Use of Remote Sensing data for Crop Yield Modelling (under CAPE, FASAL programs)

V K Dadhwal

Outline

- CAPE Project
- Simple RS-based approaches
- RS Models - Performance & Drawbacks
- Requirements for FASAL
- RS Advances & Opportunities for Yield Models
- RS & Crop Parameters
- RS & Crop Simulation Models
- RS & Crop Condition – Case Studies
- Future Outlook

CAPE

(CROP ACREAGE AND PRODUCTION ESTIMATION)

sponsored by Department of Agriculture & Cooperation since 1988

- **Aimed at district-level pre-harvest production forecasts using single-date RS data for area estimation.**
- **Spectral indices, historical data & weather inputs for yield forecasts.**
- **Aims to meet specified accuracy goals (90/90 accuracy) & transfer the technology to users.**

CAPE covers 7 major crops

wheat, rice, mustard, groundnut, cotton, rabi sorghum & sugarcane **in major growing areas in 15 states.**

(AP, Assam, Bihar, Gujarat, Haryana, HP, Karnataka, Orissa, Maharashtra, MP, Punjab, Rajasthan, Tamil Nadu, UP & W. Bengal).

Roadmap for Crop Models in CAPE

OPERATIONAL

Use of limited in season weather data

- **District-level**
  - **Wheat: Temp-based regression**
    Rice: Monthly Rainfall regression
- **State-level**
  - **Met-sub-division scale regression/**
    Wheat (temp); Rice (rainfall)
  - **Crop Simulation Models-Met only**

Single-date Crop VI from Discrimination step

District-level

VI-Yield Empirical Models

Multi-date Coarse Resolution inputs/ VI, Crop parameters, Thermal, etc

GRID - Region

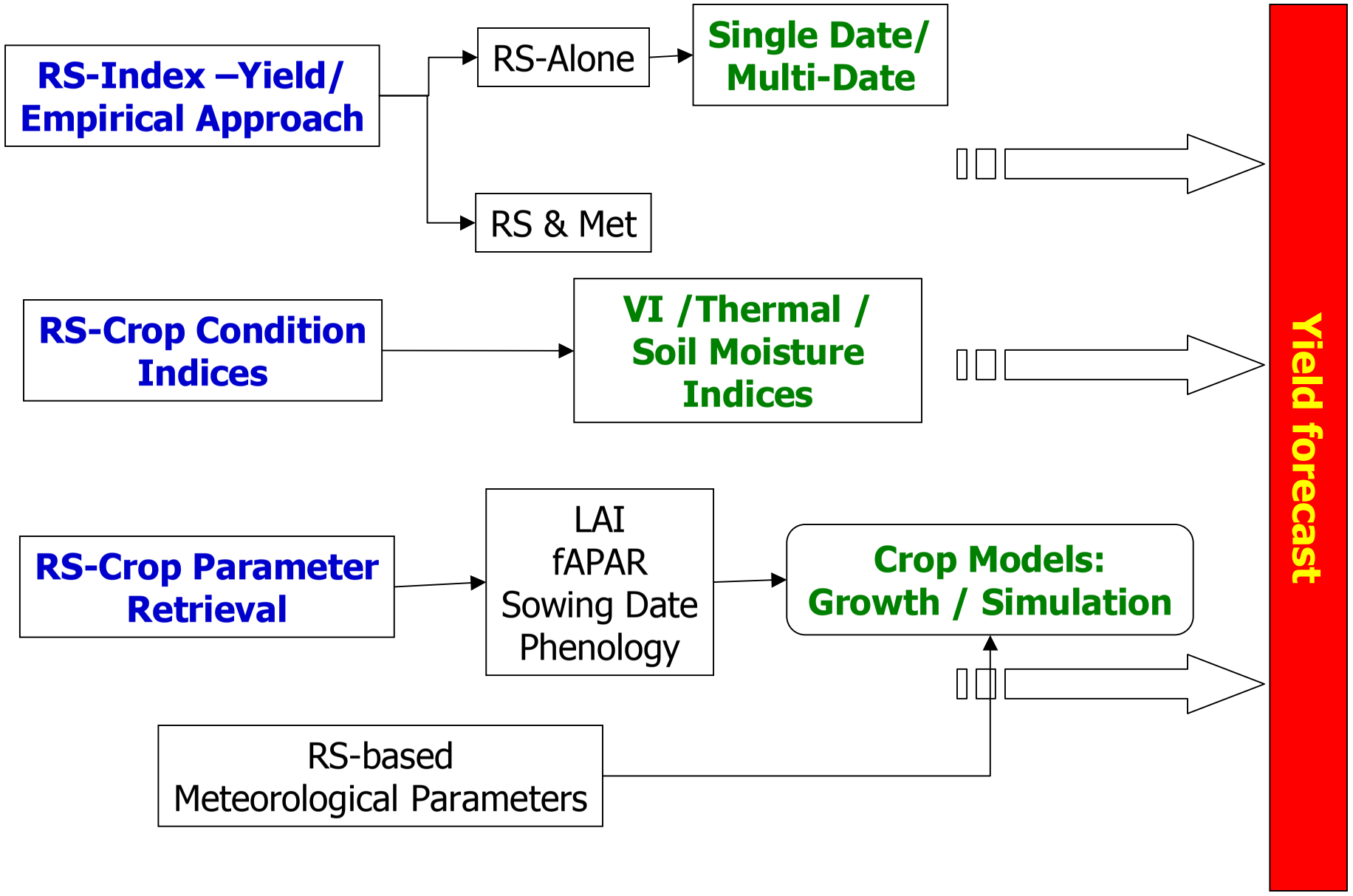
Crop Growth & Crop Simulation Models

RESEARCH

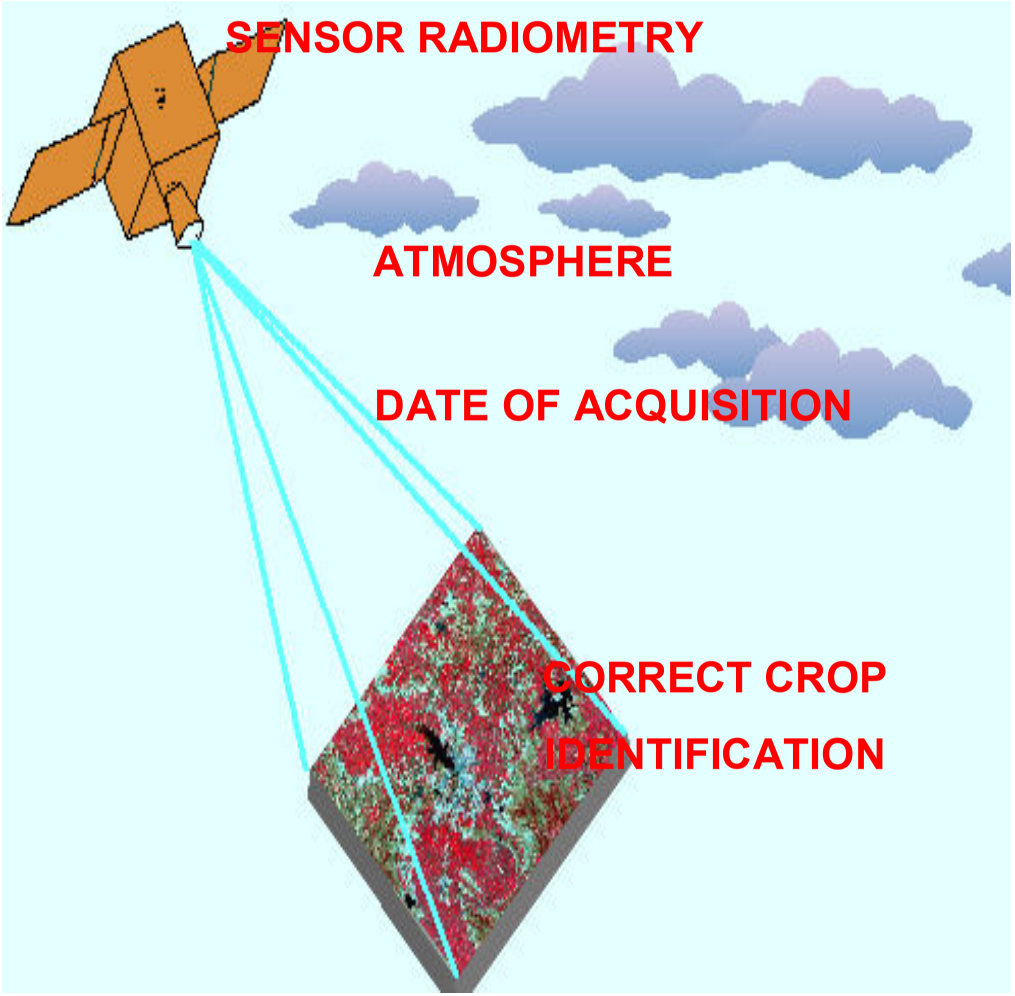
Field Scale Models

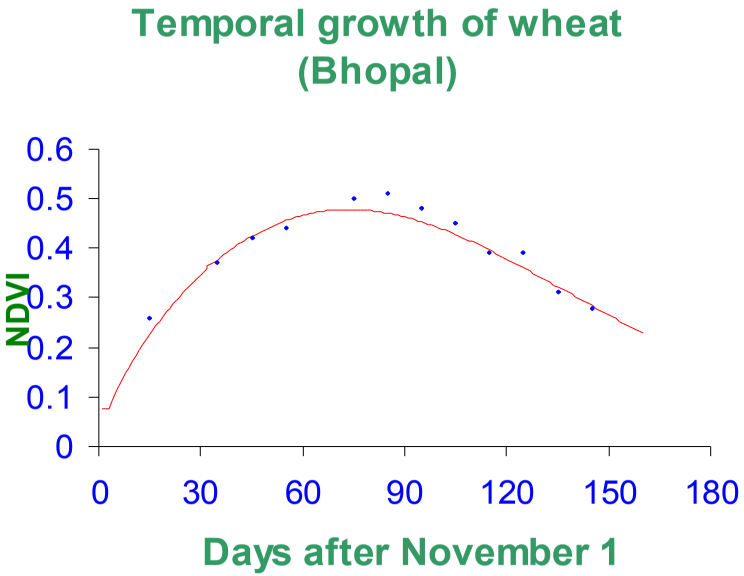
Crop Growth & Crop Simulation Models

Use of RS in Yield Prediction



SPECTRAL CROP YIELD PREDICTION : STEPS





STRATIFIED RANDOM SAMPLING &
CROP DISCRIMINATION

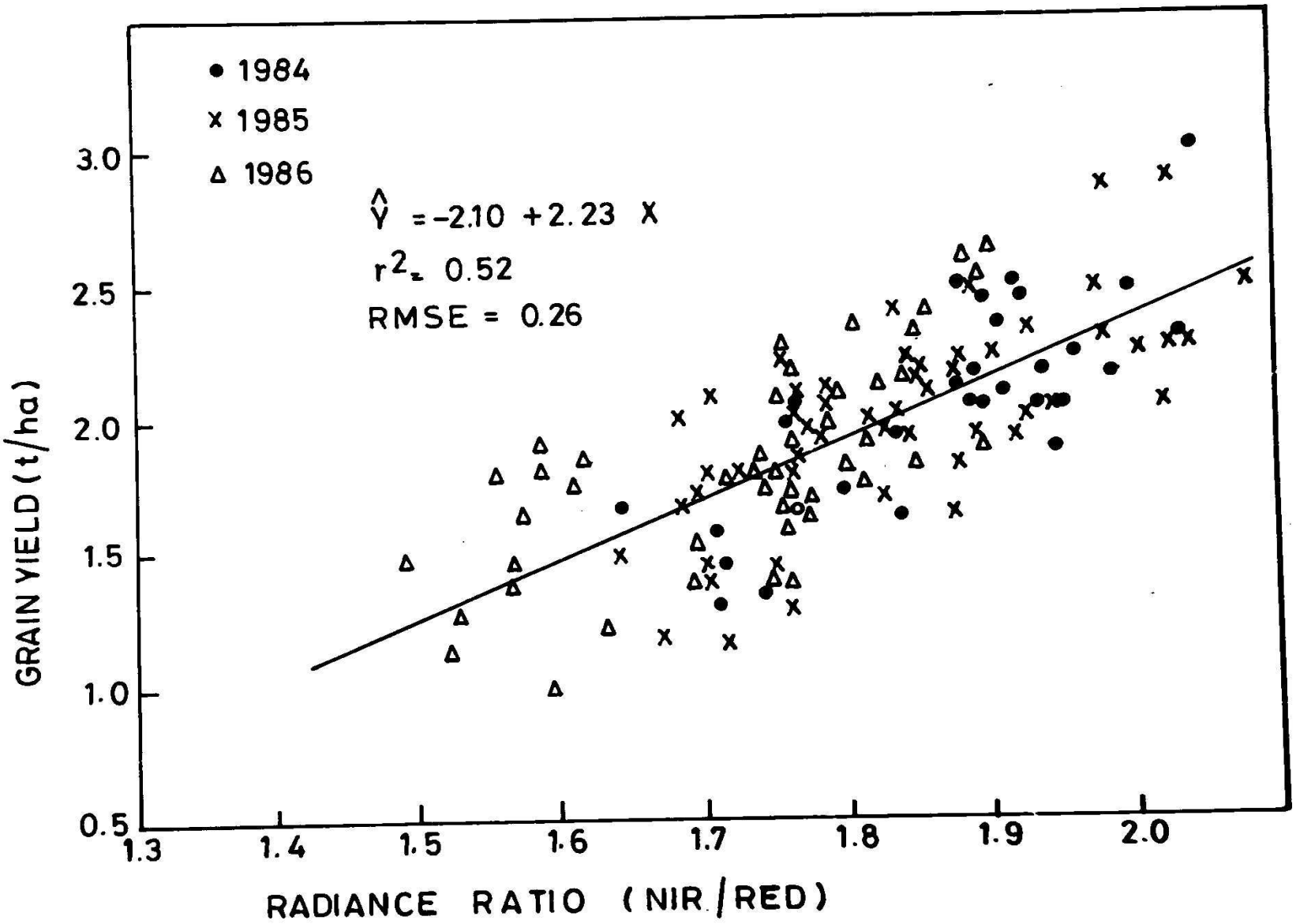
↓

DISTRICT NDVI ESTIMATION

↓

SPECTRAL YIELD PREDICTION
Yield = m NDVI + c

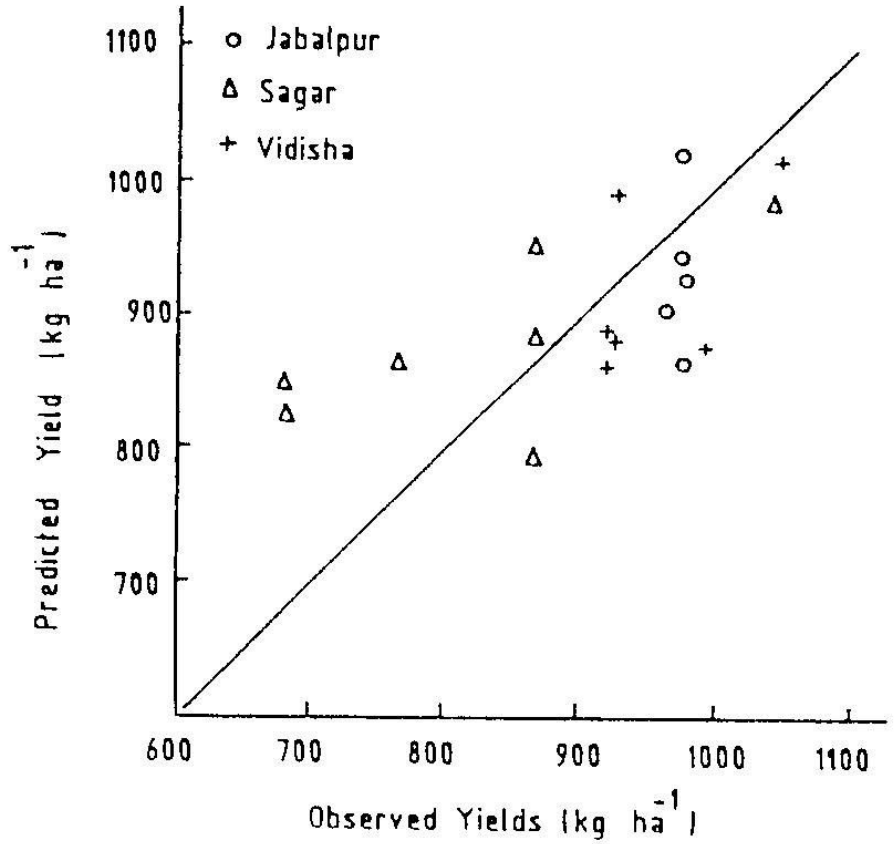
VI-Yield Model : Rice (Orissa), Landsat MSS



Rice yield versus radiance ratio relationship at block-level using LANDSAT MSS digital data in Cuttack and Puri districts of Orissa

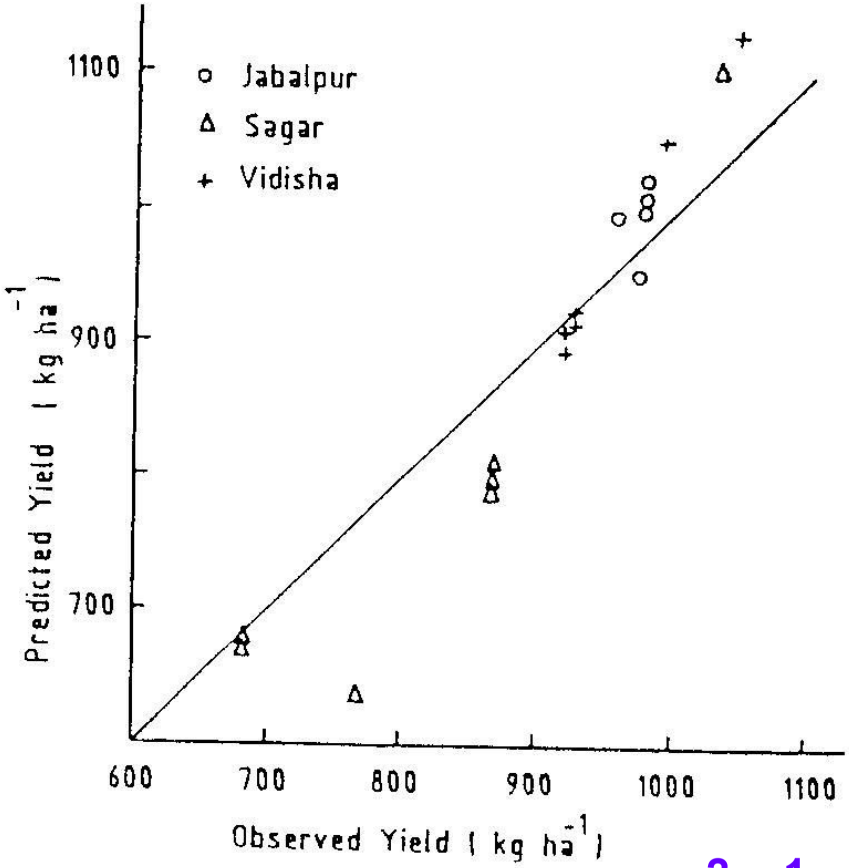
Acquisition Date Correction

Linear Model



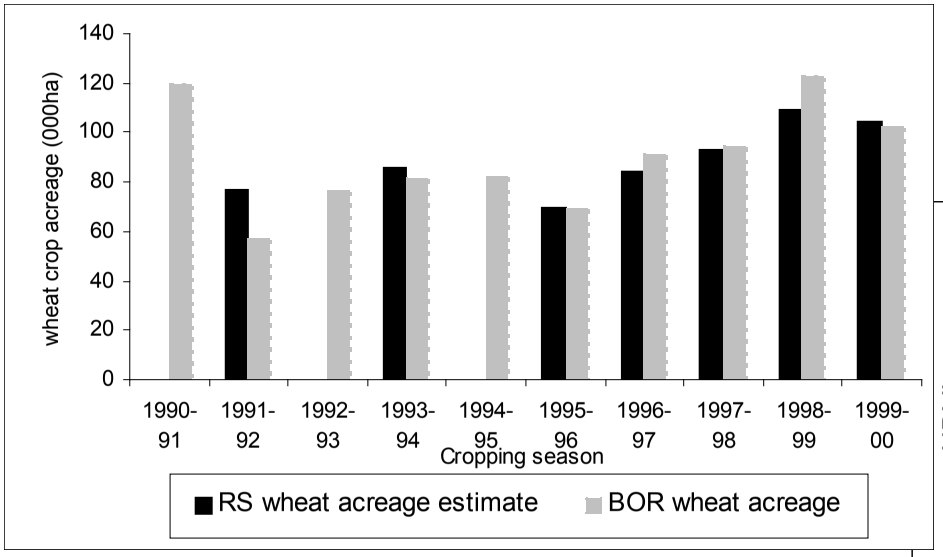
LISS-I, Wheat, M.P.

Non-Linear Model



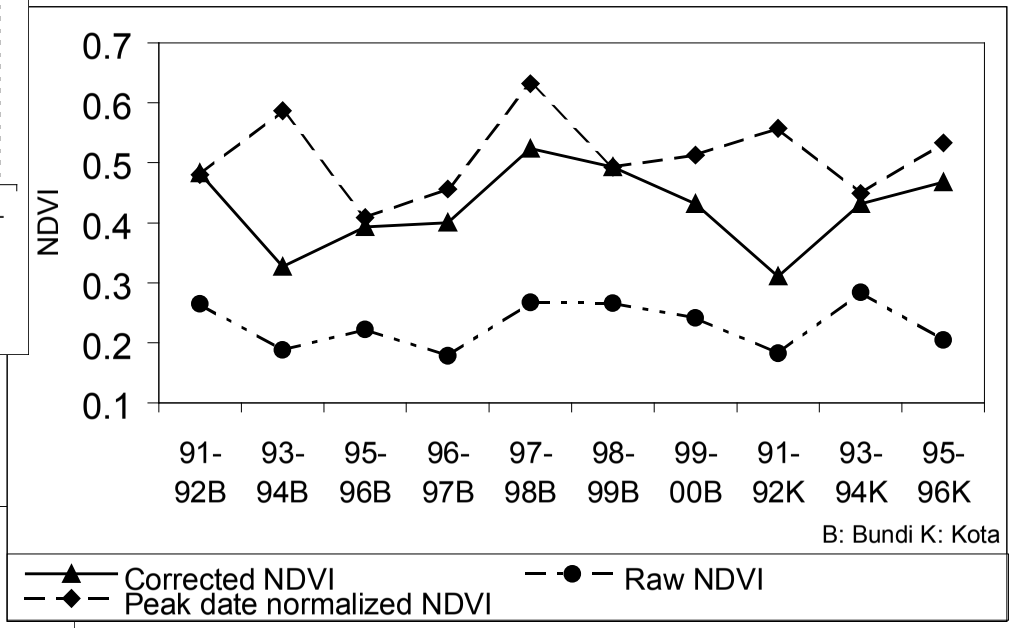
$$Y = b_0 + b_1 VI\,[1 - b_2 (t_a - t_p)^2]^{-1}$$

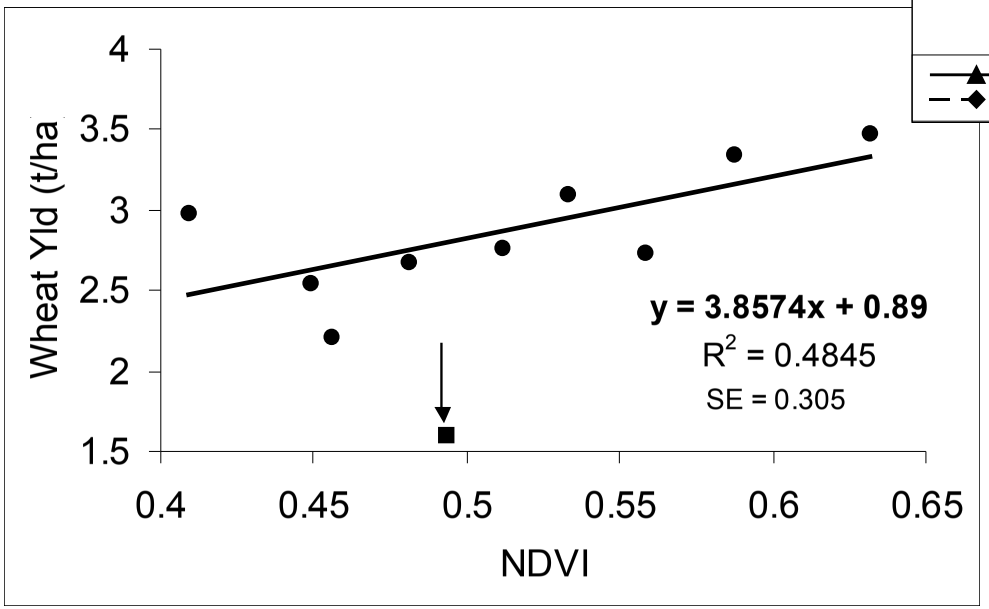
Single Date Models – Long Series



1

2

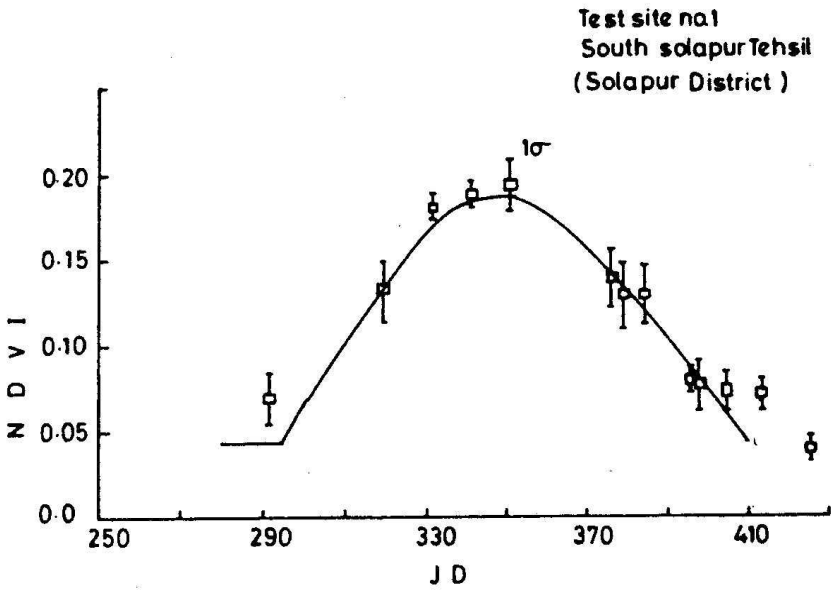


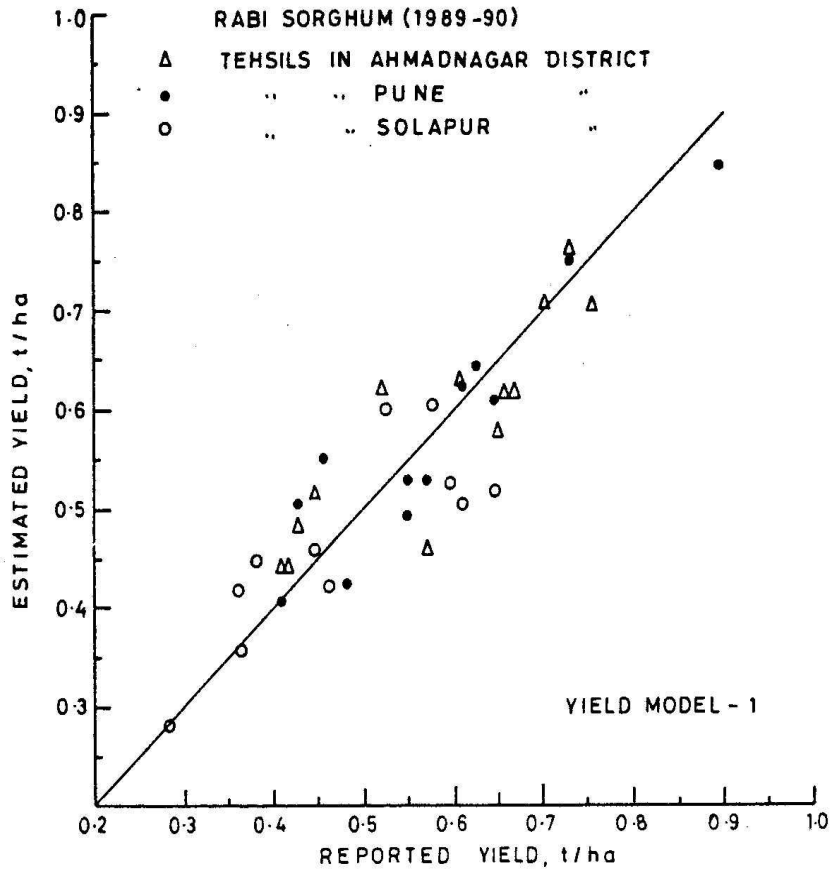


3

KOTA DISTRICT, RAJASTHAN

SPECTRAL PROFILE FOR SORGHUM



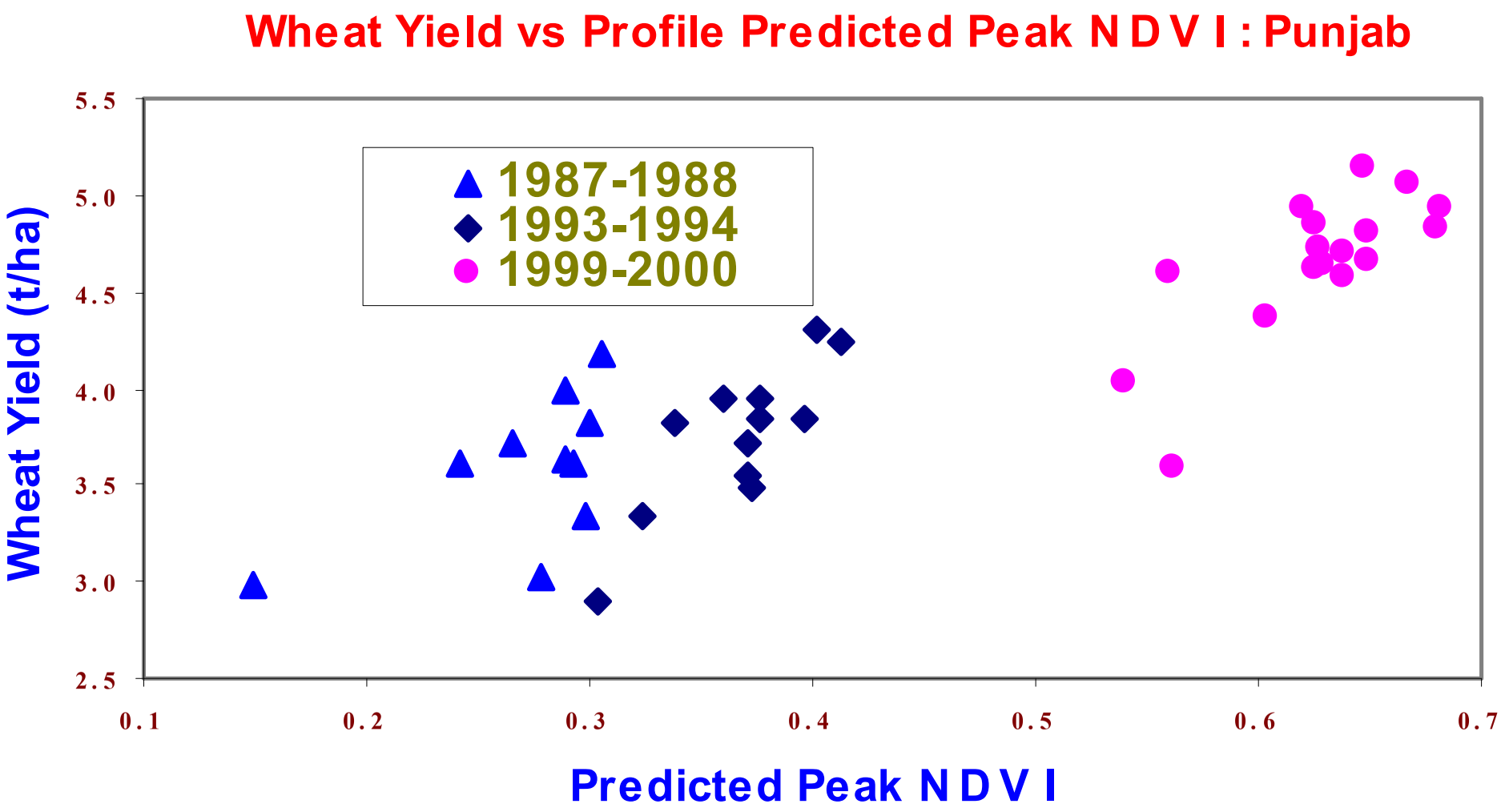


STUDY AREA : TEHSILS OF AHMEDNAGAR, PUNE AND SOLAPUR

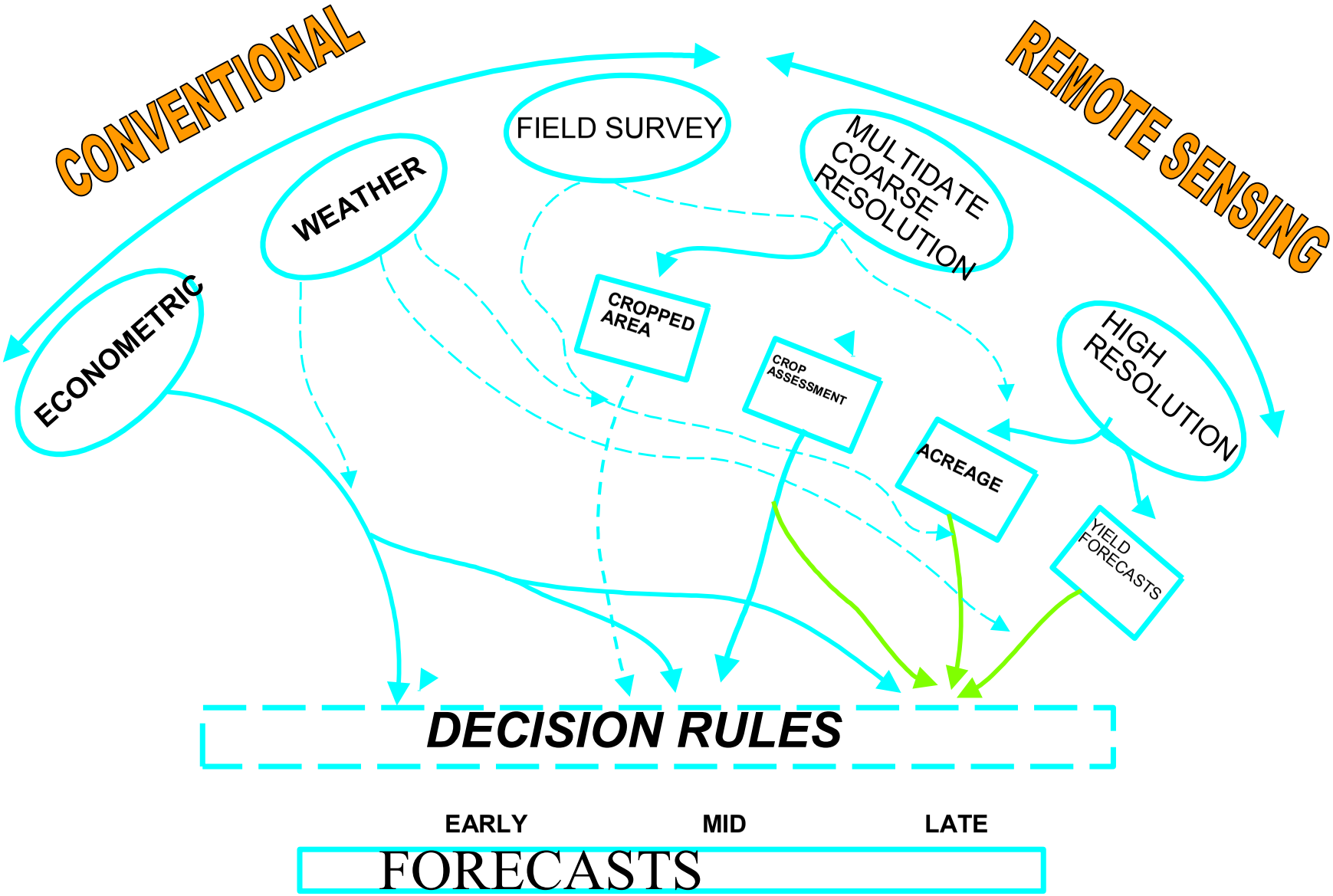
DATA USED : SPECTRAL PROFILE GENERATED FROM NOAA AVHRR DATA OF 11 DATES (1989-90)

Source : Potdar, et al. (1993)

Wheat Yield : Coarse Resolution Data

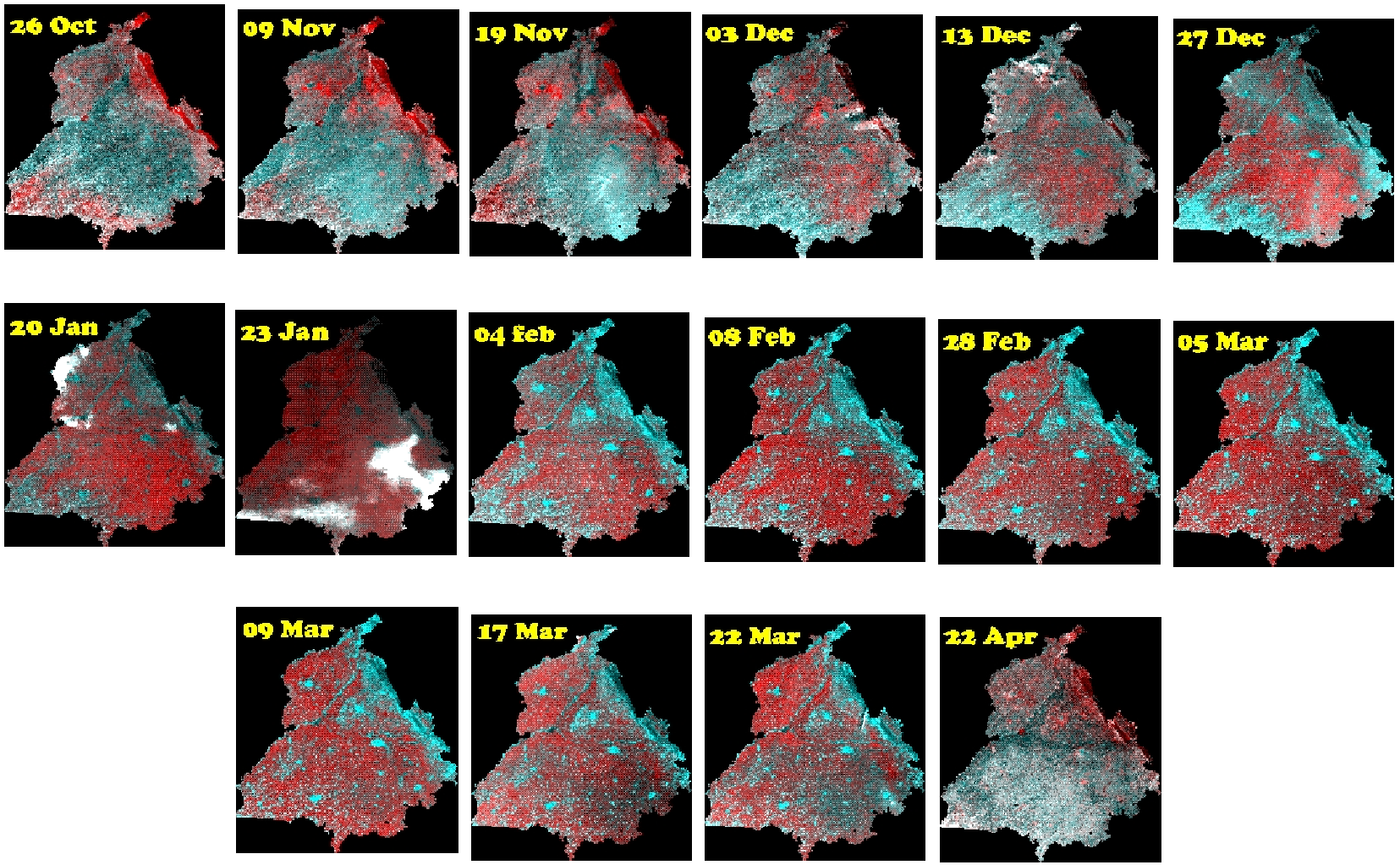


OVERALL APPROACH IN 'FASAL'



Crop Phenology

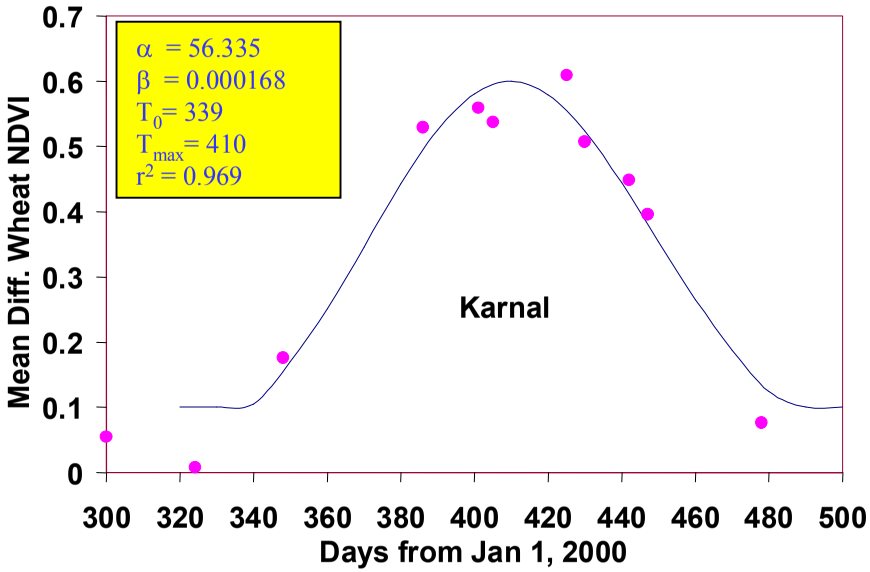
- Input is multi-temporal VI data set

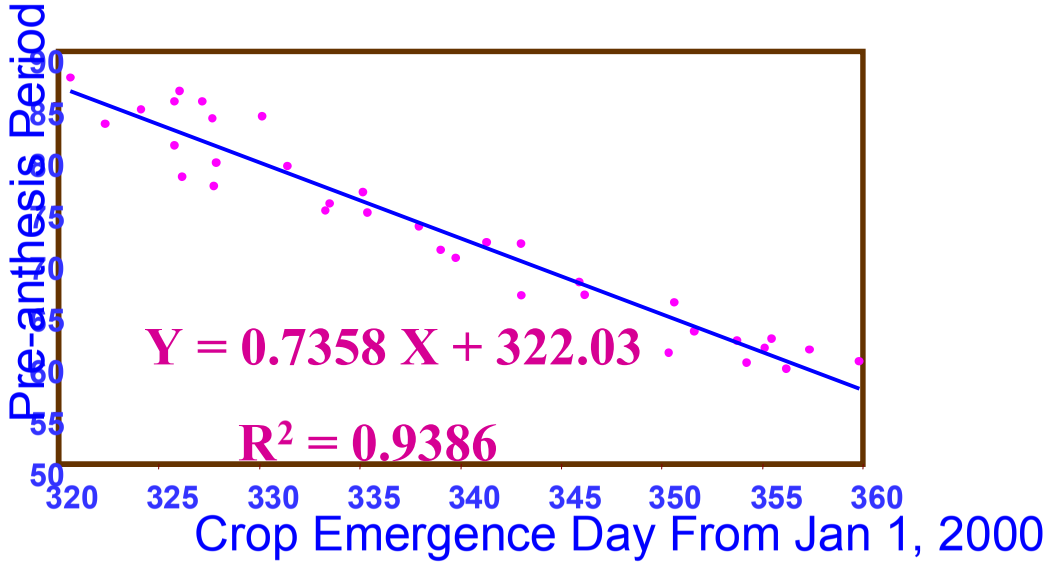


IRS WiFS Images Over Punjab : 2000-2001 Rabi Season

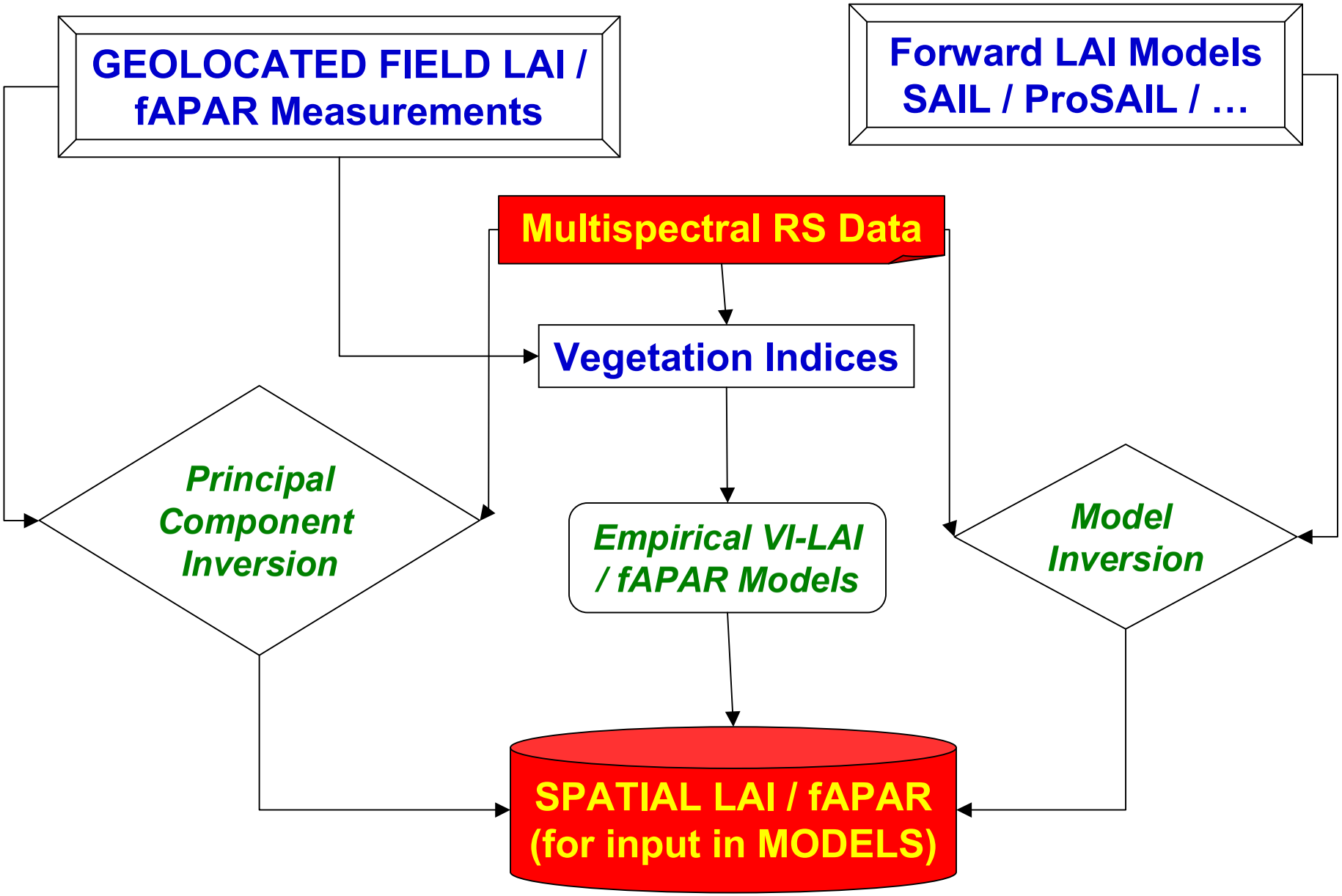
Crop Phenology

- Temporal pattern of VI
  - Parameteric, Curve-fitting approaches
  - Emergence (sp), peak VI, Length of growing period
- Use: Yield models, crop-climate, zoning





LAI / fAPAR Retrieval Approach



Field-level Yield Models

- Advantage
  - Yield Variation is larger
  - All necessary inputs can be monitored & used in models
- Disadvantages
  - Field scale soil fertility variations : Role difficult to model
  - Use of high resolution data, limited number of acquisition
- Studies (Wheat)
  - Simple VI-yield model
    - Pantnagar : Phenology correction & weather inputs
  - WTGROWS calibration & RS forcing
  - HERMES : Using RS based LAI forcing, Phenology use

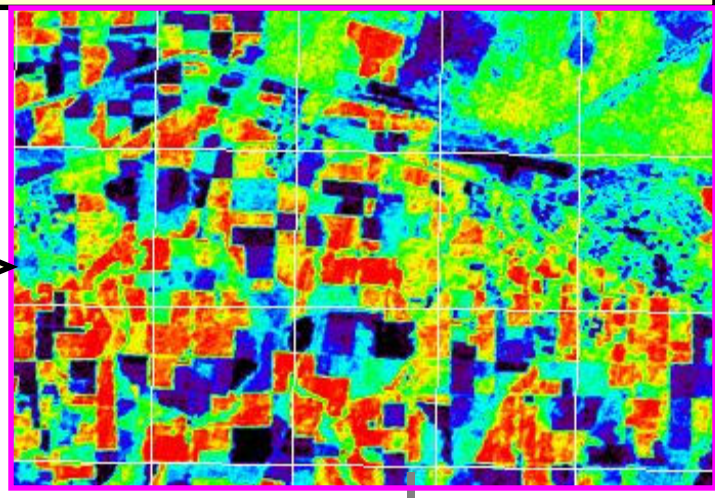
FARM LEVEL WHEAT YIELD PREDICTION USING REMOTE SENSING DATA



MULTIDATE IMAGES

PATH REDIANCE CORRECTION (DOS)

SENSOR TO SENSOR CORRECTION



MULTIDATE NDVI IMAGES

WEATEHER DATA

AGRONOMICAL DATA

SOIL INFO

INPUTS

CERES WHEAT

CROP SIMULATION MODEL IN SYSTEM

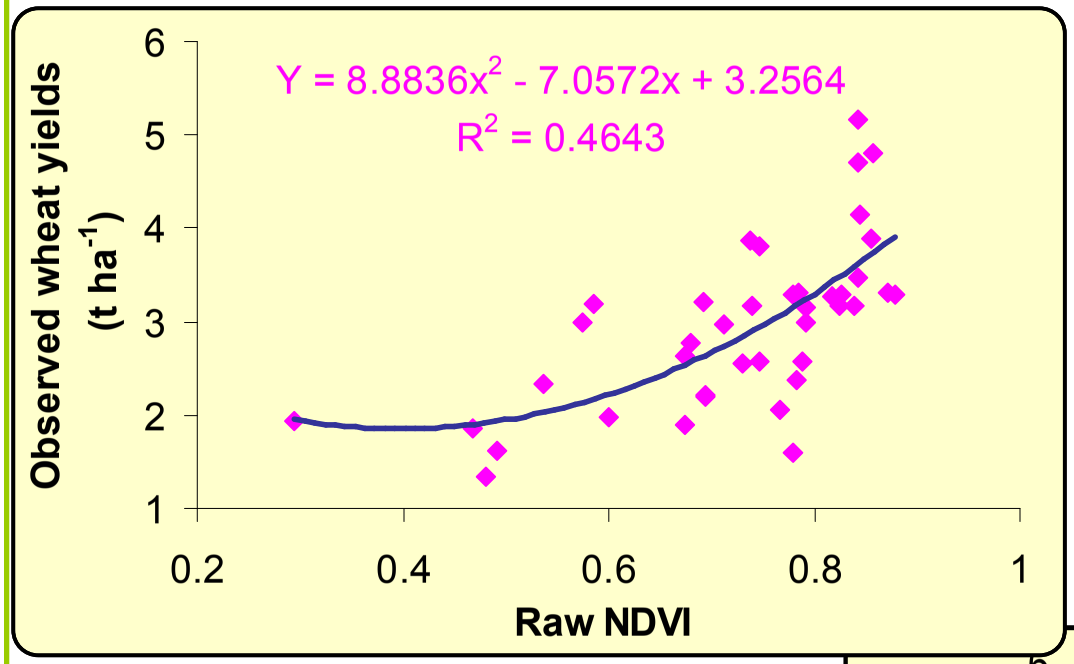
5 FEB
20 FEB 12 FEB 29JAN
9 FEB 15 FEB
14 JAN

5 FEB
20 FEB 12 FEB 29JAN
9 FEB 15 FEB
14 JAN

RAW-NDVI NORM-NDVI

DATE NORMALIZED NDVI

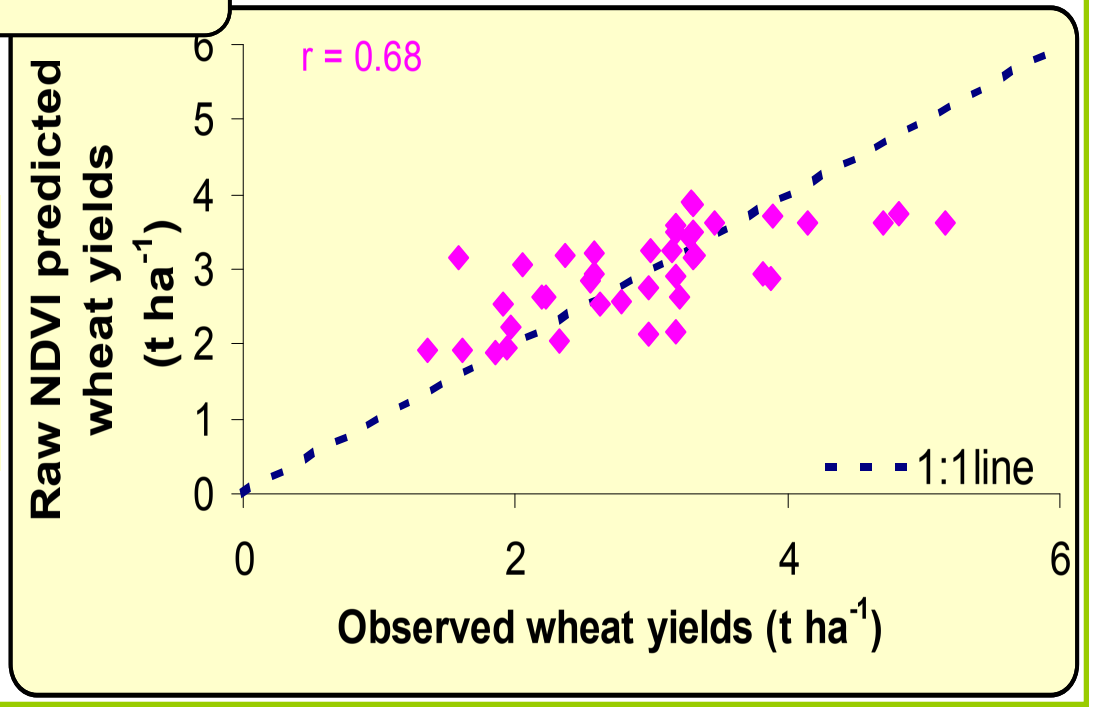
RESULTS : RAW NDVI



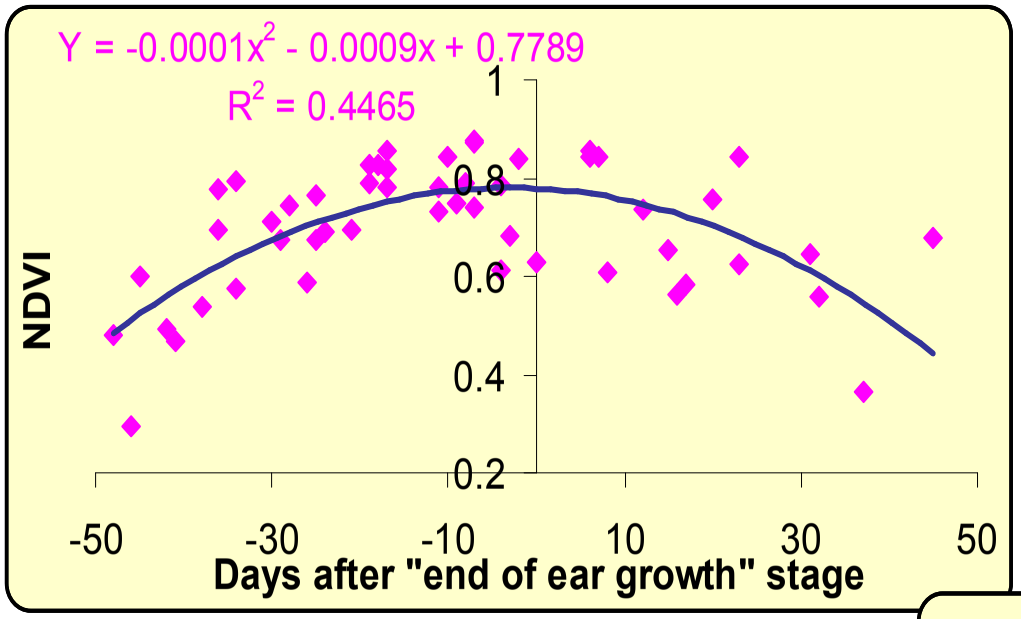
RELATIONSHIP BETWEEN OBSERVED WHEAT YIELDS AND RAW NDVI.

SCATTER PLOT BETWEEN OBSERVED WHEAT YIELDS AND PREDICTED WHEAT YIELDS USING RAW NDVI.

RAW NDVI HAS POOR PREDICTABILITY.



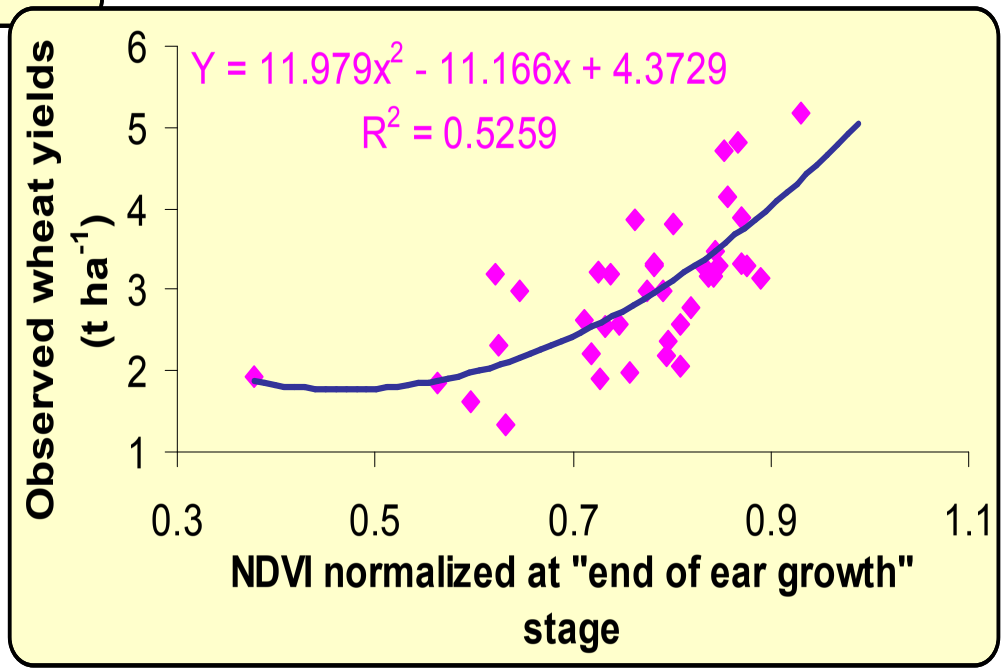
CORRECTING FOR ACQUISITION DATE



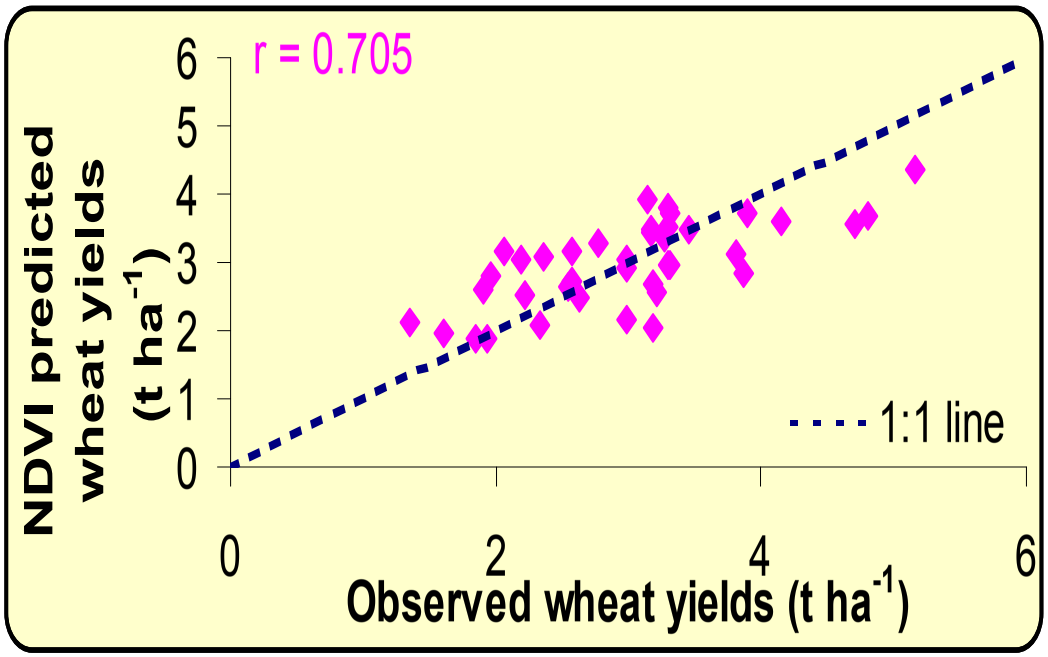
(SOWING DATE IS KNOWN)

CURVE FITTING BETWEEN NDVI AND DAYS FROM " END OF EAR GROWTH" STAGE.

RELATIONSHIP BETWEEN OBSERVED WHEAT YIELDS AND NDVI, NORMALIZED AT "END OF EAR GROWTH" STAGE.

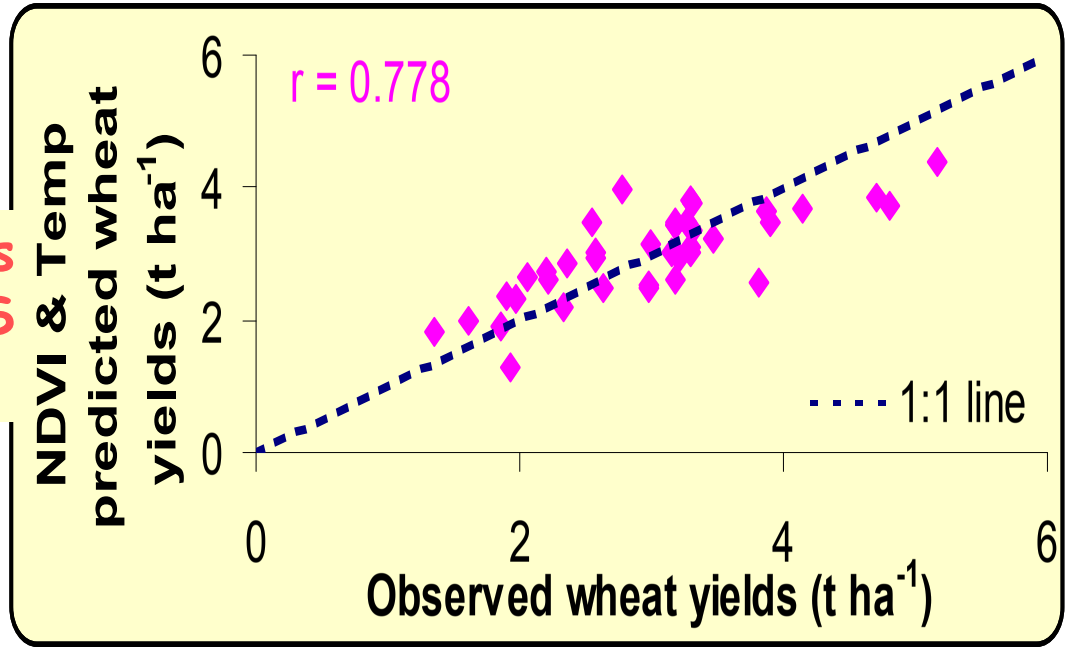


POST NDVI WEATHER IS USEFUL

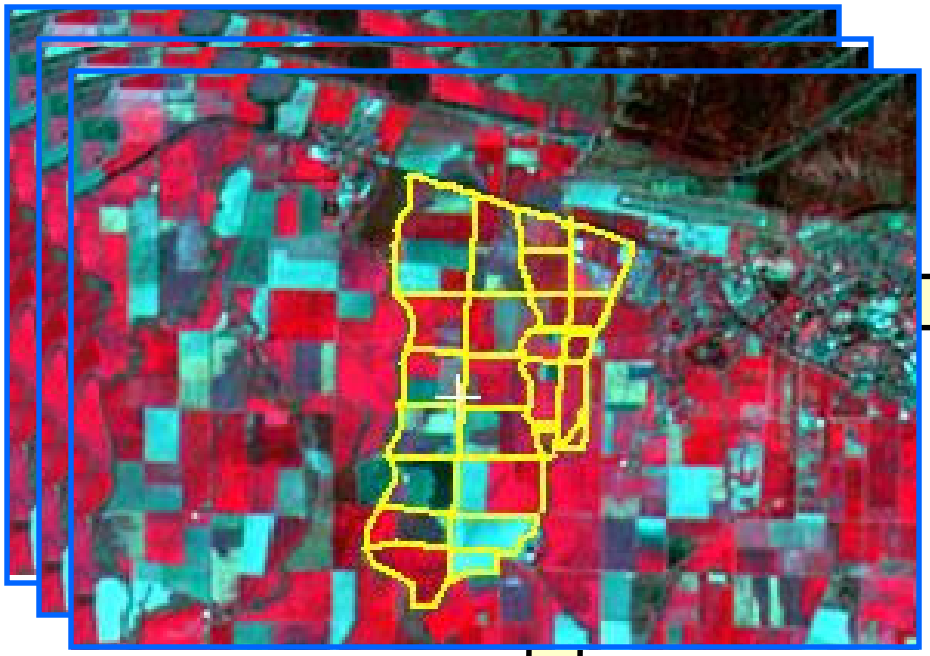


OBS. WY VS PRED. WY with NORMALIZED NDVI AT "EEG" STAGE.

OBS. WY VS PRED. WY as ABOVE with POST ANTHESIS TEMPERATURE.



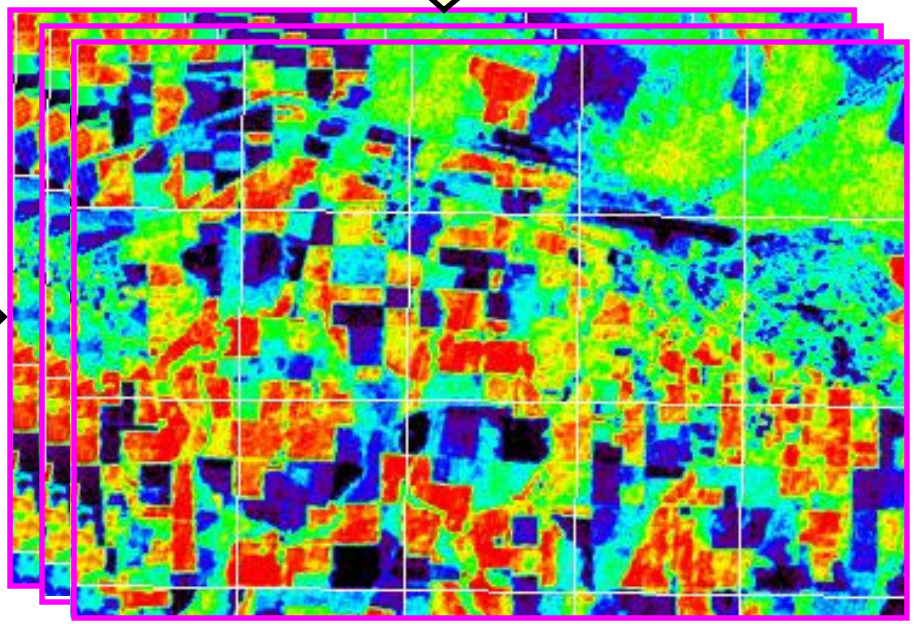
Methodology Cont..



PATH REDIANCE CORRECTION (DOS)

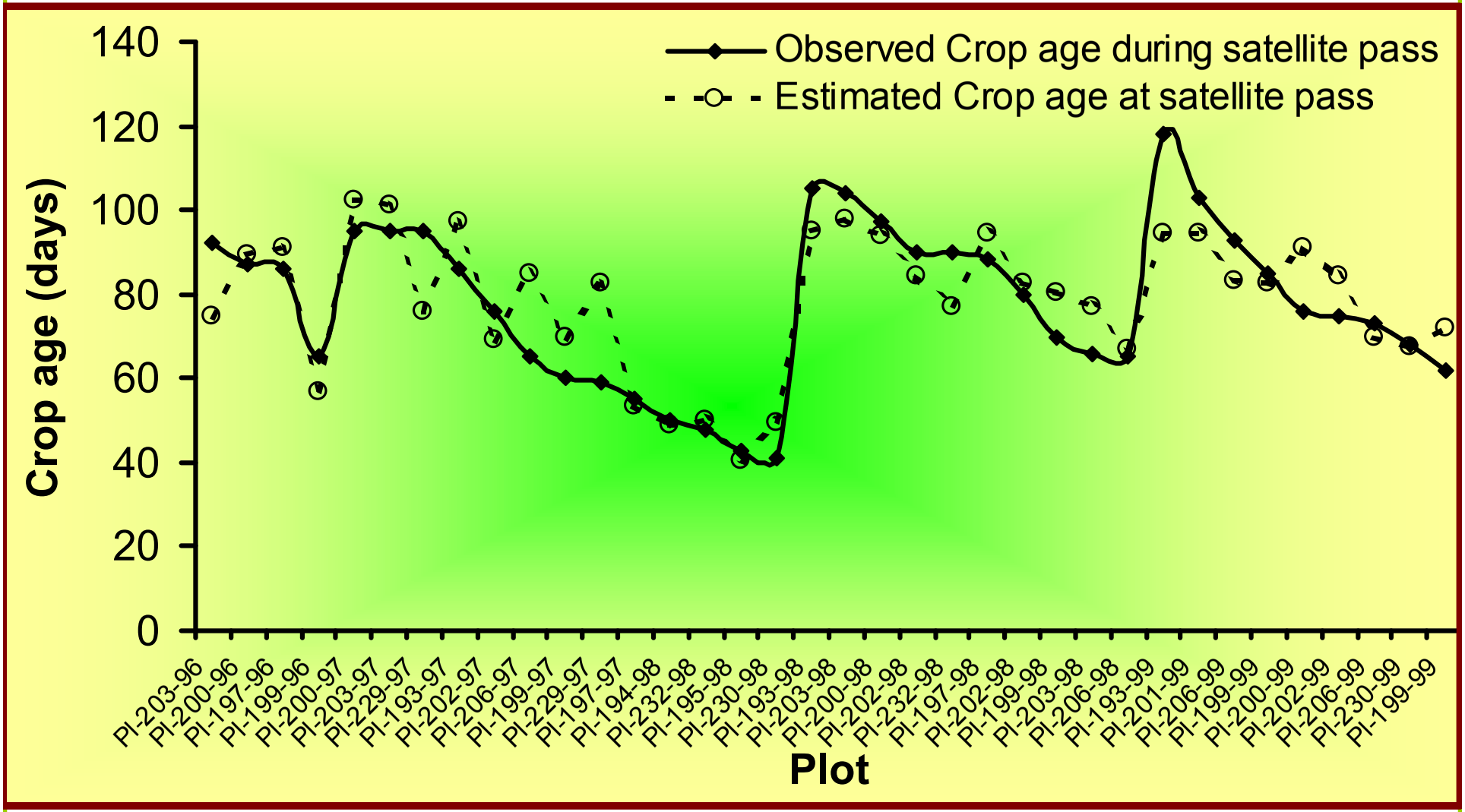
SENSOR TO SENSOR CORRECTION

NDVI = ——————————

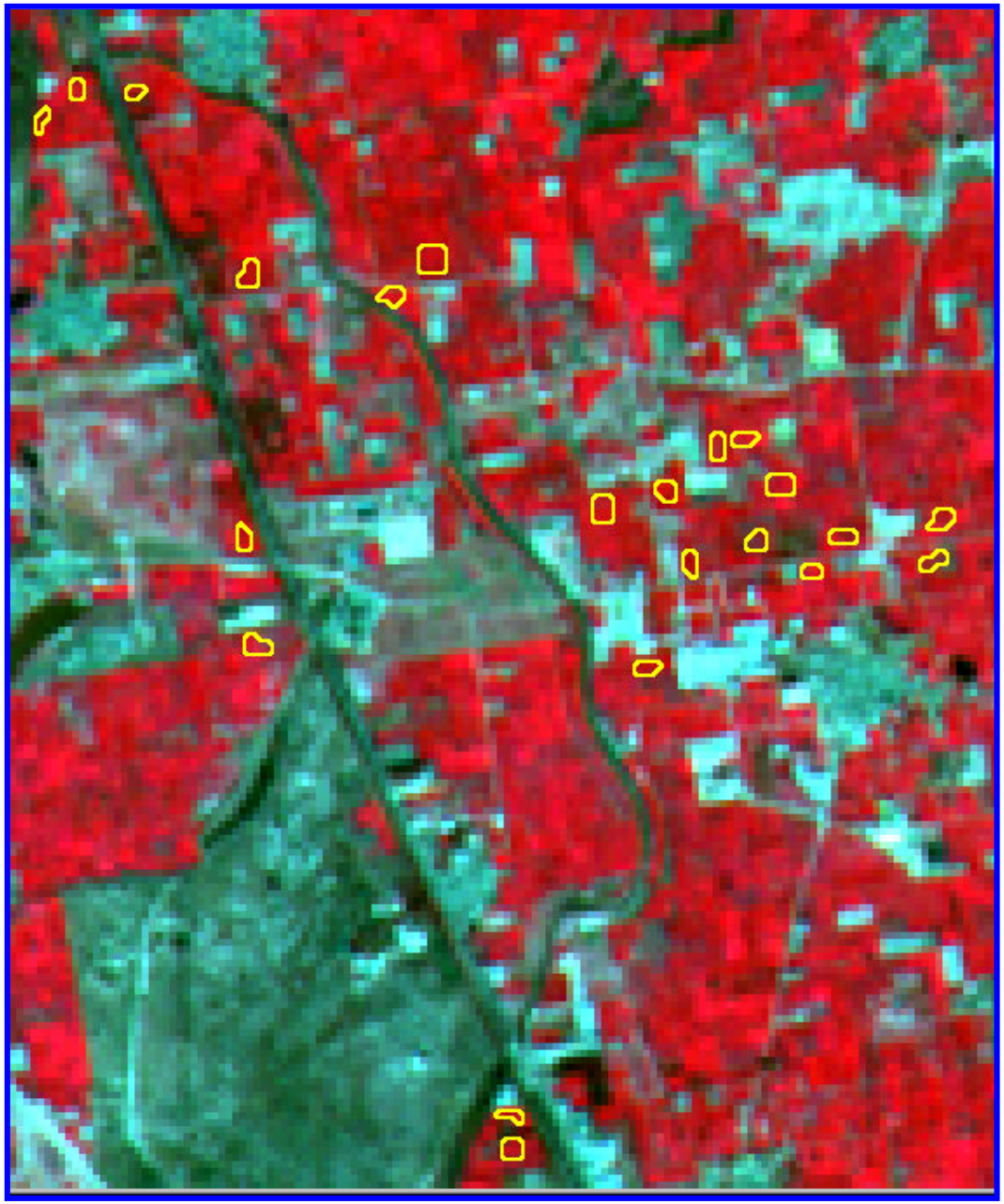


MULTIDATE NDVI IMAGES

RESULTS


Observed Crop age during satellite pass
Estimated Crop age at satellite pass
Crop age (days)
140
120
100
80
60
40
20
0
PI-203-96
PI-200-96
PI-197-96
PI-199-96
PI-200-97
PI-203-97
PI-229-97
PI-193-97
PI-202-97
PI-206-97
PI-199-97
PI-229-97
PI-197-97
PI-194-98
PI-232-98
PI-195-98
PI-230-98
PI-193-98
PI-203-98
PI-200-98
PI-202-98
PI-232-98
PI-197-98
PI-202-98
PI-199-98
PI-203-98
PI-206-98
PI-193-99
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PI-206-99
PI-230-99
PI-199-99
Plot

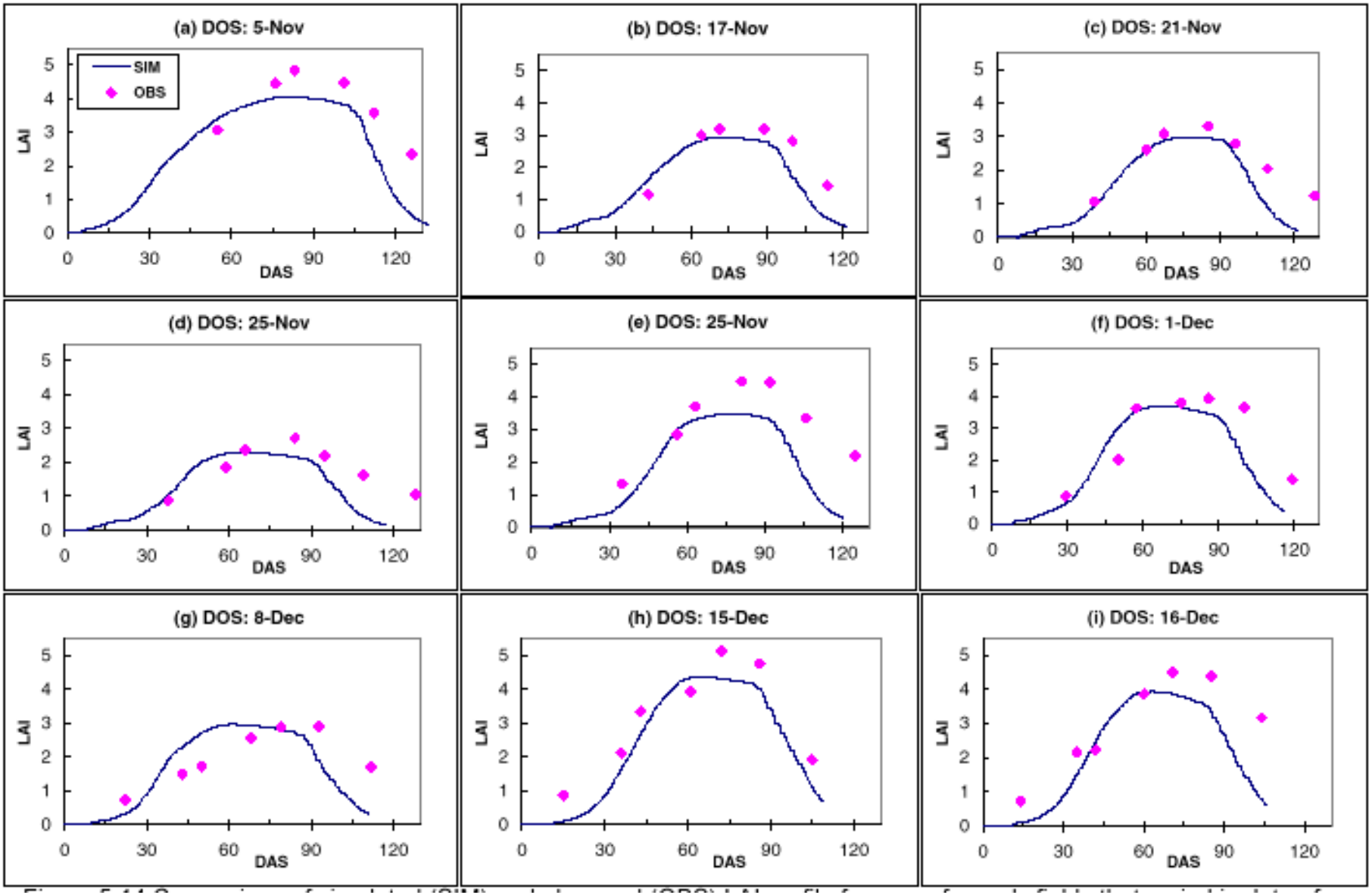
LOCATION OF STUDY FIELDS ON FCC IMAGE



22 Farmers' Fields

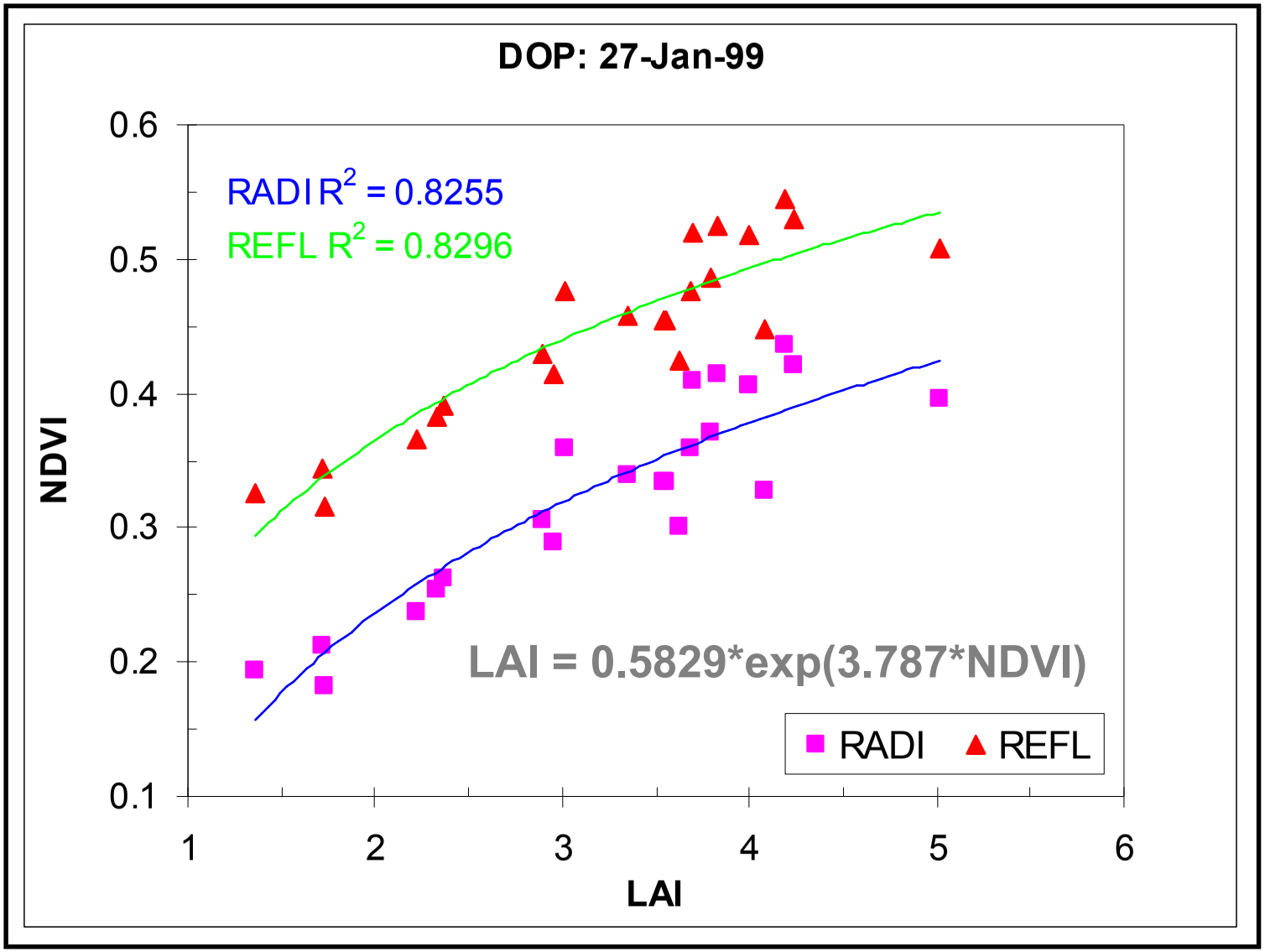
Varying Crop Management Practices

MODEL VALIDATION: Observed vs Simulated LAI

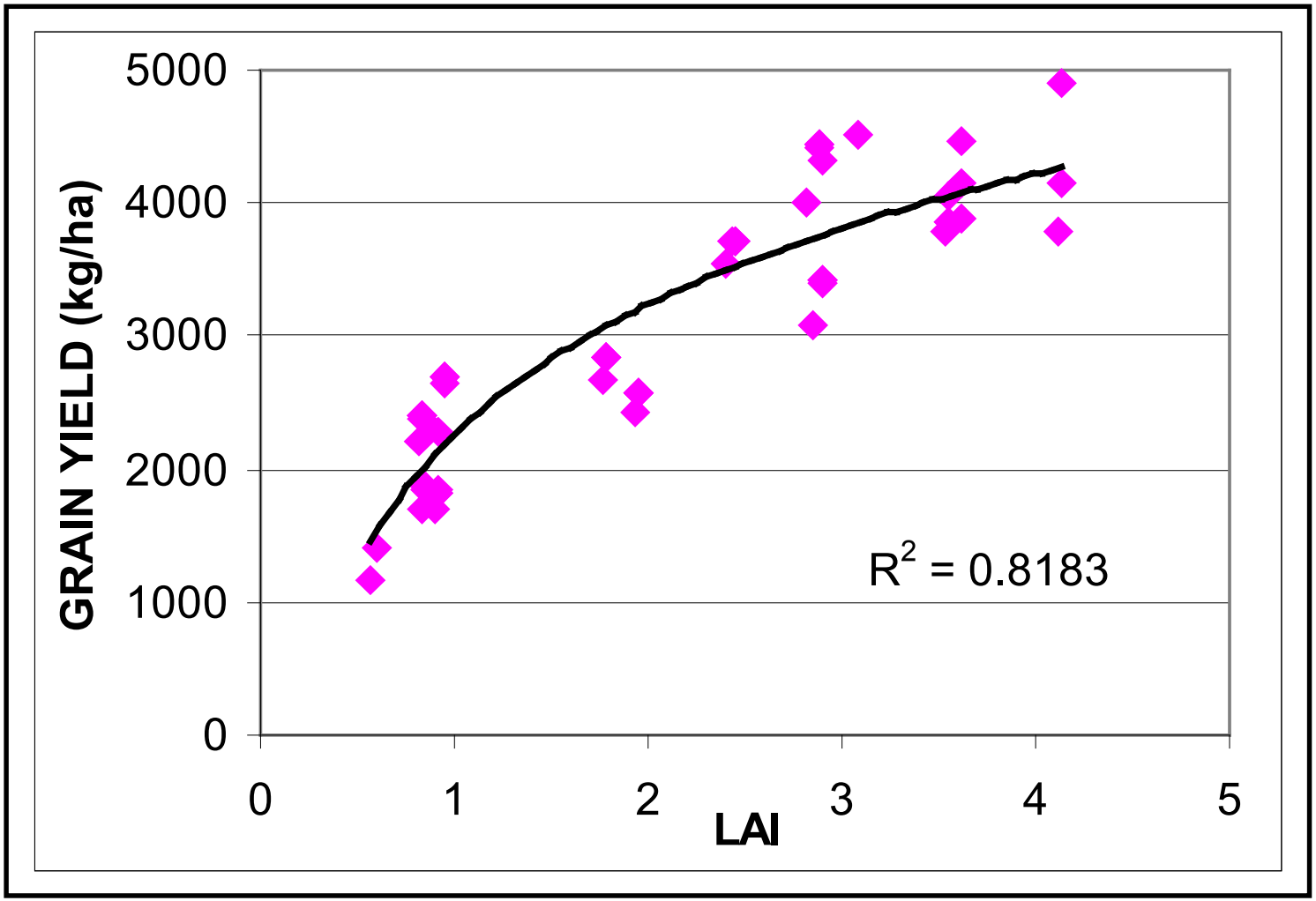


FARMERS' FIELDS: VI-LAI Relationships

IRS LISS-III 95/51 of 27-Jan-99

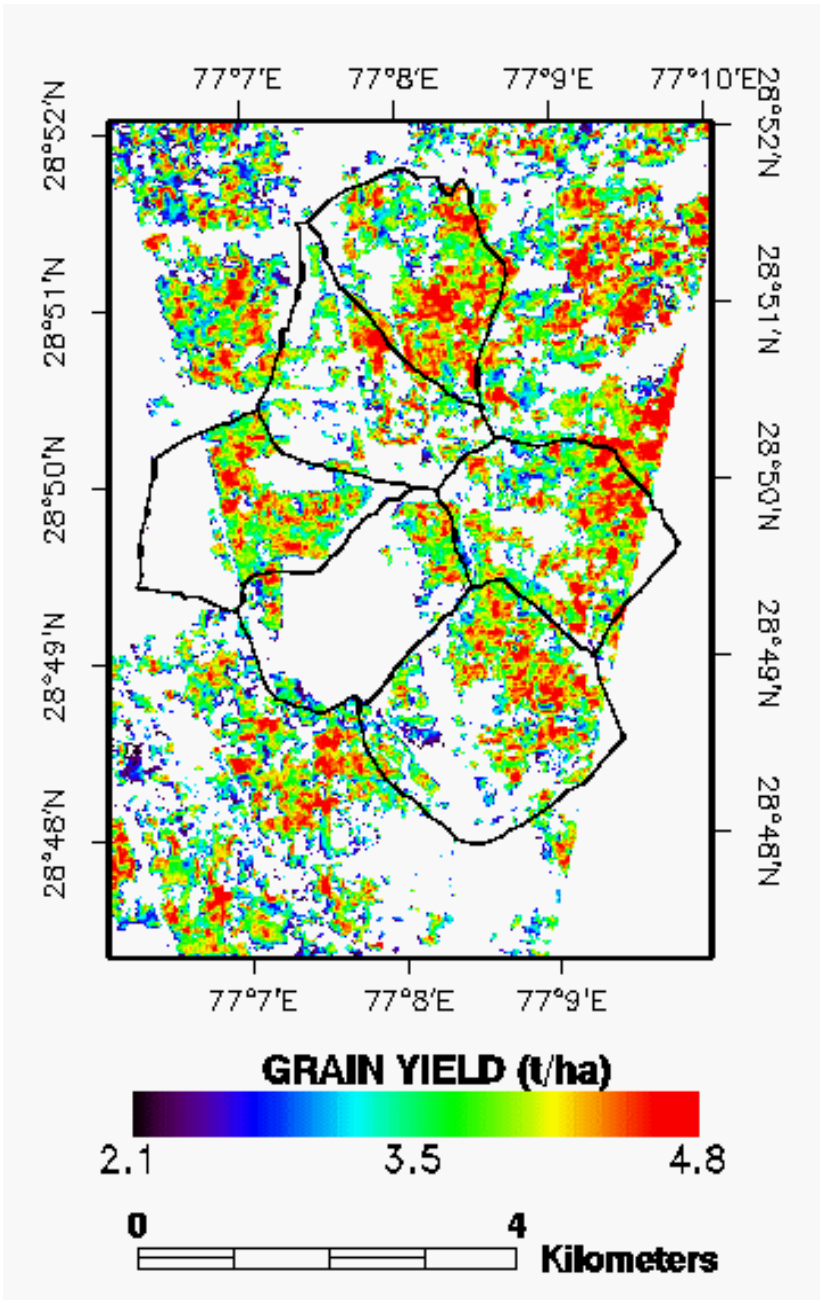


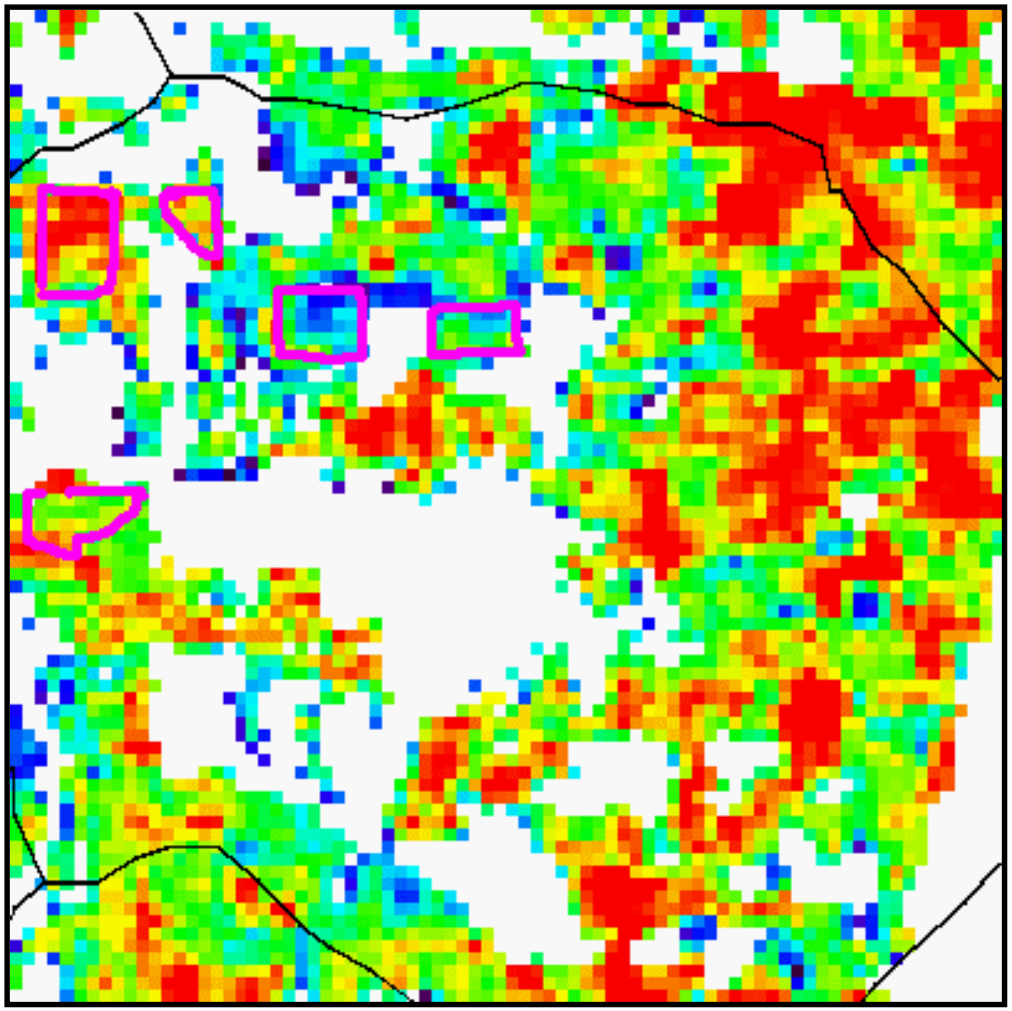
RELATIONSHIP OF SIMULATED GRAIN YIELD AND LAI



Yield = 1571.2*ln(LAI) + 2033.6

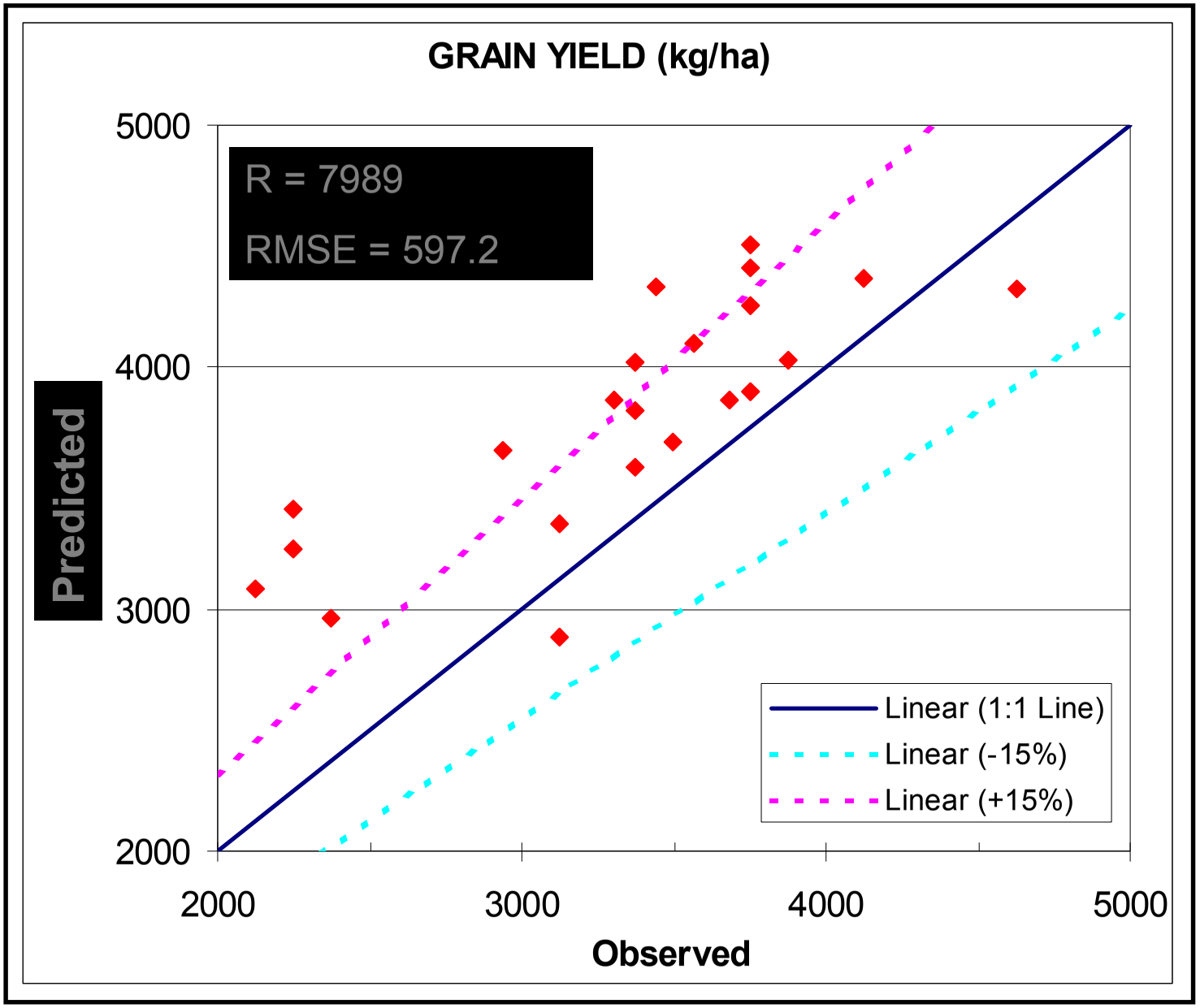
WHEAT GRAIN YIELD MAP OF FARMERS' FIELDS





Magnified View of Fields of Hamidpur Village

LINKING STRATEGY VALIDATION AT FIELD LEVEL



Using Crop Simulation Models

Wheat – Met only : CERES-WHEAT
WTGROWS

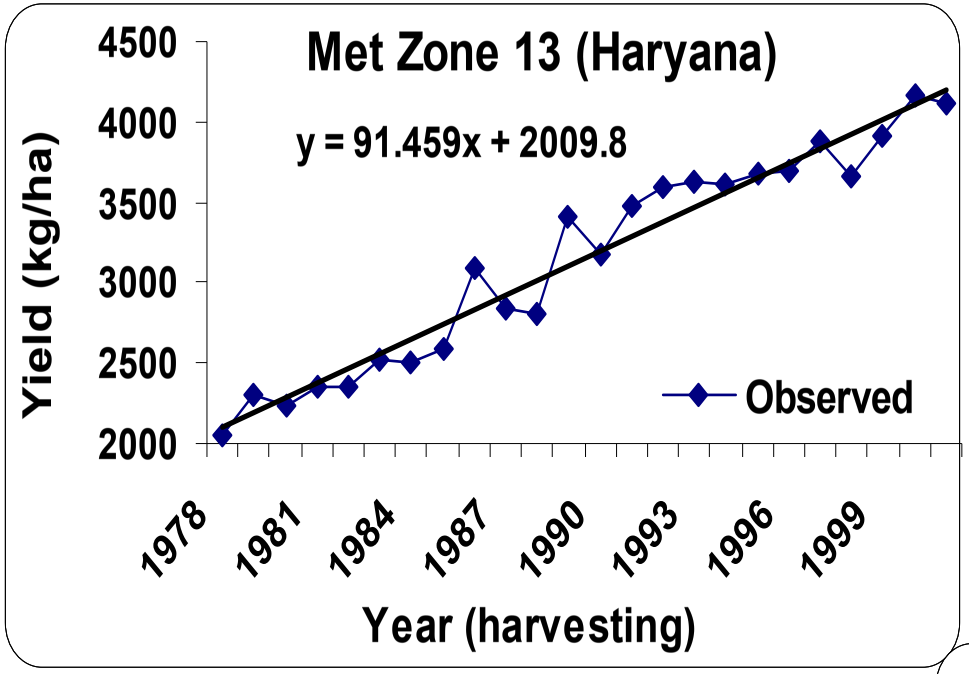
Wheat – RS & Geog : WTGROWS

Rice – RS & Geog : ORYZA

Approach : Regional Wheat Yield Prediction - CSM

Cont…

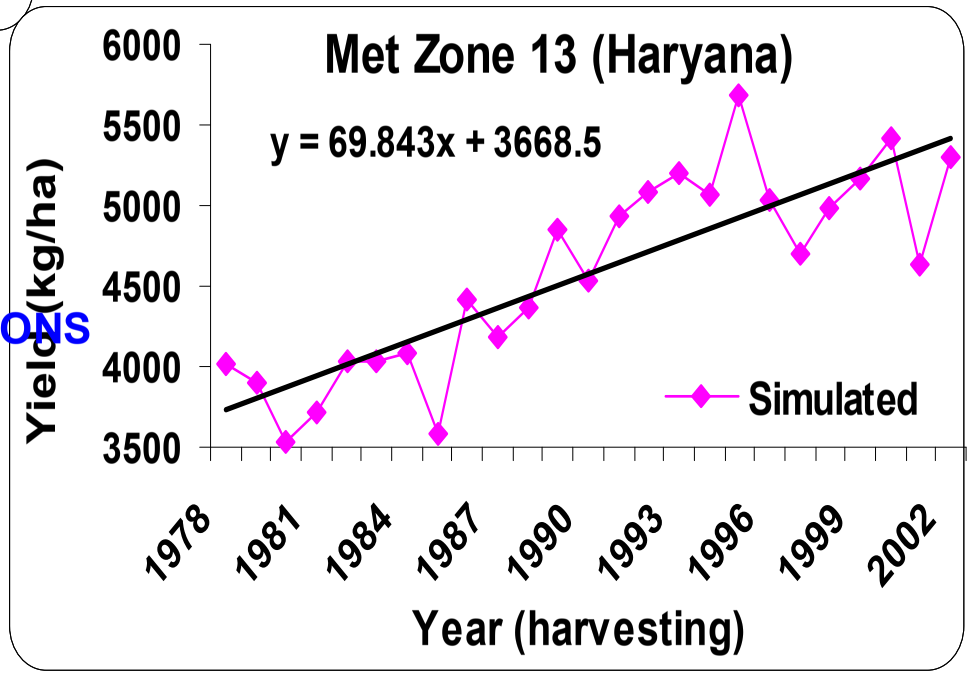
MET ZONE 13 (HARYANA)



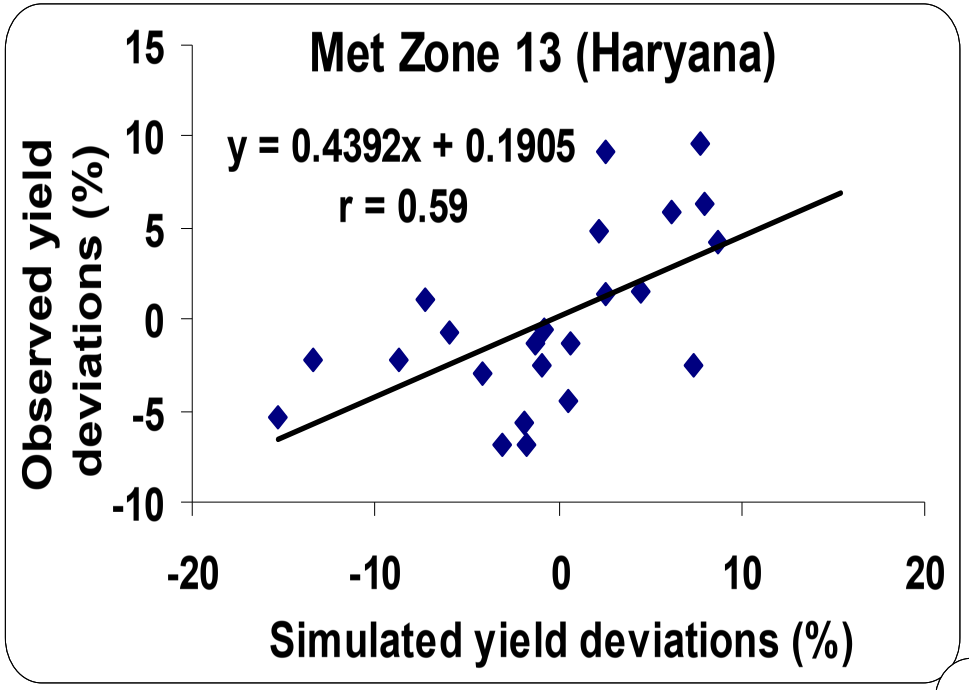
OBSEVED WHEAT YIELD AND ITS DEVIATIO FROM TREND

SIMULATED WHEAT YIELD AND ITS DEVIATIONS FROM TREND

VARYING RATE OF FERTILIZER



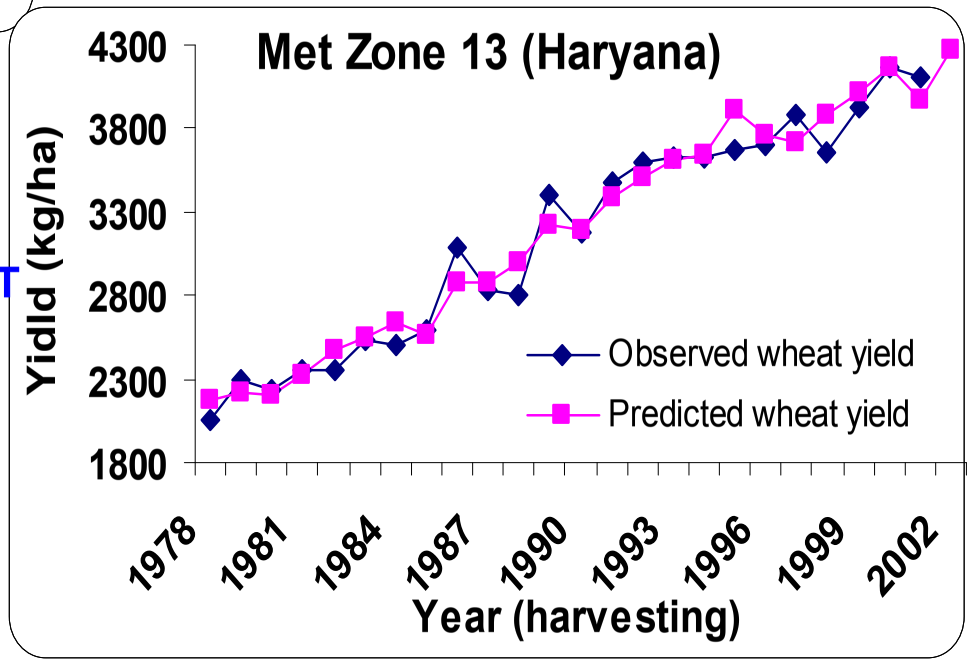
Approach : Regional Wheat Yield Prediction - CSM



MET ZONE 13 (HARYANA)

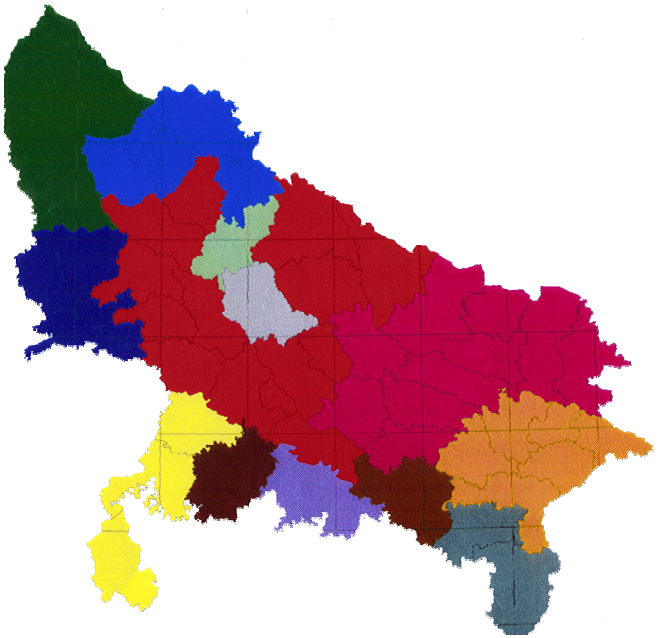
RELATIONSHIP BETWEEN OBSERVED WHEA YIELD DEVIATIONS AND SIMULATED WHEAT YIELD DEVIATIONS

COMPARISON BETWEEN OBSERVED WHEAT YIELD AND SIMULATED WHEAT YIELD



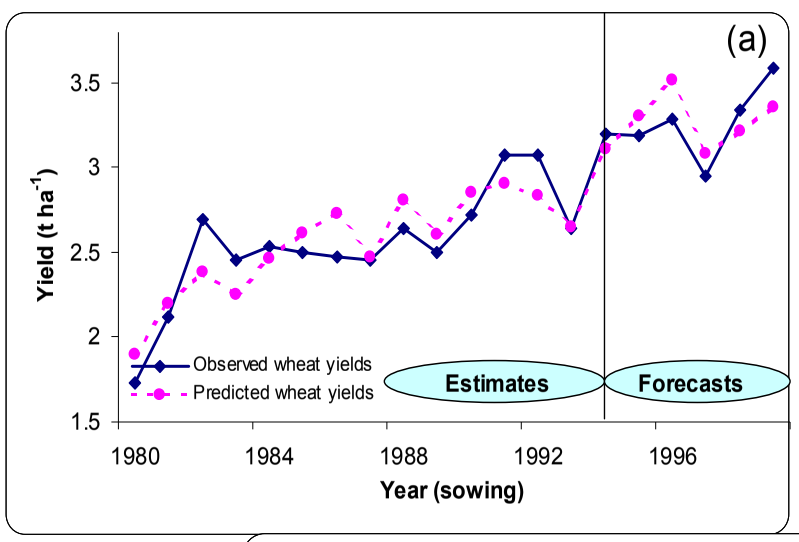
UP Wheat Modelling with CERES

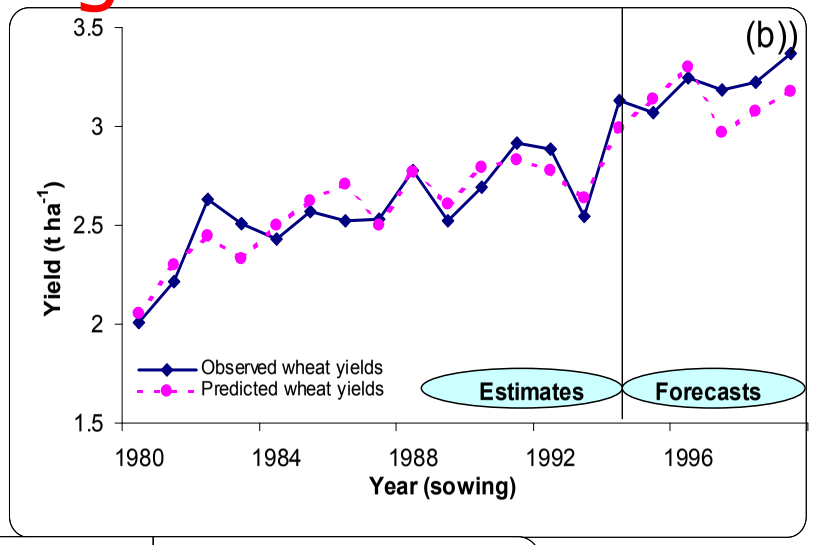
- Approach
  - Use historical Yield series for 'Coherent Yield Variability Zonation'
  - New Yield series for zones
  - Relate CERES simulated anomalies to zonal yield anomalies from trend
  - State level forecast with zonal weighted aggregation

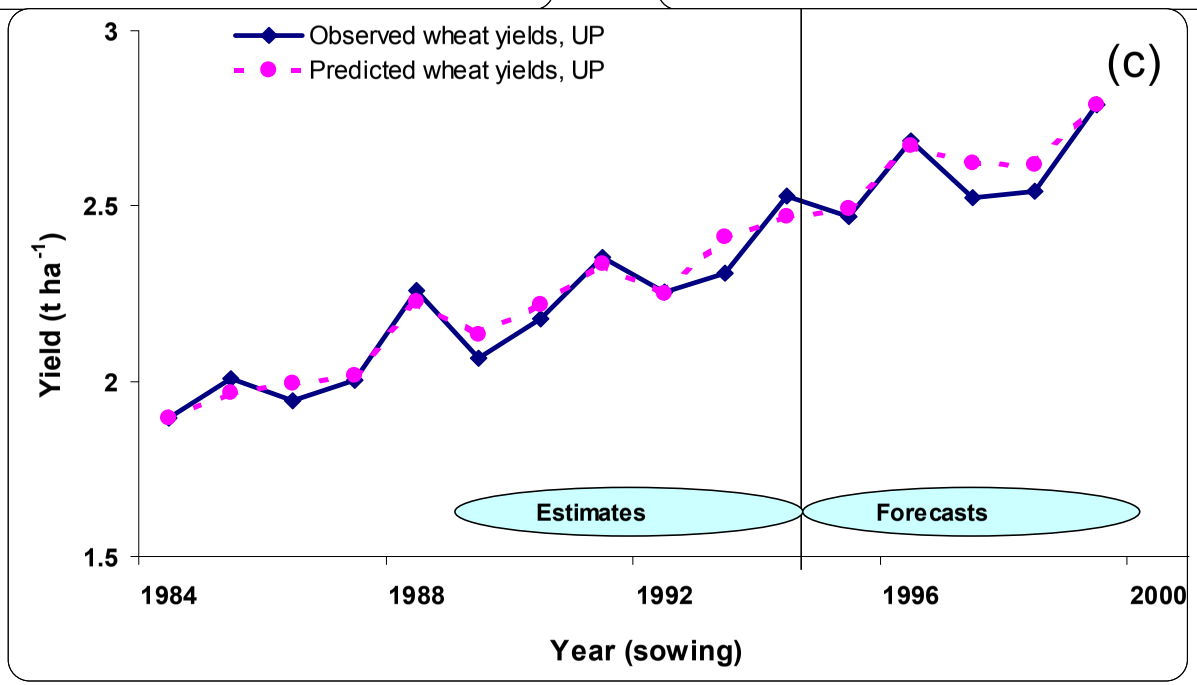


AS Nain, 2002, PhD Thesis

UP Wheat Modelling with CERES





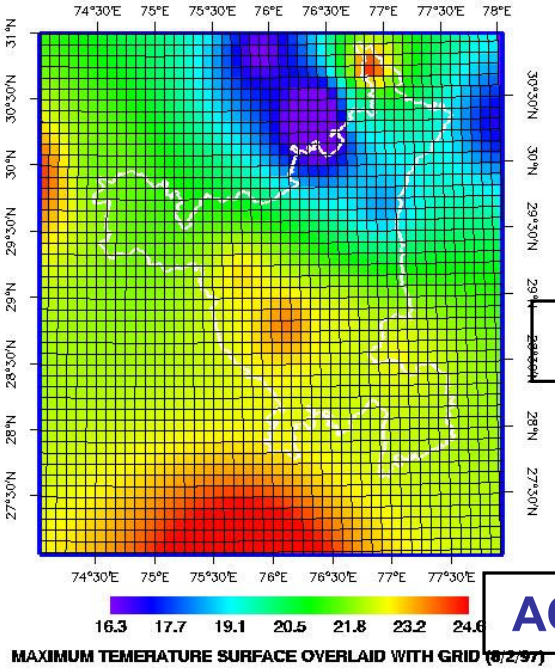


Comparision between observed and predicted wheat yield: a) district level, b) zone level, and c) state level

Coupling Models and RS Data

- DIRECT INPUT
  - As a driving variable from RS
- FORCING
  - Updating of a state variable derived from RS (e.g. LAI)
- RE-INITIALIZATION/ RE-CALIBRATION
  - Adjusting initial condition/model parameters to match simulation with RS observations
- CORRECTIVE METHOD
  - Error between simulated and RS-derived variable used as correction factor for simulated yield
- *LINK CSM – biophysical state variables to RS forward models*

CROP GROWTH MONITORING SYSTEM



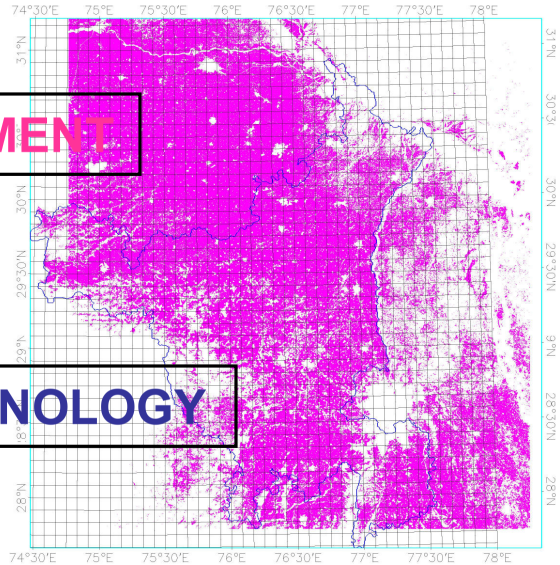
MAXIMUM TEMERATURE SURFACE OVERLAID WITH GRID (8/2/97)

DATABASE

WEATHER | SOIL | MANAGEMENT

REMOTE SENSING

ACREAGE | Leaf Area Index | PHENOLOGY



WHEAT CROP MASK DERIVED FROM MULTI-DATE WiFS DATA

SIMULATION MODEL

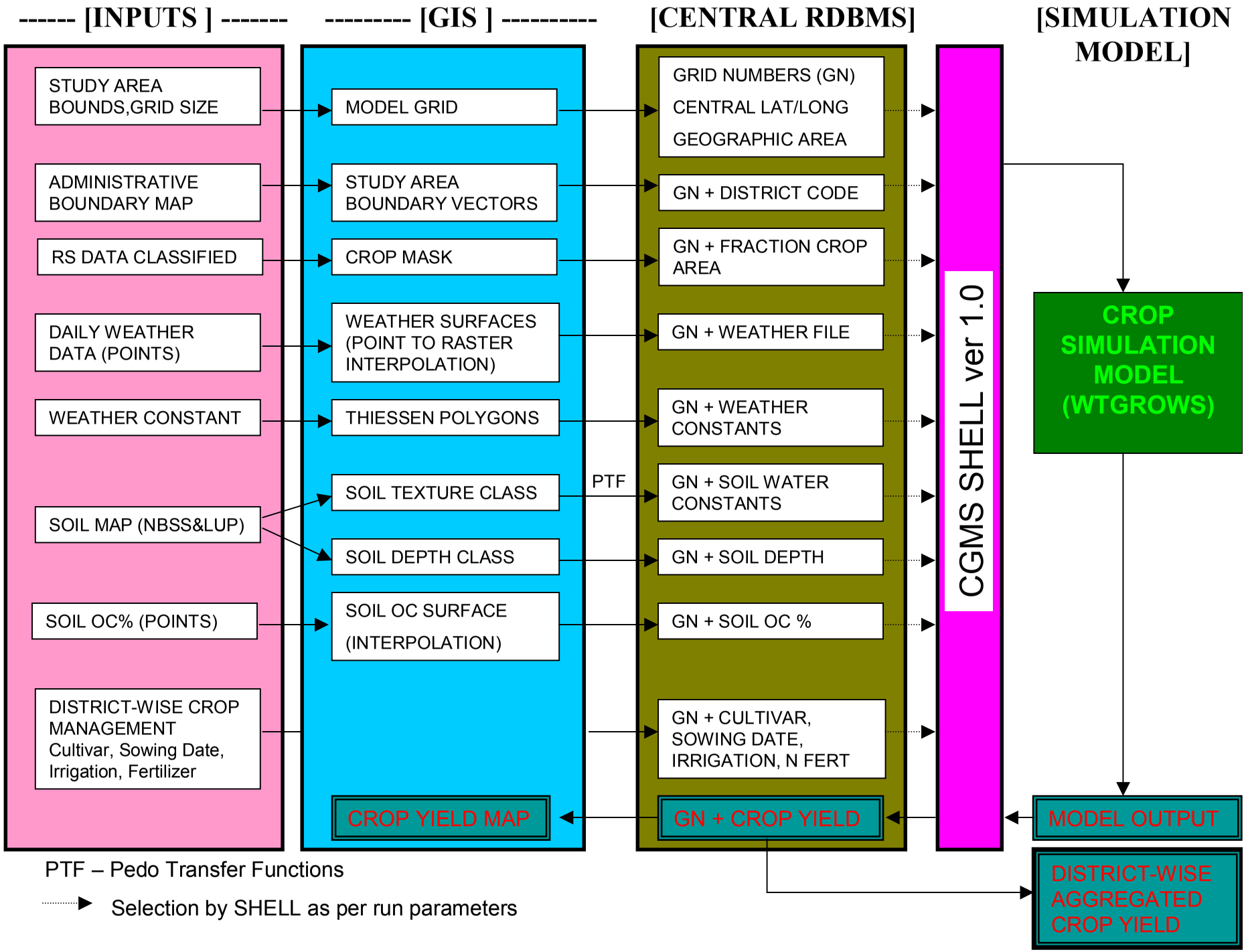
SIMPLIFICATION | VALIDATION | CORRECTION

GIS

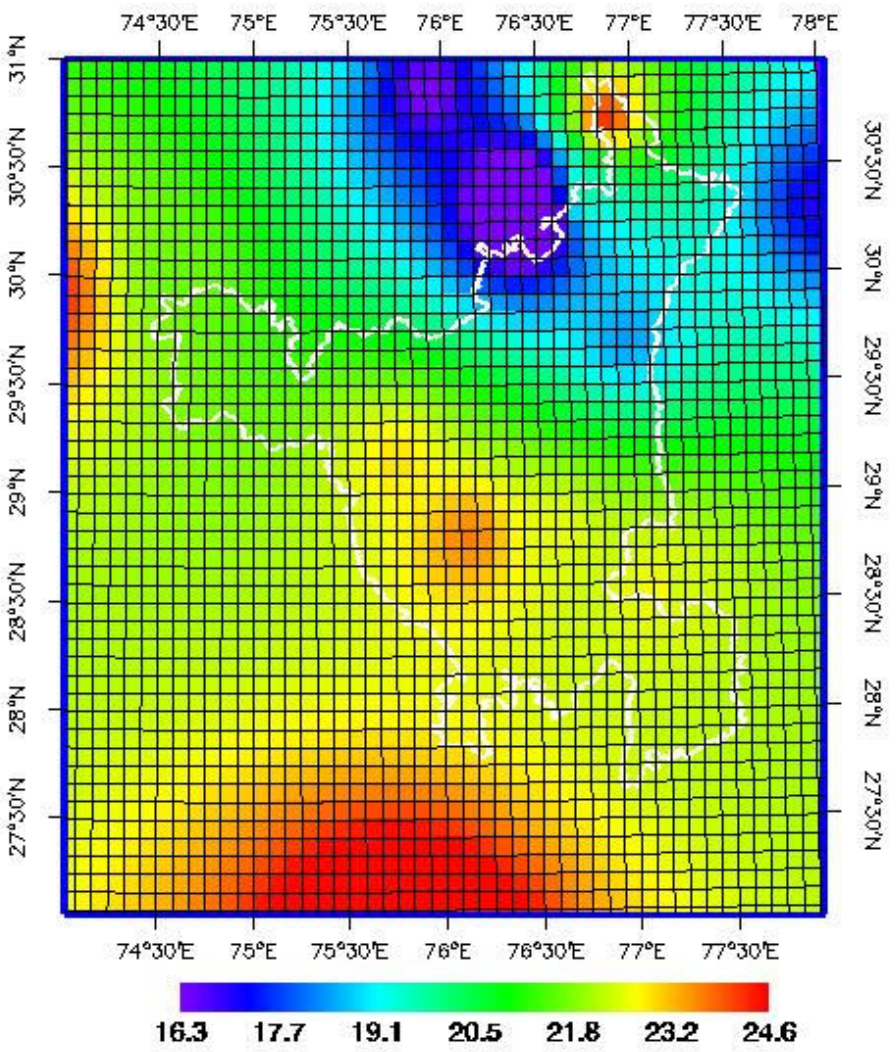
BOUNDARIES | CROP DISTRIBUTION | FRONT END TO LINK DATABASE, RS AND MODEL

OUTPUT

CROP GROWTH/ YIELD MAPS | EVAPO-TRANSPIRATION, LAI, BIOMASS MAPS | SPATIAL QUERIES FOR POLICY

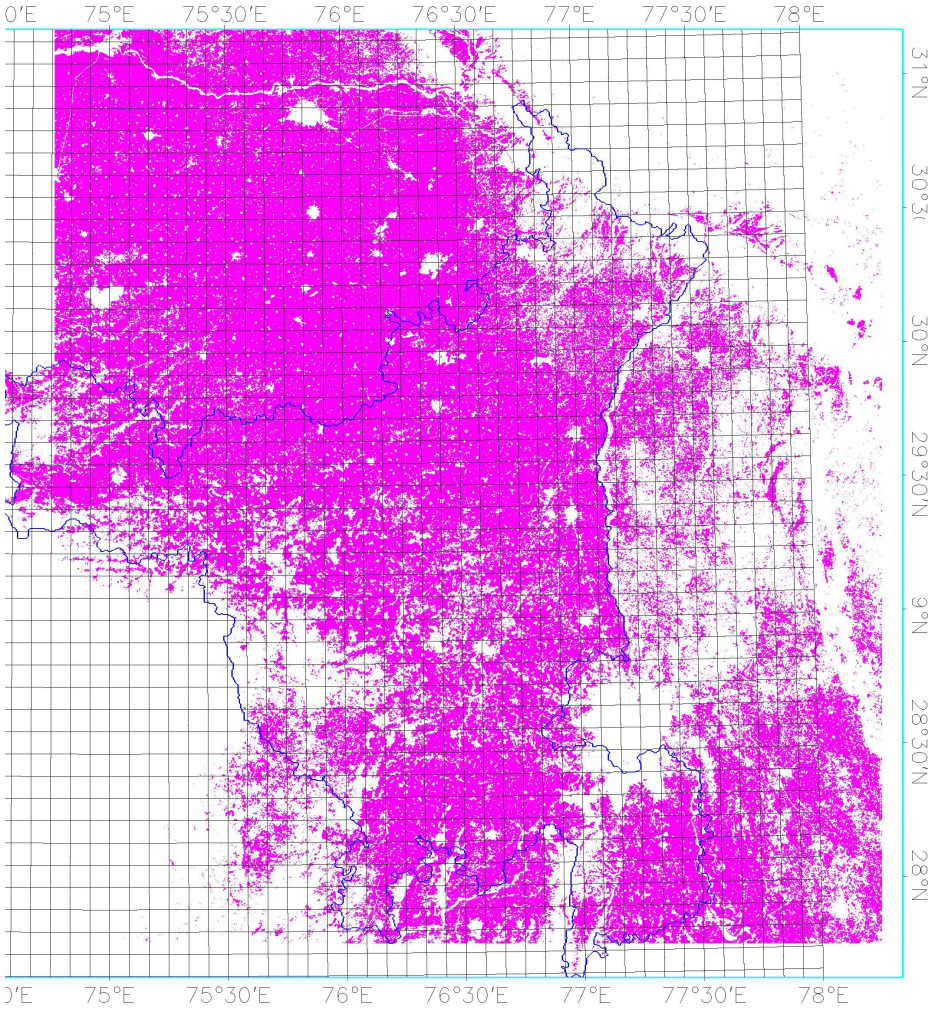

------ [INPUTS] -------
--------- [GIS] ----------
[CENTRAL RDBMS]
[SIMULATION MODEL]
STUDY AREA BOUNDS,GRID SIZE
ADMINISTRATIVE BOUNDARY MAP
RS DATA CLASSIFIED
DAILY WEATHER DATA (POINTS)
WEATHER CONSTANT
SOIL MAP (NBSS&LUP)
SOIL OC% (POINTS)
DISTRICT-WISE CROP MANAGEMENT Cultivar, Sowing Date, Irrigation, Fertilizer
MODEL GRID
STUDY AREA BOUNDARY VECTORS
CROP MASK
WEATHER SURFACES (POINT TO RASTER INTERPOLATION)
THIESSEN POLYGONS
SOIL TEXTURE CLASS
SOIL DEPTH CLASS
SOIL OC SURFACE (INTERPOLATION)
CROP YIELD MAP
PTF
GRID NUMBERS (GN)
CENTRAL LAT/LONG
GEOGRAPHIC AREA
GN + DISTRICT CODE
GN + FRACTION CROP AREA
GN + WEATHER FILE
GN + WEATHER CONSTANTS
GN + SOIL WATER CONSTANTS
GN + SOIL DEPTH
GN + SOIL OC %
GN + CULTIVAR, SOWING DATE, IRRIGATION, N FERT
GN + CROP YIELD
CGMS SHELL ver 1.0
CROP SIMULATION MODEL (WTGROWS)
MODEL OUTPUT
DISTRICT-WISE AGGREGATED CROP YIELD
PTF – Pedo Transfer Functions
Selection by SHELL as per run parameters

WEATHER SURFACE (Tmax)



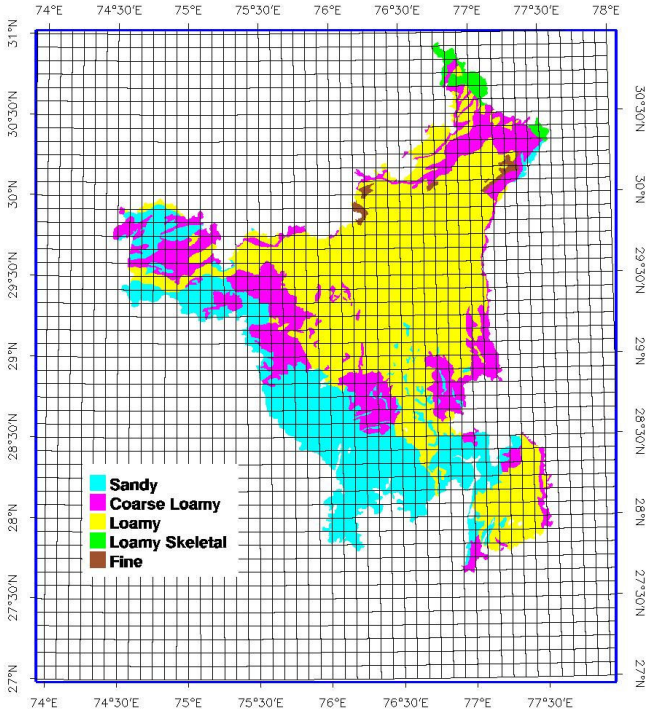
MAXIMUM TEMERATURE SURFACE OVERLAID WITH GRID (8/2/97)

CROP DISTRIBUTION MAP FROM WiFS

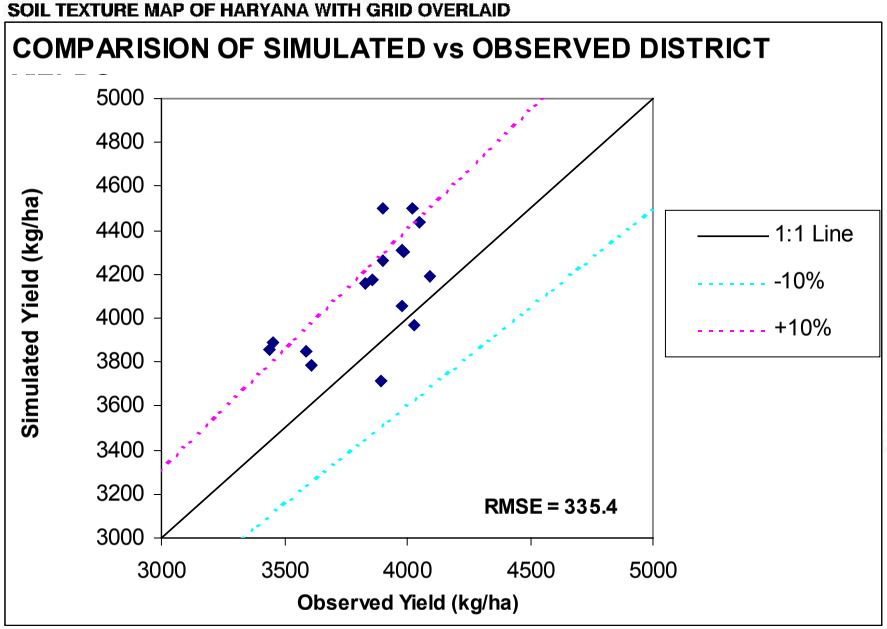


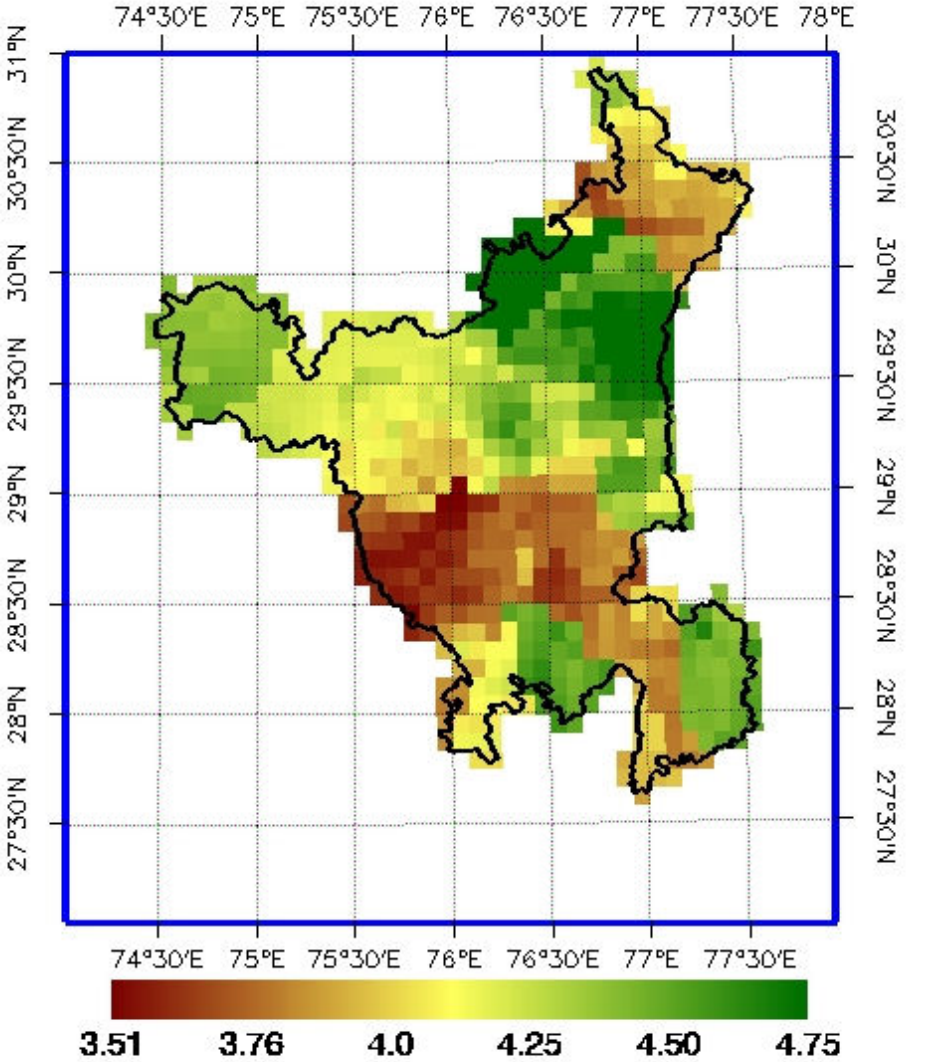
/HEAT CROP MASK DERIVED FROM MULTI-DATE WiFS DATA

SOIL TEXTURE MAP (NBSS&LUP)



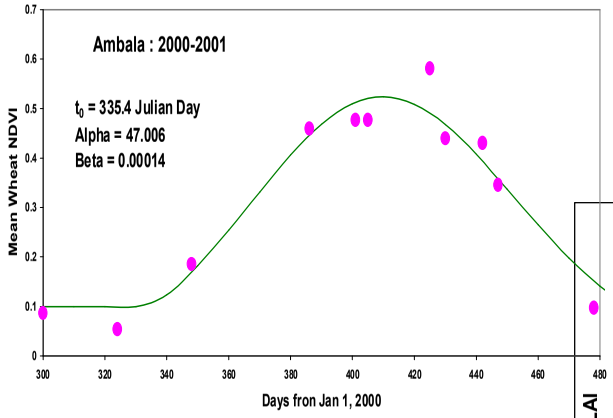
SOIL TEXTURE MAP OF HARYANA WITH GRID OVERLAID



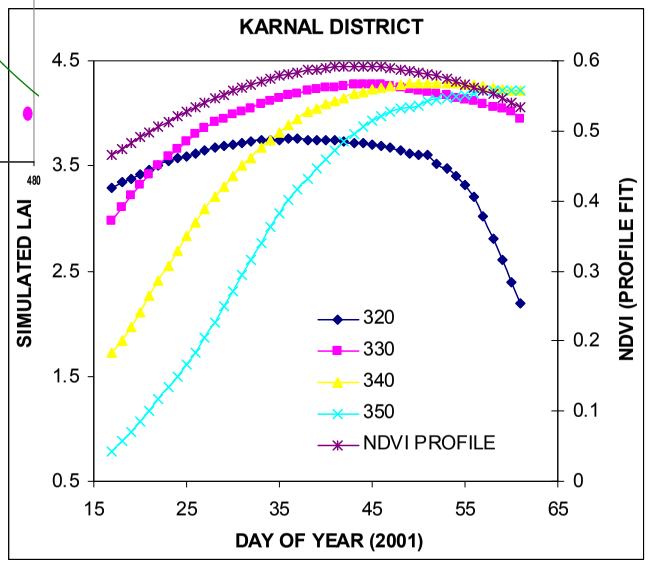


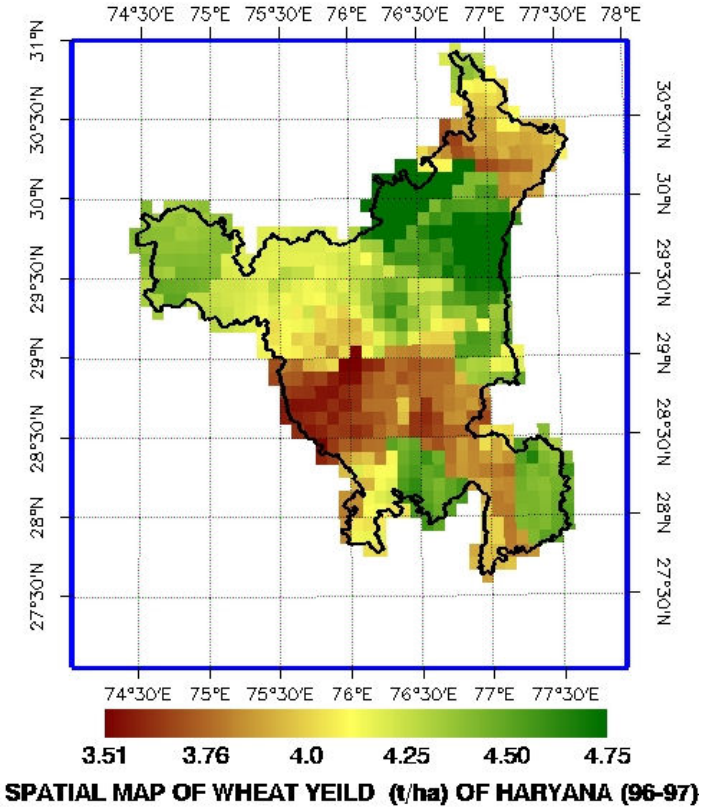
SPATIAL MAP OF WHEAT YEILD (t/ha) OF HARYANA (96-97)

DEMONSTRATING RS-CGMS LINKAGE FOR PHENOLOGY



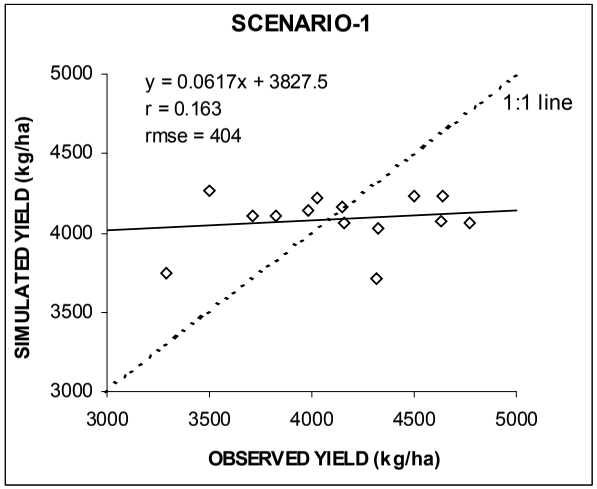
WiFS Profile



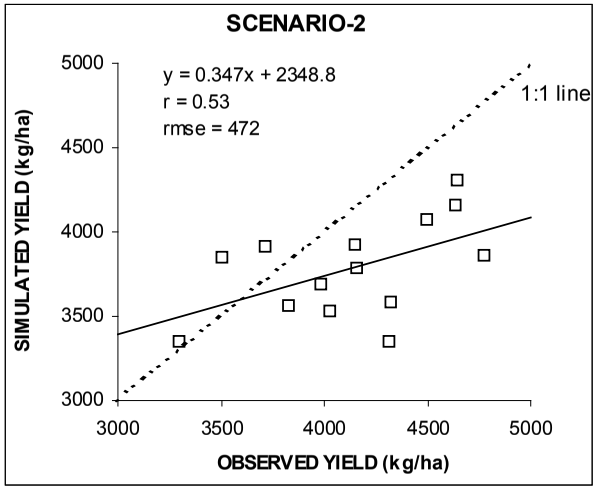


SPATIAL MAP OF WHEAT YEILD (t/ha) OF HARYANA (96-97)

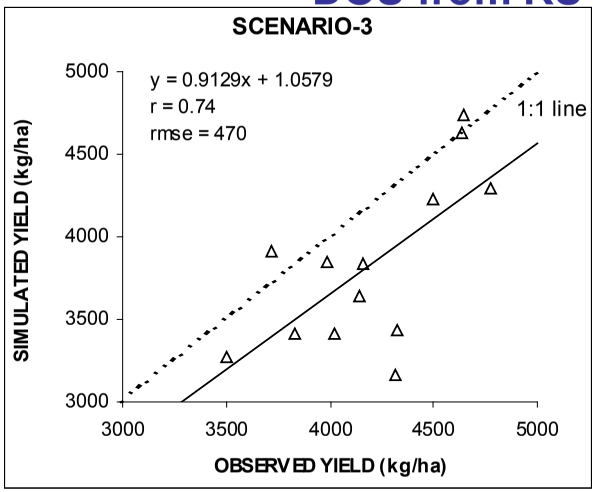
Fixed Inputs (DOS, I, N)



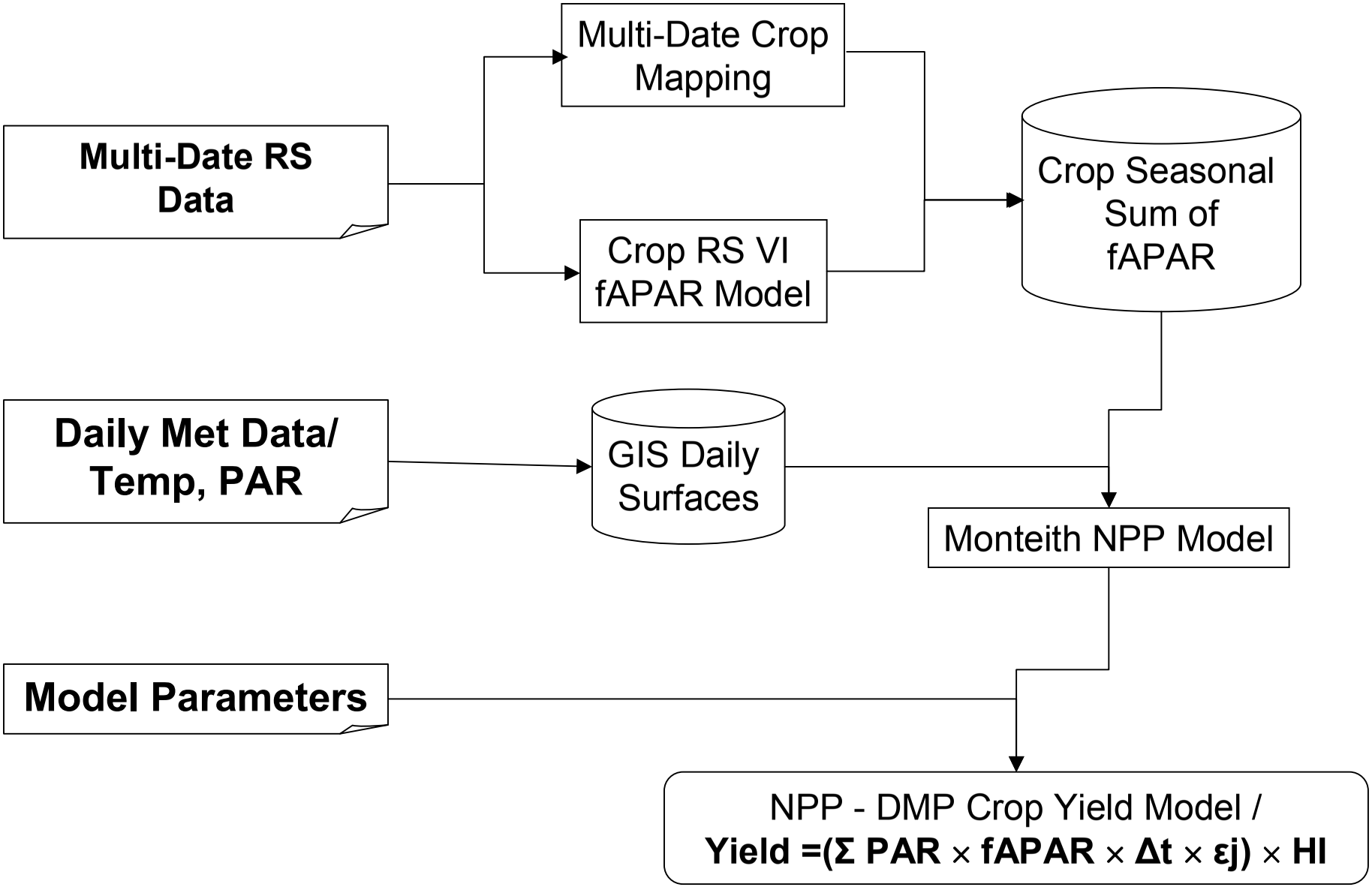
Variable Inputs (I, N)



DOS from RS



Direct RS-NPP Approach for Crop Yield



fAPAR methods

Empirical relationship *(fAPAR_M1)*

Vegetative period : $fAPAR = 0.02080 \times \exp(4.3032 \times NDVI)$ (R2 = 0.71)
Reproductive period : $fAPAR = 0.4836 + 0.5175 \times NDVI$ (R2 = 0.68)
(source : Patel et al. 2004)

Linear scaling *(fAPAR_M2)*

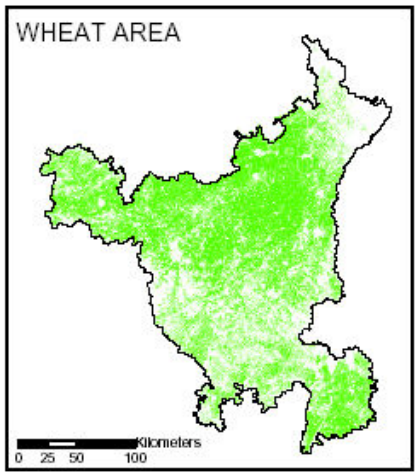
$$fAPAR = [(NDVI - NDVI_{min})\ (fAPAR_{max} - fAPAR_{min}) / (NDVI_{max} - NDVI_{min})] + fAPAR_{min}$$

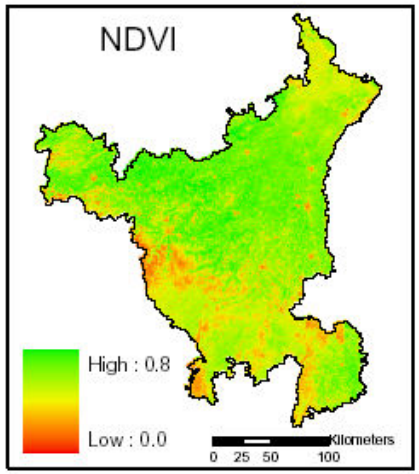
Where, $NDVI_{max}$ and $NDVI_{min}$ are defined as 98th and 2nd percentiles, respectively of maximum (Max_NDVI) and minimum NDVI (Min_NDVI) of wheat during its growth cycle. $fAPAR_{min}$ and $fAPAR_{max}$ are set equal to 0.01 and 0.95, corresponding to the extremes of potential canopy absorption of photosynthetically active radiation (Sellers *et a*l. 1996, Los *et al,* 2000).

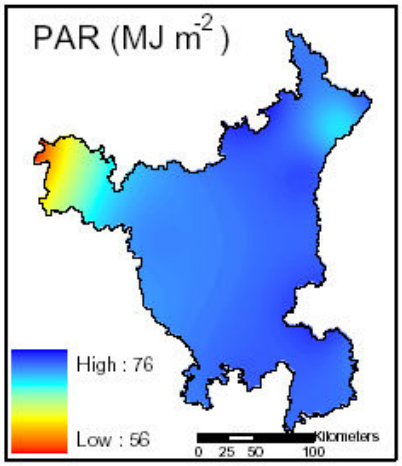
Images of maximum and minimum NDVI of wheat were obtained as,

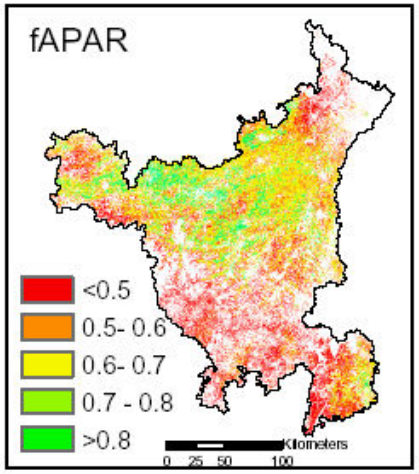
Max_NDVI = Max (NDVIt1, NDVIt2, …….. NDVItn)
Min_NDVI = Min (NDVIt1, NDVIt2, …….. NDVItn)
The subscripts t1, t2 , ….tn indicates period corresponding to NDVI images of wheat crop.

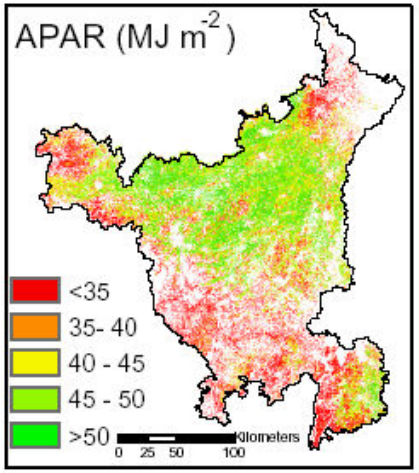
Retrieval of essential crop parameters by fAPAR_M2

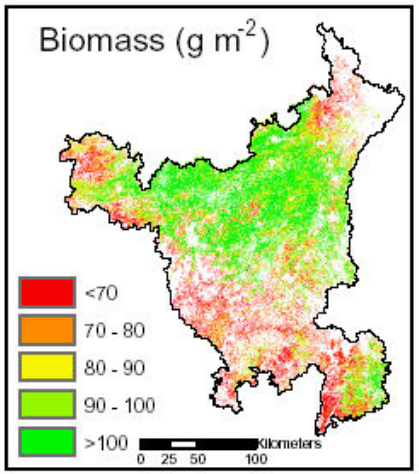




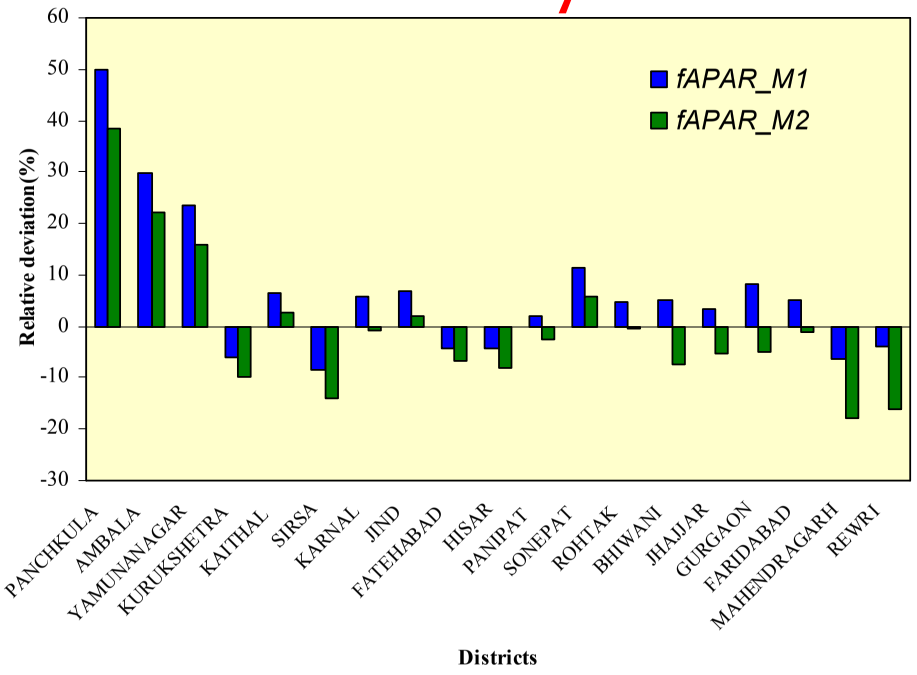


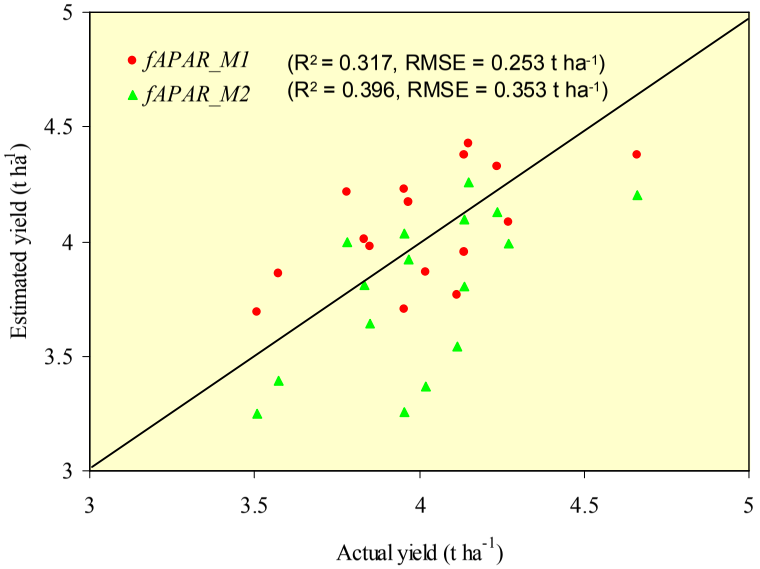




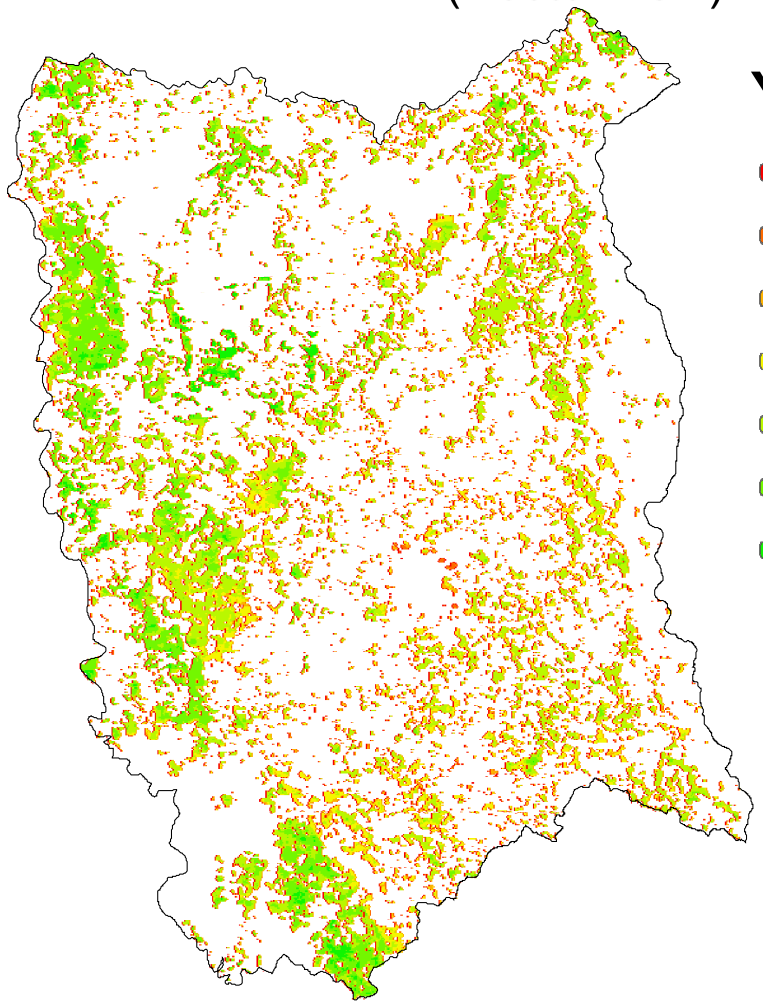


Comparison between officially reported actual and estimated yield of wheat by two fAPAR methods



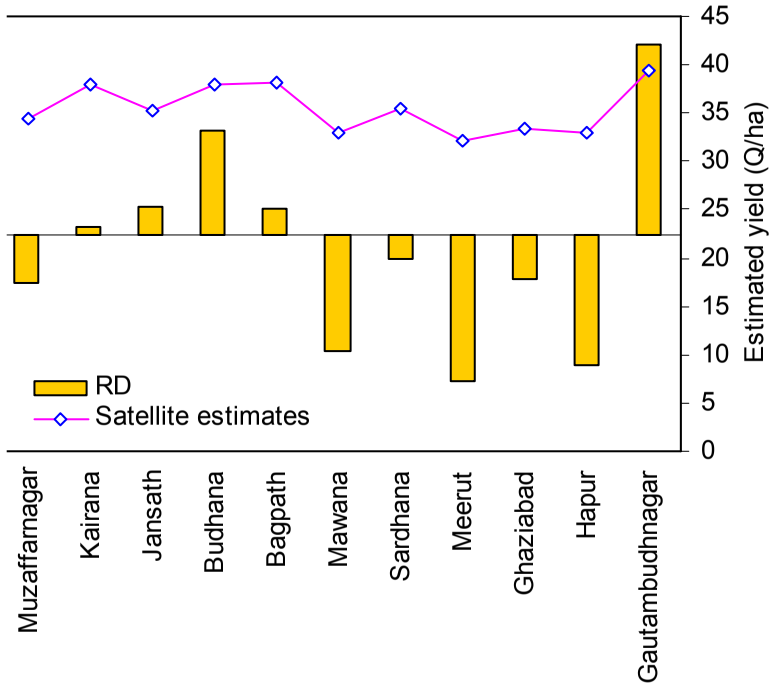


Wheat yield estimates from Determimistic biomass model (western UP)



Yield (q/ha)

- < 30.00
- 30.00 - 35.00
- 35.00 - 40.00
- 40.00 - 42.50
- 42.50 - 45.00
- 45.00 - 47.50
- > 47.50



Future Outlook

- RS moves from Data to Products
- Products on web in NRT
- Large GIS & other spatial data bases
- Web-GIS, Server Computing
- New Delivery models for DSS