Crop Yield Forecasting using Agromet Model: Indian experience

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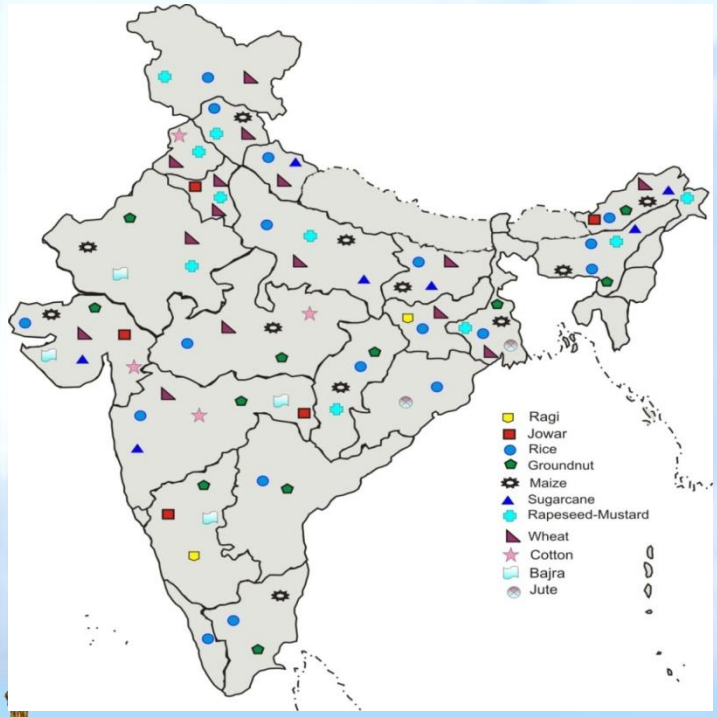
OUTLINE

- Objective
- Background of AAS system
- Weather Monitoring & Forecasting
- Agromet Models and Database
- In-season Crop Yield Forecast
- Future Plan

FASAL (**F**orecasting **A**griculture using **S**pace, **A**grometeorology and **L**and based observations)

Objective : Providing multiple pre-harvest production forecasts of crops at National/State/ District level

Forecast schedule:
- F1: Vegetative
- F2: Flowering
- F3: Pre-Harvest stage.



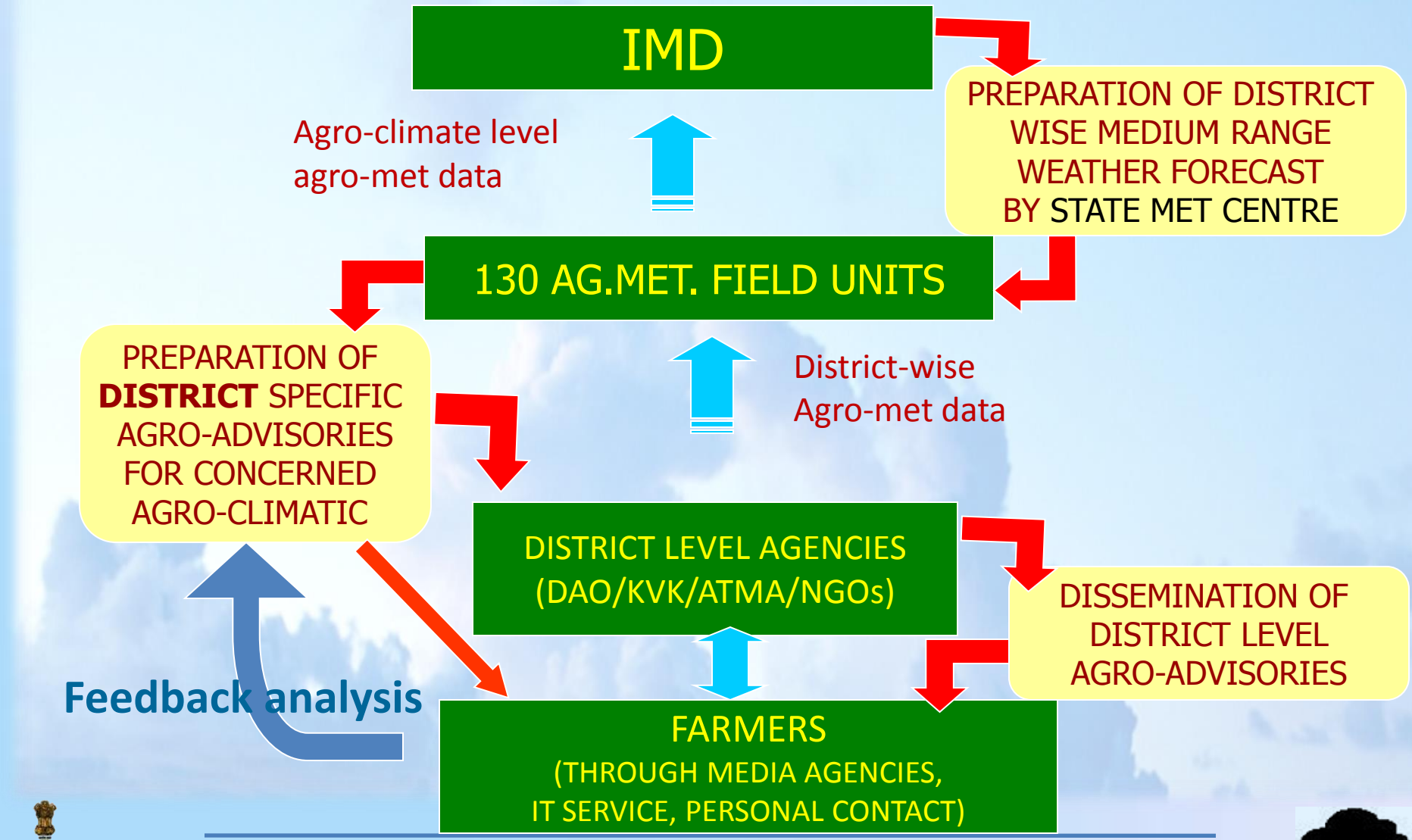
Crops under FASAL

- Rice
- Wheat
- Maize
- Jowar
- Bajra
- Ragi
- Groundnut
- Sugarcane
- Rape seed &Mustard
- Cotton
- Jute

Crops under CHAMAN

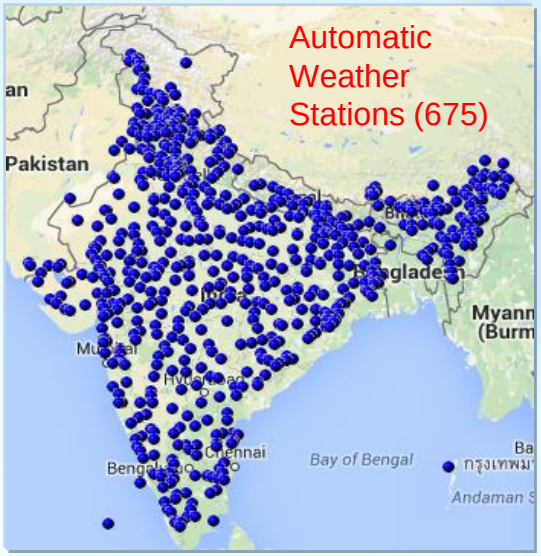
- Potato
- Tomato
- Chilli
- Onion
- Mango
- Banana
- Citrus

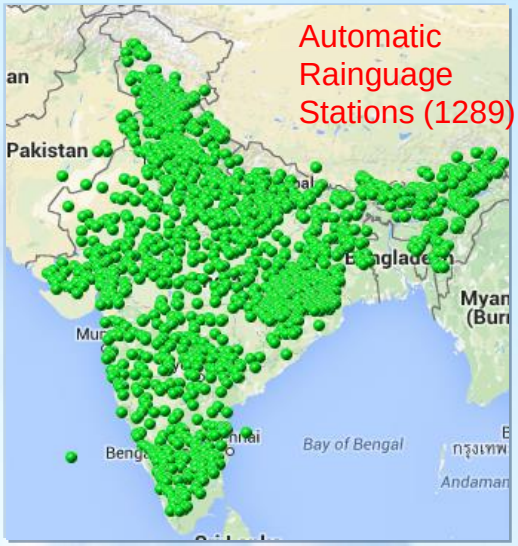
Agromet Advisory Service (AAS) System to support the Objectives of FASAL

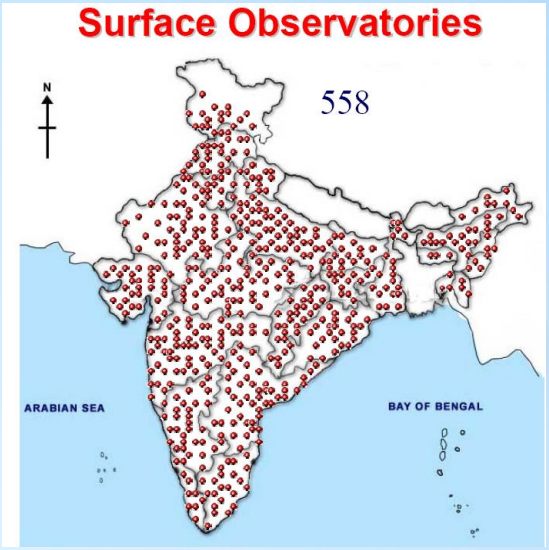


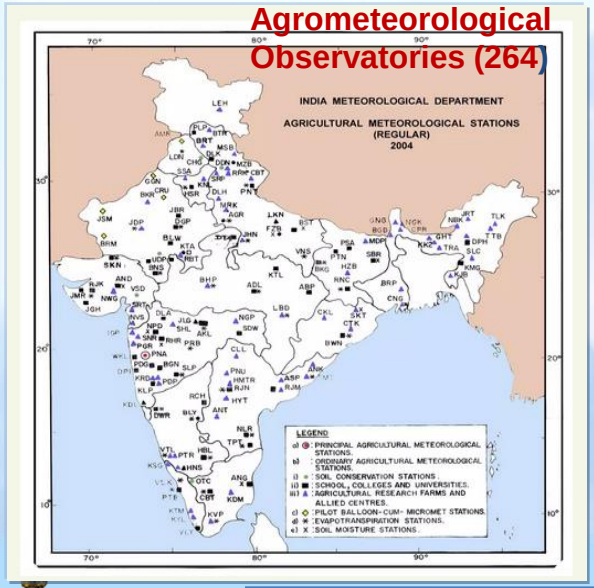
Weather Monitoring & Forecasting

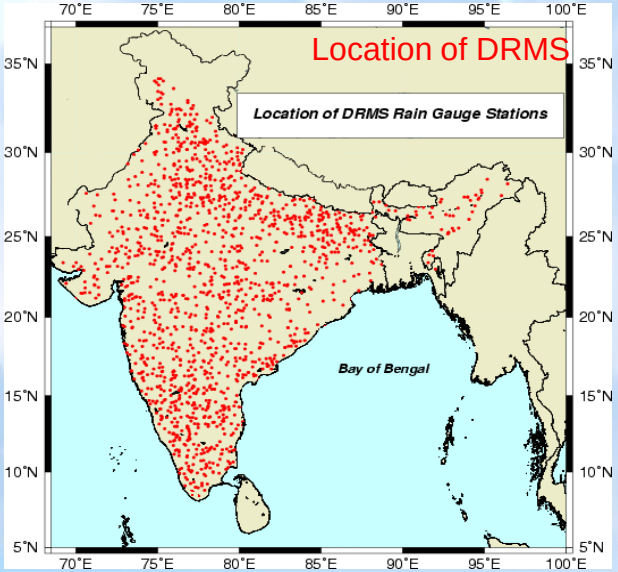
Weather Observation System

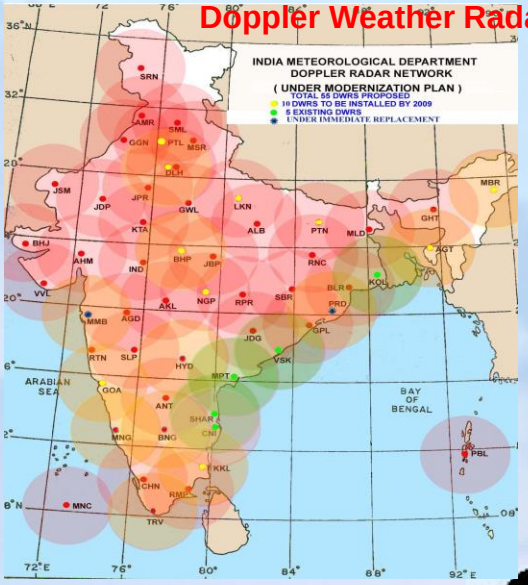












Weather Observation System …

Gridded Weather data

Rainfall :	1.0*1.0 degree,
	0.5*0.5 degree,
	0.25*0.25 degree
Max & Min Temperature:	1.0*1.0 degree
	0.5*0.5 degree

Satellite data :
(for use in crop model)

Insolation,
Land Surface Temperature (LST),
Soil Moisture,
NDVI based sowing dates.

Agromet Models and Database

AGROMET MODELS

- **Statistical Models**
- **Crop Simulation Models**

Statistical model based on weather indices

- Correlation coefficients after adjusting yield for trend effect
- Effects as linear function of respective correlation coefficients
- Effects of quadratic terms of weather

$$Y = A_0 + \sum_{i=1}^{p}\sum_{j=0}^{1} a_{ij} Z_{ij} + \sum_{i\neq i'=1}^{p}\sum_{j=0}^{1} a_{ii'j} Z_{ii'j} + cT + e$$

Where,

$$Z_{ij} = \sum_{w=1}^{m} r_{iw}^{j} X_{iw} \quad \text{and} \quad Z_{ii'j} = \sum_{w=1}^{m} r_{ii'w}^{j} X_{iw} X_{i'w}$$

- Models using correlation coefficients based on yield adjusted for trend effect better
- Inclusion of quadratic terms of weather did not improve the model
- Second power of correlation coefficient did not improve the model

r_{iw} is correlation coefficient of yield with i^{th} weather variable (x) in w^{th} period

$r_{ii'w}$ is correlation coefficient of yield with product of i^{th} and i'^{th} weather variables (x) in w^{th} period

m is period of forecast

p is number of weather variables used

e is random error distributed as $N(0,\sigma^2)$.

T is technology factor

Rice yield forecast (F2), 2015-16 using Statistical Model for West Bengal

SN	District	Equation	Weather Parameters	Forecast Yield (kg/ha)	R^2	F	Std Error
1	Cooch Behar	Y=3652.94+37.91*Time+ 12.37*Z51-0.01*Z230	RHII, Tmin*RF	2077	0.93	64	92
2	Jalpaiguri	Y=3045.95+43.96*Time+ 53.93*Z21+0.18*Z41-4.04*Z21	Tmin, RHI,	2032	0.94	58.6	79.8
3	South Dinajpur	Y=1338.07+57.32*Time+ 1.44*Z31	RF	2807	0.92	136	123
4	Uttar Dinajpur	Y=1245.73+48.29*Time+ 0.76*Z151+0.10*Z150	Tmax*RHII	2647	0.89	77	136
5	Burdwan	Y=188.33+43.77*Time+ 0.77*Z231+0.271*Z251	Tmin*RF, Tmin*RHII	3207	0.80	---	---
6	Mursidabad	Y=1740.92+36.01*Time+ 0.25*Z451+0.04*Z131+ 0.78*Z251	Tmax, Tmin, Rainfall, RHI, RHII	2830	0.89	---	---
7	Nadia	Y=1623.00+27.54*Time+ 3.45*Z121 +0.04*Z131+ 2.14*Z151+0.53*Z150	Tmax*Tmin, Tmax*RF, Tmax*RHII	2680	0.84	---	---
8	Howrah	Y=3056.37+7.09*Z141+ 2.18*Z140 +16.85*Time + 0.02*Z341	Tmax*RHI, RF*RHI	1482	0.76	---	---
9	Hooghly	Y=2164.86+50.91*Time- 0.24*Z351+ 208.24 *Z41+ 142.46*Z51-1.15*Z451+ 0.75*Z131	RF*RHII, RHI, RHII, RHI*RHII, Tmax*RF	3651	0.90	---	---
10	North 24 Parganas	Y= -2872.60+41.32*Time+ 1.14*Z151+1.20*Z241	Tmax*RHII, Tmin*RHI	2834	0.89	---	---
11	West Midnapur	Y= 975.68+Time*45.67+ Z120*3.77	Tmax*Tmin	2839	0.87	91.82	273.89
12	Bankura	Y= 1674.88+Time*43.27	---	3059	0.80	122.0	433.57
13	Birbhum	Y=1737.32+Time*48.85	---	3300	0.84	154.2	468.80
14	Purulia	Y=7831.85+Time*29.04+ Z11*114.91+Z151*0.41	Tmax, Tmax*RHII	2468	0.85	50.6	429.33
15	Malda	Y=58.707*Time+146.53*Z11+ 0.05*Z231+2714.88	Tmax, Tmin*RF	3065	0.92	100.5	167.12
16	South 24 Parganas	Y=34.48*Time+91.88*Z11+ 0.73*Z31+46.66*Z41+520.41	Tmax, RF, RHI	2171	0.89	48.8	135.31
17	East Midnapore	Y=1251.57+169.43*Time+ 0.05*Z351	RF*RHII	2724	0.73	29.7	178.2

Crop Growth Simulation Models

Crop Growth Simulation Model estimates

1. **Phenological development or duration of growth stages as influenced by plant genetics, weather, and soil factors.**

2. **Growth of leaves, stems, roots and grains**

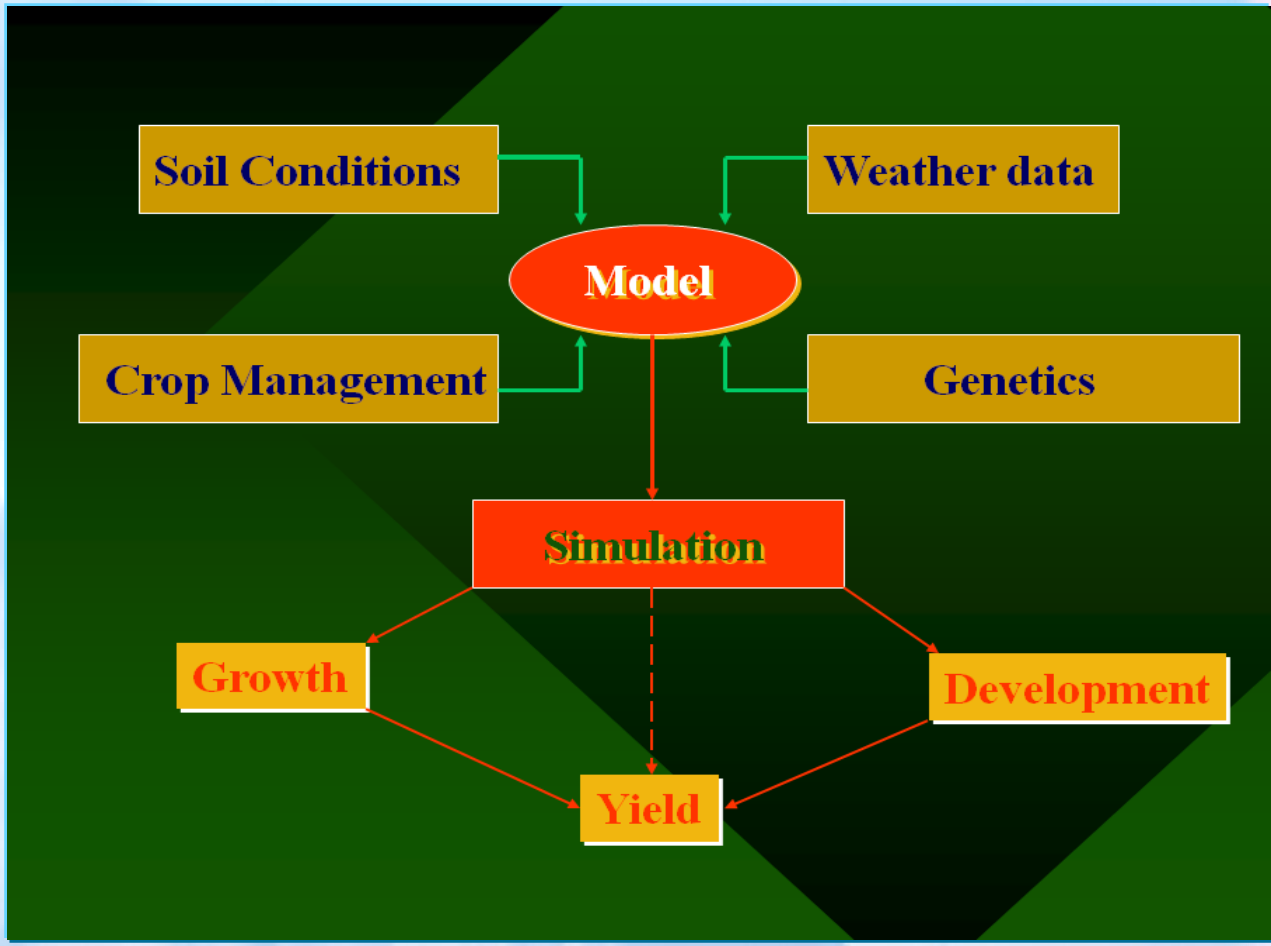
3. **Biomass production and partitioning**

4. **Effects of soil-water deficit and nitrogen deficiency on photosynthesis and photo-synthate partitioning in the plant system.**

Agricultural Models- System approach

Used under Indian condition

- DSSAT
- WOFOST
- APSIM
- EPIC
- WTGROWS
- INFOCROP
- ORYZA
- BRASSICA



What are the Crops covered

Cereals	Legumes	Oil seeds	Tuber crops	Horticultural Crop	Cash Crop /other crops
Barley	Chickpea	Canola	Cassava	Pepper	Sugar cane
Maize	Cowpea	Sunflower	Potato	Cabbage	Cotton
Pearl millet	Dry bean	Mustard	Tanier	Tomato	Bahia Grass
Rice	Faba bean		Taro	Sweet corn	Brachiaria
Sorghum	Lentil			Green bean	
Wheat	Peanut			Pineapple	
	Pigeon pea				
	Soybean				
	Velvet bean				
	Moong bean				

INPUTS: Minimum Data Set

Weather Variables

Solar radiation / bright sunshine hours
Maximum air temperature
Minimum air temperature
Precipitation
Latitude (to calculate day length)

Soil Variables

General Soil classification
Surface slope & Albedo
Runoff
Permeability & Drainage
First stage soil evaporation

For each Soil layer

Lower Limit
Drained Upper Limit
Saturated soil water content
Bulk Density
Clay & Silt (%)
Relative root distribution
Initial soil water content

Crop Management Variables

Cultivar selection (genetic coeff.)
Planting date
Plant population
Row spacing
Irrigation (dates and amount)
Fertilizer (dates and amount)
Initial conditions
Crop rotations
Pest (damage)

Network programme

- **ICAR- AICRPAm:** All India coordinated Research Programme on Agrometeorology- 25 locations
- **FASAL:** 47 Agro-Met Field Units in different agro-climatic zones

Crop Model calibration, validation and sensitivity analysis :

- Continuous evolution of model by field experimental testing across diverse environment, soil and cultural practices
- Information feedback from scientist/farmers and farm managers

Field Experimental Layout

Field experiments proposed under FASAL project consider following aspects

- 1 or 2 popular cultivars grown in the region for each crop under study
- 3 - 4 Date of sowing
- N management - Time, amount and method of application
- Phenology
- Growth- Biomass at different stages
- LAI and soil moisture at different stages
- Crop observations serve purpose of ground truth for RS data to link with CSM

Derivation of Genetic Coefficient for crop cultivars

Indian workers have derived Genetic coefficients for few ruling cultivars of following crops in different agro-climatic zones –

- Rice, Wheat, Maize, Sorghum, Millet, Peanut, Soybean, Sugarcane, potato, chickpea, Sunflower

- A new crop cultivar needs model calibration and validation to derive the G.C. This requires crop observations from field experiments.

Available Database

Crop data

- Area, Production & Productivity - district wise, 1990 onwards for all major crops of India
- Genetic coefficient of all major crops derived from field experiments

Weather Data

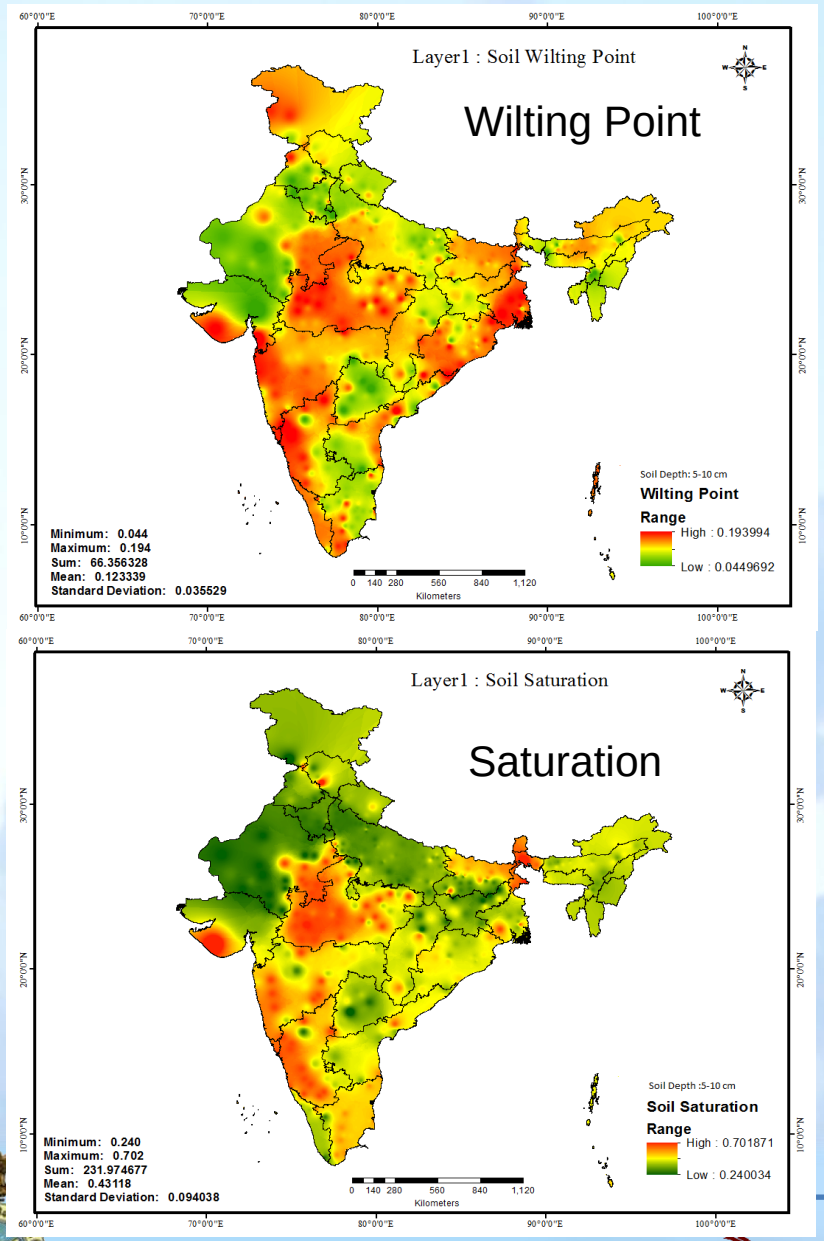
- Daily Max & Min Temperatures, Rainfall, RH-I & RH-II, BSSH - district level, 1971 onwards.

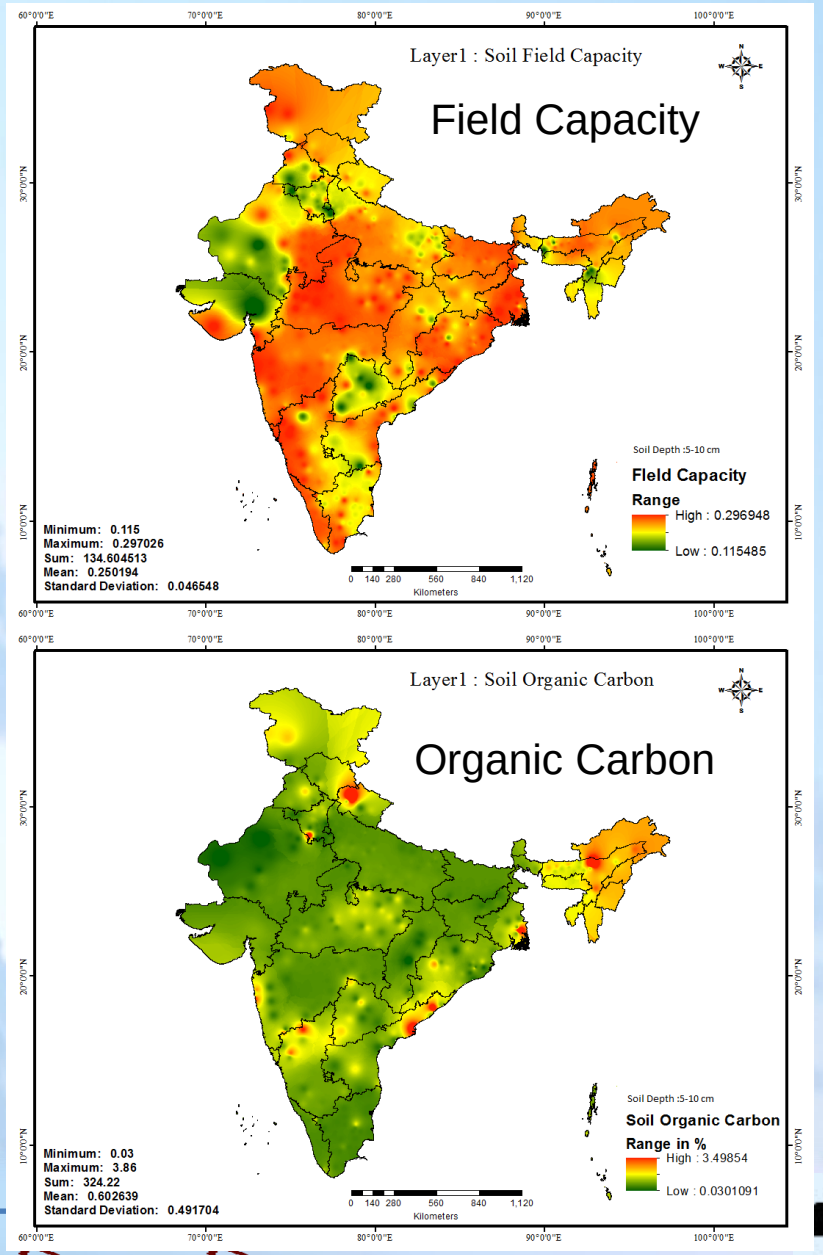
Soil Data

- Layer wise Hydro-physico-chemical properties required for CSM- district wise

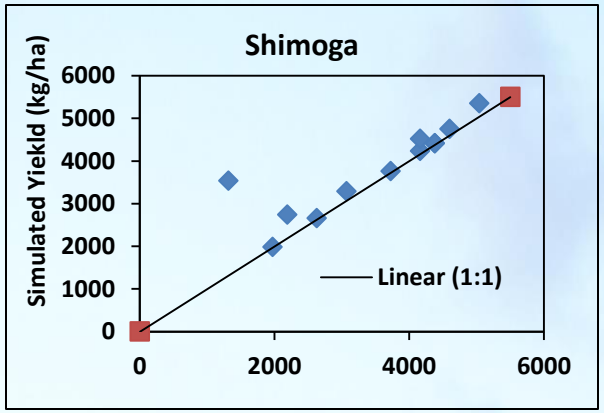
Crowd sourcing is done regularly to improve the data accuracy through different networks.

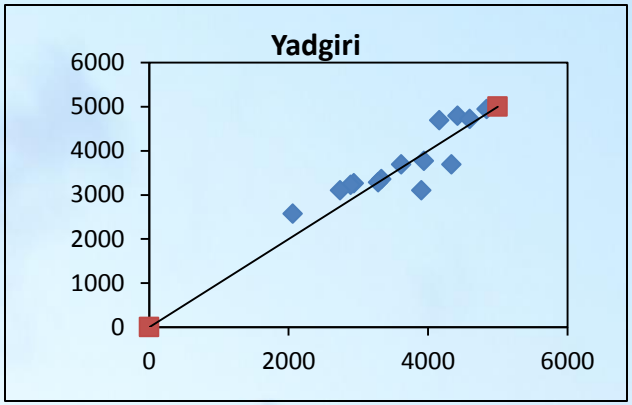
District wise soil information- Layer 1

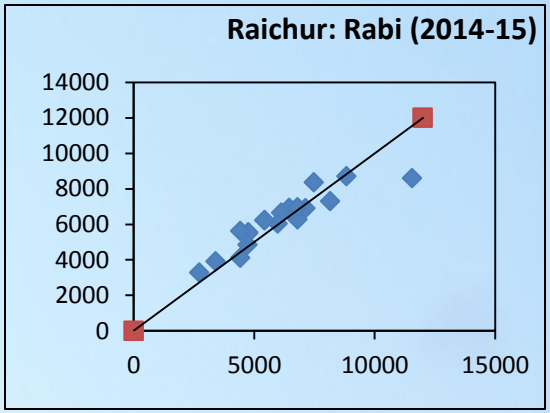


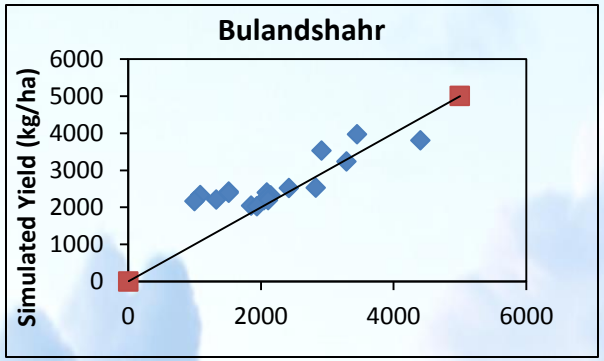


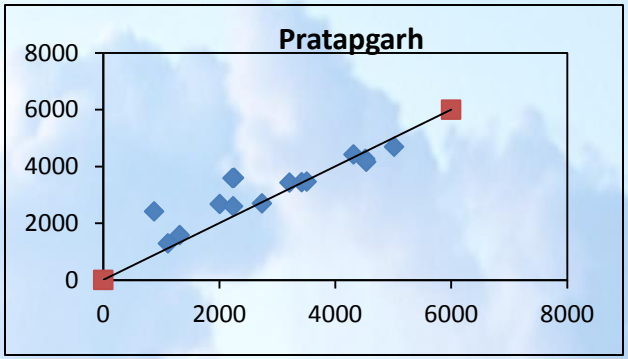
Model Evaluation in Farmer's field: CCE Yield Vs. Simulated Yield of Kharif Rice 2014

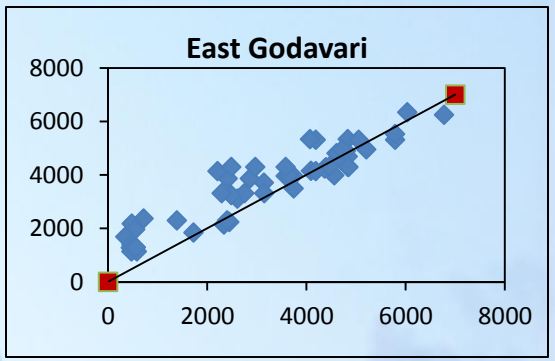


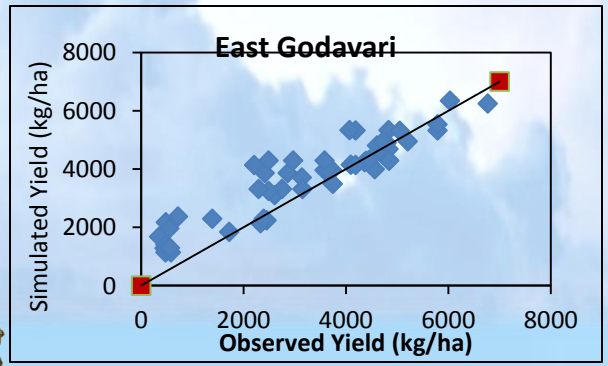


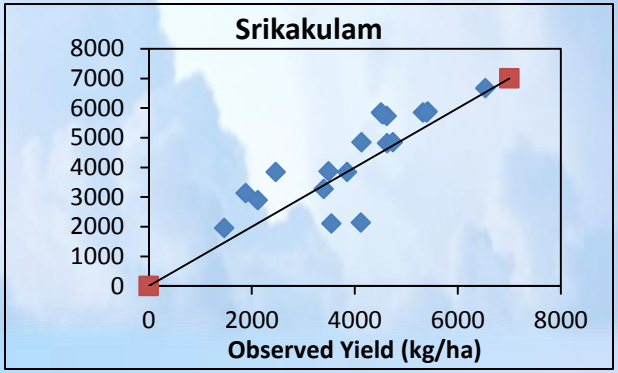


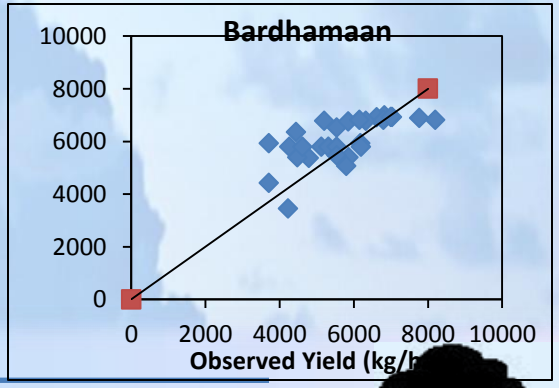








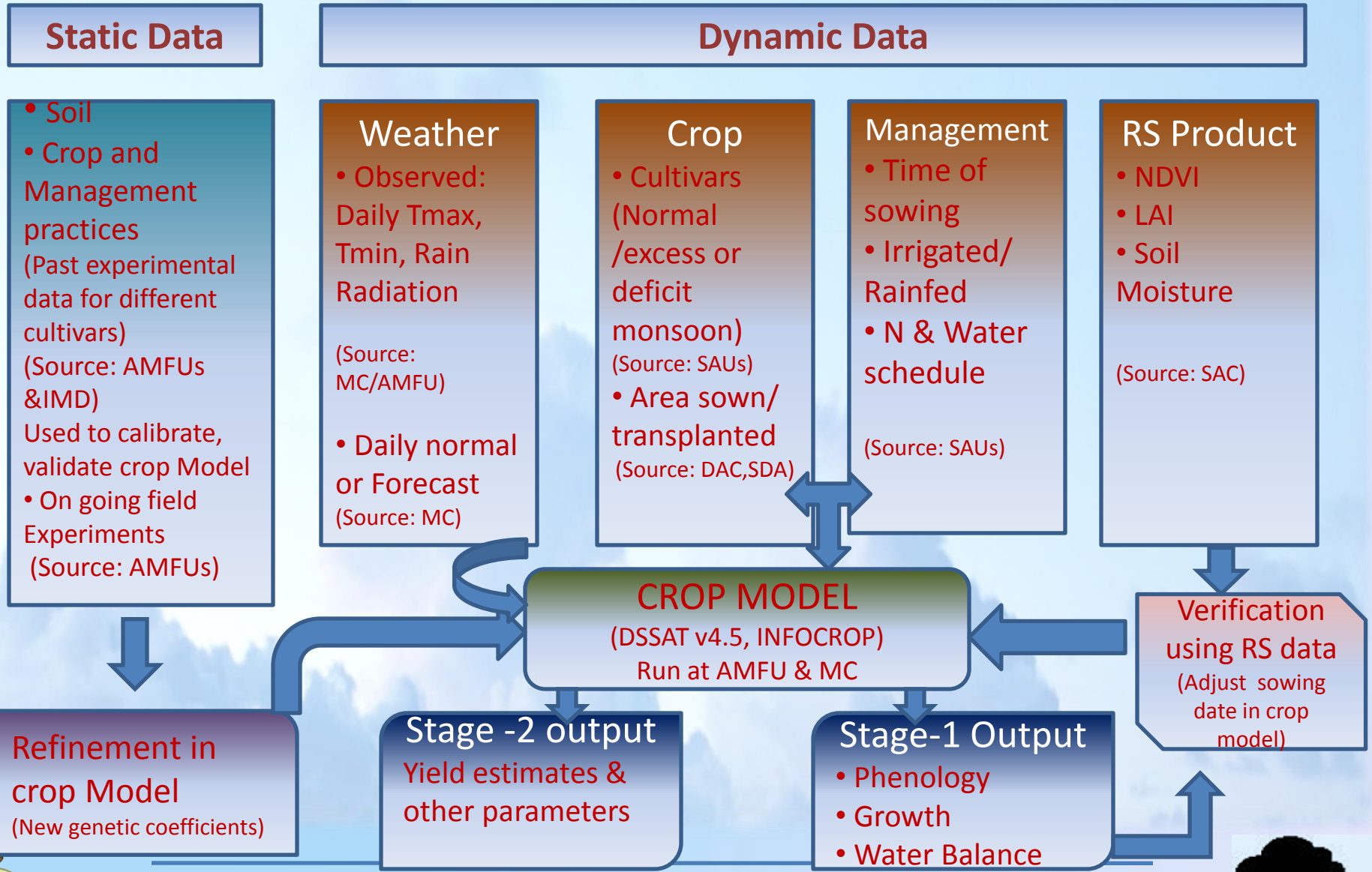




In-season Crop Yield Forecasting

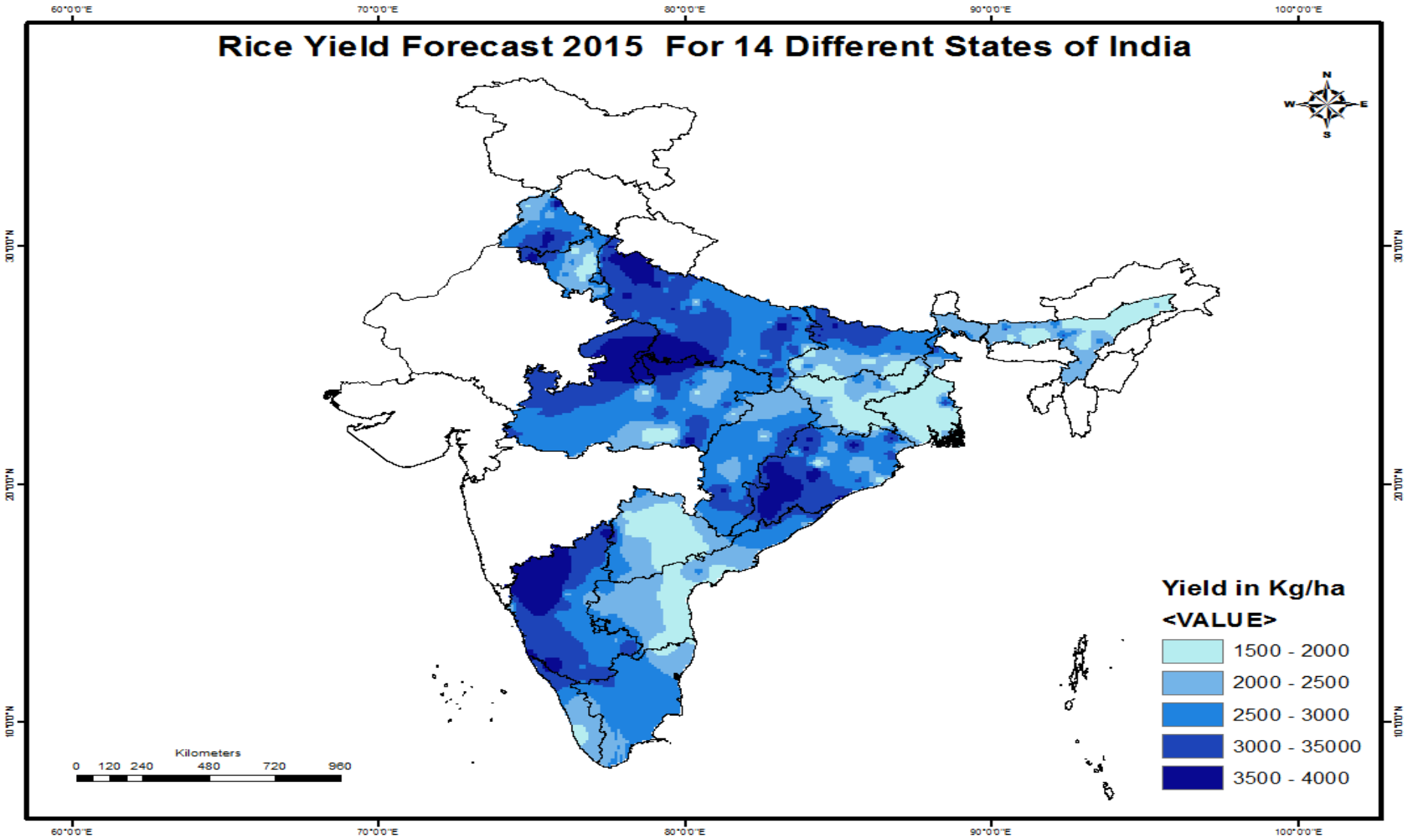
Methodology & Result

Spatial Crop Yield Forecasting: Methodology and Data flow

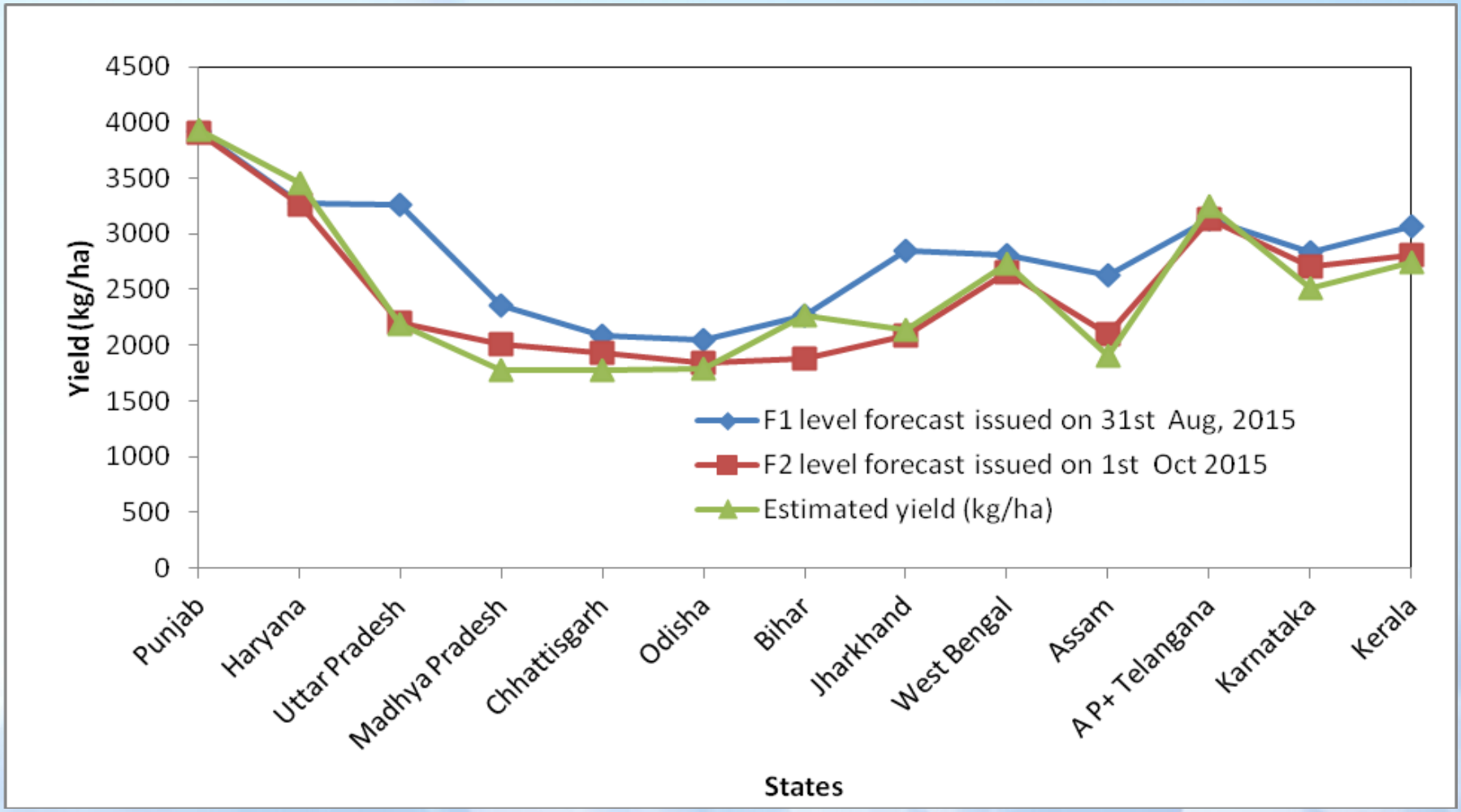


भारत मौसम विज्ञान विभाग
INDIA METEOROLOGICAL DEPARTMENT

Crop Simulation Model based operational district level Rice Yield Forecast *Kharif* -2015



Model performance for Rice Yield for different state-2015



Source : DAC&FW (MoAg&FW)

Bottlenecks in developing crop yield forecast

- Long term Meteorological data and / or crop yield data are not available for some districts.
- Poor accuracy of yield forecast models for the regions where there is high variability in weather and crop yield over the years.
- Due to socio-economical & Govt. policy, Sudden changes in cultivation practices and varieties causing sharp changes in yield pattern.
- Due to establishment of new districts, there is non-availability of long term weather and yield data for these districts.
- Damage caused due to Extreme events are not accountable in the model.

Future considerations

- Weekly progress of Area sown under different crops at district scale
- Improvement in Estimation of daily solar radiation using routine weather data such as MaxT, MinT, rain, cloud cover – important during monsoon season. Also Satellite derived insolation (8 km & 4 km res.)
- Improvement in soil data base
- Linking RS data with Crop model
  - Forcing of LAI etc. into CSM at the time of prediction
  - Re-run crop model- adjust sowing date to match simulated crop condition (LAI)
- Use of other crop model -InfoCrop model etc.
- Develop methodology to ensemble/ hybridize the multi crop simulation and statistical models' estimates to improve final forecast

THANK YOU