# Space Technology and Agriculture


## A.S. Kiran Kumar

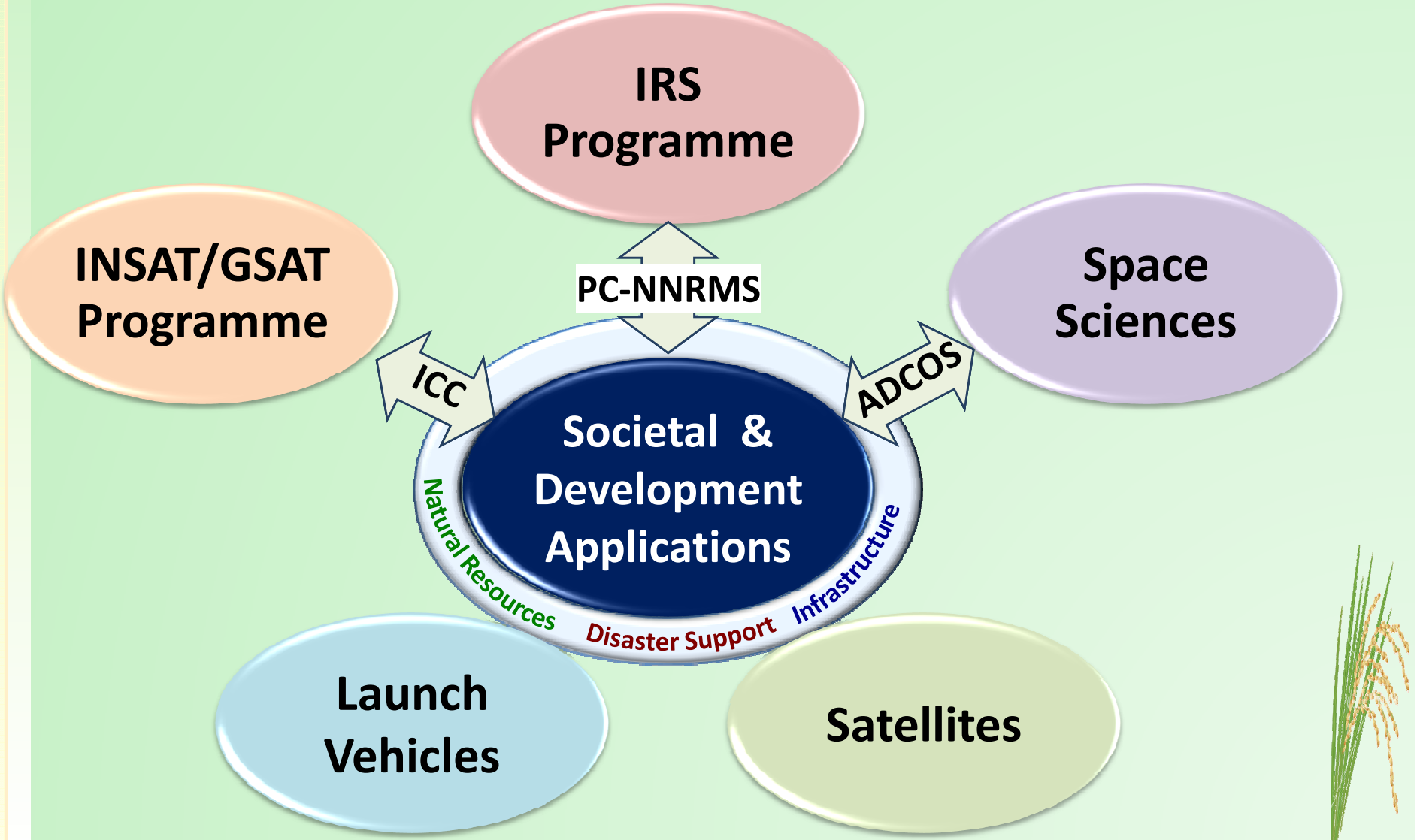
**Secretary, Department of Space**
**Chairman, Space Commission**
**Chairman, Indian Space Research Organisation**


**October 09, 2015**

**Foundation Day and Award Ceremony**
**09, October 2015**
**University of Agricultural Sciences, Bengaluru**

# Indian Space Programme: Dimensions

**Vision:** Harness space technology for national development, while pursuing space science research and planetary exploration



# Accomplishments in Space

**126**
**MISSIONS**

**49**
**Launch Vehicle Missions**

**75**
**Spacecraft Missions**

**01**
**Space Capsule Recovery Experiment**

**01**
**Crew Module Atmospheric Re-entry Experiment**

- Realized 30 successive successful flights of PSLV
- Development of GSLV with Indigenous Cryogenic Stage
- Development of Heavy Lift Launcher GSLV Mk III
- State-of-the-Art Remote Sensing Satellites
- State-of-the-Art Communication Satellites
- Indian Regional Navigation Satellite System
- GAGAN (GPS Aided GEO Augmented Navigation)
- Mission to Moon and Mars
- Operationalisation of Space Applications
- Indigenous Development of 8” Wafer Fab
- Launched 51 Satellites of 20 Countries

# INDIAN STRIDES IN SPACE TRANSPORTATION SYSTEM

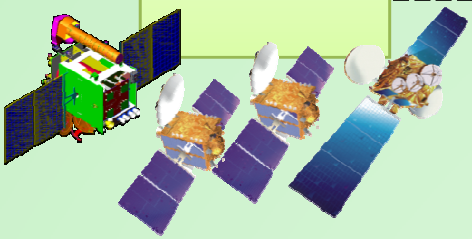
Two launch pads in Sriharikota


| Launch Vehicle | SLV | ASLV | PSLV | GSLV | GSLV Mk III (Under development) |
|---|---|---|---|---|---|
| Lift-off weight (Tonnes) | 17 | 40 | 295 | 450 | 644 |
| Payload (kg) | 40 (LEO) | 150 (LEO) | 1800 (SSO)<br>1400 (GTO) | 2200 (GTO) | 4000 (GTO) |

# Twelve Communication Satellites in Orbit

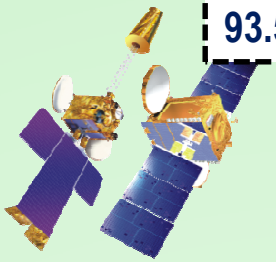
GSAT-8
GSAT-16
55$^0$ E

INSAT-3C
INSAT-4CR
GSAT-7
GSAT-14
74$^0$ E



INSAT-4A
GSAT-10
GSAT-12
GSAT-6
83$^0$ E

INSAT-3A
INSAT-4B
93.5$^0$ E

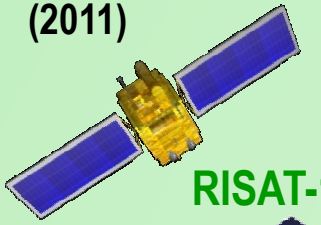


| | |
|---|---|
| **Telecommunication** | 2.30 Lakh VSATs |
| **Television and DTH services** | 100% National Coverage and > 4.2 Crores DTH Subscriptions |
| **News gathering** | On-spot; Real-time news coverage |
| **Radio-networking** | 415 AIR Stations |
| **Mobile services** | Emergency communication link |
| **Search and Rescue services** | 13,800 Indian Beacons from Maritime and Aviation Agencies |
| **MET DATA dissemination service** | ~1900 AWS and ~1200 Rain Gauge Stations ; 40 Dissemination Stations |
| **Tele-education** | 83 Networks covering 26 States & 5 UTs |
| **Tele-medicine** | 60 Specialty Hospitals; > 300 Remote Hospitals |

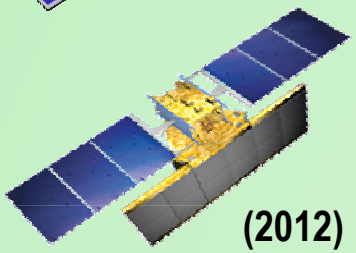
# Earth Observation Satellites

## LAND & WATER

RESOURCESAT-2
(2011)



RISAT-1

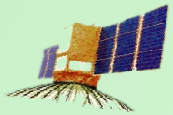


(2012)

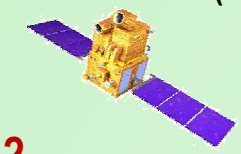
## HIGH RESOLUTION

CARTOSAT-2; 2A; 2B

(2007) (2008) (2010)



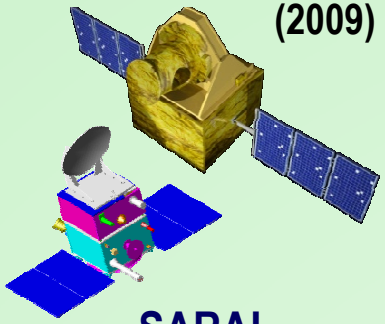
RISAT-2
(2012)



CARTOSAT-1
(2005)

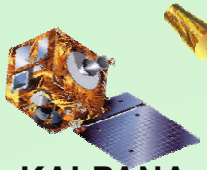
## OCEAN

OCEANSAT-2
(2009)

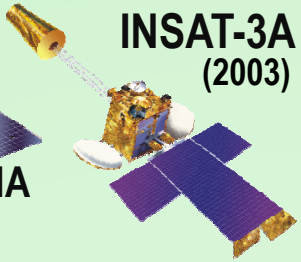


SARAL
(2013)

## WEATHER; CLIMATE



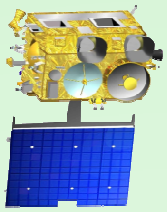
KALPANA
(2002)



INSAT-3A
(2003)

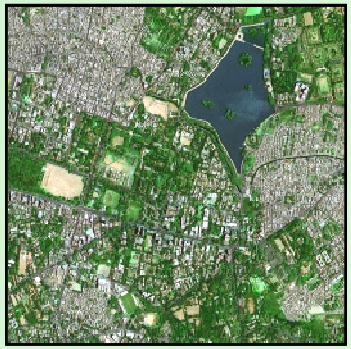
MEGHA-
TROPIQUES

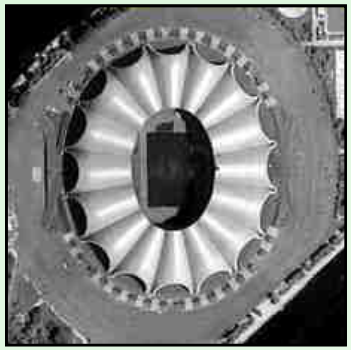
(2011)



INSAT-3D
(2013)

1 KM ← IMAGING CAPABILITY → 0.8 M





Resourcesat-2A, SCATSAT-1, Cartosat 2C/2D/2E, Cartosat-3, Oceansat-3, INSAT-3DR, GISAT being added during 2015-17 for continuity of services and new capability.

# Satellite Navigation

## GAGAN
### GPS Aided Geo Augmented Navigation

- RNP and APV-1 certification obtained from DGCA for Approach services for "**En-route Navigation**" over Indian Airspace
- India is the third country to offer safety of life navigation services to aviation sector

## Applications

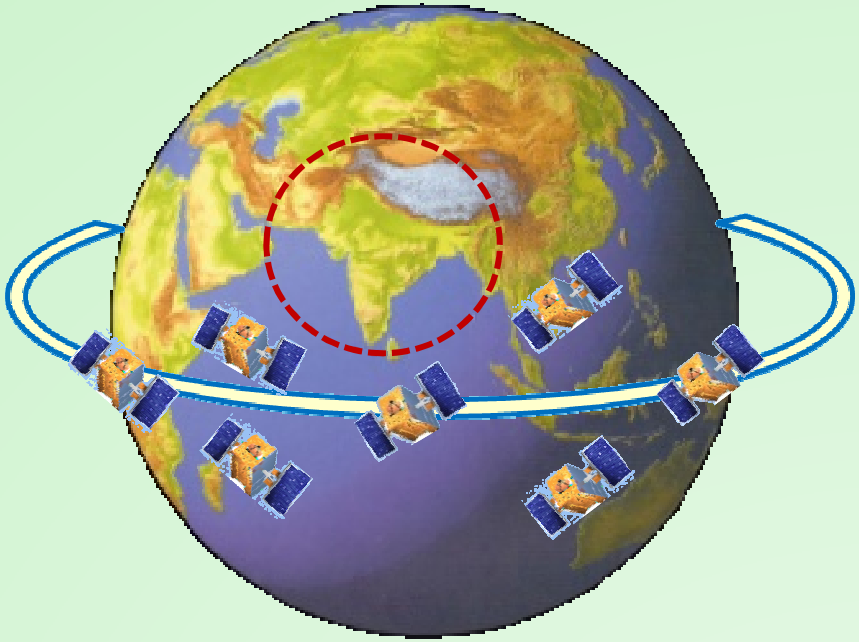
**CIVIL AVIATION**

- Certified for Safety of Life Application
- Used by Aircrafts & Helicopters as En-route Navigation aid
- Procedure development & other activities in progress for Precision Approach applications

**NON-CIVIL AVIATION**

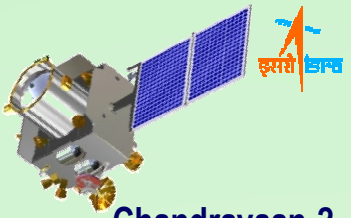
- Surveying
- Location Based Services
- Intelligent Transport System
- Maritime Applications, Railways
- Mapping services

## IRNSS
### Indian Regional Navigation Satellite System



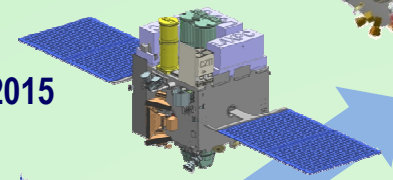
- **7-Satellite Constellation**
- **4 Satellites (IRNSS-1A, IRNSS-1B, IRNSS-1C & IRNSS-1D) already in Orbit**
- **Full constellation by 2015-2016**
- **Coverage ~ 1500 km beyond Indian territory**
- **Estimated horizontal position accuracy of 10-20 m in over India and adjoining areas**

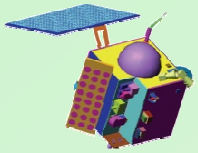
# Space Science



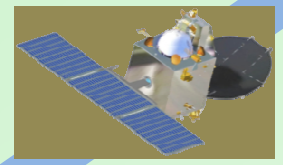
Chandrayaan-2
(Future)

ASTROSAT
September 28, 2015





Chandrayaan-1
October 22, 2008

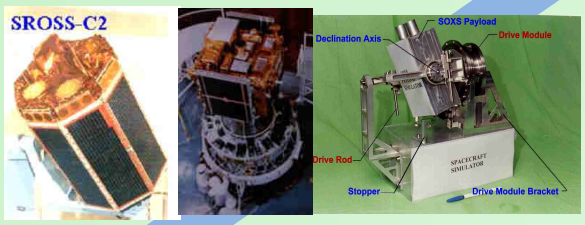


Mars Orbiter Mission
Nov 05, 2013

X-RAY Astronomy Payload
onboard IRS-P3 Satellite
Mar 21, 1996

Solar X-RAY Spectrometer
onboard GSAT- 2
May 8, 2003

Jul 13, 1988



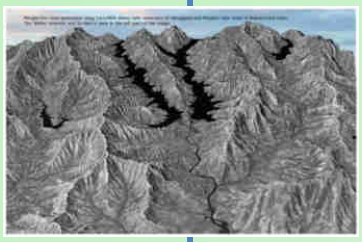

SROSS-C, C2, IXAE, SOXS -
X-ray Astronomy and
Atmospheric sciences

Aryabhata carried payloads
for Astronomical &
Atmospheric Sciences
April 19,1975

(1963) The first rocket flight had atmospheric science payload

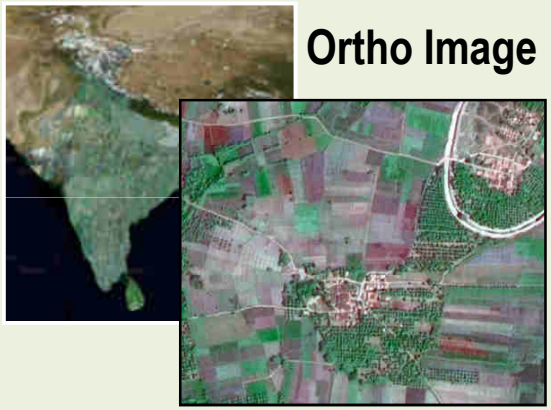
# Space Technology Inputs

Digital Elevation Model

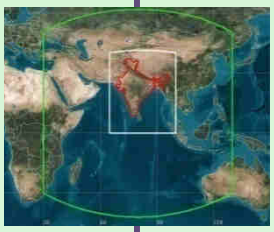


Optical & Microwave
Multi-Spectral
Multi-Spatial, Multi-Temporal

Ortho Image



GAGAN Enabled Positioning



In-situ Sensors

DCPs

Mobile Data Collection

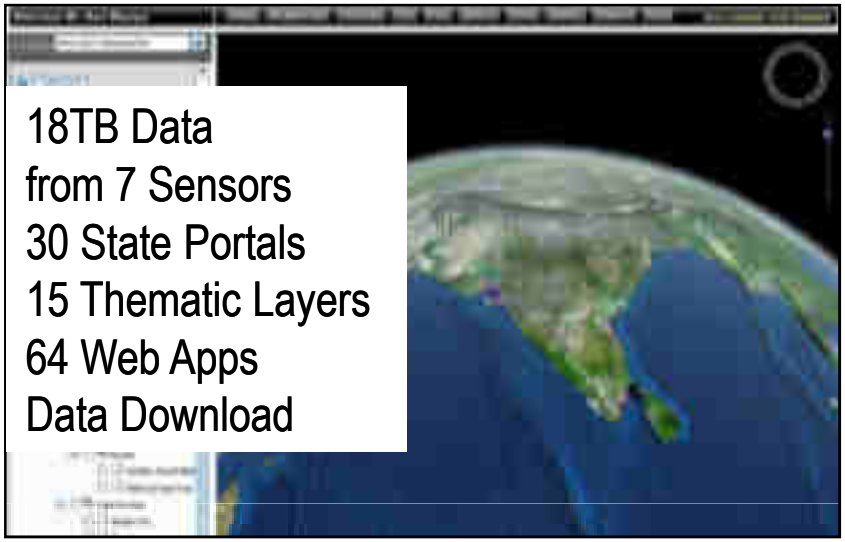
Model

Geo-Platforms

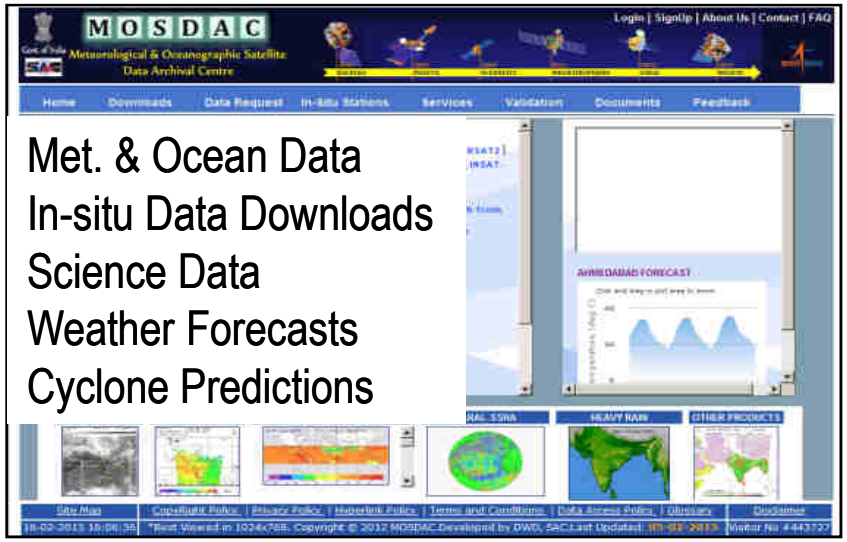
Suite of Applications

# Geo-Platforms

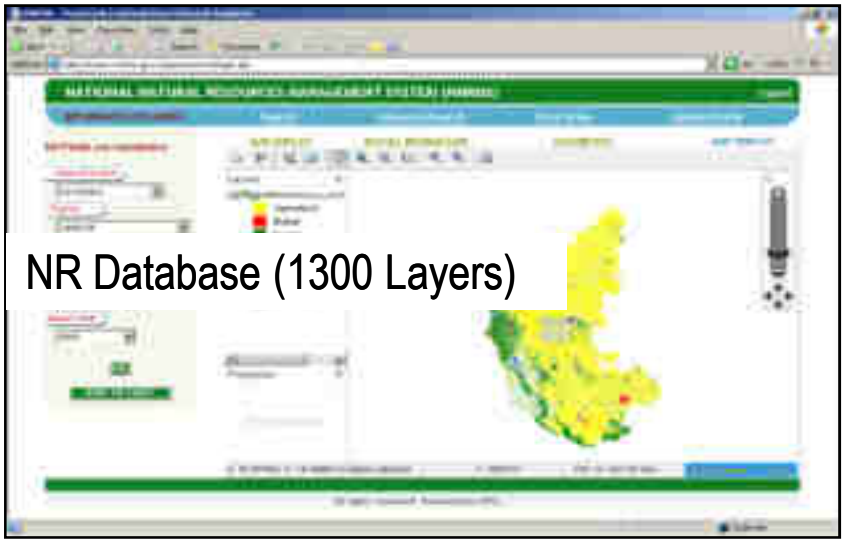
http://www.bhuvan.nrsc.gov.in



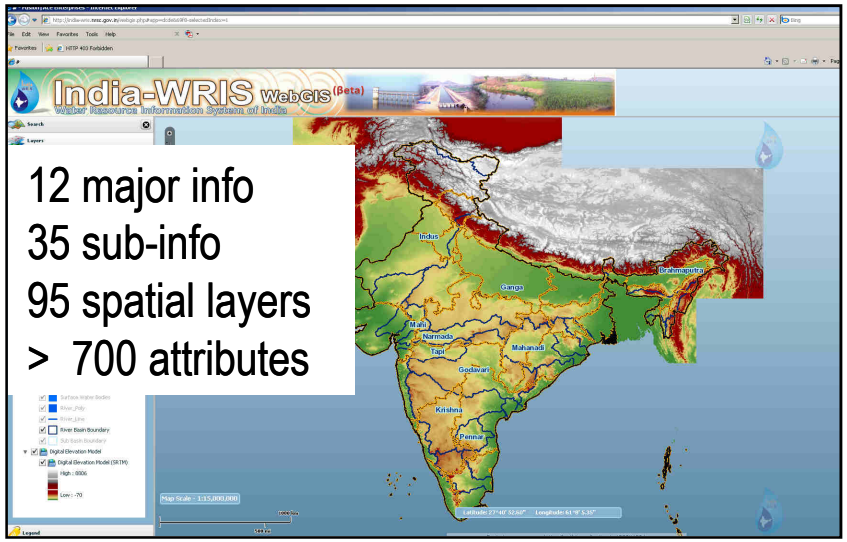

http://www.mosdac.gov.in



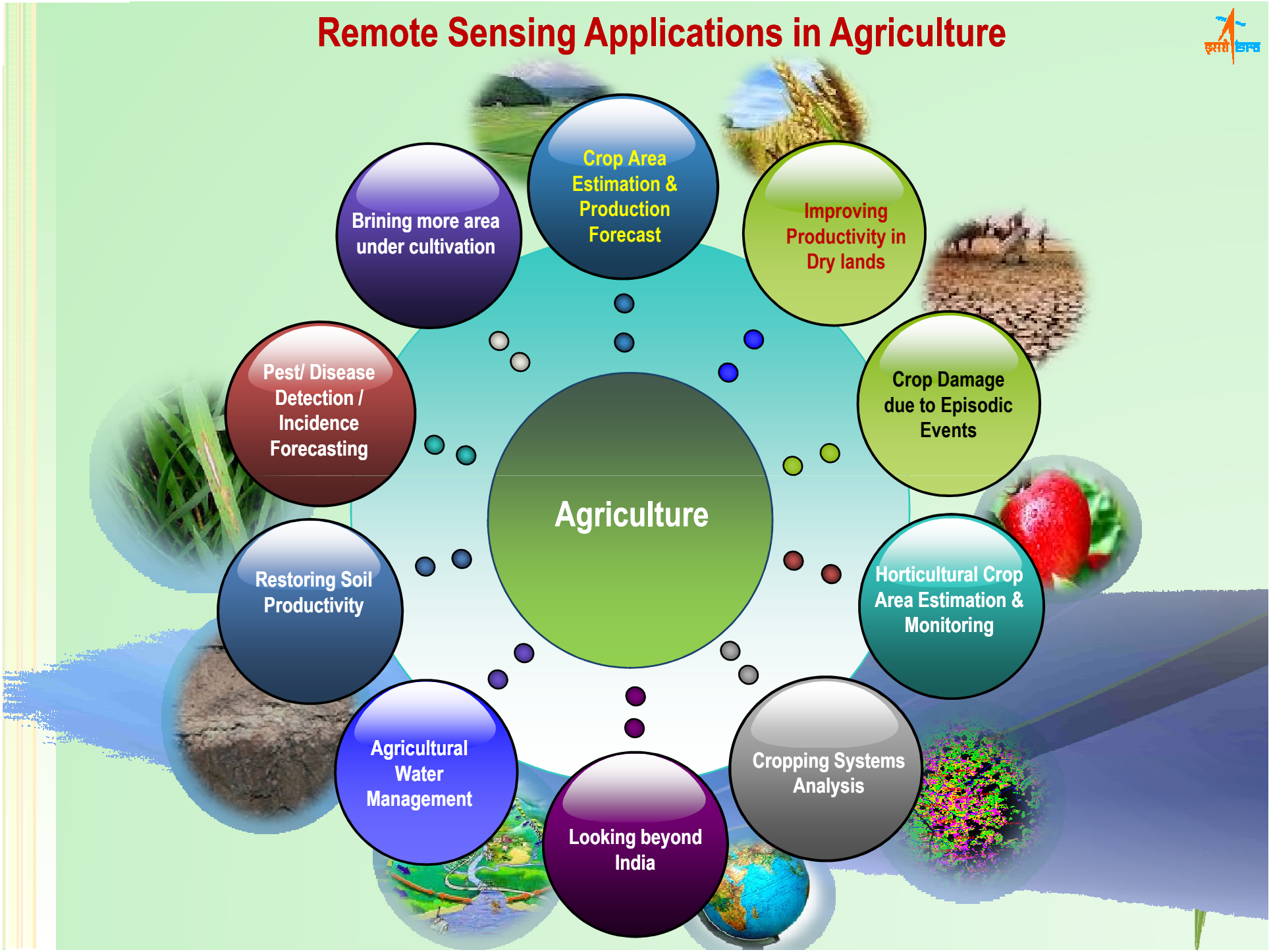

http://www.nnrms.gov.in




http://india-wris.nrsc.gov.in



# Remote Sensing Applications in Agriculture



# 45 Years of Use Of Space Technology In Agriculture

1969 ISRO-NASA-MoA → 1988 CAPE Project → 2007 FASAL → 2012 NCFC

**FASAL – Forecasting Agricultural output using Space, Agro-meteorology and Land based observations**

- Coconut Root Wilt study in Kerala
- Area & production Estimates of major crops at State level.
- District-State-National forecasts using multiple approaches & satellites for multiple forecasts
- Operationalisation of Space Technologies developed by ISRO

## Pre-harvest Production Forecast

**Rice, Wheat, Rapeseed/Mustard, Rabi Sorghum, Winter Potato, Sugarcane, Cotton, Jute**

**National level:** Kharif rice, rabi rice, wheat, jute, potato, mustard

**District level** : Wheat, cotton, mustard, sorghum, sugarcane

**First Estimate**
**Early stage**

Satellite Images
Ground Data
Temp./ Rainfall

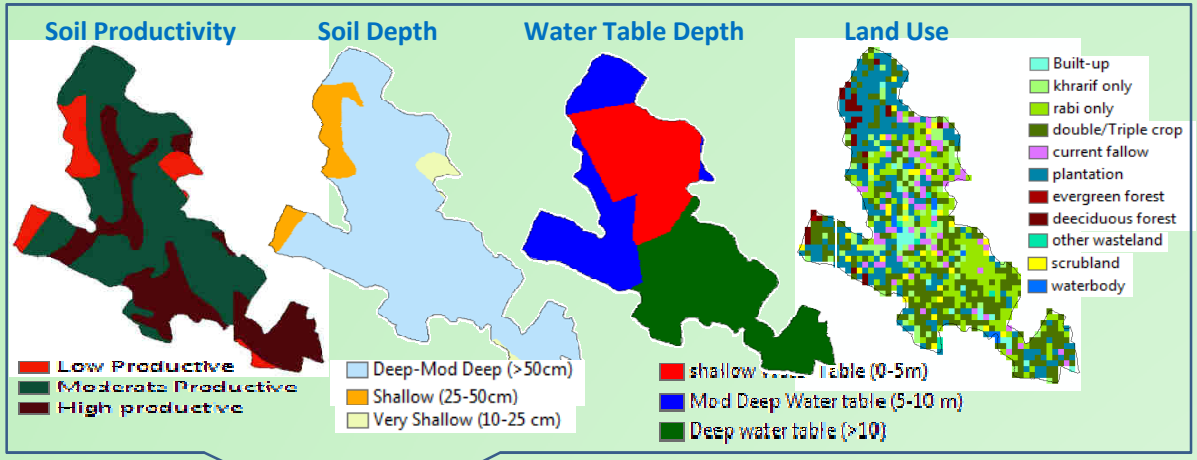
**Second Estimate**
**Mid Season**

Satellite Images
Meteorological data
Ground data

**Third Estimate**
**Before harvest**

Integrated Models
Remote Sensing &
Agro-meteorology

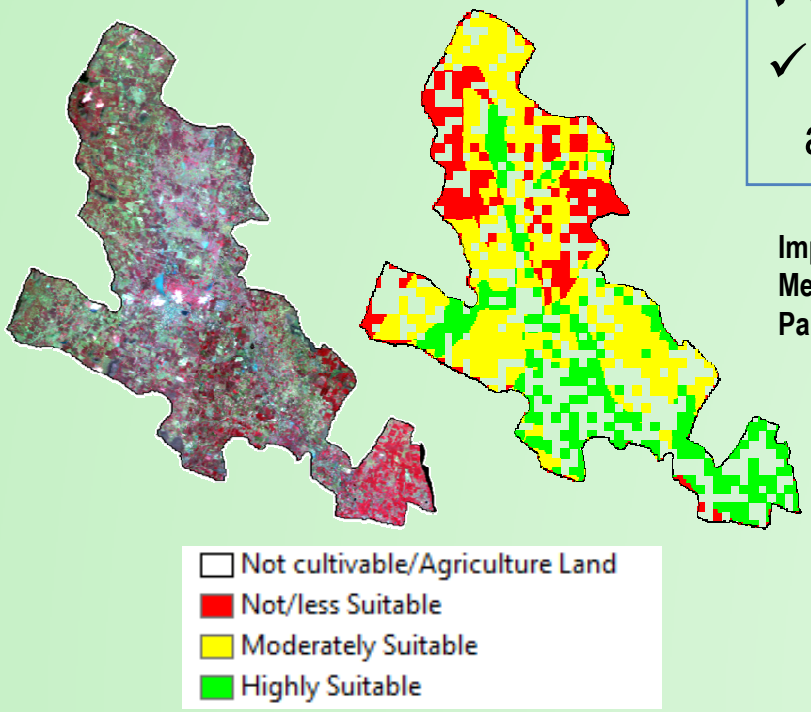
# Site Suitability Analysis for Horticulture - Mango Plantation




**180 districts in 11 states for 7 crops**

- **Fruits**: Banana, Mango & Citrus
- **Vegetables**: Potato, Onion & Tomato
- **Spices**: Chilli

**Suitability Map for Mango Plantation**
**Nuzvid Mandal, A.P.**



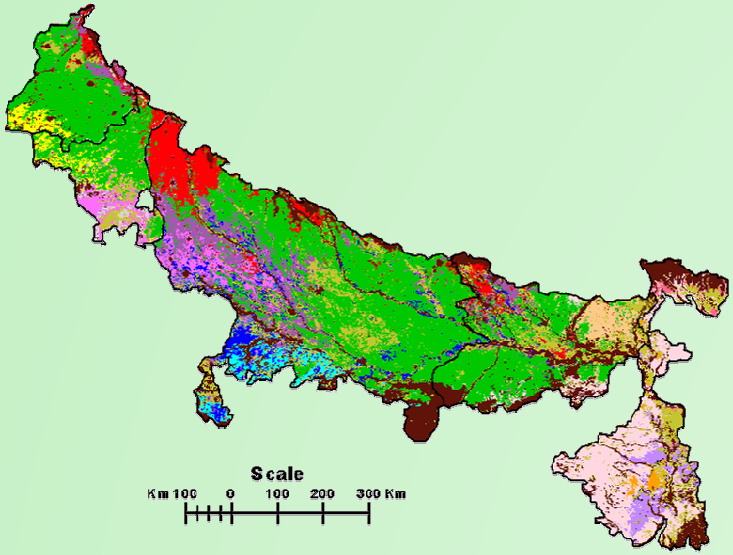

- ✓Site-suitability for introduction / expansion of plantation
- ✓Crop Intensification in regions, which are under-utilized
- ✓Infrastructure Planning to minimizing losses (as these are perishable)

**Implementing Agencies:** MNCFC and Indian Agricultural Statistics Research Institute
**Methodology:** ISRO.
**Partner Institutions:** IMD, State Horticulture Departments & SRSAC

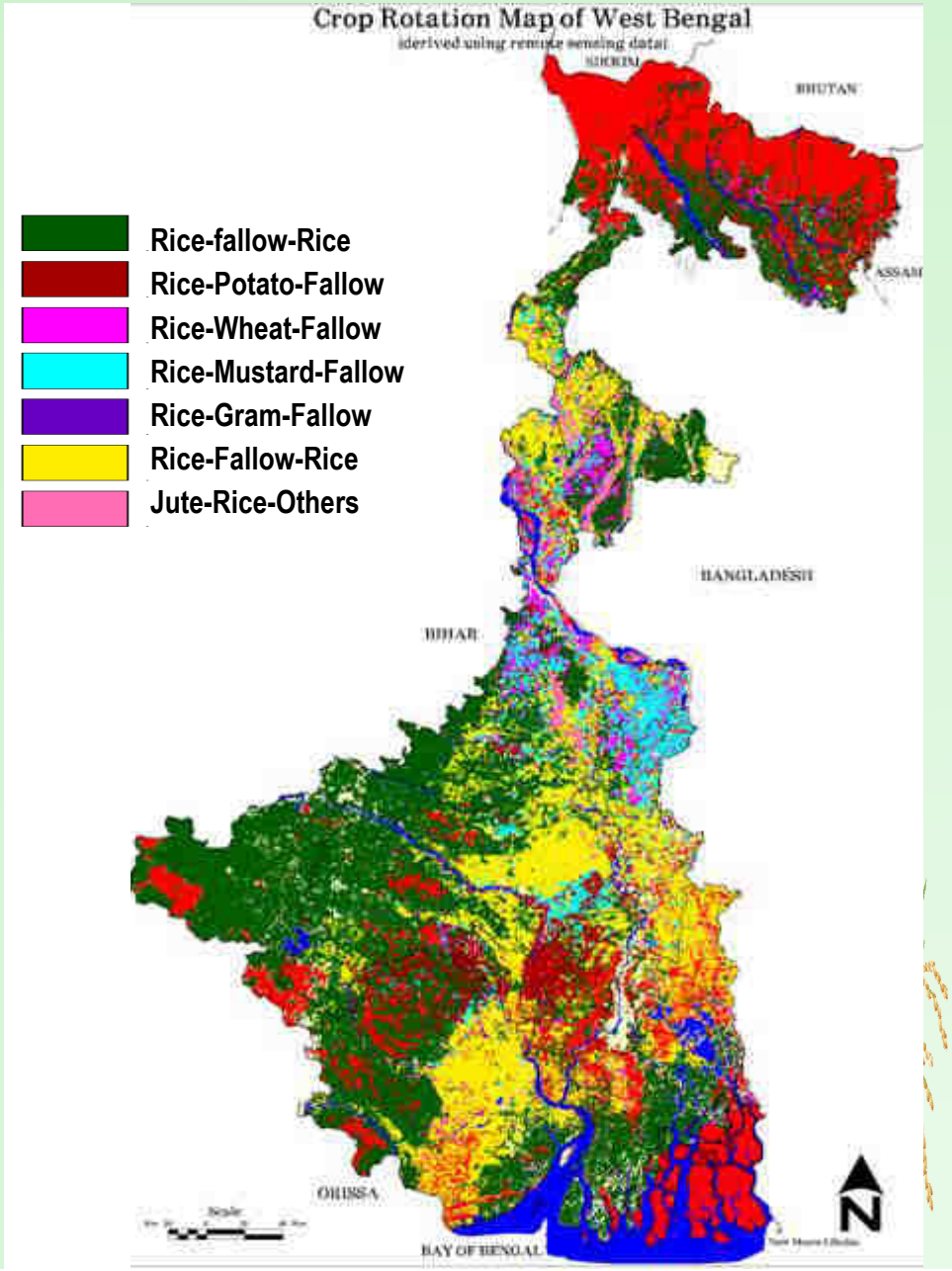
| Categories | Suitable Area (ha) | Actual area under mango (ha) |
|---|---|---|
| Highly suitable | 5019 | 820 |
| Moderately suitable | 8343 | 2636 |
| Not/Less Suitable | 3561 | 1270 |

# Cropping Intensity - Cropping Systems Analysis

- Seasonal cropping pattern - database
- Crop rotation and cropping diversity
- Areas for specific management
- Crop intensification
- Long term changes in cropping system

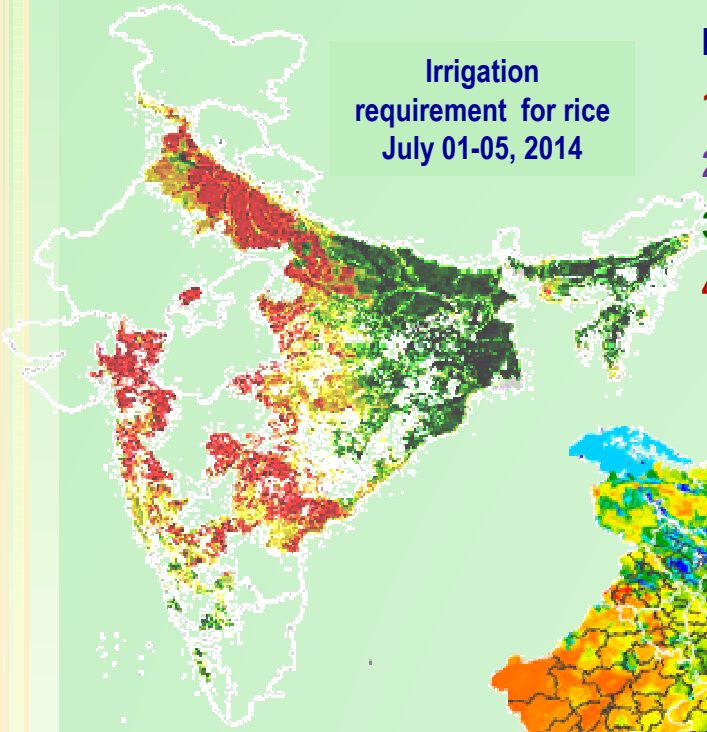



- Rice-Wheat
- Sugarcane Based
- Cotton-Wheat
- Rice-Potato
- Maize-Wheat
- Pearlmillet-Wheat
- Rice-Fallow-Rice
- Rice-Fallow-Fallow
- Rice-Fallow-Jute
- Rice-Wheat-Other
- Fallow-Pulse
- Fallow-Wheat
- Minor Crop Rotations
- Fallow
- Non-Arable



# Early season crop prospect forecast

## Development of early crop prospect forecasting using combination of Weather Remote sensing and ancillary data

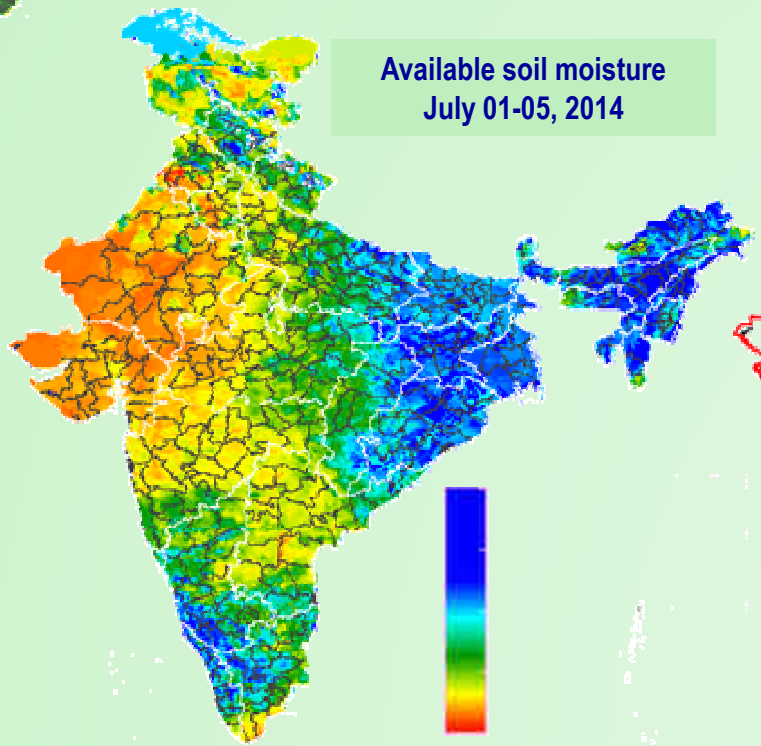


Irrigation requirement for rice July 01-05, 2014

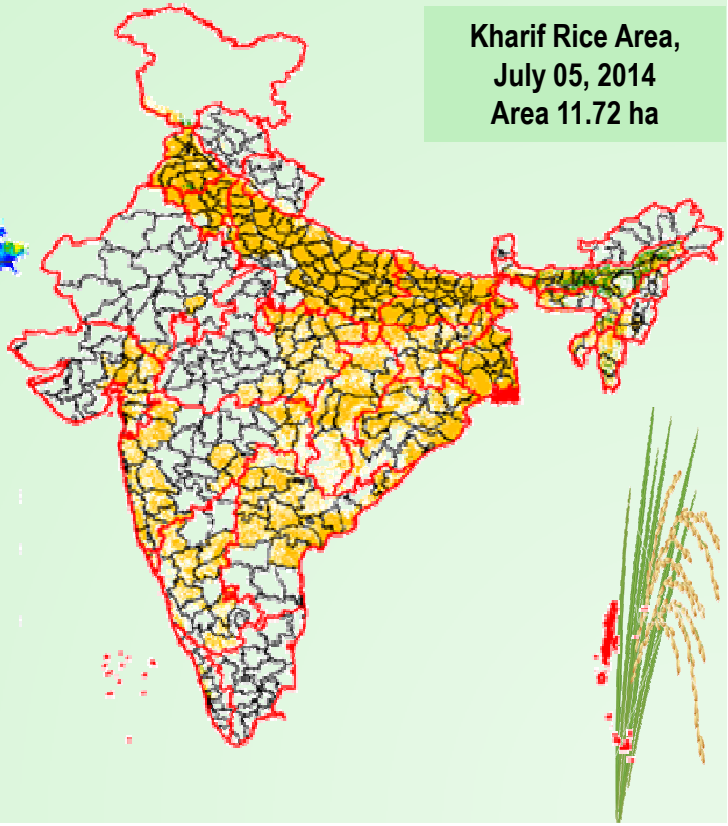
No Net irrigation
0 mm / day
25 mm / day

**Inputs:**

1. Soil Texture Class Map (12 Class)
2. Daily PET (Computed/Climatic)
3. Crop Coefficient Maps
4. Agricultural/Crop Class Maps
5. Crop Specific Calendars (Maps)
6. Administrative Boundaries
7. Daily Gridded Rainfall Data (mm/day)
8. Daily Gridded Irrigation Data (mm/day)

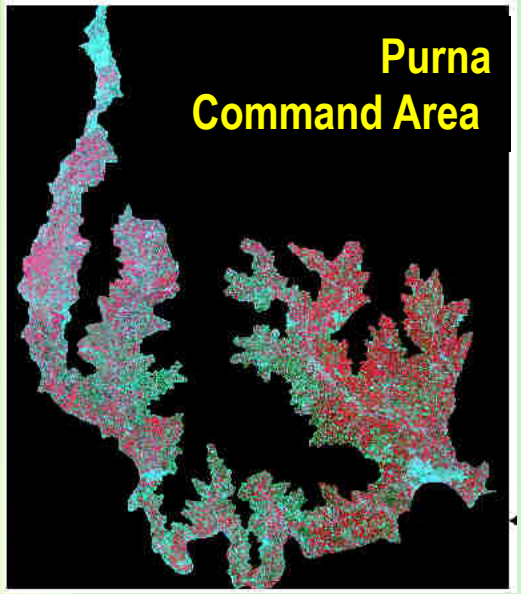


Available soil moisture July 01-05, 2014

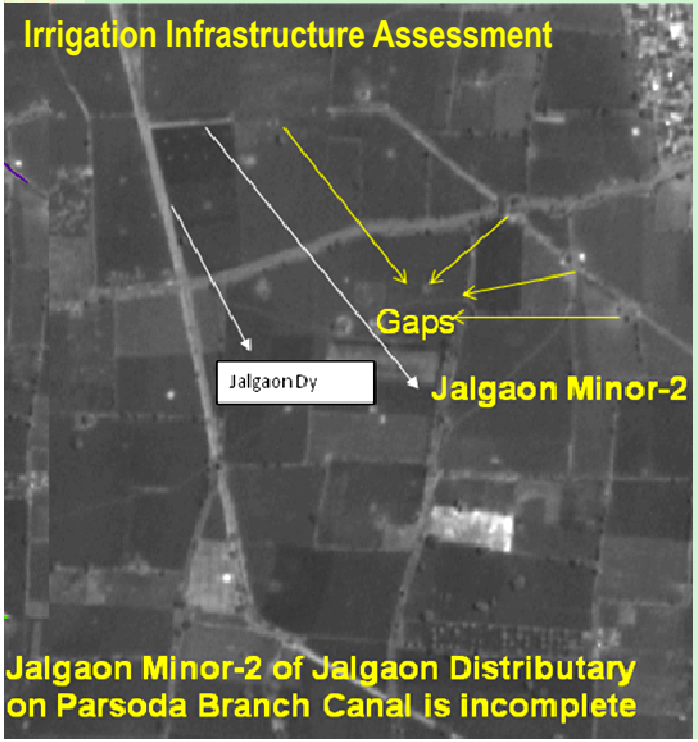


Kharif Rice Area, July 05, 2014
Area 11.72 ha

# Agricultural Water Management




- Command Area Development
- Irrigation Infrastructure Assessment
- Reservoir Capacity Evaluation
- Tank Inventory
- Canal Alignment
- Ground Water Exploration & Recharge




## Command Area Development

**Assessment of:**

- Land use/ cover
- Soils
- Land irrigability

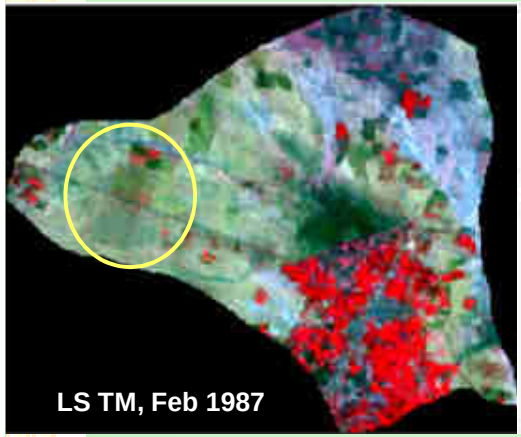
**Leading to:**

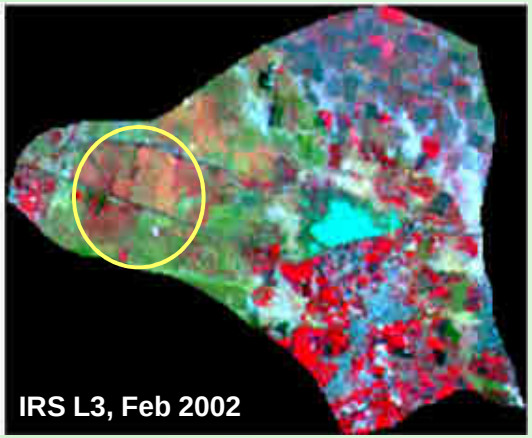
- Alignment of distributaries / canal network
- Identification of irrigable areas under each distributary
- Designing cropping pattern
- Fixing design discharges at head of the distributaries

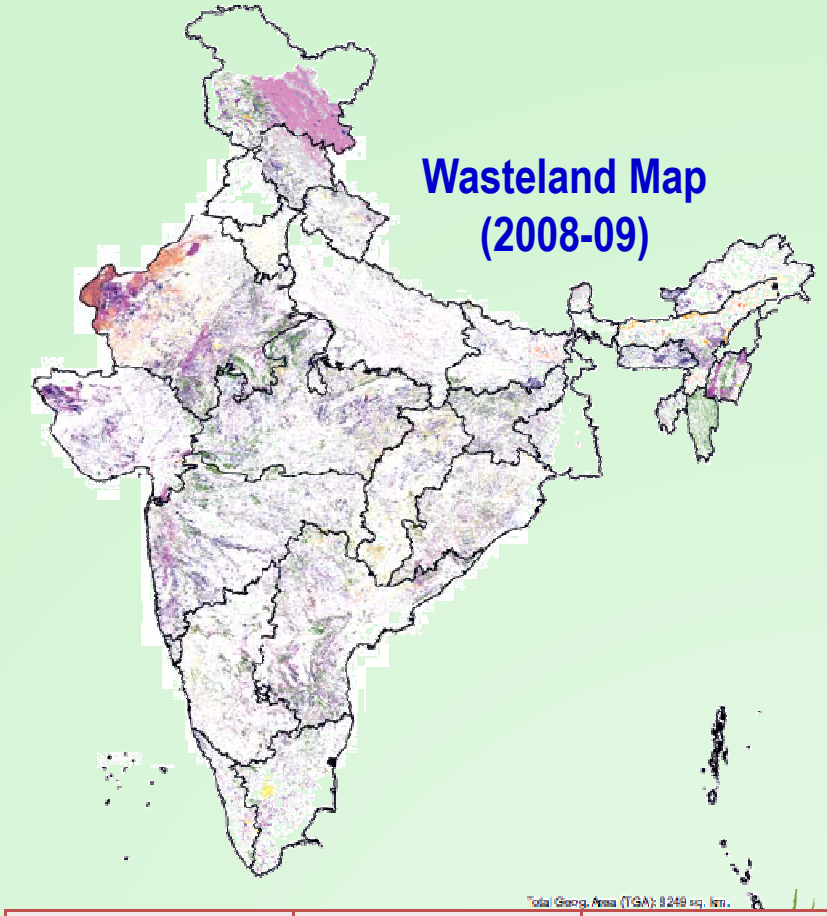
# Brining More Area under Cultivation - Wasteland Mapping

- Bring culturable wastelands under cultivation
- Enhance food grain production
- Bring 30% under green cover

- National Wasteland Inventory Project (1986 - 2000)
- National Wasteland Updation Mission (2003 - 2004)
- Monitoring of the wasteland areas (2005-06)
- Wasteland Change Analysis (2008-2009)
- Coverage : Entire India in 1:50,000 scale
- No. of Wasteland categories : 28



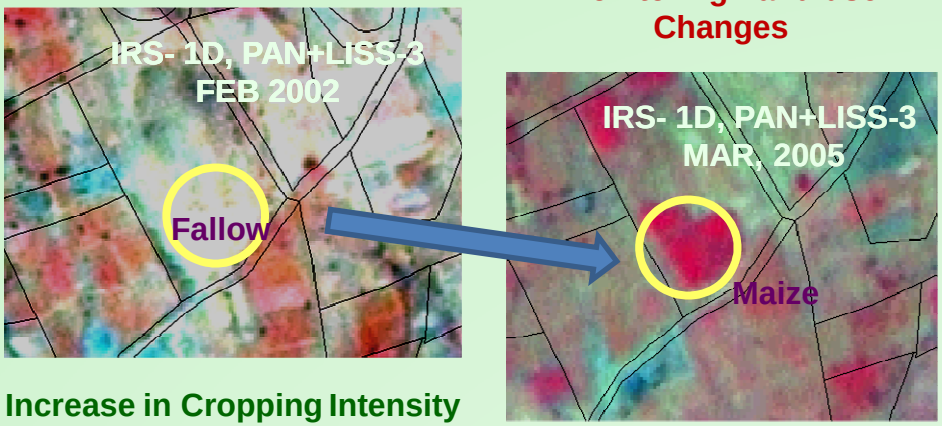

| Area (Mha) | % of TGA | Year of Data |
|---|---|---|
| 63. 85 | 20.17% | 1986 -2000 |
| 55.27 | 17.45% | 2003 |
| 47.22 | 14.91% | 2005 |
| 46.73 | 14.76% | 2009 |

# Improving Productivity in Dry lands

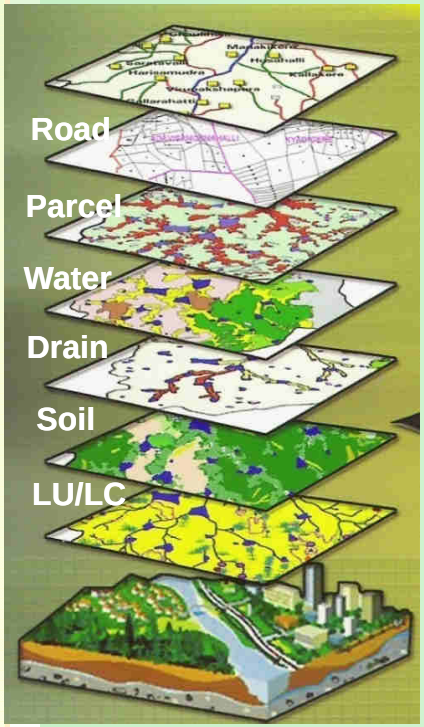
- **Phase-wise implementation of Sujala Watershed Project Karnataka**
- **Work in progress in more than 50 thousand micro watersheds**

- Watershed prioritization & Development using EO inputs
- Improve productive potential of degraded watersheds & cropping intensity
- Create alternate livelihood options
- Process Monitoring & Mid-course correction
- Improves the quality of life

**Monitoring Land use Changes**




**Increase in Cropping Intensity**




**Participatory Implementation**

**Farm Pond**

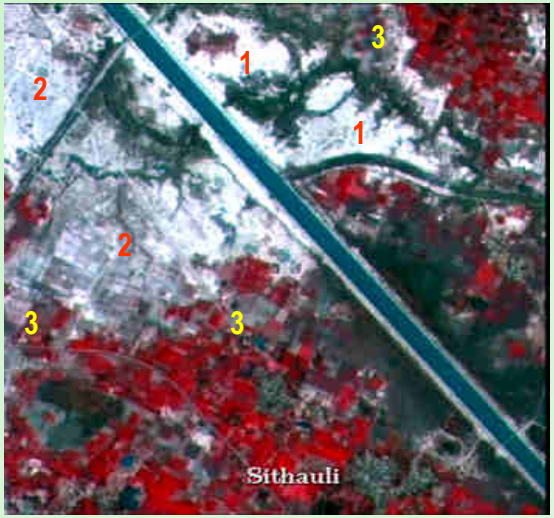
**Watershed Community**

**Nala bund**

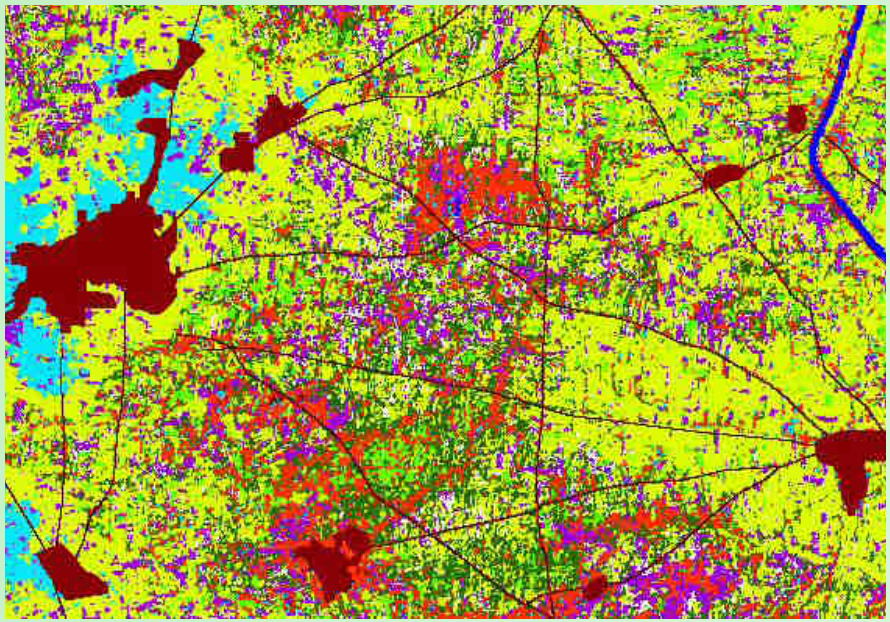
**Outcome**

# Restoring Soil Productivity

- Problematic soils have been mapped.
- Monitoring of the reclamation of the salt affected soils has also been done using muti-date satellite imagery
- Waterlogged areas – Mapped and monitored




1 Strongly Saline- Sodic Soils
2 Moderately saline –Sodic Soils
3 Slightly saline – Sodic soils



Ahmednagar, Maharashtra

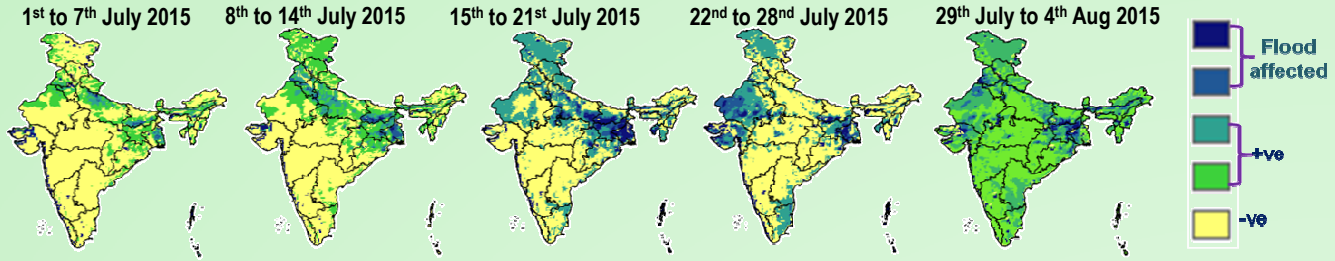
Slightly Salt affected
Moderately Salt affected
Severely Salt affected
Water logged

Salt affected plot of sugarcane

# Weekly Agricultural Outlook of India from Space-based Observations during July-August 2015

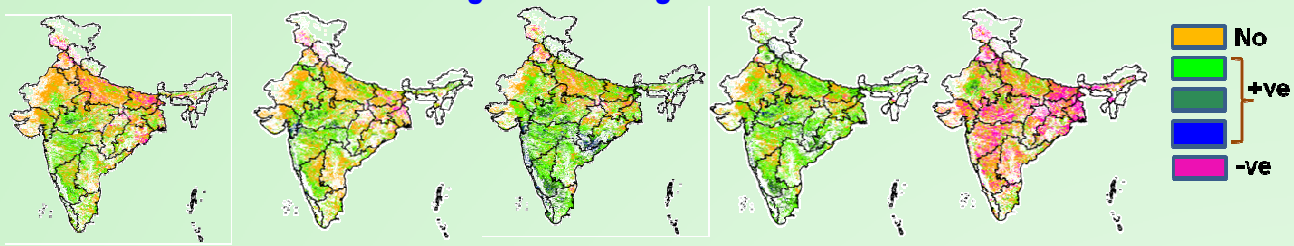
## Change in soil moisture status from long term mean

### *Status of Surface Soil Moisture from Passive Microwave Radiometer, AMSR-2*

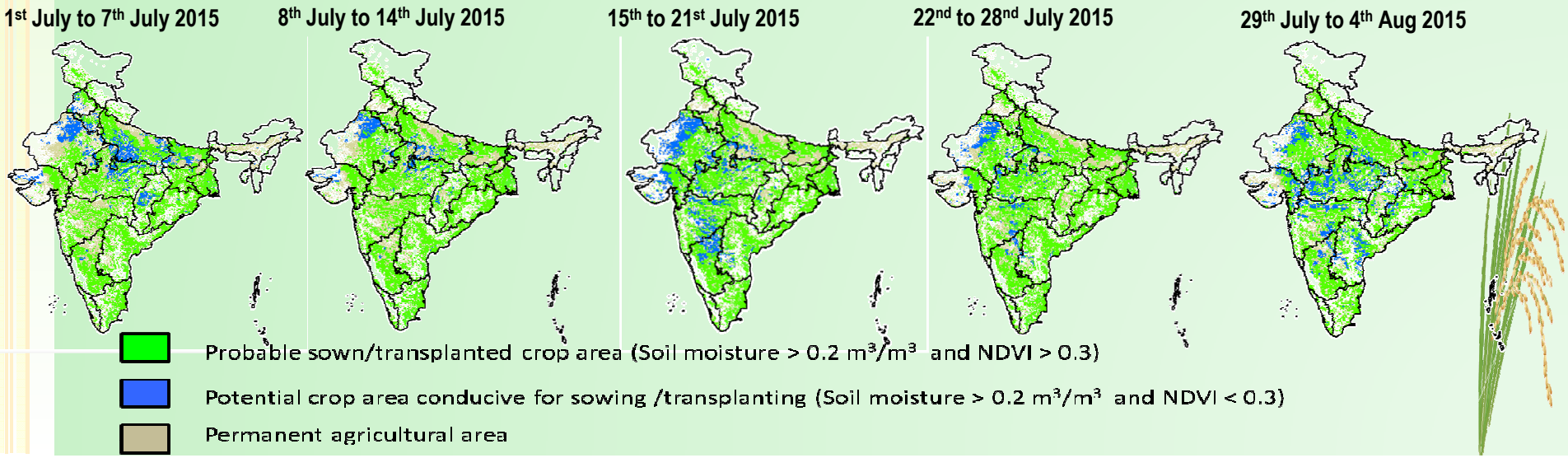



## Change in agricultural vigour from long-term mean

### *Status of Agricultural Vigour from INSAT 3A*

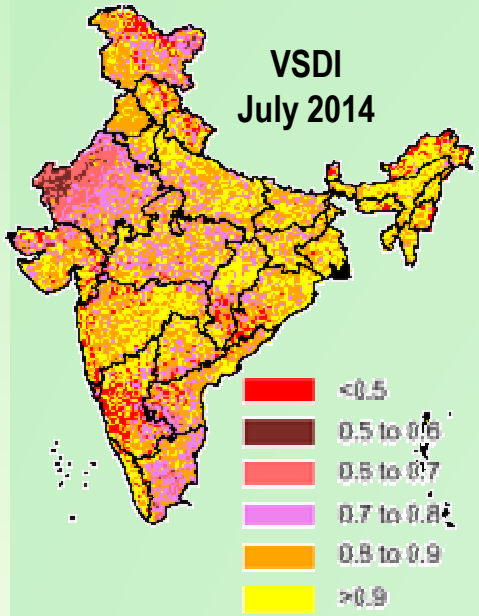


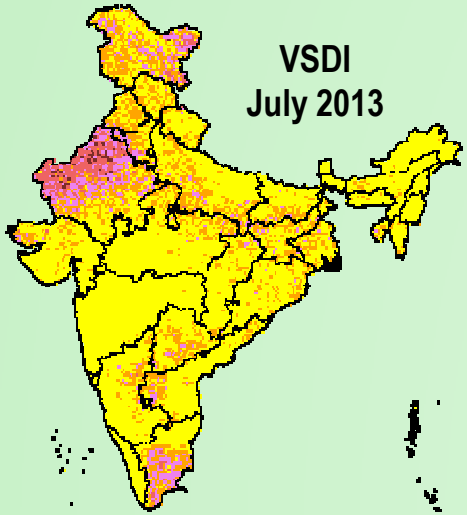

## Analysis of INSAT 3A CCD NDVI and AMSR-2 Soil moisture for July for early agricultural situation over India



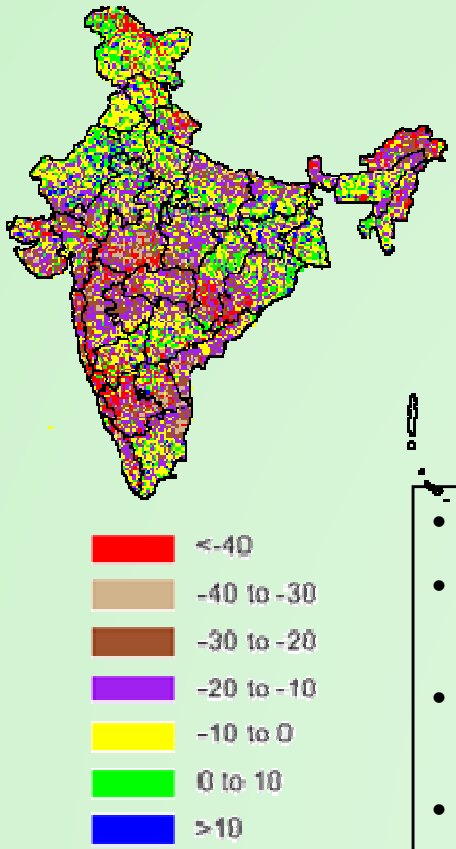
# Studies on new indices for operational drought monitoring
# Visible and Shortwave Infrared Drought Index (VSDI)

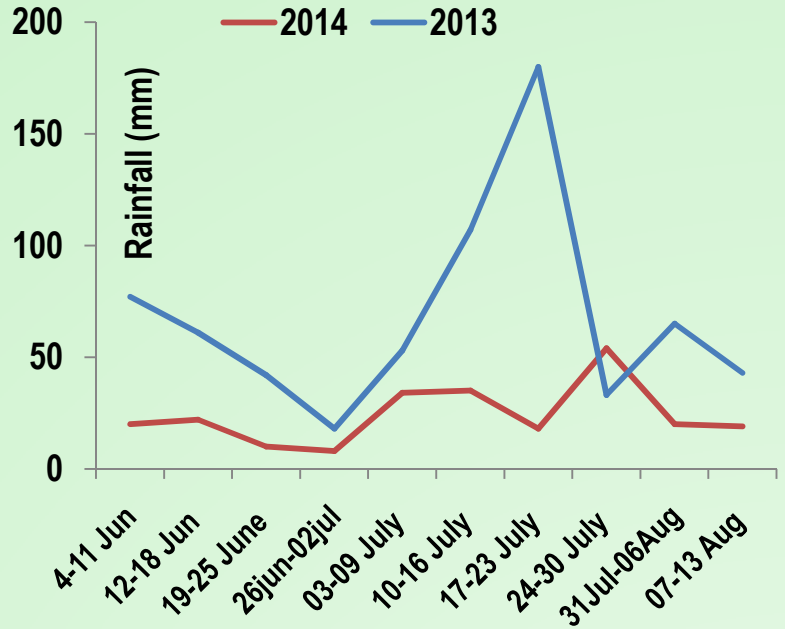
## Detecting early season drought conditions of 2014 using this new index



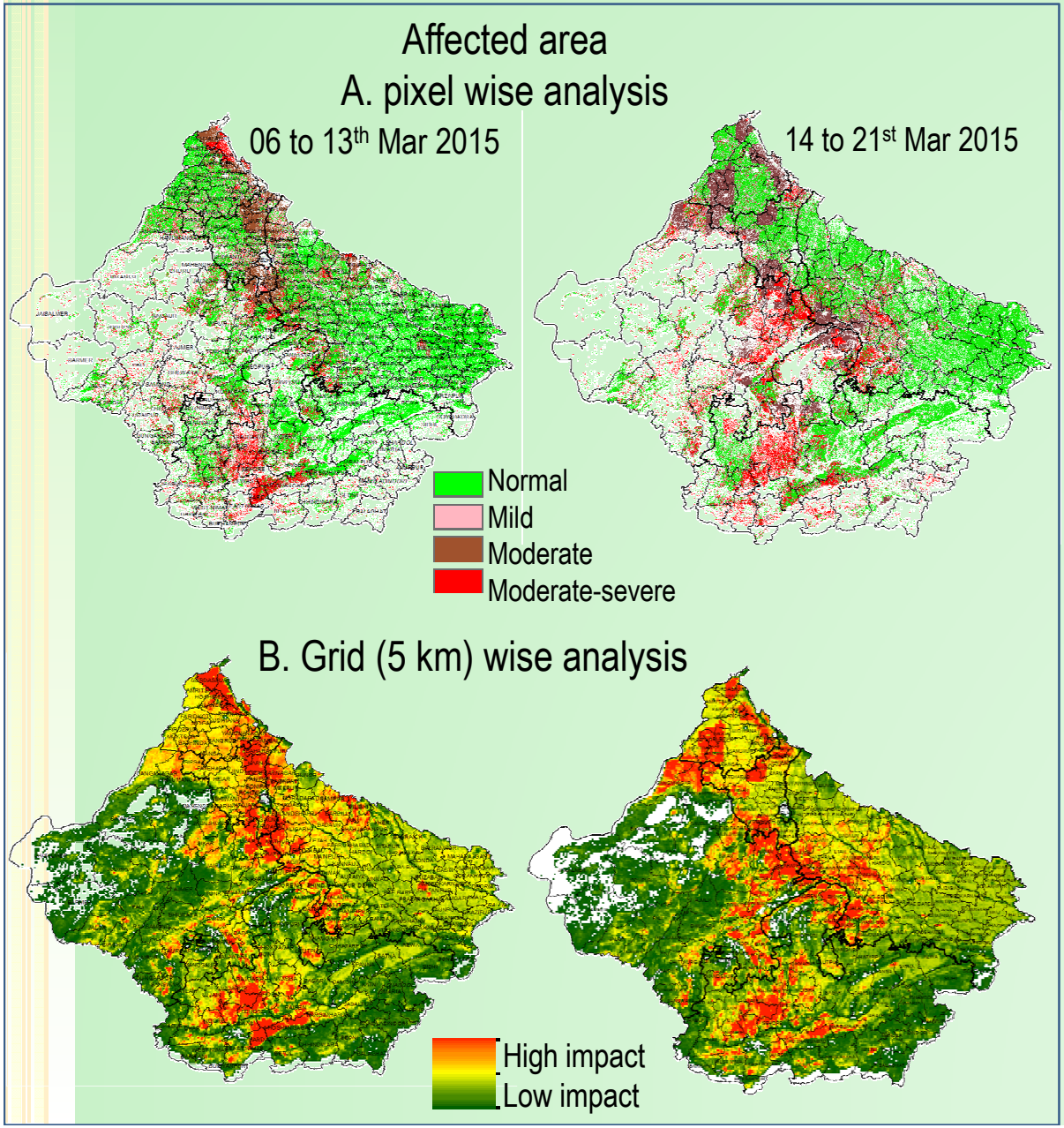

VSDI deviations showing drought conditions in July 2014




- VSDI = 1- $[(\rho_{SWIR} - \rho_{blue}) + (\rho_{red} - \rho_{blue})]$
- Moisture sensitive SWIR and Red bands and insensitive blue band
- Range of index is 0 to >1 representing increasing wetness.
- Studies conclude that VSDI is found to be an effective surface wetness indicator at regional level.

# Geospatial analysis of the impact of untimely rains during March, 2015
# Punjab, Haryana, UP and Rajasthan




## Methodology

**Inputs**
- Spectral indices -LSWI and NDVI)
- (LISS-III, AWiFS, TM, MODIS)
- Rainfall
- Temperature
- Wind Speed
- Cropped area images

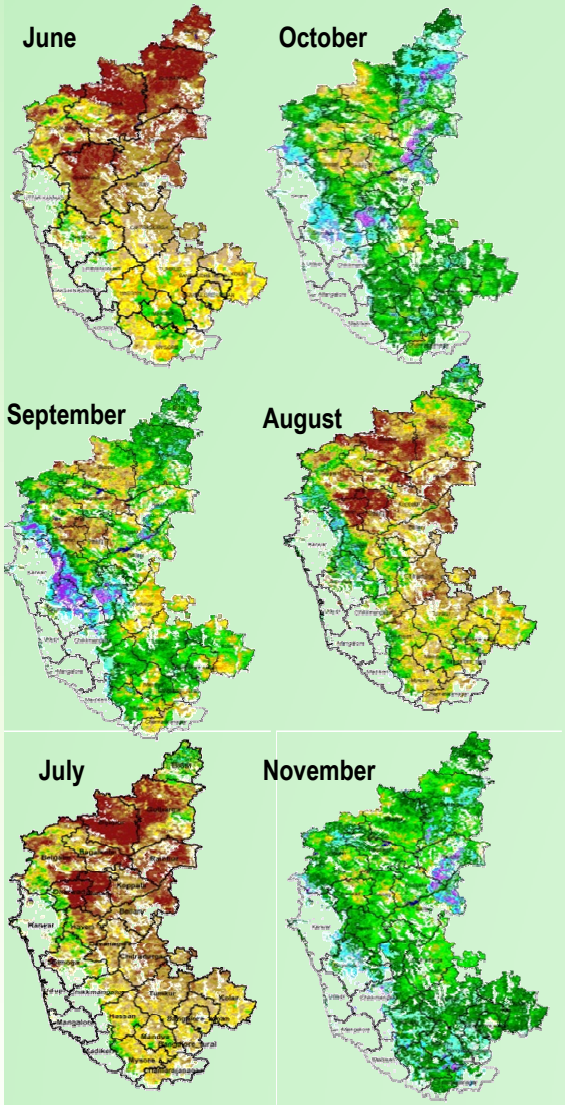
**Derivatives**
- Surface wetness
- Crop vigour
- Growing degree days
- Days before harvesting
- Heavy rainfall events
- High wing speed events

Integration & Decision rules (major crop groups)

Final outputs
- Affected area map
- Impact rating

# National Agricultural Drought Assessment and Monitoring System (NADAMS)

## NOAA- AVHRR based Normalized Difference Vegetation Index (NDVI)-2012





(It covers total 13 States: 9 States at District Level and 4 states at sub-district level, including Karnataka)

## Drought Assessment map of Kharif -2012


Normal
Mild
Moderate

## District Wise Rainfall deviations-2012

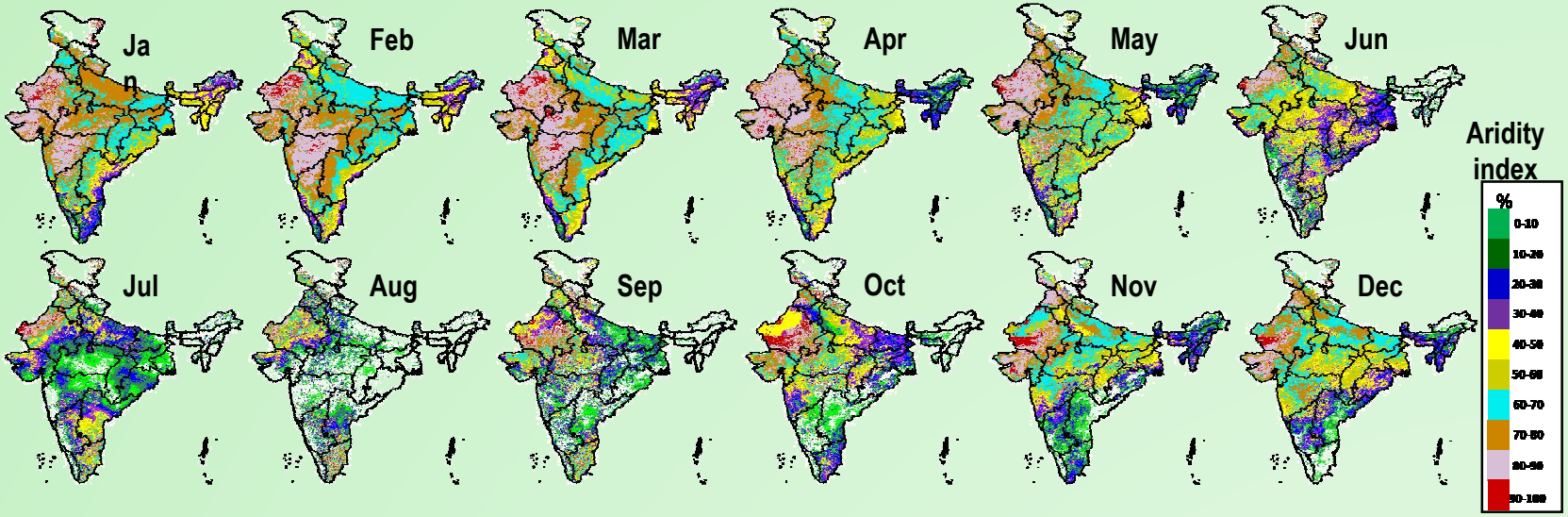
(No. of Taluks)

| District | Normal | Mild | Moderate |
|---|---|---|---|
| Bagalkot | 0 | 3 | 3 |
| Bangalore rural | 0 | 2 | 2 |
| Bangalore urban | 0 | 2 | 2 |
| Belgaum | 3 | 5 | 2 |
| Bellary | 0 | 0 | 7 |
| Bidar | 5 | 0 | 0 |
| Bijapur | 0 | 0 | 5 |
| Chamarajanagara | 0 | 1 | 3 |
| Chickballapur | 3 | 1 | 2 |
| Chikmagalur | 6 | 1 | 0 |
| Chitradurga | 0 | 3 | 3 |
| D. Kannada | 5 | 0 | 0 |
| Davangere | 0 | 4 | 2 |
| Dharwad | 1 | 0 | 4 |
| Gadag | 0 | 0 | 5 |
| Gulberga | 0 | 4 | 3 |
| Hassan | 1 | 3 | 4 |
| Haveri | 1 | 3 | 3 |
| Kodagu | 3 | 0 | 0 |
| Kolar | 2 | 2 | 1 |
| Koppal | 0 | 0 | 4 |
| Mandya | 0 | 5 | 2 |
| Mysore | 0 | 4 | 3 |
| Raichur | 0 | 2 | 3 |
| Ramanagara | 1 | 2 | 1 |
| Shimoga | 7 | 0 | 0 |
| Tumkur | 1 | 6 | 3 |
| Udupi | 3 | 0 | 0 |
| Uttara Kannada | 11 | 0 | 0 |
| Yadgir | 2 | 0 | 1 |
| Total | 55 | 53 | 68 |

# Aridity index using Indian geostationary data (K1 and INSAT 3A CCD)

## Aridity Index 2009 (Drought year)

Aridity index (P/PET) has been computed using combination of actual and potential evapo-transpiration



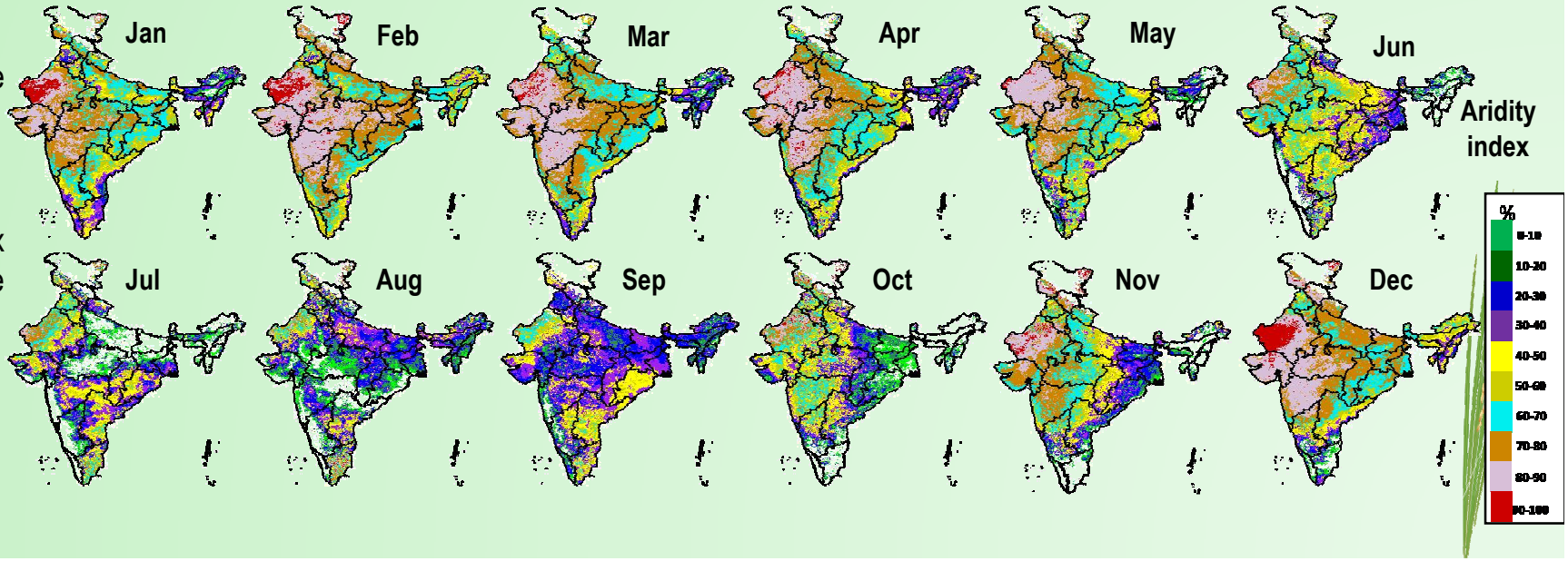

## Aridity Index 2011 (Normal year)

**Future work**

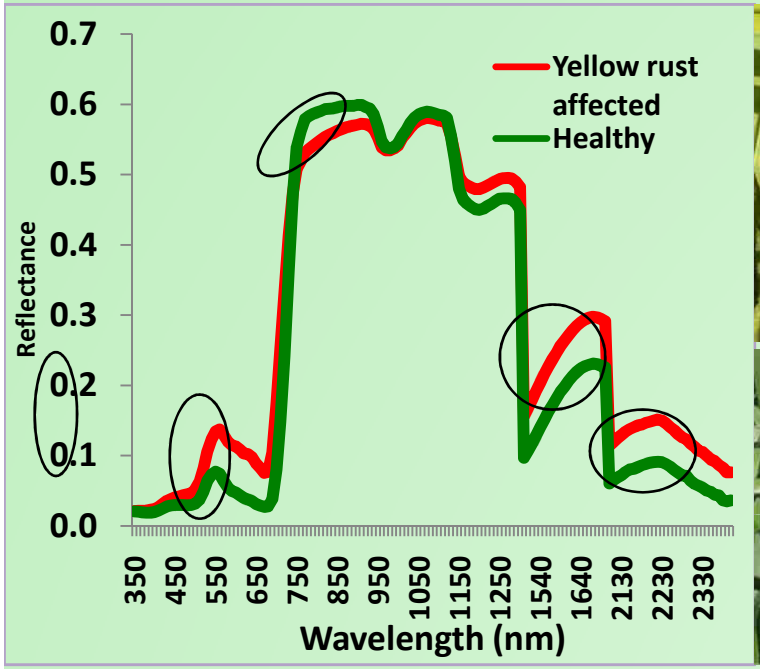
To add the other agromet parameters in this index to enhance its capability.

**User**

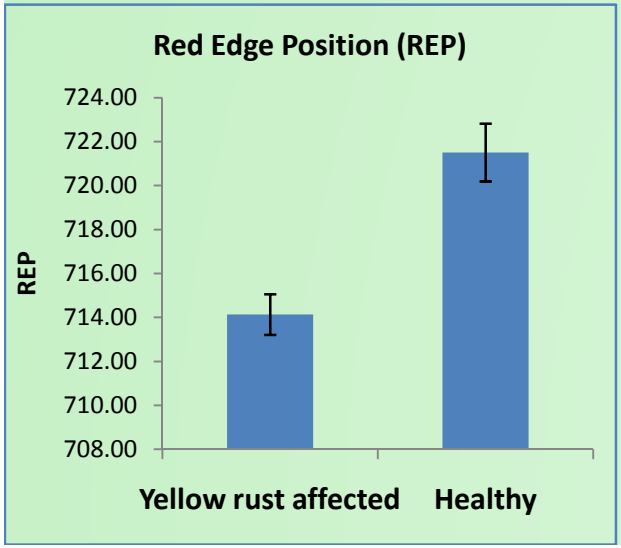
IMD and MNCFC

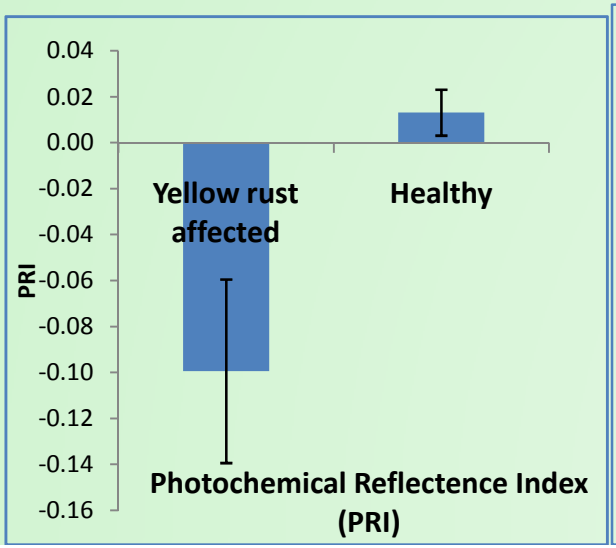


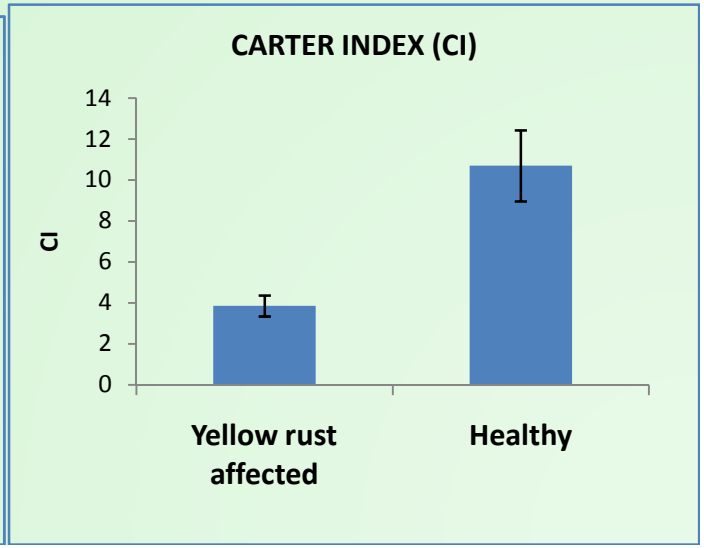
# Hyperspectral studies for detection of yellow rust affected wheat crop




| S NO | Central wavelength / Index | Healthy | Diseased (yellow rust affected) | % change |
|---|---|---|---|---|
| 1 | 660 | 0.03 | 0.08 | 188.90 |
| 2 | 680 | 0.03 | 0.08 | 176.08 |
| 3 | 1500 | 0.10 | 0.16 | 62.01 |
| 4 | 550/680 | 2.82 | 1.79 | -36.71 |
| 5 | (800-550/1660+680) | 2.02 | 1.10 | -45.40 |
| 6 | 800/1660 | 2.59 | 1.84 | -29.15 |
| 7 | 1660/680 | 8.45 | 3.92 | -53.59 |
| 8 | 1660/550 | 2.99 | 2.25 | -24.88 |

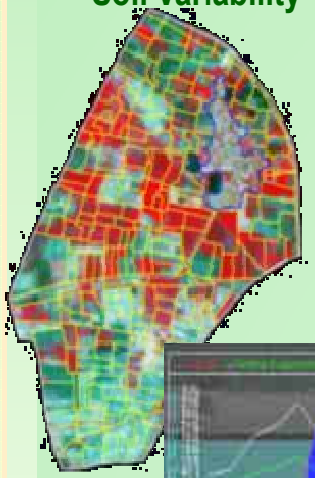


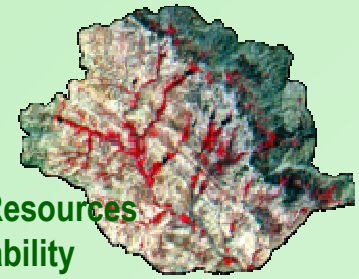



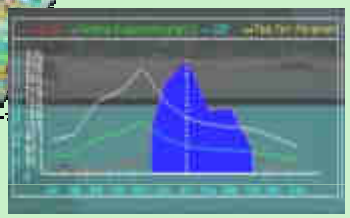
# Remote Sensing Inputs to Precision Agriculture

Soil Variability

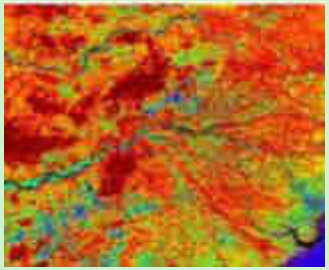




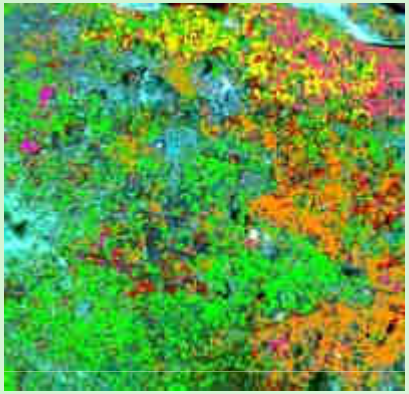
Natural Resources Variability



Crop Weather Interaction



Yield Variability



In-season crop map

**Mid-Course Corrections**

- Irrigation
- Fertilizer Appl.
- Insect/Pest Control
- Variable rate technology
- .....

**Indirect: Remote Sensing + In situ data**

**Databases RS/GIS/GPS**
Crops, Weather & Soils

⟺

**Modeling**
Crop Simulations

⟺

**Decision Support System**
Package of Practices

Productivity Gaps/ Variations

Inputs Optimization Strategy

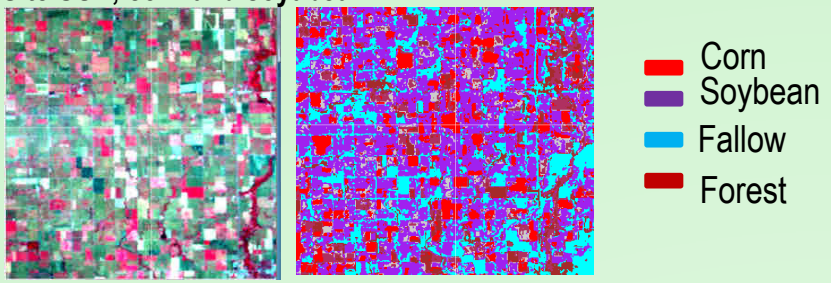
Impact Analysis

# Experimentation on International Crop Assessment using Earth Observation Data

## Objective

- Evaluation of IRS RS 2 data for assessment of major crops in GEO JECAM sites
- Use of RISAT data for Asia-Rice technical demonstration sites in S.E. Asian countries for rice crop mapping in selected sites

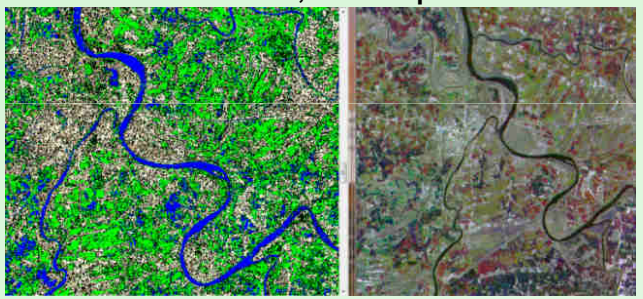
Site USA, corn and soyabean




## Results

- Classified wheat area for Pakistan 2015.
- Classified GEOGLAM sites of S.E. Asia for rice crop in North Vietnam, Indonesia and Thailand using RISAT 1 MRS data 2014.

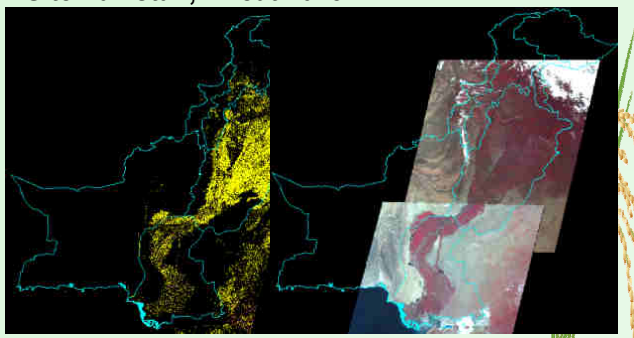
Site North Vietnam, Rice crop



## Future Plan

- Rice area estimation using RISAT MRS data for Bangladesh kharif 2015
- Wheat area estimation for Pakistan for rabi 2016 using AWIFS data
- Crop classification for USA and Canada sites 2015

Site Pakistan, wheat 2015

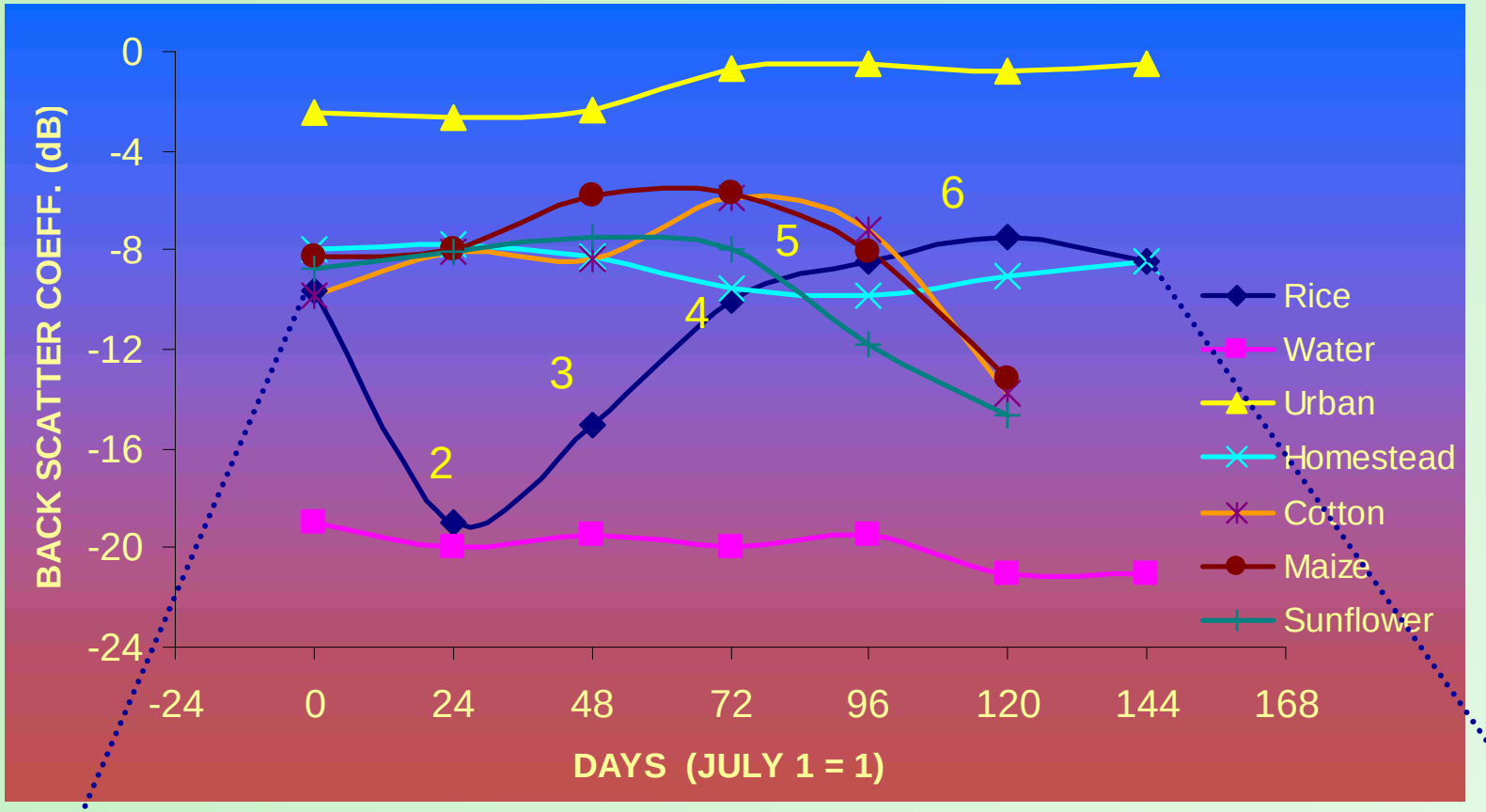


| Province 2013-14 | RS AREA '000 ha | Reported '000 ha 2014 | R.D. % |
|---|---|---|---|
| Punjab | 8110 | | |
| Sindh | 798 | | |
| Pakistan | 9899 | 9039 | 9.5 |

# Microwave Remote Sensing

- Operational Applications Acreage and production estimation of Rice and Jute crops
    - Technique Development for crop discrimination using Compact Polarimetric data
- Forest Biomass Estimation
- Soil Moisture Estimation
- Flood inundation and Damage Assessment

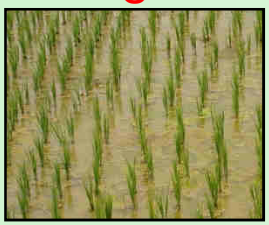
# Crop Discrimination with Temporal SAR Ddata



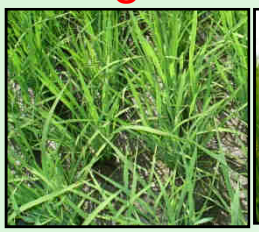


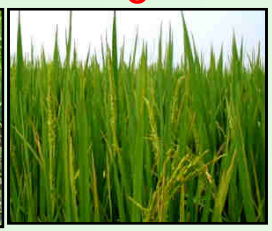
Pre-transplantation


Transplantation


Tillering


Vegetative

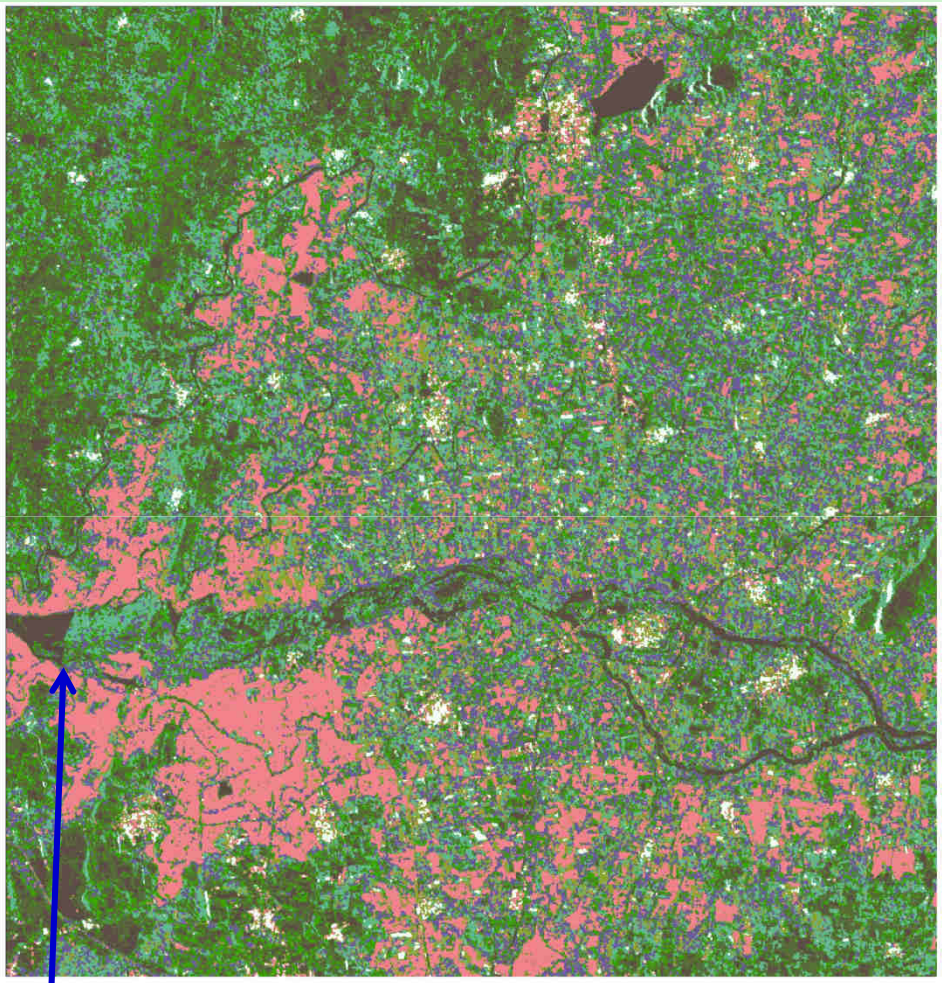

Peak-vegetative


Heading


Maturity

# Paddy Discrimination: Single Date RISAT-1 Hybrid Data

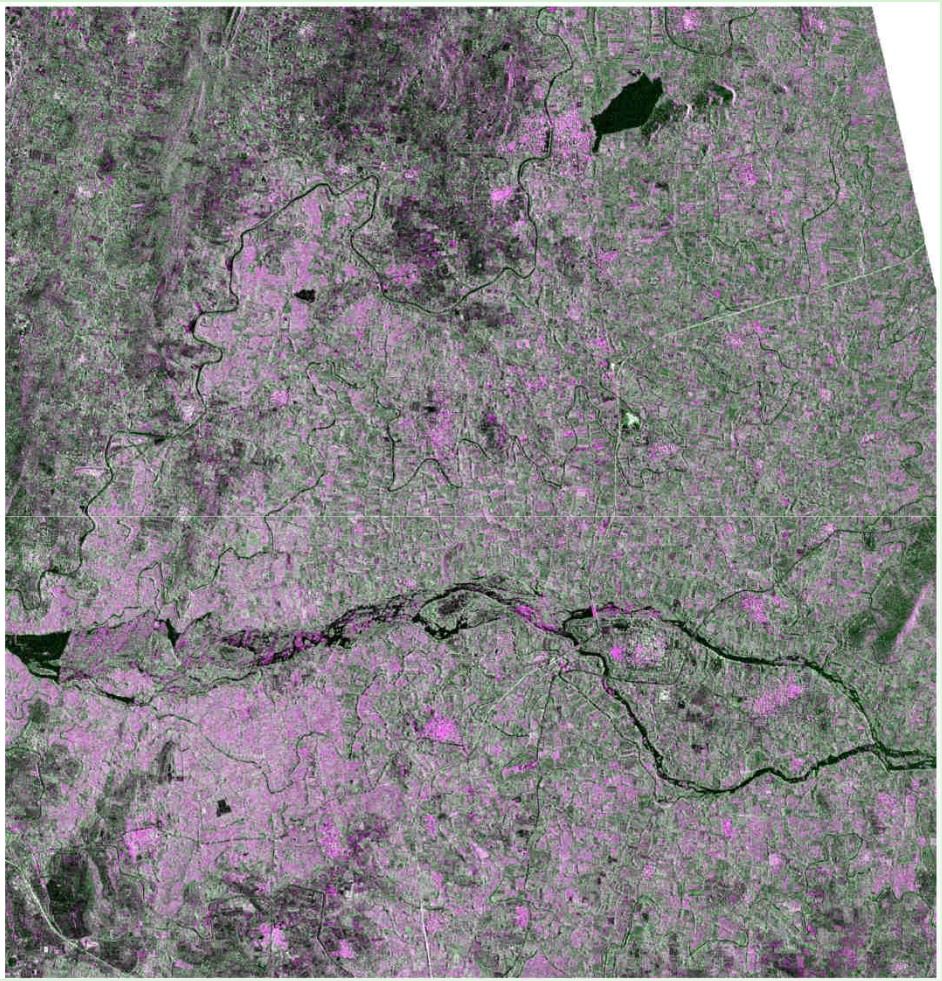
## Hybrid Polarimetric data



Rice Crop during heading stage (near maturity) clearly demarcated

Cauvery River (KRS Dam left side)

## Linear Polarimetric data



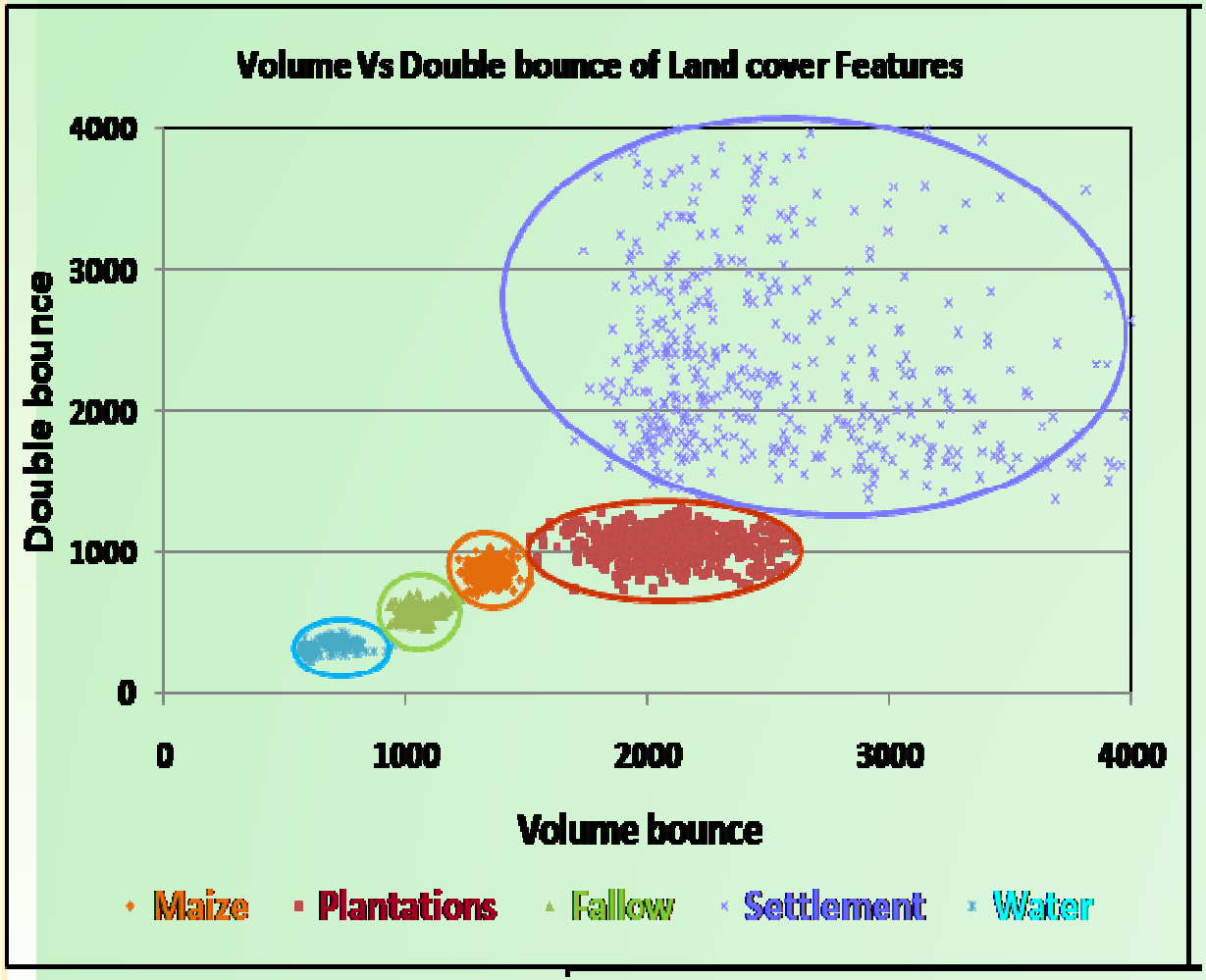
Red : HH; Green: HV; Blue: HH

Legend

- Water
- Trees
- Barren
- Fallow
- Rice
- Settlements
- Coconut
- Mixed Veget

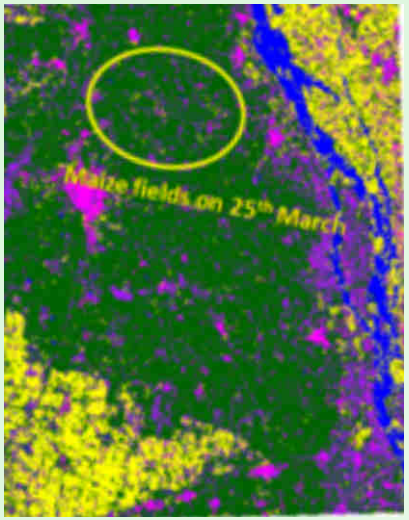
# Maize Discrimination: Single Date RISAT-1 Hybrid Data

Single date RISAT-1 FRS1 hybrid polari-metric RH, RV data for rabi maize (2014) discrimination and mapping




Decomposition image


Classified image

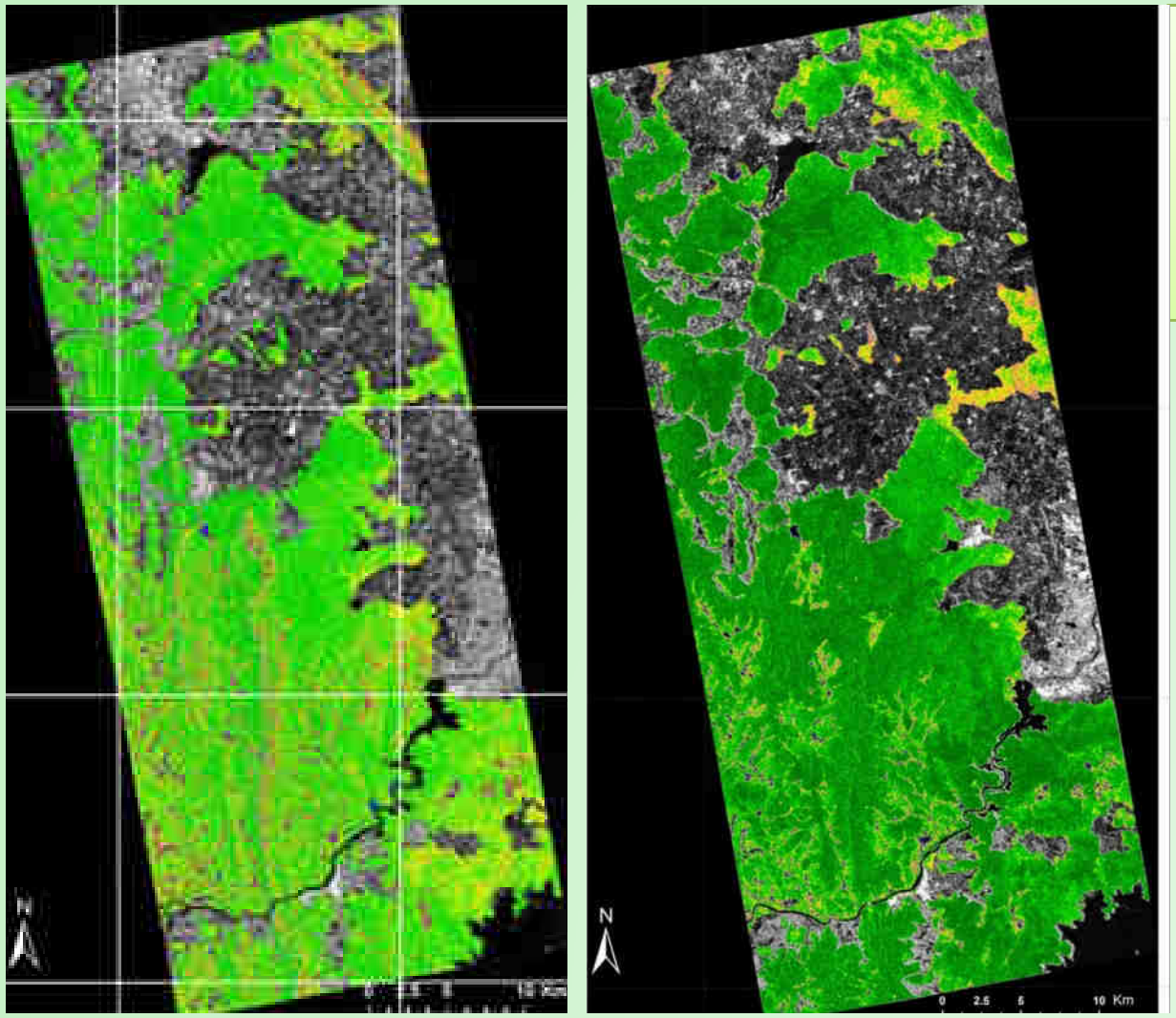



Maize

# Comparison of biomass estimated from C-band(RISAT-1) and L-band (ALOS-PALSAR-1)
## Area: Shimoga District, Karnataka, India

RISAT-1 FRS Data (HV-pol) - 2014

ALOS PALSAR-1 (25m HV-pol) -2010

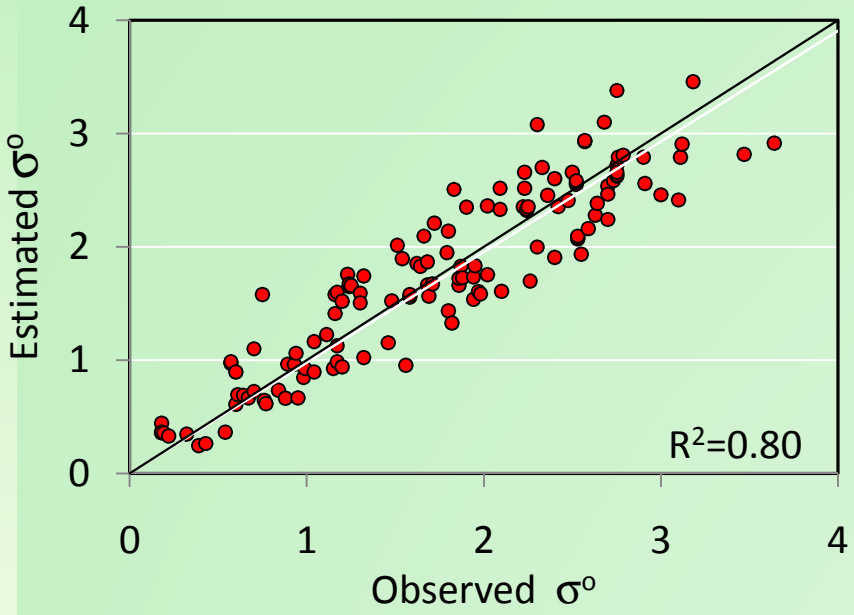



C-band SAR data (left image) shows biomass saturation at 80 t/ha and L-band SAR data (right image) shows saturation beyond 120 t/ha.

**Biomass (ton/ha)**

- No forest
- < 20
- 20 – 40
- 40 – 60
- 60 – 80
- 80 – 120
- > 120
- > Water body

# Soil Moisture: Value Added Product Generation using risat-1 SAR Data




## Soil Moisture Retrieval Model

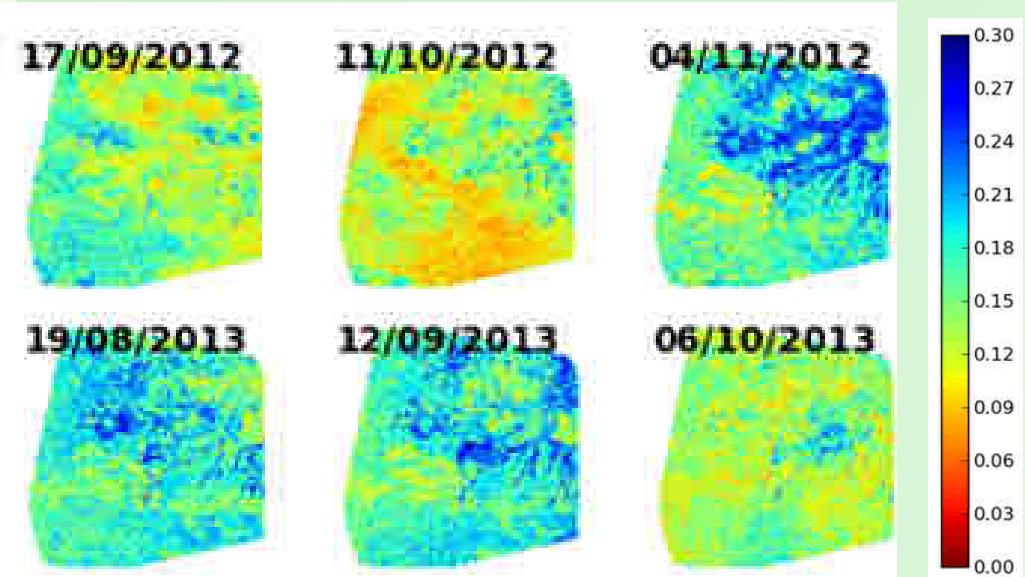
$$SSM = \theta_{wp} + (\theta_{fc} - \theta_{wp}) * F_{BC}(\sigma^{o})$$

SSM- Surface Soil moisture (SSM)

$\theta_{wp}$ - Soil Moisture (SM) at Wilting Point

$\theta_{fc}$ - Soil Moisture at field capacity

$\sigma^{o}$ – Backscattering Coefficient (BC)




Soil Moisture (%)

## SM estimation influenced by

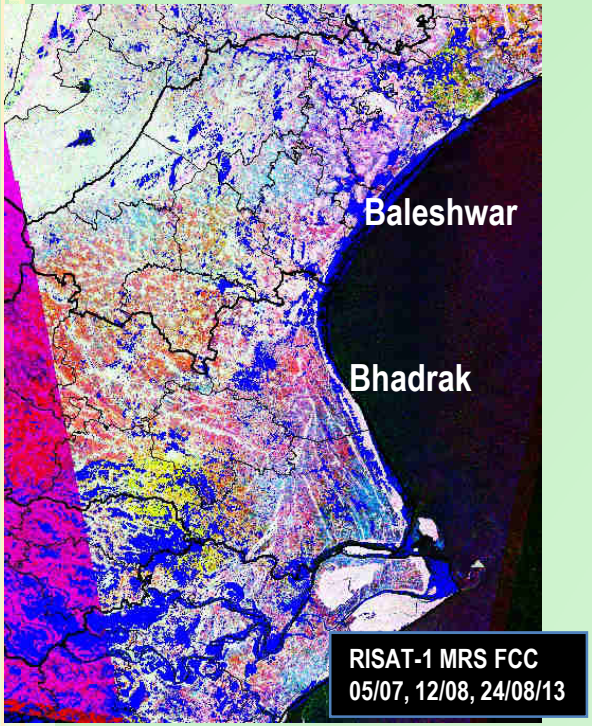
**Surface Parameters**

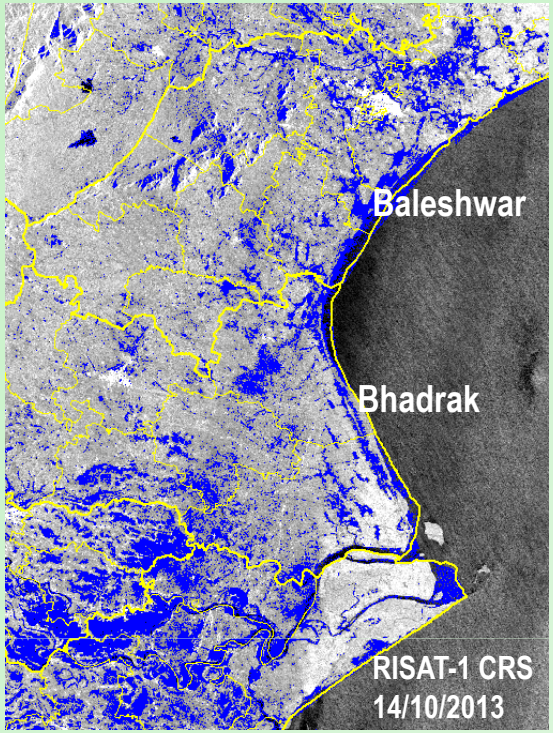
- Surface roughness
- Presence of vegetation

**System Parameters**

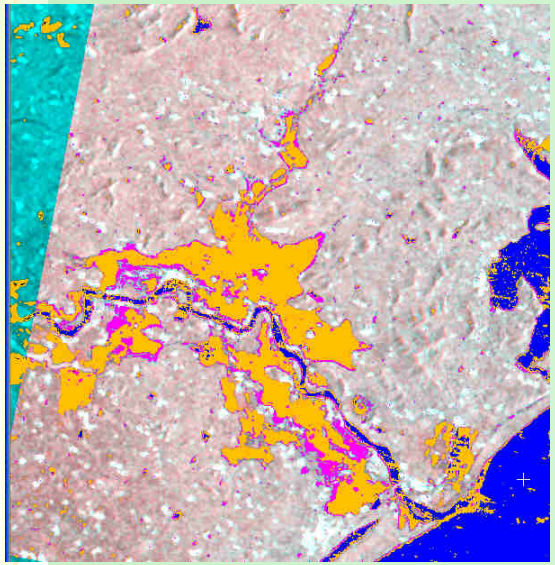
- Wavelength
- Polarization
- Incidence Angle

# Damage Assessment by floods due to Phailin Cyclone, 2013, Odisha




Flood affected area as on October 14, 2013 (Superimposed on pre cyclone (L) and post cyclone (R) images)

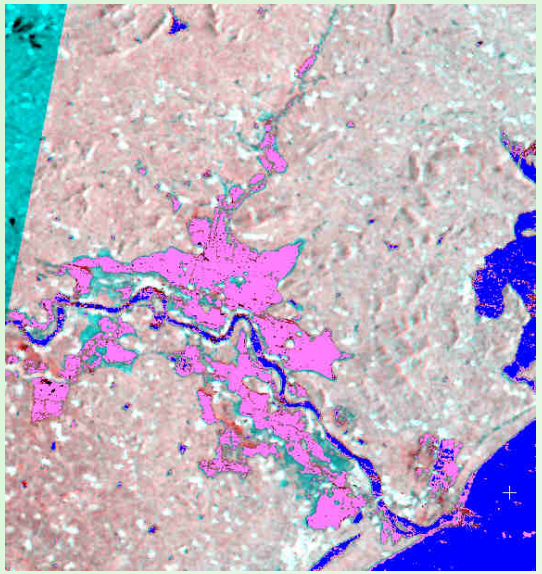


Area flooded on 14 & 25 Oct, 2013

Flood Oct 14, 2013

Additional area (25 Oct)

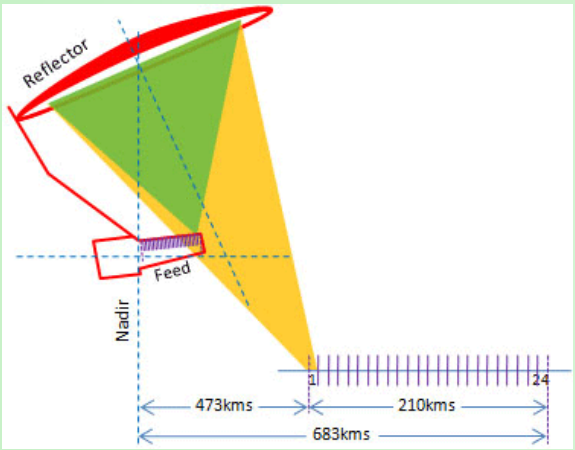
Permanent water body



# NASA-ISRO SYNTHETIC APERTURE RADAR (NISAR)

- **Design & Development of Dual frequency (L & S Band) Radar Imaging Satellite jointly by ISRO & NASA;**
- **Explore newer application areas using L and S band microwave data.**


| JPL, NASA | ISRO |
|---|---|
| • Development of L-Band SAR | • Development of S-Band SAR |
| • Payload structure & Thermal Control | • I-3K Spacecraft Bus |
| • Unfurlable Antenna | • Ka Band Data Transmission System |
| • Very high precision GPS | • Launch using GSLV |
| • 12 TB Recorder | • Spacecraft Operations |

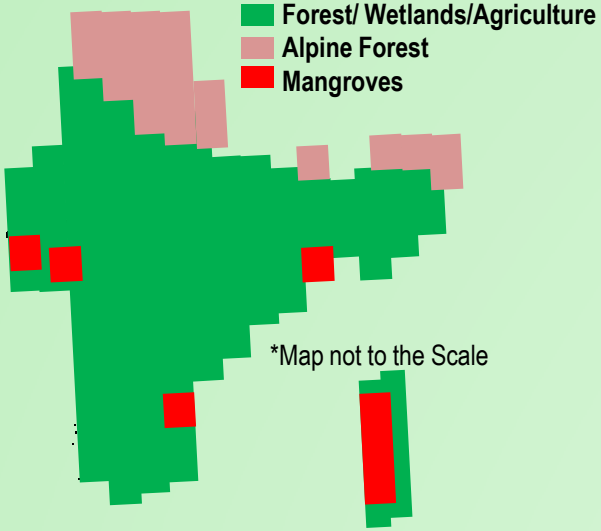



## MAJOR APPLICATIONS

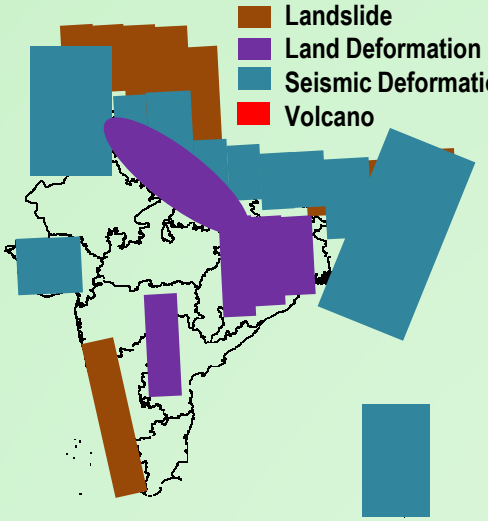
- Agriculture Biomass and Forest Biomass estimation
- Soil Moisture
- Mountain / glacier snow; Mountain Glacier dynamics
- Land Subsidence & Landslide
- Coastal erosion & High tide lines
- Floods, Oil slick, Forest fires
- Inter seismic strain; Co-seismic deformation
- Ice sheet dynamics; Sea Ice thickness & dynamics

# NISAR: Overall Science Plan

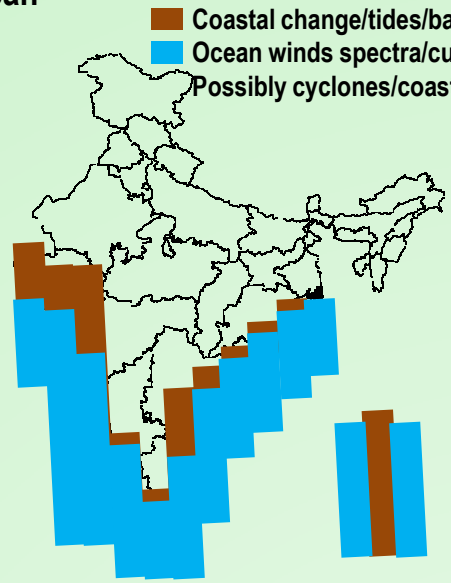
## Ecosystem



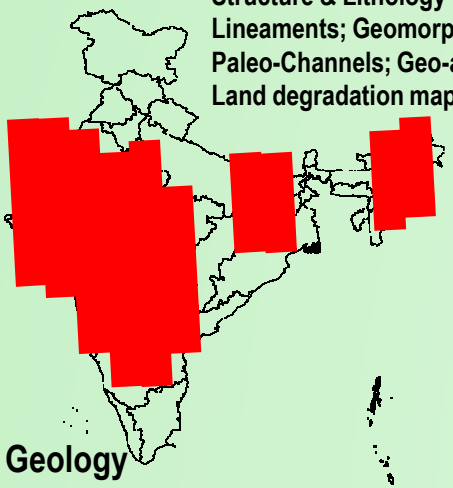

## Deformation



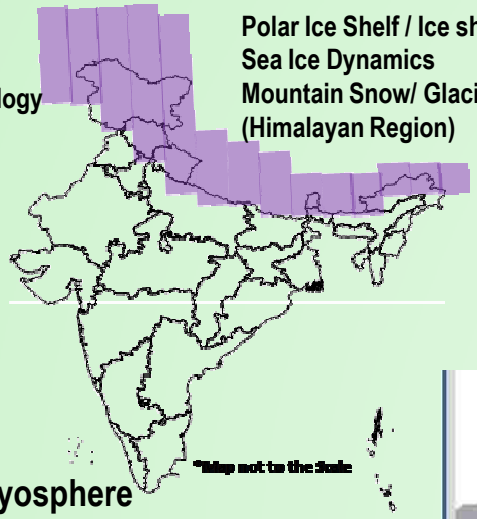

## Ocean




## Geology

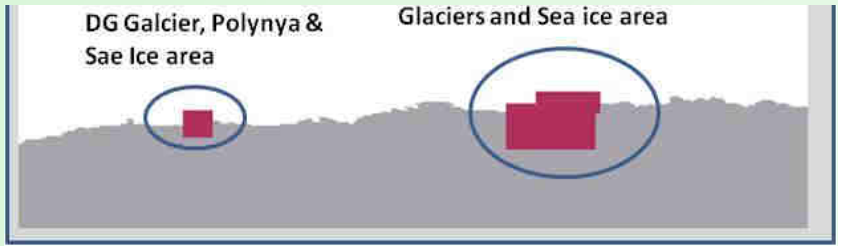



## Cryosphere




## Disaster Response and Mitigation:

**Floods; Forest Fire; Oil Spill; Earthquakes; Glacier hazards; marine navigation**



# Research Focus In Agriculture & Way Forward

- Crop-wise/Field-wise impact and yield loss assessment
- Crop conditions Assessment and forecasting tools Development
  - Pest & Disease Surveillance - Crops and Animals
  - Crop loss assessment due to extreme weather events
  - Value added improved agro-advisories
- Yield loss projection to compensation
- Enhancing irrigation & water use in irrigation commands
- Improving productivity in rainfed areas
- Building disaster resilience & enhancing coping mechanisms
- Further R&D efforts: Hyperspectral, Thermal, Microwave, etc.
- Capacity Building

- Availability of databases for more than 4 decades
- Databases include satellite data, derived geophysical products, ground data, information for climate change research
- Strong mechanisms for data archival and disseminations through web portal
- Improved science inputs & innovative means (modeling & algorithms, data assimilation……) - Collaboration with academic Institutions

इसरो ISRO

# *Thank You*