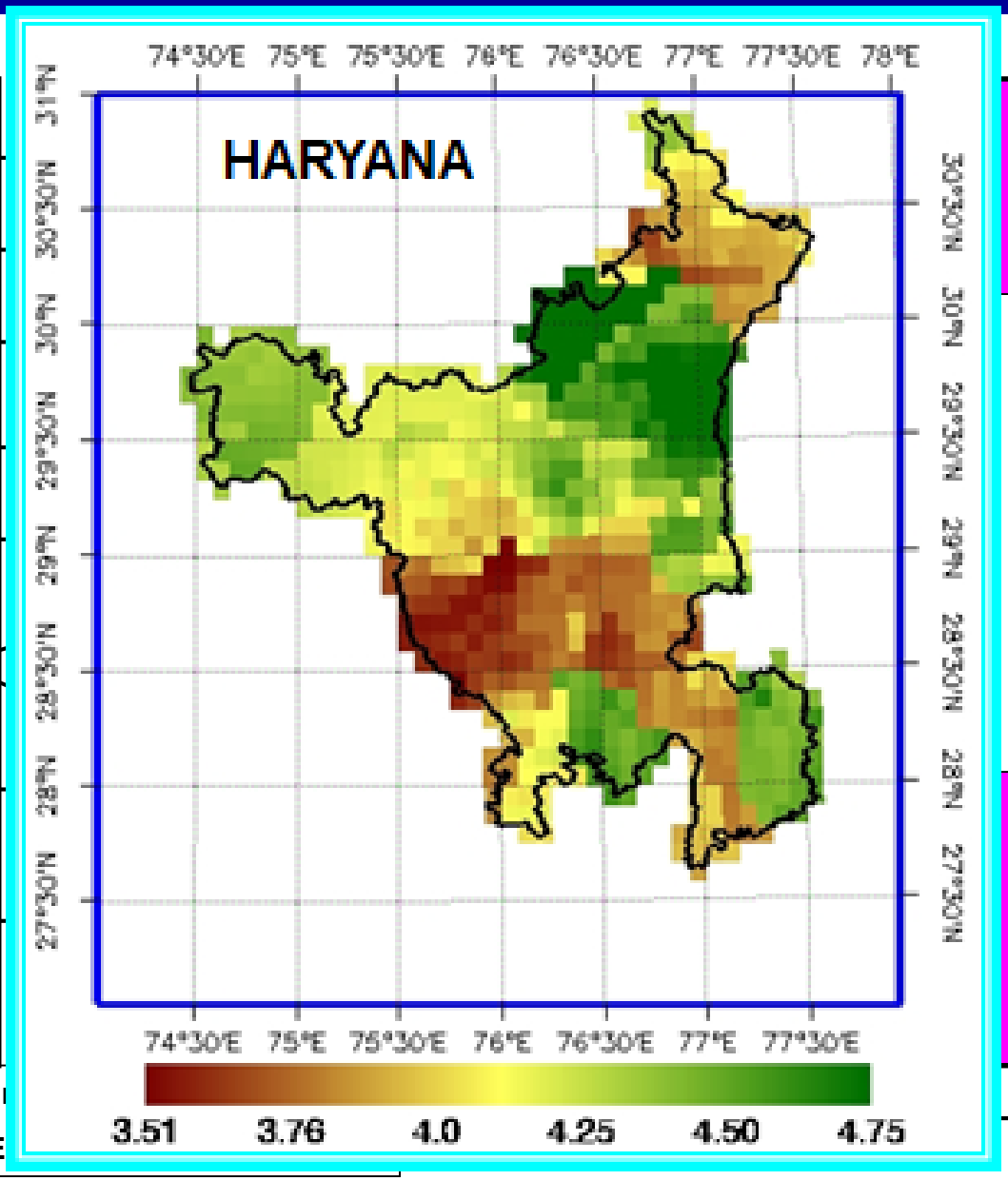
SCHEMATIC DIAGRAM OF CGMS

------ [INPUTS] -----

- STUDY AREA BOUNDS,GRID SIZE
- ADMINISTRATIVE BOUNDARY MAP
- RS DATA CLASSIFIED
- DAILY WEATHER DATA (POINTS)
- WEATHER CONSTANT
- SOIL MAP(NBSS&LUP)
- SOIL OC% (POINTS)
- DISTRICT-WISE CROP MANAGEMENT Cultivar, Sowing Date, Irrigation, Fertilizer

PTF – Pedo Transfer Fu

·····► Selection by SHE



[SIMULATION MODEL]

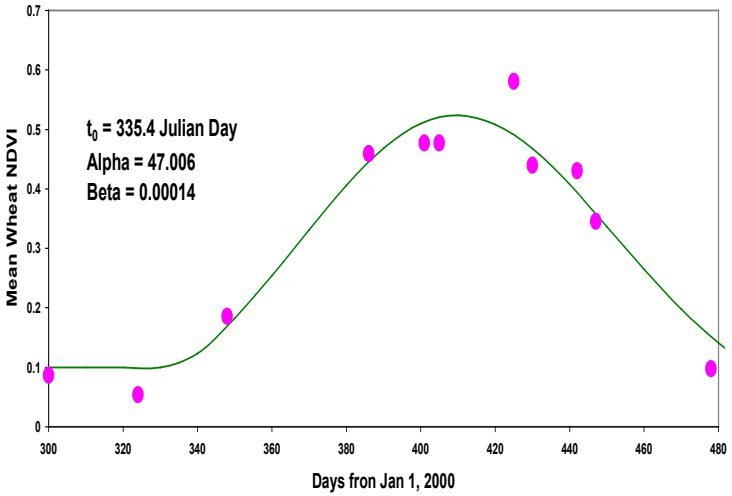
CROP SIMULATION MODEL (WTGROWS)

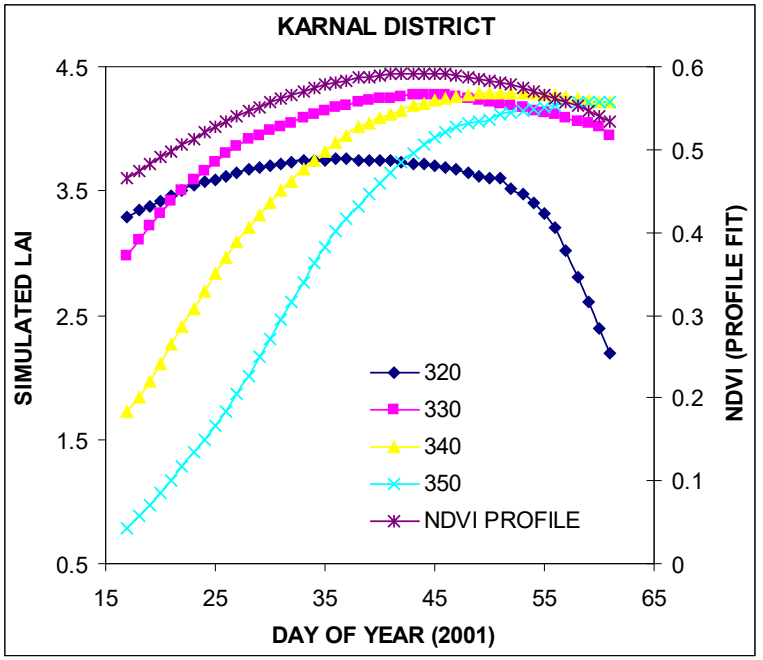
MODEL OUTPUT

DISTRICT-WISE AGGREGATED CROP YIELD

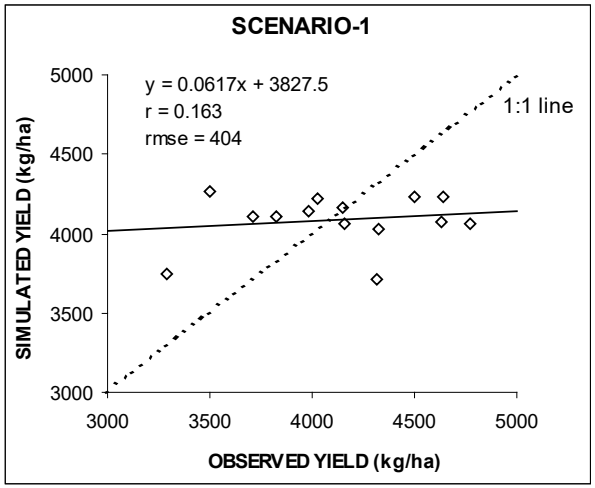
DEMONSTRATING RS-CGMS LINKAGE FOR PHENOLOGY

WiFS Profile

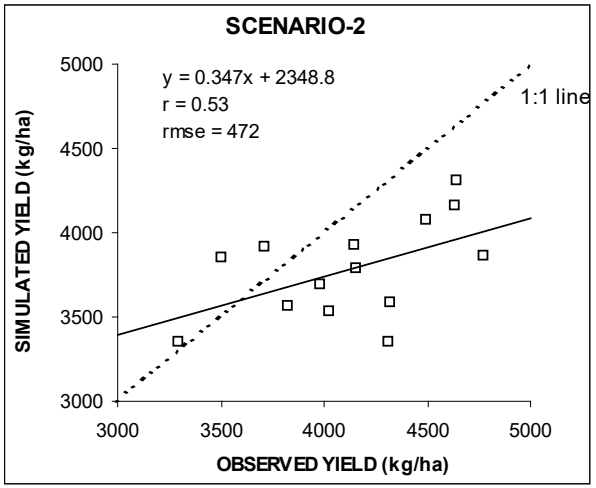




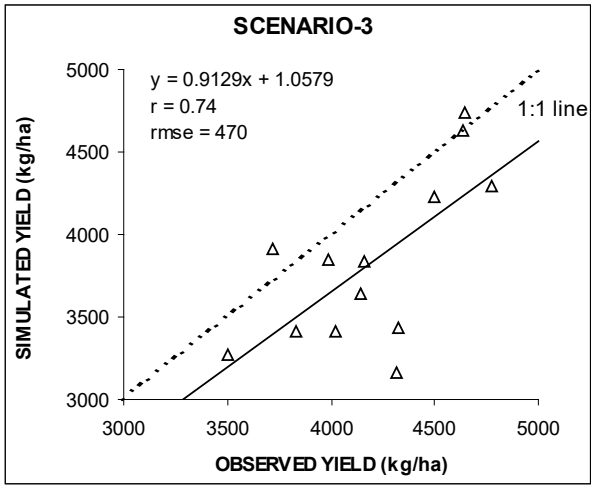
Fixed Inputs (DOS, I, N)



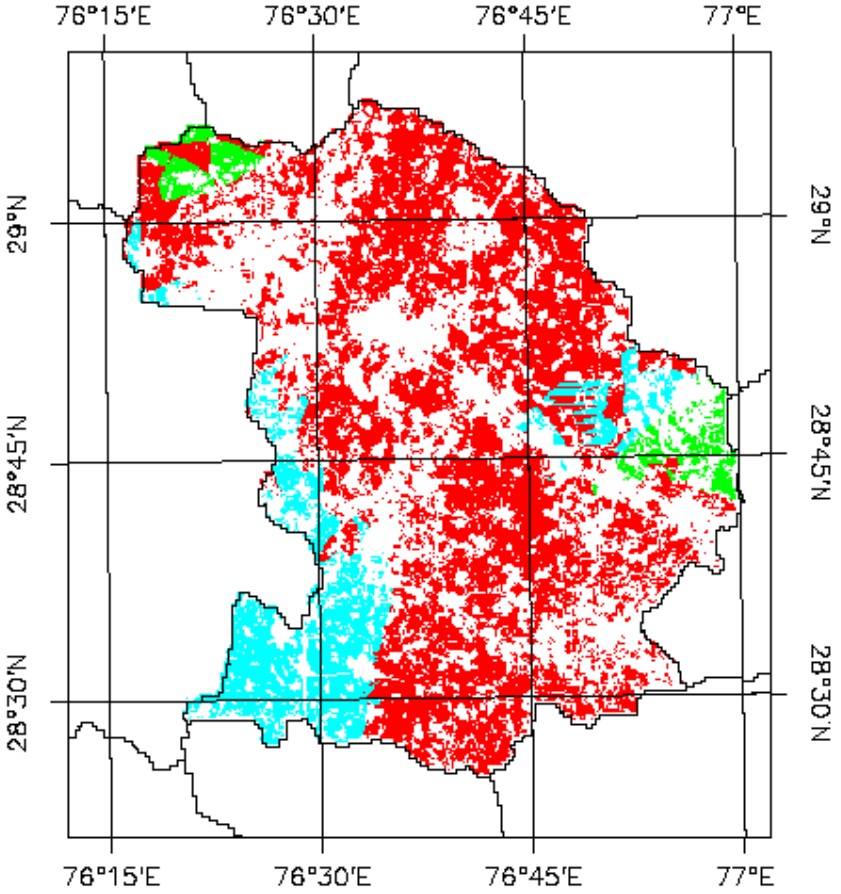
Variable Inputs (I, N)



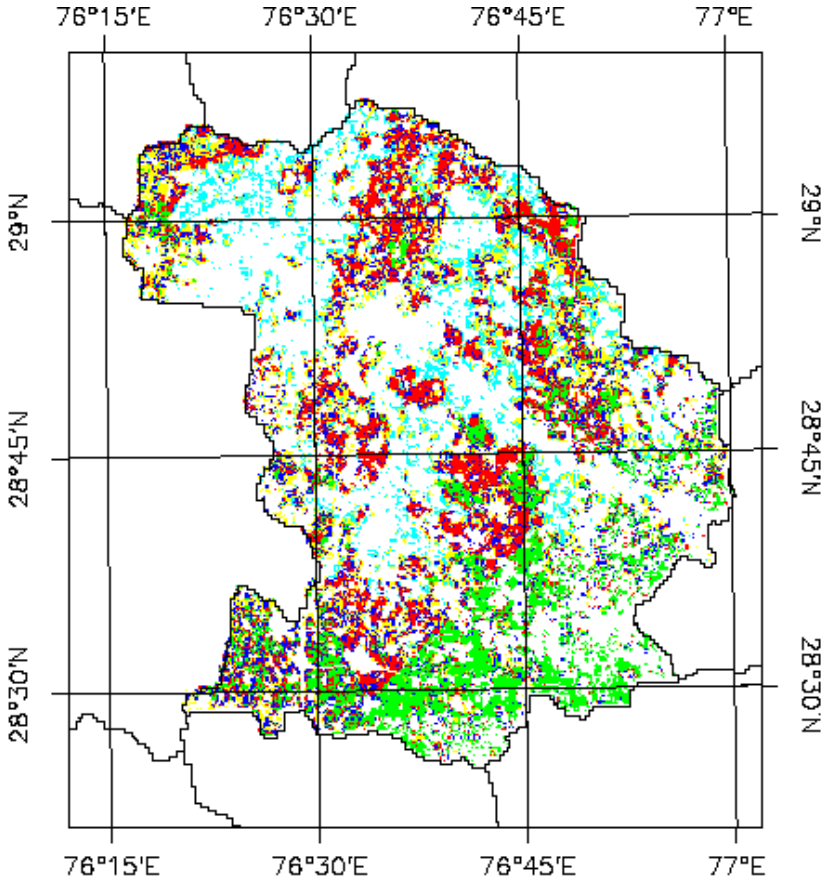
DOS from RS



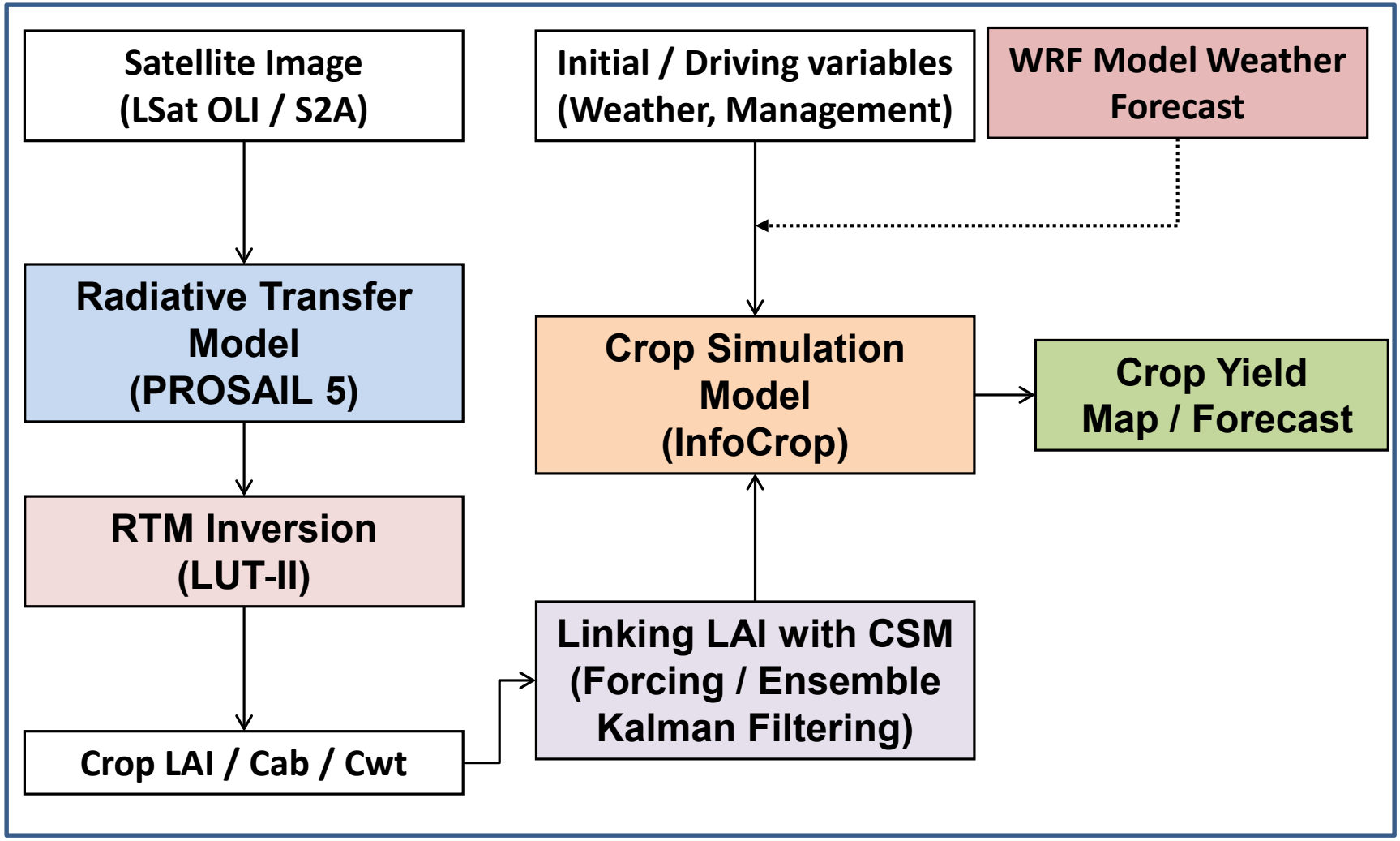
Without Assimilation



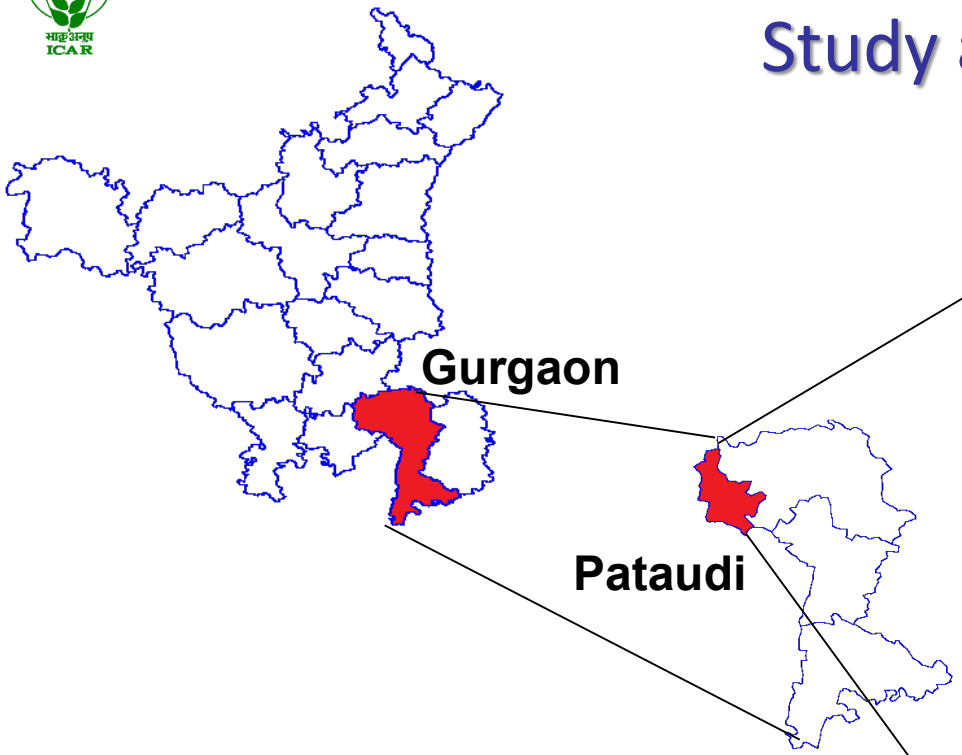
With Assimilation

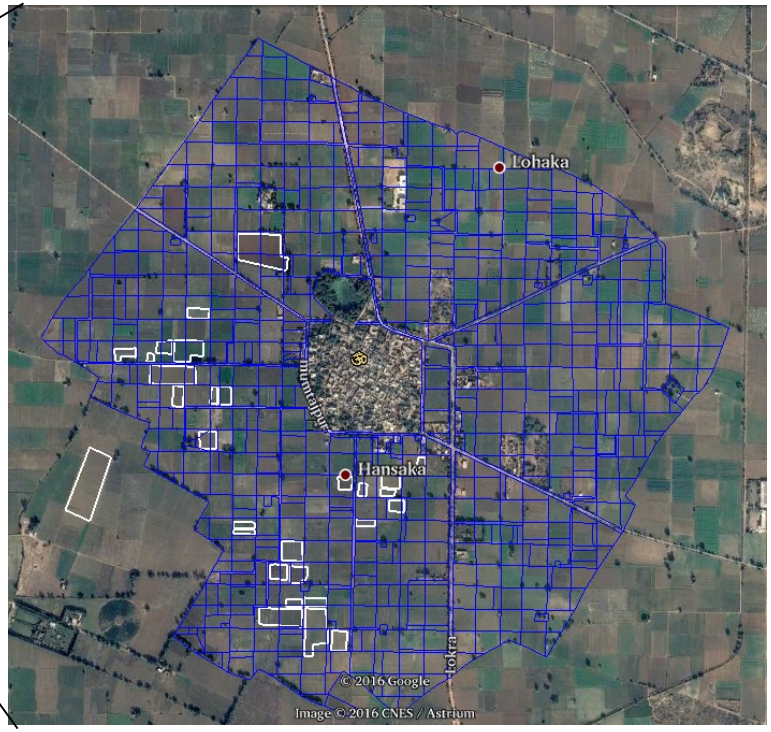


Wheat Crop Yield Modelling : RS Assimilation

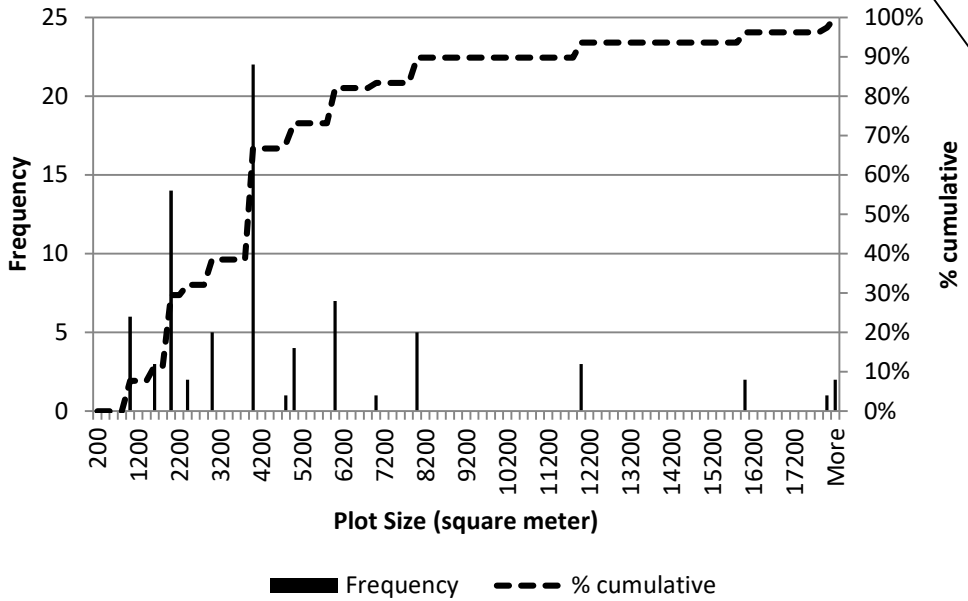


Study area

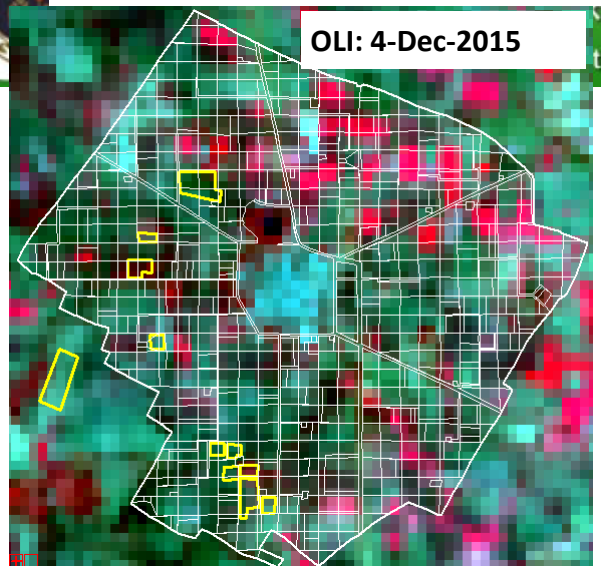


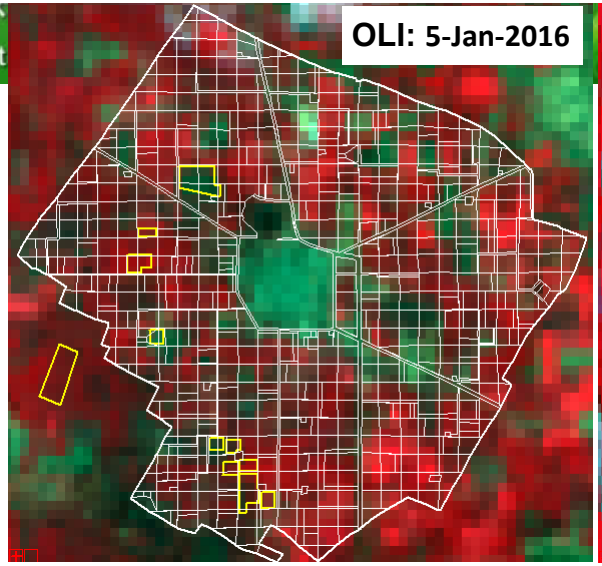


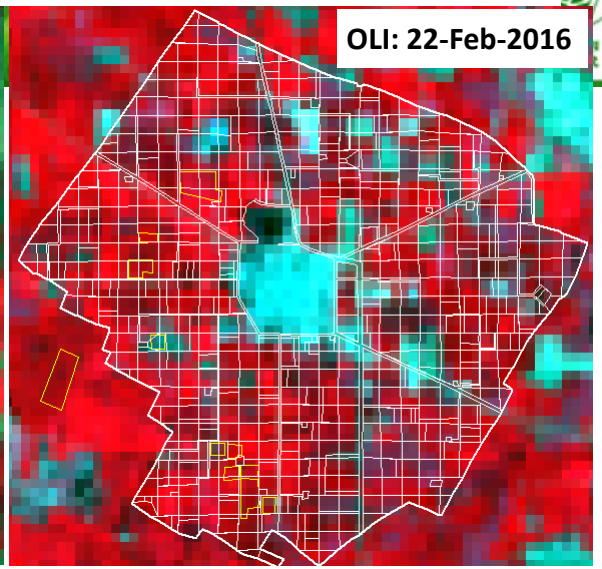
Mumtazpur & Lokra



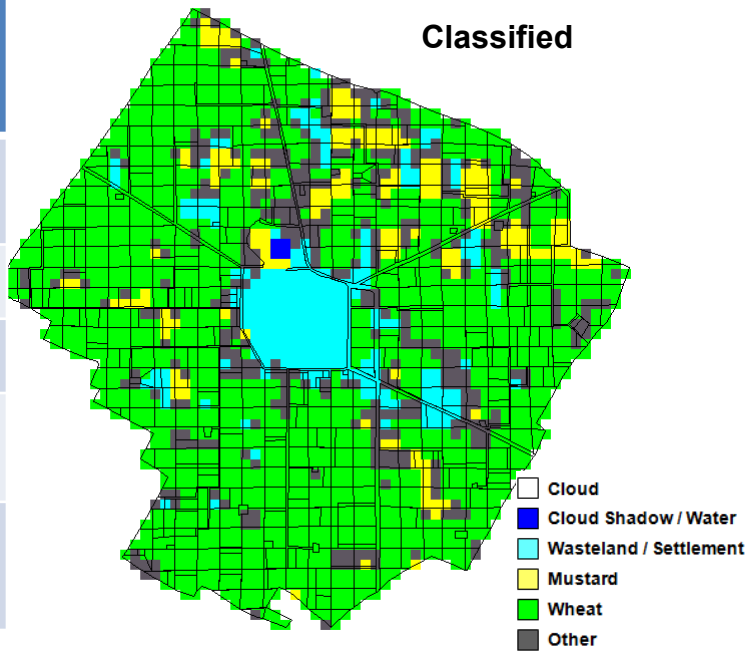
LandSat OLI Time-series Images of Mumtazpur Village

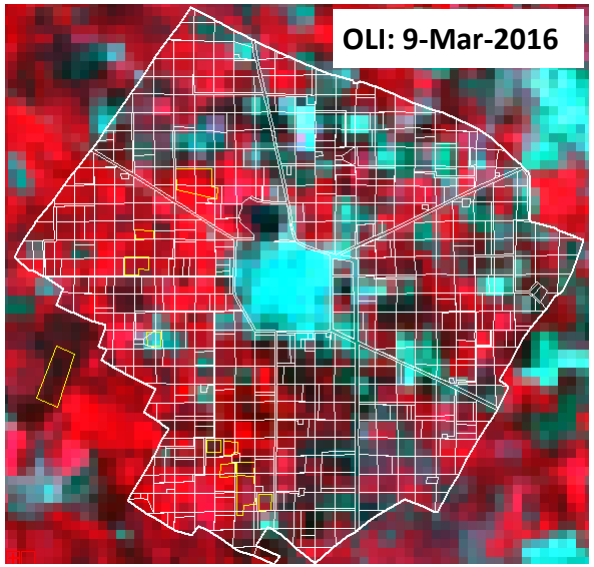




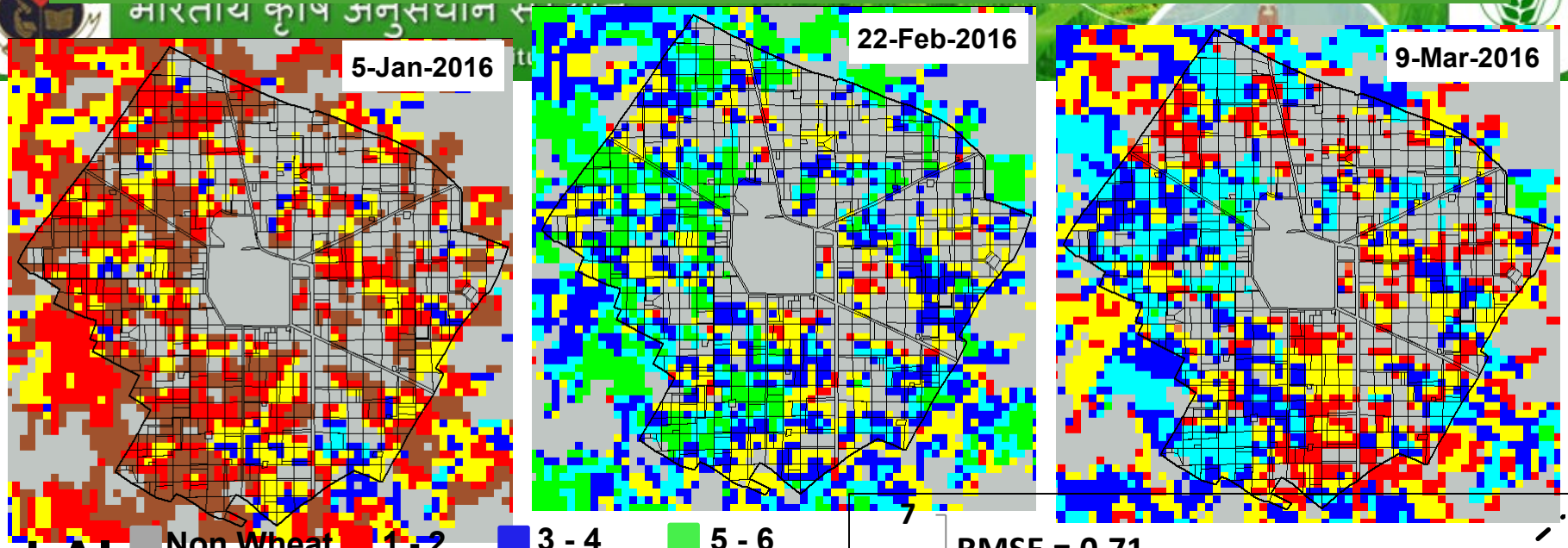


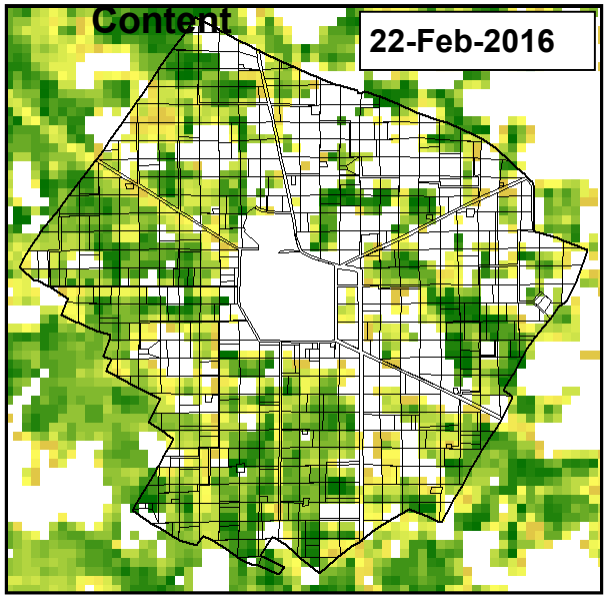
Category	Area (ha)	% of Total
Non-Agril	21.0	09.85
Mustard	15.0	07.14
Wheat	141.0	67.08
Other Veg	34.0	17.03
Village Area	211.0	100.00

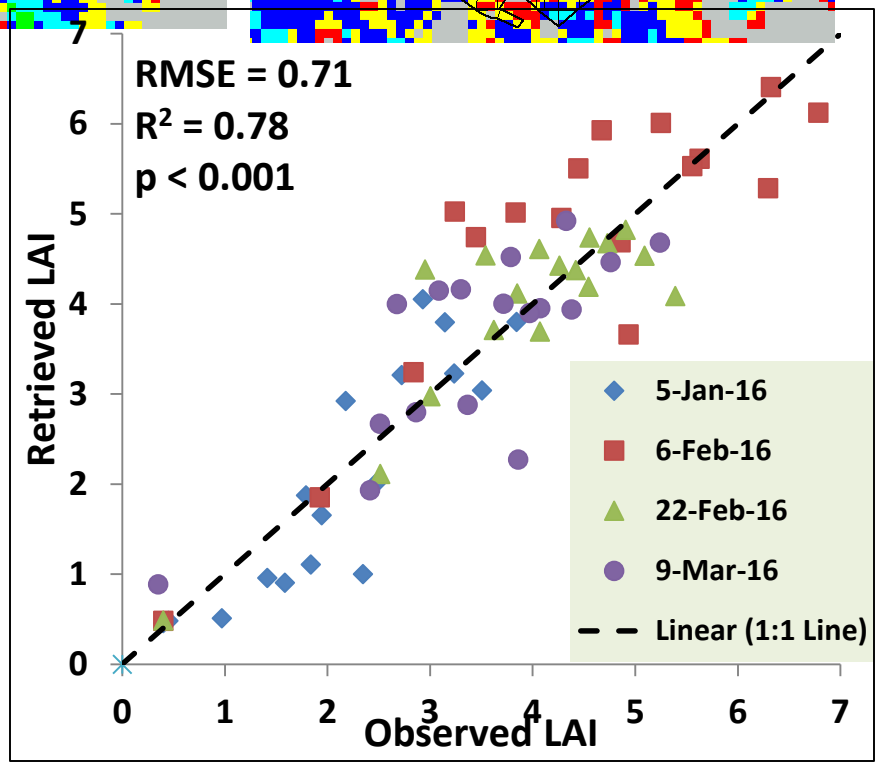




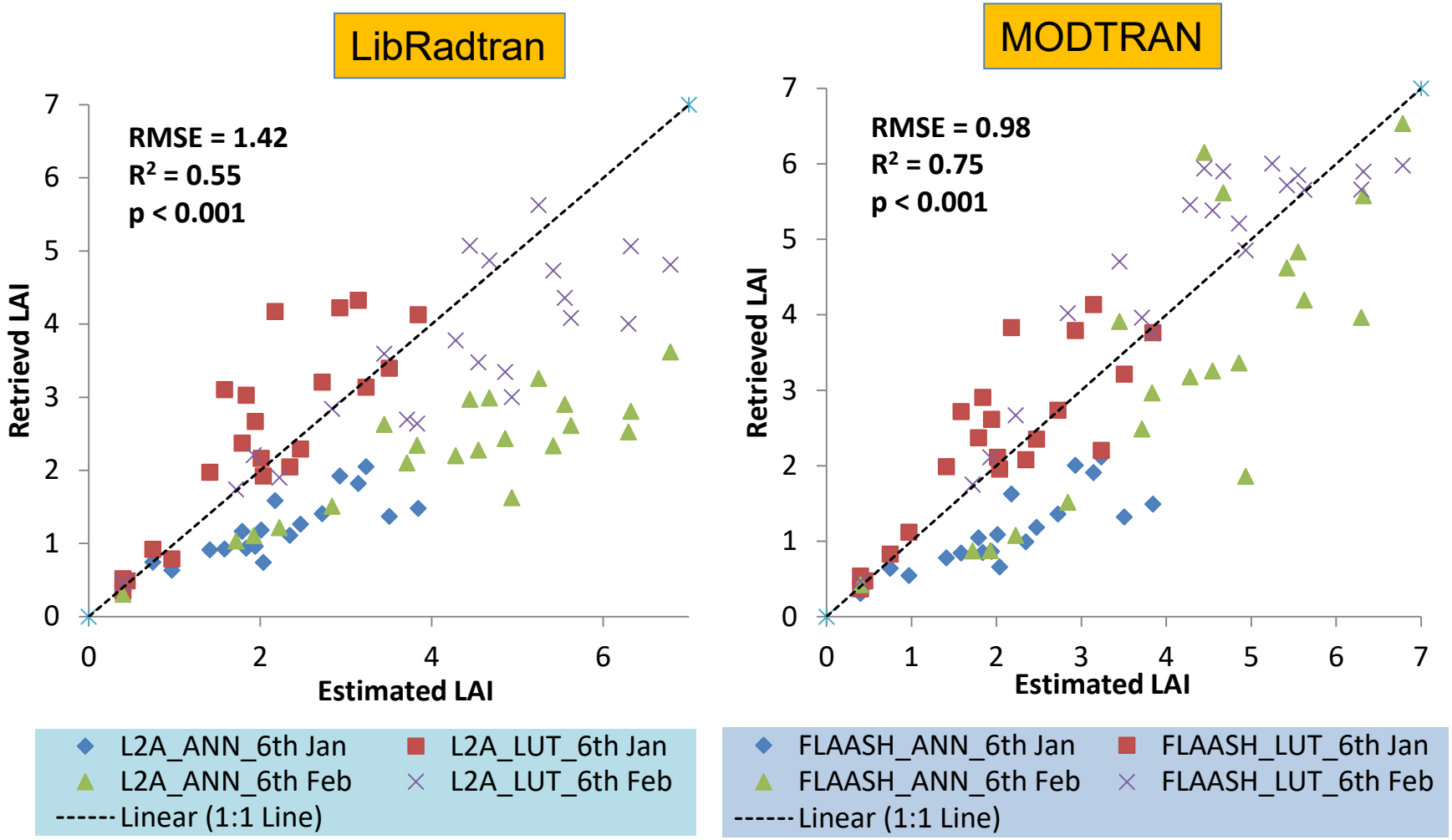
MODEL INVERSION RESULTS



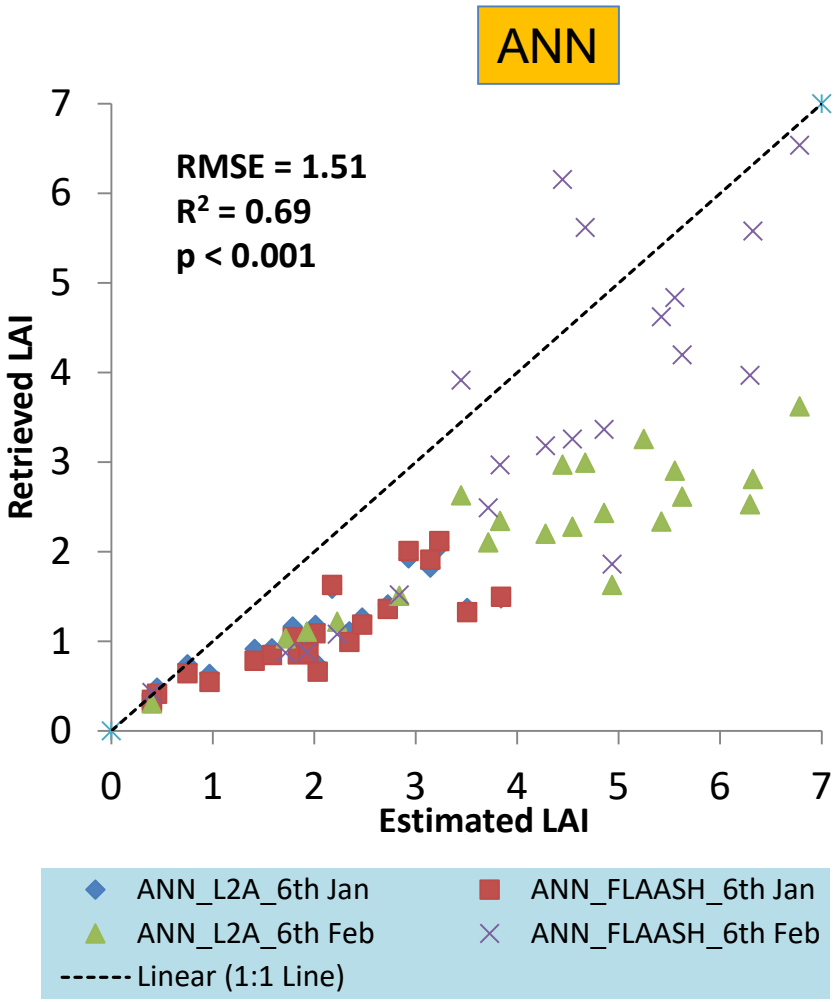


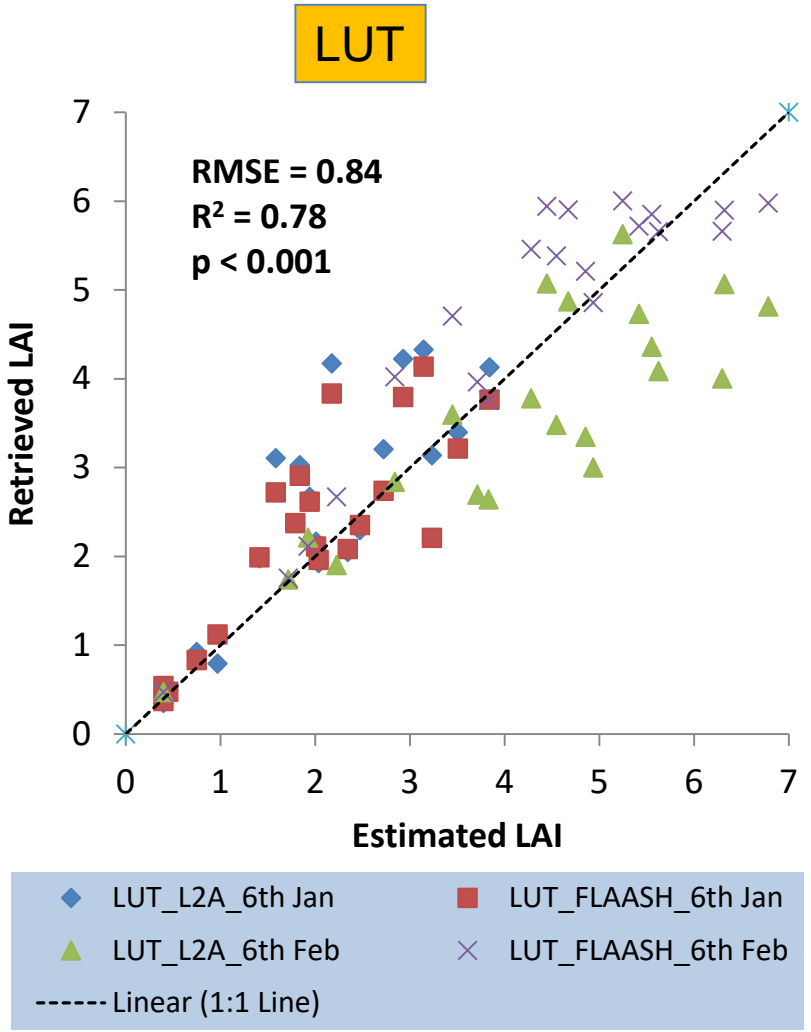


Effect of atmospheric correction algorithms for Sentinel-2



Comparison of inversion approach (ANN & LUT) for Sentinel-2



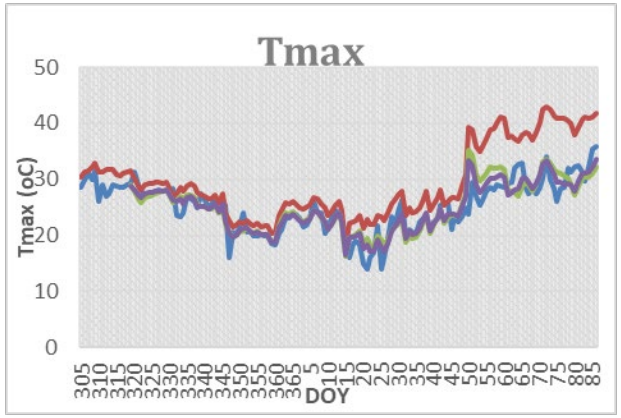


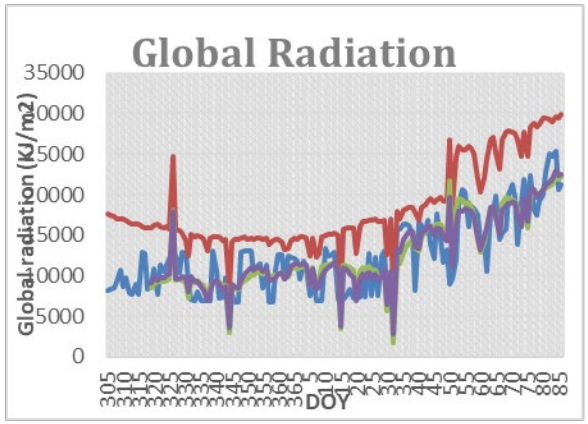
Student t-test statistics to compare the effect of spatial and spectral resolutions on LAI retrieval.

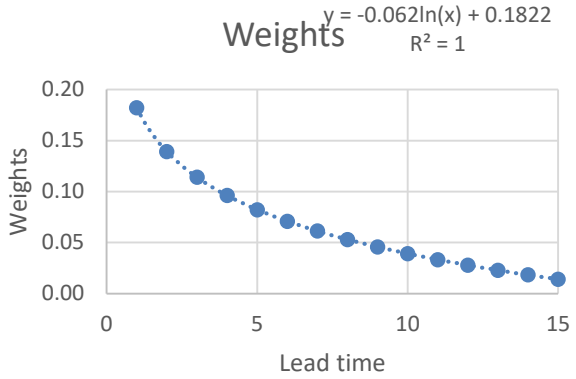
Spectral bands	OLI_6bands	S2A_6 bands	S2A_6bands + VNIR	S2A_6bands + rededge1_2	S2A_6bands+VNIR+ rededge1_2
OLI_6bands		0.24			
S2A_6 bands			-0.21	2.0373**	2.2007**
S2A_6bands + VNIR				2.1063**	2.2588**
S2A_6bands + rededge_1_2					0.22
S2A_6bands+VNIR+rededge1_2					

(**significant at $p < 0.05$)

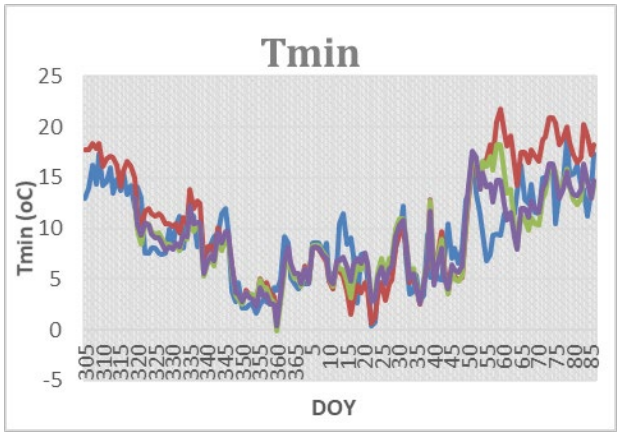
Weighted Adaptive Bias correction of WRF model forecasted weather

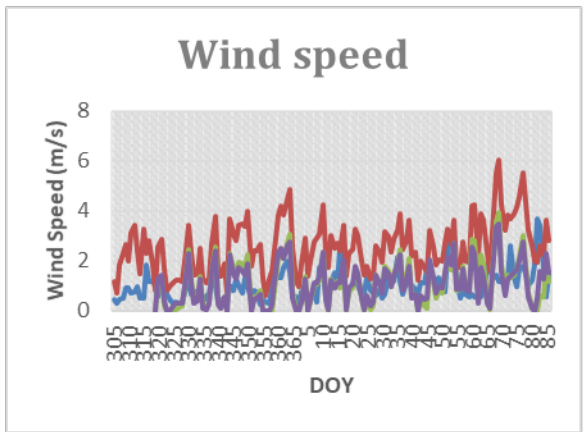


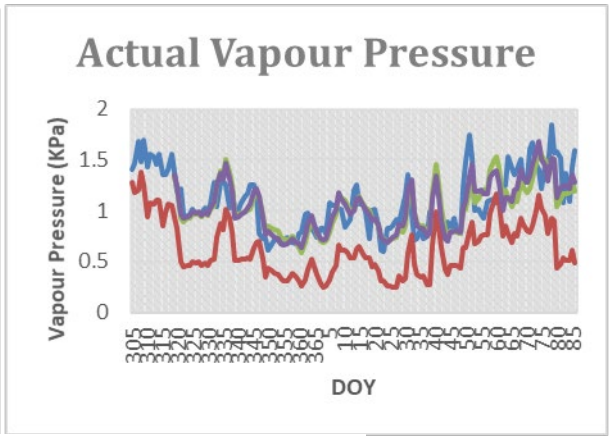




✓Tmax, Tmin, WS, SR, VP



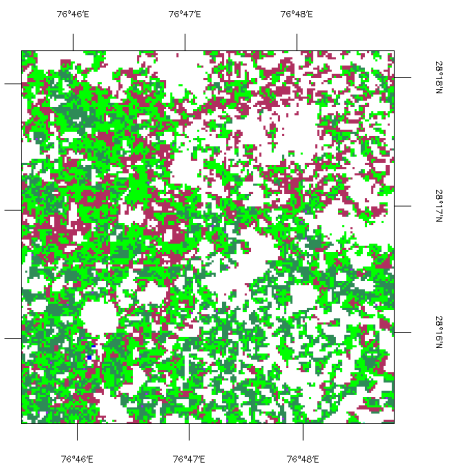
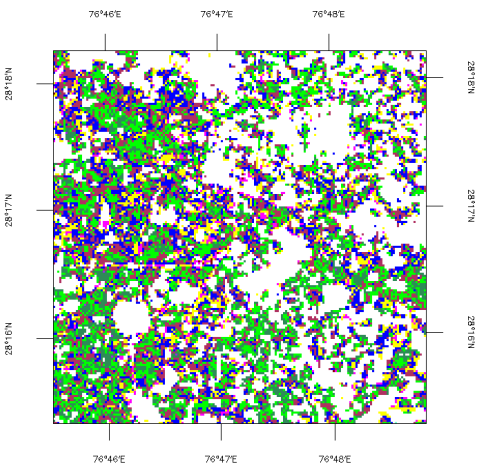
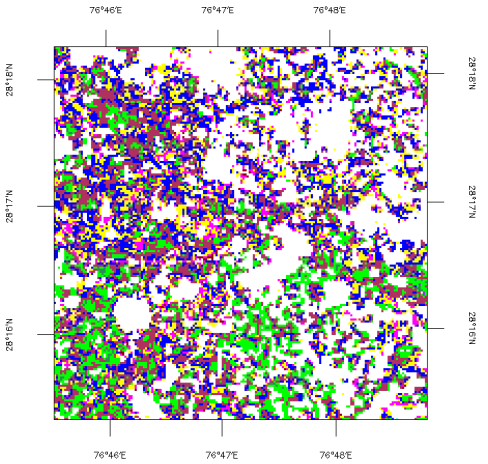
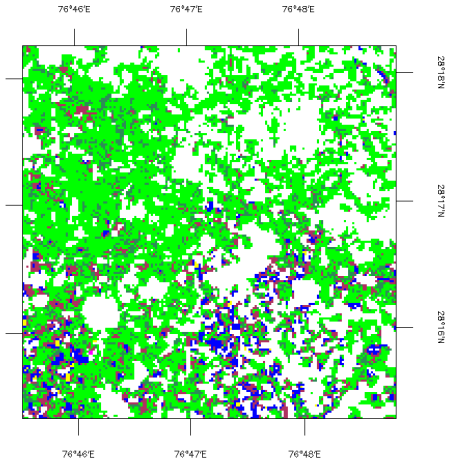
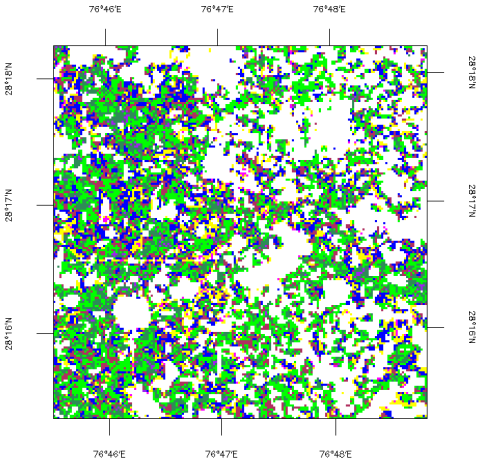
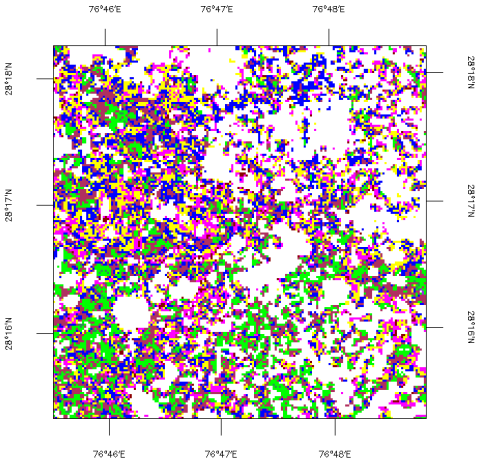




Observed
WRF
Non-weighted adaptive bias corrected
Weighted adaptive bias corrected

Exp No.	Season	Initial Soil moisture	Soil parameters	Irrigation	Fertilizer	Date of sowing	LAI assimilation	Phenology adjustment
1	2015-16	Fixed	Fixed	Fixed	Fixed	Measured	FORCING	No
2	2016-17	Fixed	Fixed	Fixed	Fixed	Measured	FORCING	No
3	2015-16	Fixed	Fixed	Fixed	Fixed	Measured	ENKF	No
4	2016-17	Fixed	Fixed	Fixed	Fixed	Measured	ENKF	No
5	2015-16	Fixed	Fixed	Fixed	Fixed	Fixed	FORCING	No
6	2016-17	Fixed	Fixed	Fixed	Fixed	Fixed	FORCING	No
7	2015-16	Fixed	Fixed	Fixed	Fixed	Fixed	ENKF	No
8	2016-17	Fixed	Fixed	Fixed	Fixed	Fixed	ENKF	No
9	2015-16	Fixed	Fixed	Fixed	Fixed	Fixed	FORCING	Yes
10	2016-17	Fixed	Fixed	Fixed	Fixed	Fixed	FORCING	Yes
11	2015-16	Fixed	Fixed	Fixed	Fixed	Fixed	ENKF	Yes
12	2016-17	Fixed	Fixed	Fixed	Fixed	Fixed	ENKF	Yes
13	2015-16	Fixed	Fixed	Fixed	Fixed	Fixed	No	Yes
14	2016-17	Fixed	Fixed	Fixed	Fixed	Fixed	No	Yes
15	2015-16	Fixed	Fixed	Fixed	Fixed	Fixed	No	No
16	2016-17	Fixed	Fixed	Fixed	Fixed	Fixed	No	No
17	2015-16	Fixed	Fixed	Fixed	Fixed	Measured	No	No
18	2016-17	Fixed	Fixed	Fixed	Fixed	Measured	No	No

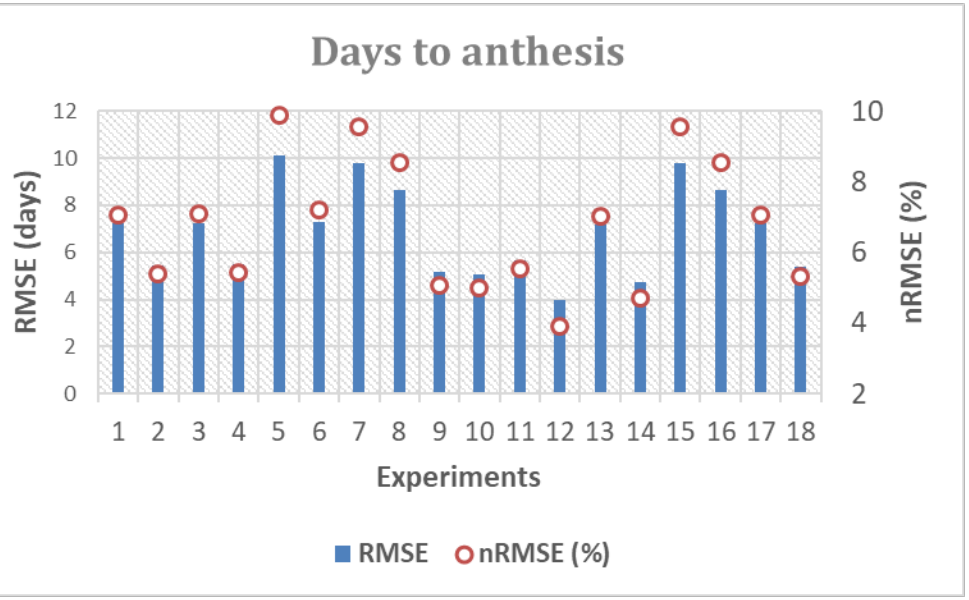
Crop Yield Maps

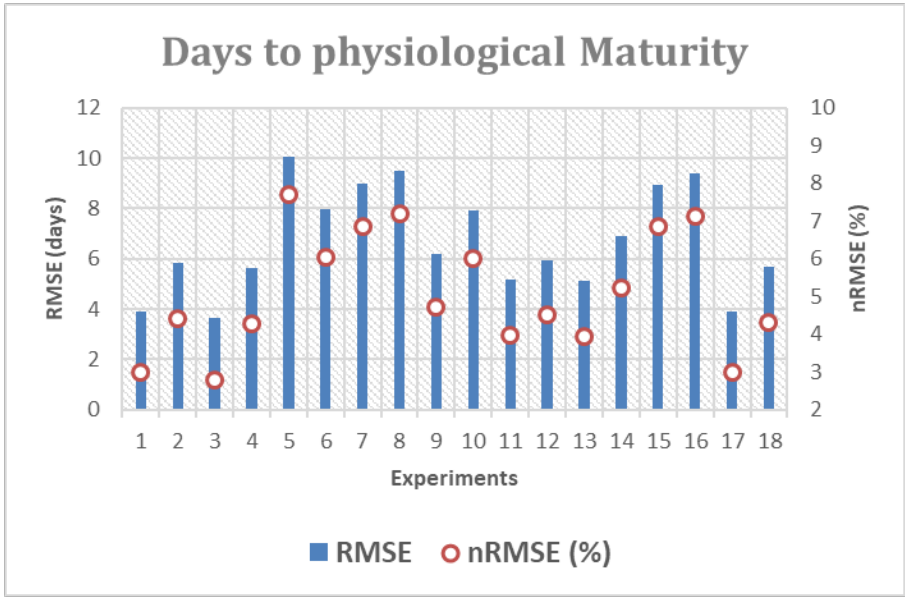
	LAI1	LAI2	LAI3
LAI + AW assimilation			
LAI + WF assimilation			

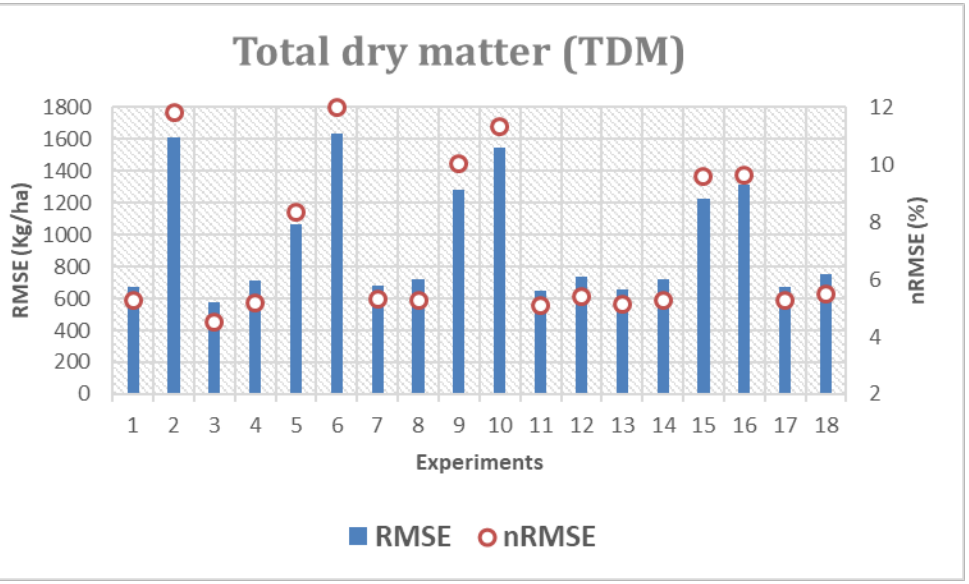
Grain Yield (Kg/ha)

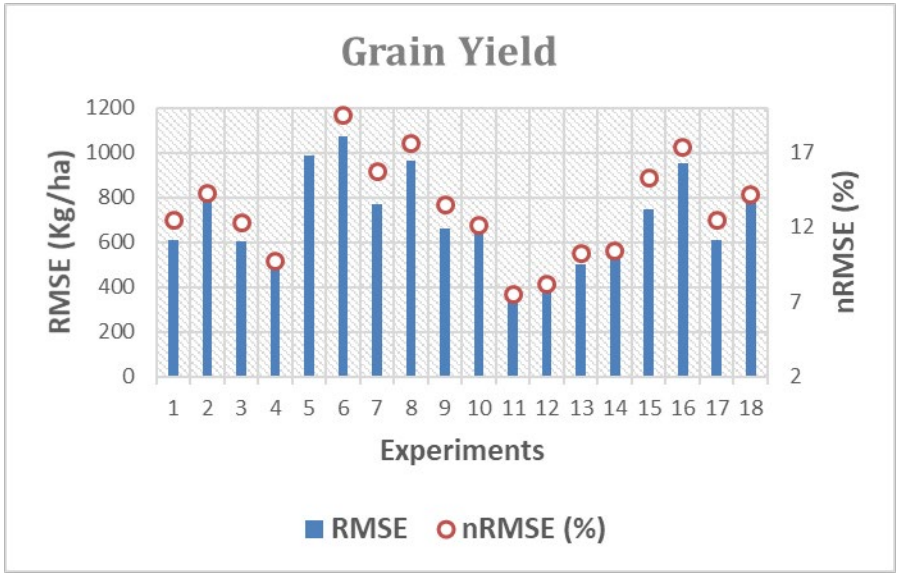
- < 2.5
- 2.5 - 3.0
- 3.0 - 3.5
- 3.5 - 4.0
- 4.0 - 4.5
- 4.5 - 5.0
- 5.0 - 5.5
- 5.5 - 6.0
- 6.0 - 6.5
- 6.5 - 7.0
- > 7.0

SIMULATION PERFORMANCE

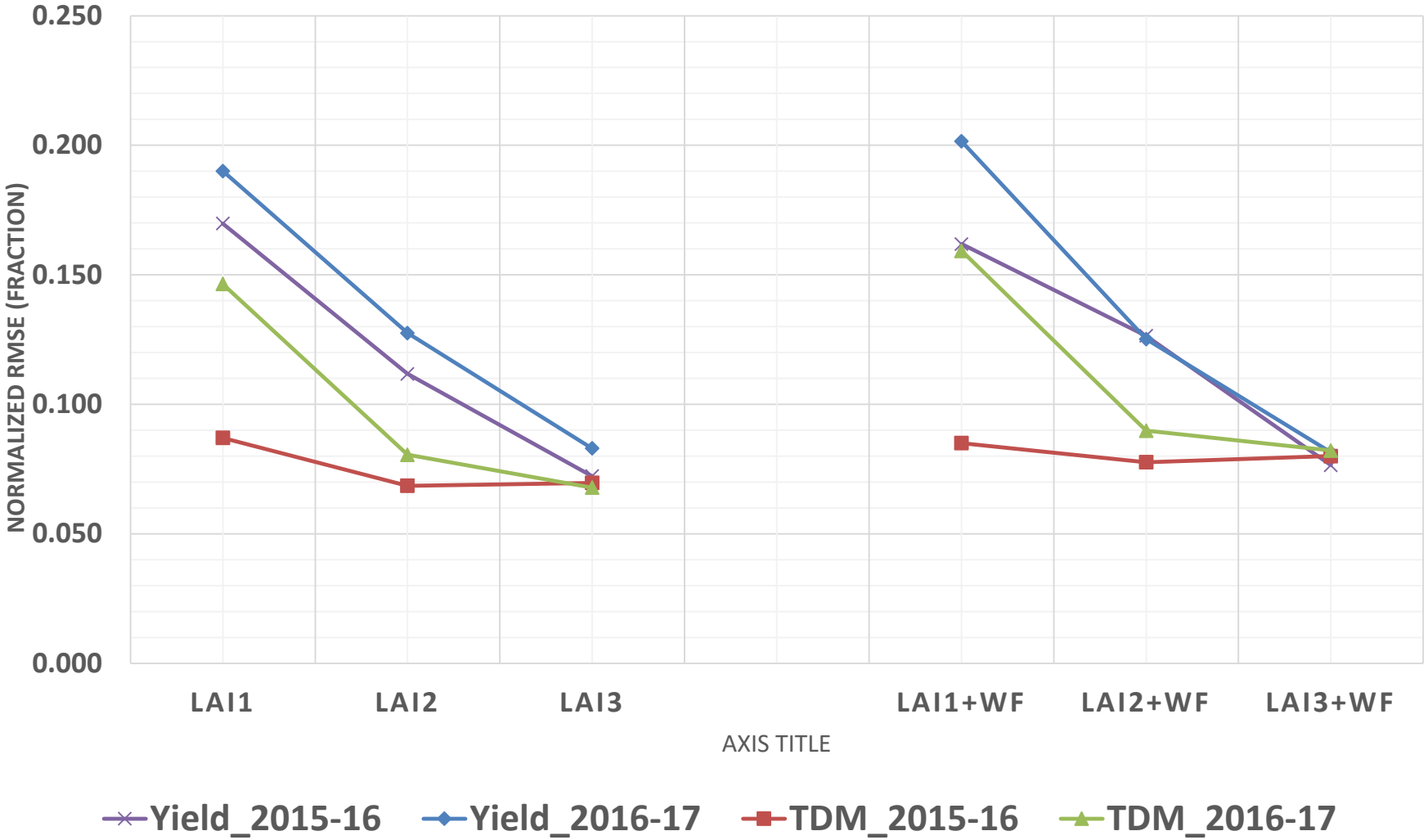








Effect of progressive LAI assimilation on model outputs of phenology, TDM and yield

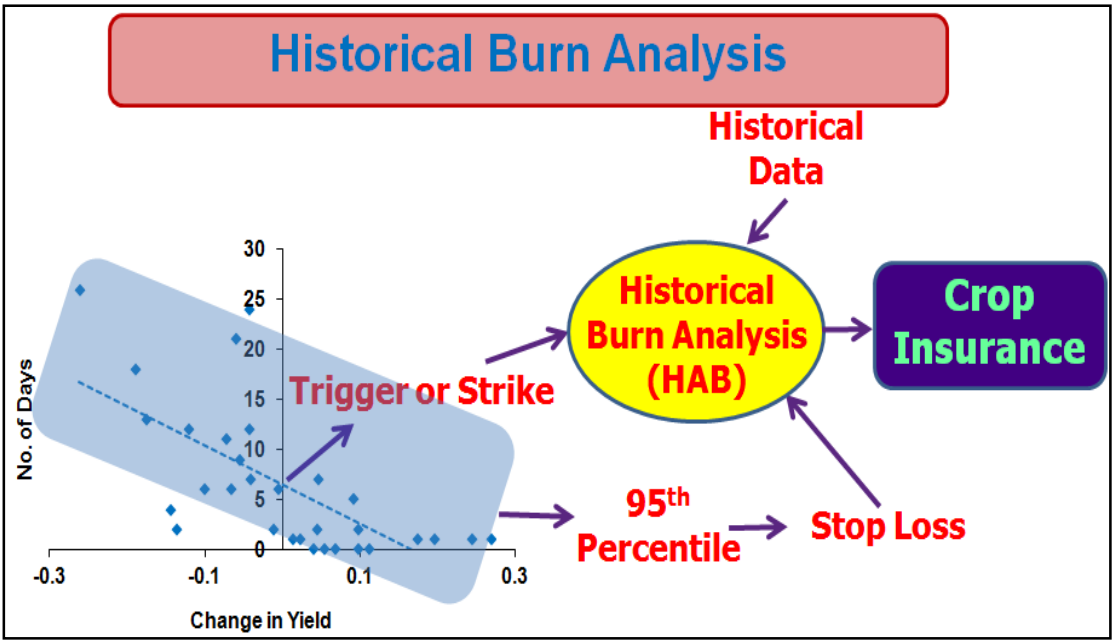


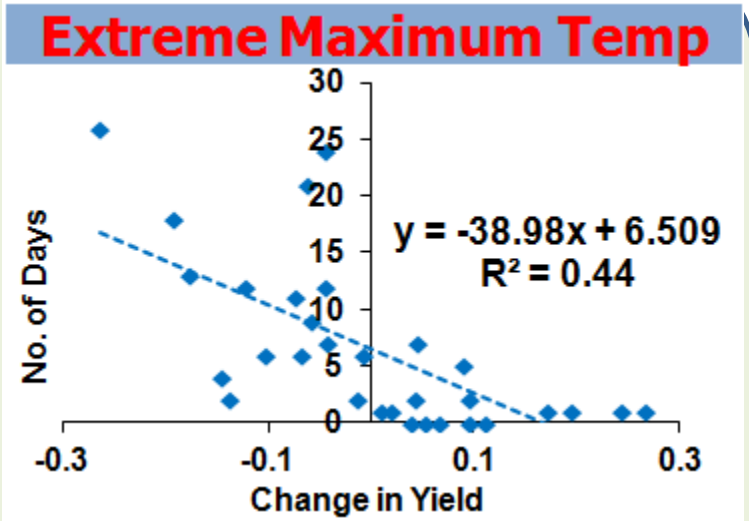
Crop Insurance

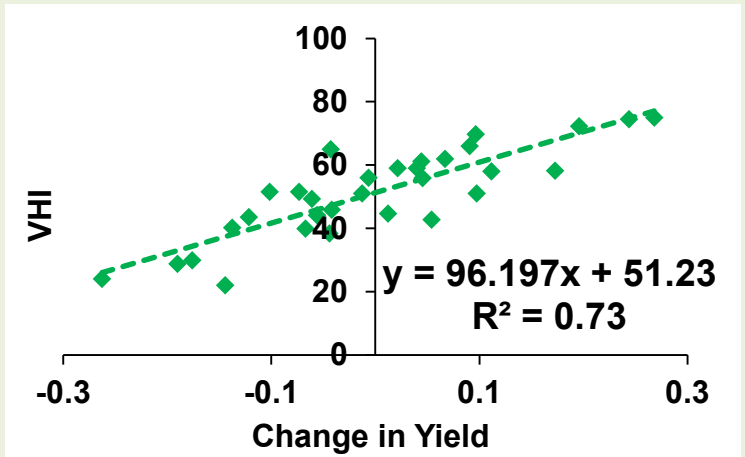
Crop Insurance

EO Data Applications:

- Efficient CCE sampling plan
- Improved weather index insurance
- RS based Index Insurance Product
- Crop loss for indemnity







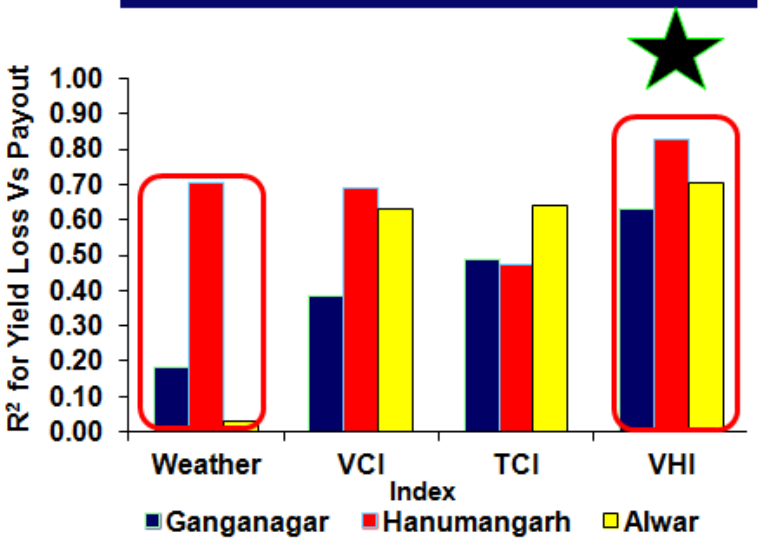
Wheat Crop Insurance:

- Peril; high temperature stress during anthesis
- RS Parameters: Phenology, NDVI, LST
- Ganganagar district

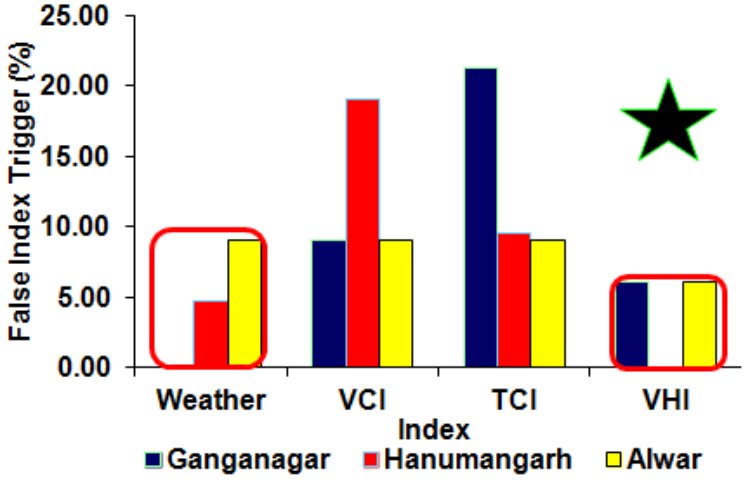
Source: IARI

RS Based Index Insurance Product Evaluation

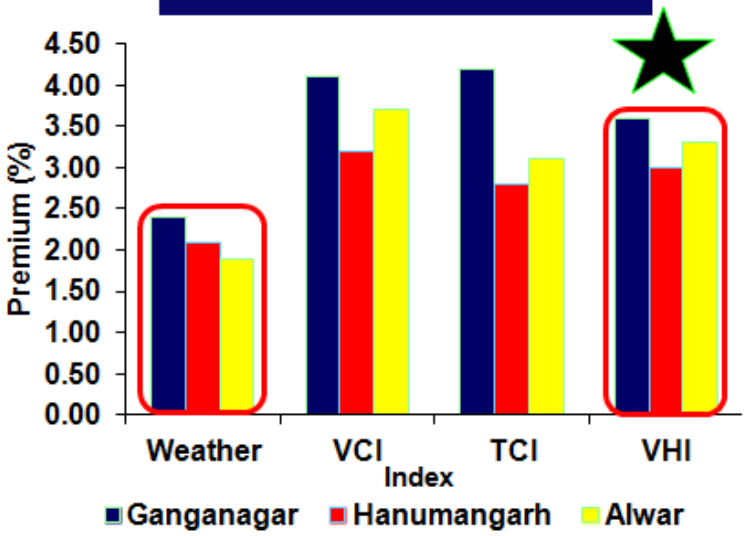
R^2 for Yield loss & Payout



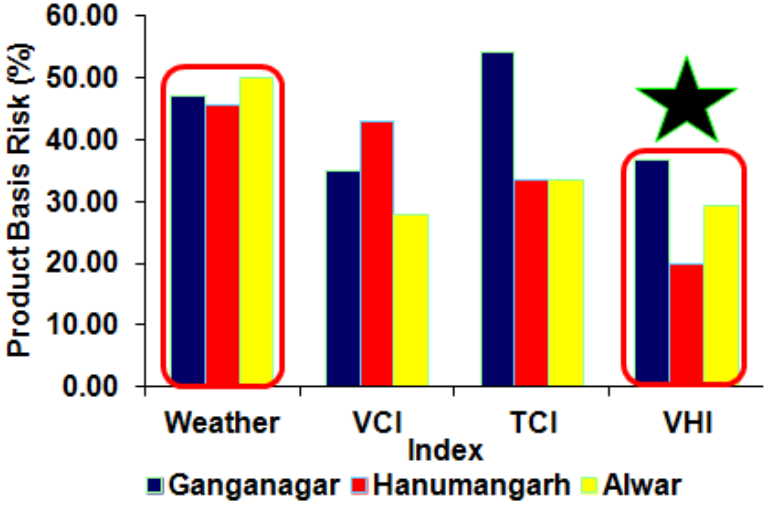
False Trigger



Premium

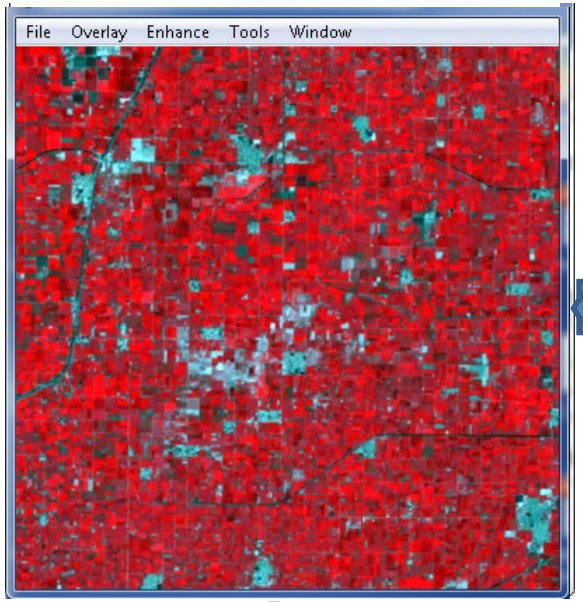


Basis Risk



Methodology of Yield Loss Modelling

LandSat 7 ETM+ Image



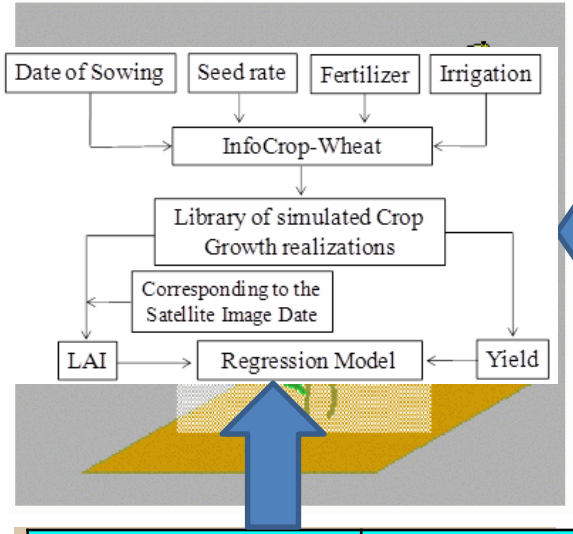
Yield Map

Pixels

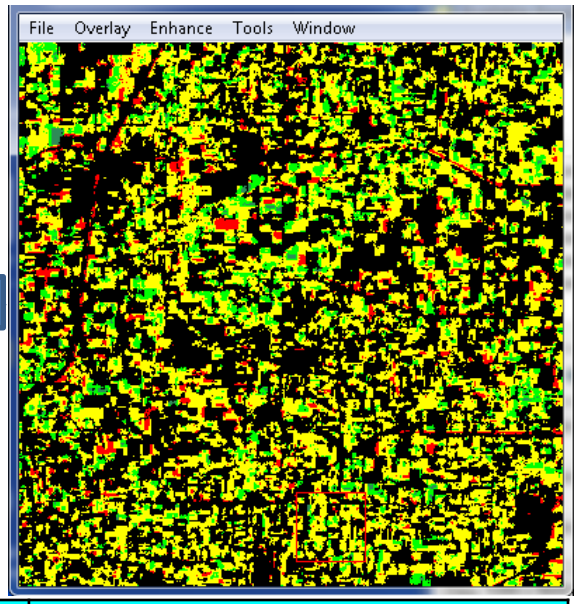
3232370 = 3.2 Million

Sri Ganganagar District

PROSAIL Model

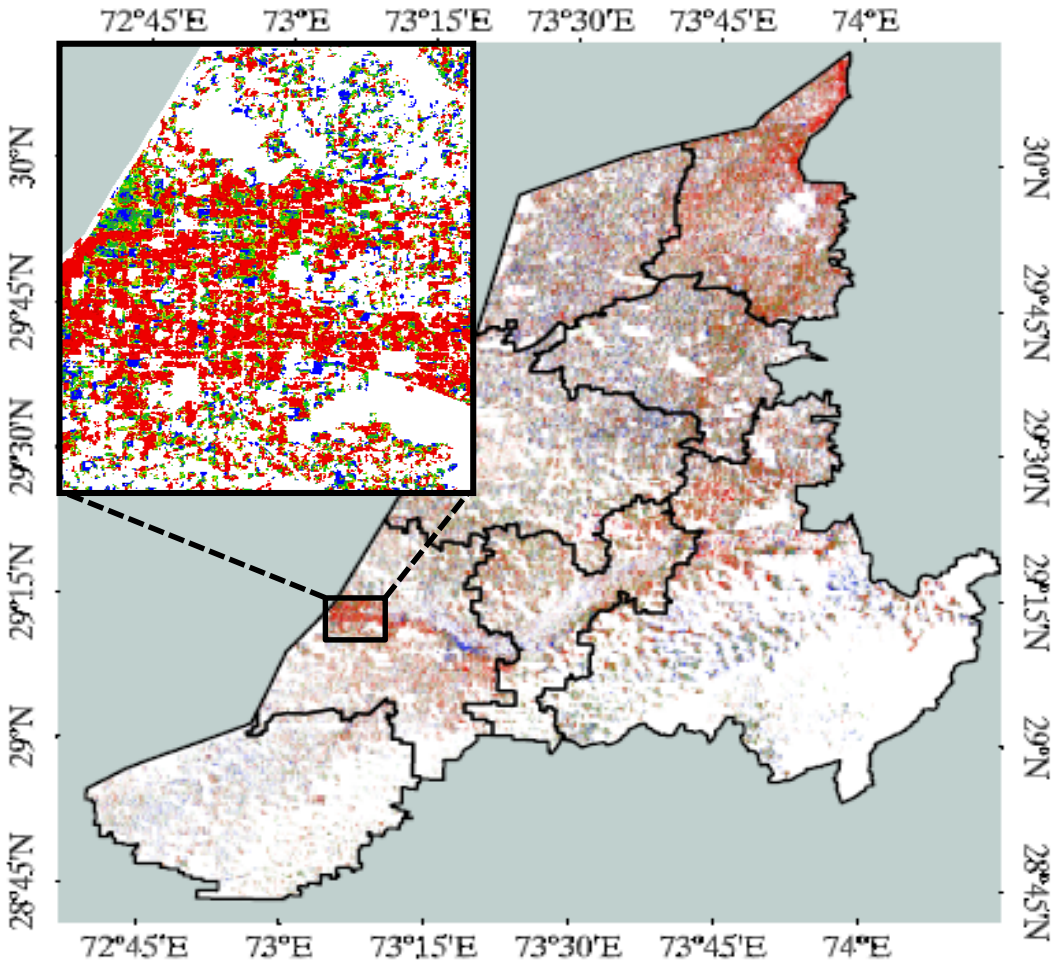


Leaf Area Index Image

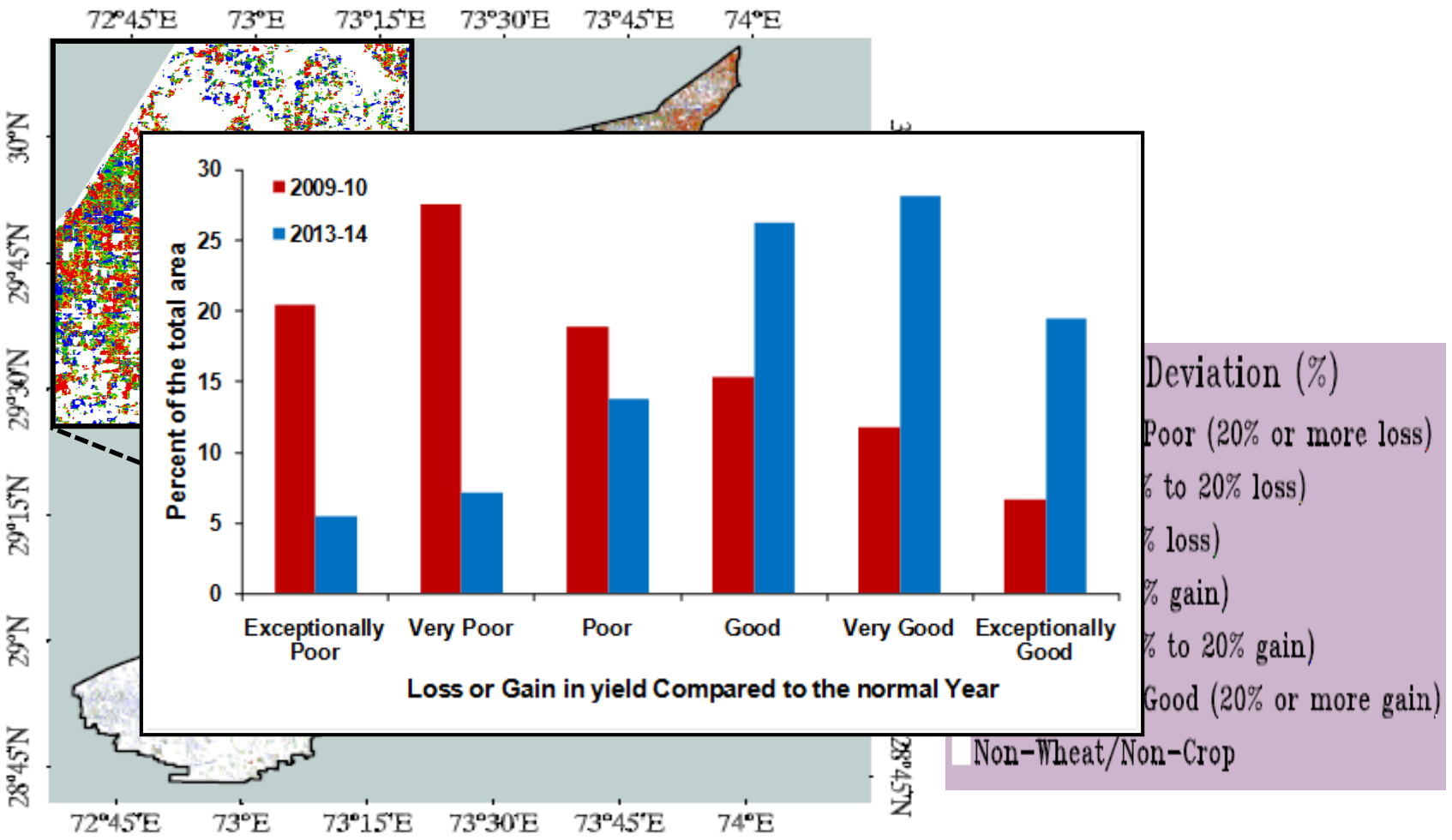


Crop Status	Crop Year	Yield (t/ha) DES Data
Bad Year	2009-10	2.85
Normal Year	2012-13	3.86
Good Year	2013-14	4.17

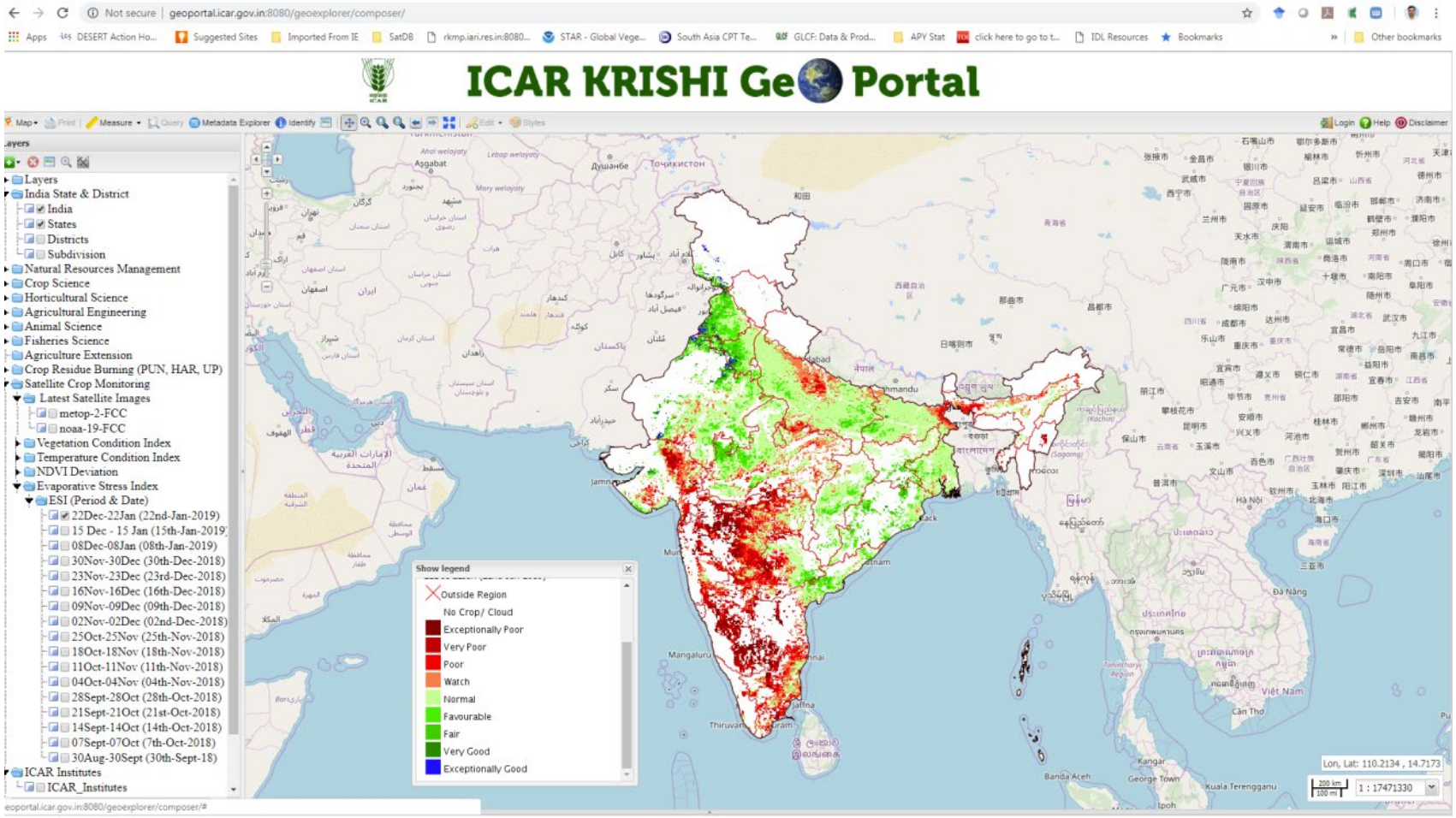
Yield deviation map of Ganganagar district for the rabi season of 2009-10 w.r.t 2012-13



Yield deviation map of Ganganagar district for the rabi season of 2013-14 w.r.t 2012-13



Operational System : Geo-Portal



Way Forward

- Developing a operational system to implement LAI retrieval and assimilation into Crop simulation model and use of WRF weather forecast for wheat
- Convergence of evidence in season from ground observations and other evidences
  - Satellite weather based indices
  - Crop condition indices
  - Mapping vulnerability of crops to hazard
- Need to build capacities of students and users to make use of EOS data and tools for real world applications

Thank You

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http://krishi.icar.gov.in