Earth observations and Agricultural monitoring: 

Indian experience

K. R. Manjunath
Space Applications Centre, ISRO
Ahmedabad, India
Email: krmanjunath@sac.isro.gov.in

“Food Security, Earth Observations and Agricultural Monitoring” November 21, 2013- Brussels
Indian Space Programme: Vision & Initiatives

‘We must be second to none in the applications of advanced technologies to the real problems of man and society’

Space Infrastructure
- Launch vehicles (PSLV, GSLV)
- Spacecrafts (Communication-11, RS-)
- Sensors and Transponders

Applications – Remote Sensing
- Agriculture
- Water Resources
- Watershed development
- Drinking water
- Drought assessment, monitoring & proofing
- Flood/cyclone monitoring
- Fuel wood/fodder assessment
- Land Information Systems
- Wasteland mapping & monitoring
- Groundwater prospecting
- Potential Fishing Zone
- Rural roads connectivity

Applications - Communications
- Education/Awareness
- Healthcare/Hygiene
- Training/Skill development
- Info Dissemination
- Strengthening Panchayat Raj
- Rural Empowerment

Institutionalization
- National Natural Resources Management System
- Involvement of stake-holders from the planning level
- Antrix & NDC

...the focus is on needs and opportunities
Institutional Framework

Department of Space (Nodal Agency)

PC – NNRMS
Chair: Member (Science), Planning Commission

Secretaries of Ministries, Govt. of India

State Governments
State Remote Sensing Application Centers

Academia, R&D Institutions

Industry NGOs

State Departments

Govt. of India Ministries

Thematic Standing Committees
Chair: Secretary of the respective Ministry of Government of India

Implementation

Academia
National Institutes

1) Agriculture & Soils
2) Bio-resources & Environment
3) Cartography & Mapping
4) Geology & Mineral Resources
5) Ocean Resources & Meteorology
6) Rural Development
7) Urban Management
8) Water Resources
9) Training & Technology

……..Bringing the technology to the end-user
Earth Observation Capabilities
........towards enabling solutions

**Earth Observation Capabilities**

**(Land Observations)**
- **(High Spatial Resolution & Stereo)**
  - IRS-1A/1B/P2 (1988,1991,1994)
    - LISS-I: 72.5m, 4XS
    - LISS-II: 36.5m, 4XS
  - IRS-1C/1D (1995,1997)
    - LISS-3: 23/70 m, Steerable
    - PAN: 5.8 m, WiFS: 188 m

**Earth Observation Capabilities**

**(Multi resolution, Frequent observations, Better radiometry)**
- Resourcesat-1/2 (2003, 2011)
  - LISS-3: 23 m, 4 XS,
  - LISS-4: 5.8 m, 3-XS,
  - AWiFS: 56 m, 4-XS

**Earth Observation Capabilities**

**(High Repetitivity/Revisit , High Spatial Resolution)**
- IRS-P3 (1996)
  - WIFS, MOS, X-Ray
- Oceansat –1 & 2(1999, 09)
  - OCM, MSMR, SCAT, ROSA

**Earth Observation Capabilities**

**(Ocean Observations)**
- IRS-1A/1B/P2 (1988,1991,1994)
  - LISS-I: 72.5m, 4XS
  - LISS-II: 36.5m, 4XS

**Earth Observation Capabilities**

**(Atmospheric Observations)**
- INSAT
  - VHRR (2.0 km Vis, 8 km IR WV)
  - CCD (1 km MS)

**Earth Observation Capabilities**

**Recent**
- **INSAT-3D:** (6 Channel Imager & 19 Channel Sounder)
- **Radar Imaging Satellite – RISAT – 1** (C-band SAR; 3-50m resolution; 10-240 km SWATH)
- **SARAL** (Satellite with Argos and Altimeter) (Ka-band altimeter; DORIS, Laser Retro-reflector Array)
- **Megha Tropiques** (MADRAS, SCARAB & SAPHIR)

**Earth Observation Capabilities**

**Hyperspectral**
- IMS-1 (2008)
  - HySI (64 bands, 506 m)
  - TWSAT-MX (4 bands, 37 m)
Indian Agriculture: Resources and Constraints

**Resources**
- India is home to 23.3% of the world’s farming population
- 2nd in world's wheat and rice production, first in pulses production
- 51.8% of India’s population is involved in agriculture
- Agriculture provides about 57% of India’s total employment and 73% of rural employment
- Net sown area: 142 Mha
- Total food grain production is around 220 Mt
- Agri. GDP is about 18.3%

**Constraints**
- Low crop productivity
- Highly degraded land (~57%)
- High erosion
- Average operational holding 1.32 ha
- Low cropping intensity (135.3%)
- Indian agriculture is highly dependent on monsoon (NIA/NSA is 38.8%)
- Low fertilizer consumption

BROAD ISSUES: Poverty Alleviation, Food Security, Ecological Crisis, Emerging Global Environmental Change

GOALS: Within Existing Land Holdings & Other Constraints, the Goals are:
- To increase crop yield, To diversify/intensify agriculture
- To reduce cost of cultivation (by optimizing agricultural inputs)
- To reduce the environmental impact
- To enrich the agricultural enterprise – in terms of information, science

Remote Sensing Applications in Agriculture

- Agro-climatic Monitoring
- Crop Area Estimation & Production Forecast
- Crop Area Estimation & Monitoring
- Pest/Disease Detection / Incidence Forecasting
- Inland fishery Development
- Agricultural Land Monitoring
- Agricultural Drought Assessment & Monitoring
- Horticultural Crop Area Estimation & Monitoring
- Soil and Problem Soil Mapping & Monitoring
- Command Area/Water Resources Monitoring
- Cropping Systems Analysis
- Global : crop programme
Information Need in Agriculture and Sources
(Crops, Horticulture, Fisheries, Agriculture, Dairy)

Information Need: Forecast, actual area sown, stage, production, condition, anomaly,

<table>
<thead>
<tr>
<th>Weather Forecast</th>
<th>Initial Moisture</th>
<th>Actual Rainfall</th>
<th>Weather</th>
<th>Crop Vigour</th>
<th>Weather</th>
<th>Pest diseases</th>
<th>Infrastructure, Price</th>
<th>Residual Moisture</th>
</tr>
</thead>
</table>

Source: SAR, Optical, Sounders, Field, expert knowledge

$krm$
Remote Sensing based Crop Monitoring in India

- The methodology has evolved over past 25 years.
- Remote sensing, field observations, meteorological and ancillary data are used.
- Major crops (wet season rice, dry season rice and other crops such as Jute, wheat, mustard, potato) are covered.
- Other crops are at various stages of operationalisation.
- Multiple in-season assessments are being made.
- User agencies have their own institute with complete infrastructure for RS data based crop monitoring.

**FASAL Concept:** The diagram above illustrates the various sources of data, timing of input and analysis, interlinkages and preharvest estimate time in relation to crop stage.
Rice and Jute Crop Assessment using SAR Data

Three date SAR data is used for assessing Jute and Rice.

The non-agricultural area is masked and rice crop proportion is used as basis for stratification. Stratified random sampling approach with 5 X 5 km grid with 15% sample size is used.

Groundtruth during the cropping season is carried out.

Hierarchical classification is used for extracting rice pixels based on backscattering pattern.

This covers 90% of the area and three estimates are given.

The yield models are based on agrometeorological models.

Three estimates are given during cropping season.
FOCUS

FASAL- operational -multi-forecast

- Rice (Kharif & Rabi)
- Jute
- Wheat
- Rapeseed / Mustard
- Winter potato

In the developmental stage-II

- Sugarcane- AWiFS(K)
- Cotton- SAR/AWiFS(K)

In the developmental stage-I

- Sorghum (KR)
- Maize(K)
- Pearl Millet (K)
- Finger Millet (K)
- Groundnut- (KR)

Outputs

Sugarcane:
- Early area estimation of Sugarcane crop, two estimates (UP, Maharashtra, Gujarat, Karnataka).
- Current year first estimate for UP and Maharashtra is complete.

Cotton:
Identification using multidate SAR data, analysis is in progress

Inputs from State agencies:
Early inputs on location information on current seasons increase/decrease for groundtruth
• Satellite Data Based Inputs are used
• Use of Spectral indices in empirical Models
• Satellite Based Crop Parameters are derived
• Tested for wheat crop
Periodic soil moisture assessment and crop suitability

**Inputs:**
1. Soil Texture
2. Daily PET
3. Crop Coefficient
4. Agricultural/Crop Maps
5. Crop Calendars
6. Daily Gridded Rainfall
7. Daily Gridded Irrigation Data

**Outputs (at 1: 5 M scale map eqv.)**
(Daily/Weekly/Monthly/Any):
1. Daily Available Soil Moisture
   Various Indices: ASM, Moisture Avail. Index, Aridity Index
2. Drought Status
3. Crop Sowing Suitability
4. Crop Growth Suitability
5. Progressive Crop Acreage
6. Irrigation Requirement
7. Flood Risk Assessment

**Usage**
District and State wise:
(Daily/Weekly/Monthly/Any):
1. Crop Sowing Suitability
2. Crop Growth Suitability
3. Progressive Crop Acreage
4. Irrigation Requirement
5. Drought Status

**Inputs/States**
- Ground Validation of output
- Updated Crop Calendars (district wise)

Kharif Rice Area: 39.1 Mha (Projected)
Drought Assessment

- NADAM - Operational drought assessment is being made by MNCFC.

- Agricultural drought vulnerability Analysis with time series NDVI.

- Agricultural Drought Vulnerability is referred as exposure, sensitivity and adaptability of agricultural area to the reduced soil moisture availability.

- 1173 blocks in 185 districts of 13 states – 120 M ha as drought prone.

Usage/Application
- Sub-district level planning for drought.
- Preparing contingency plan.
- Longterm strategies

Time series NDVI derived metrics
System Studies: Cropping Pattern and Crop Rotation

Cropping Pattern and Crop Rotation

Before June 15 | June 15 to July 15 | July 15 to Aug. 15
--- | --- | ---
Potato | Mustard | Wheat
March 31 | April 30
Rice-Fallow-Fallow | Rice-Fallow-Jute | Rice-Fallow-Rice
Rice-Wheat-Fallow | Fallow-Pulse | Fallow-Wheat
Rice-Mustard-Fallow | Minor Crop Rotations
Rice-gram-Fallow | Fallow
Rice-Fallow-Rice | Non-Arable
Jute | Rice
Others

Crop Rotation Map of West Bengal (derived using remote sensing data)

Cropping intensity (%) WB

<table>
<thead>
<tr>
<th>Type</th>
<th>1998-99</th>
<th>2004-05</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Cropped</td>
<td>55.4</td>
<td>49.6</td>
</tr>
<tr>
<td>Double Cropped</td>
<td>42.1</td>
<td>37.6</td>
</tr>
<tr>
<td>Triple cropped</td>
<td>2.5</td>
<td>12.8</td>
</tr>
</tbody>
</table>
Crop Intensification and Diversification

Inputs – Intensification in West Bengal

15 Classes
- Deep > 5m.
- Shallow < 5m.
- Fine
- Loamy
- Sandy
- Acidic > 6.5
- Neutral 6.5 to 7.5
- Alkaline < 7.5
- < 1500 mm.
- 1500 to 2000
- > 2000

Geomorphology
- Ground water
- Particle Size
- Soil pH
- Rainfall
- Fallow Map

Physiography
- Problem soils
- Rainfall
- Soil texture

Equi-potential zones
- 1
- 2
- 3
- 4
- 5
- 6
- 7
- 8
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16

Crop Intensification and Diversification

Rabi Diversity
- 1988-89
- 1998-99

Alternate cropping pattern

Wheat
- Other crop
- Non-Agrl.
- Cloud

13
HORTICULTURAL APPLICATIONS

- National database of creation of major horticulture crops
- Seasonal and early trends of major crops
- Inventory, characteristics and monitoring of orchards/plantations
- Site suitability and integrated plan for development of commercial horticulture
- Monitoring of peri-urban horticulture crops
- Post-harvest infrastructure information
- Hot-spot monitoring
- Crop/Spectral library

Grape Orchard distribution in Niphad Taluq (Nashik)
Early assessment of annual horticulture crops:

Winter potato area estimation

Onion crop area estimation was initiated at NHRDF, Nashik

Talaja, Bhavnagar district

Garlic

Wheat

Maize

Bajra

Onion

Cotton

Vegetables
Impact of Agriculture: Perspective View of Methane Emission

<table>
<thead>
<tr>
<th>Emission (Tg)</th>
<th>1.797</th>
<th>3.386</th>
<th>5.216</th>
</tr>
</thead>
</table>

SIF: $74.05 \pm 43.28 \text{ kg/ha/season (n=471)}$

Temporal Emission Pattern

Methane Emission (kg/ha/yr)
- <25
- 25 – 50
- 51 – 75
- 76 – 100
- 101 – 125
- 126 – 150
- 151 – 200
- 201 – 300
- > 300

Temporal Emission Pattern
• All-India Total NPK consumption: 16.8 Mt, ~ 90 kg ha\(^{-1}\)
• ‘vulnerable districts’ of NPS pollution - intensive agriculture areas in North (Punjab), coastal areas in the East (AP, WB), and peri-urban area (Bangalore)
Kharif rice: Bangladesh using C band SAR data

<table>
<thead>
<tr>
<th>Continent</th>
<th>Mean</th>
<th>Median</th>
<th>Field samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Africa</td>
<td>1.04</td>
<td>0.97</td>
<td>1361</td>
</tr>
<tr>
<td>Asia</td>
<td>1.30</td>
<td>1.12</td>
<td>2186</td>
</tr>
<tr>
<td>Europe</td>
<td>8.15</td>
<td>10.78</td>
<td>786</td>
</tr>
<tr>
<td>N America</td>
<td>25.31</td>
<td>27.99</td>
<td>295</td>
</tr>
<tr>
<td>S America</td>
<td>35.19</td>
<td>29.03</td>
<td>1705</td>
</tr>
<tr>
<td>Australia</td>
<td>55.82</td>
<td>55.82</td>
<td>847</td>
</tr>
</tbody>
</table>
Rice Cultural Types of South and Southeast Asia

The south Asia (7): 43.7% of rice area, Bangladesh, Nepal, India, Pakistan, Sri Lanka.
The Southeast Asia (11): 30.4% of rice area, (Philippines, Indonesia, Malaysia, Vietnam, Burma, Laos, Cambodia, Thailand)

Major Objectives:
• Derivation of Rice cultural type maps.
• Quantification of Methane emission from Rice ecosystems

Future Plan:
Methane spatial maps generation and documentation
Watershed Development

- Inventory of surface water bodies (tanks, reservoirs), Performance evaluation of irrigation commands, Ground water prospecting/recharge structures, Glacier inventory, retreat

Improve productive potential of degraded watersheds and poverty alleviation

Constraints and Problems of Study Area

- Low, uncertain & uneven Rainfall
- Recurring occurrence of drought
- Considerable area under wastelands
- Migration for employment
- Degraded Lands - Erosion, overgrazing
- Lack of infrastructure and facilities

Implementation Funding M & E
Watershed Dept., Gov NGO Gov, NGO
• Wetland (of > 2.25 ha in size) map of entire country has been generated at 1:50,000 scale using IRS Satellite data.

• Total wetland area estimated is 15.260 Mha (4.63 % of the geo. Area).

• Total 201503 wetlands. Small wetlands – 5,55,557 (<2.25 ha).

• Data is available in all categories.

Application

Useful to plan seasonal water needs of crops, crop planning for subsequent seasons.

Useful for inland fisheries as part of Integrated Farming Systems management.
Disaster Monitoring and Mitigation

Floods
- 40 M ha flooding
- 4.2 crore people in 2002

Landslides
- Sub-Himalayan/ Western Ghats
- 8% of TGA 5000 people in 2002

Cyclones
- 5700 km long coastline
- 15,000 people in 2002

Earthquakes
- 55% of area in Seismic Zone III-IV
- 40,000 people in 2001

Drought
- 68% net sown area in 116 dist.
- 30 crore people in 2002

Forest Fires
- ≈65% of total forests under potential threat of ground fire

Flood affected area as on 14/10/13 (Superimposed on image)

Odisha, October 2013
Agricultural applications from Suite of INSAT satellites

Advantages: High temporal frequency, quicker, regular, country-scale monitoring

Current Agro-met products: NDVI, rainfall, NDVI, LST

Target applications: Sowing dates, Crop progress, Drought, Yield prediction
Agro-advisory service, Agricultural water management
Conclusions

- India has suite of sensors/satellites in different resolutions for addressing different aspects of agriculture.
- The launch of RISAT data has added another dimension to address the EO application.
- Applications have been demonstrated in many fields.
- India has EO capabilities to address various aspects of agriculture.
- In-situ observations in support of data’
- Portals and outreach.
- Advisories by NGOs/kiosks support through institutions
Thank you

Acknowledgements

• European Commission
• Ms. Barbara J. Ryan, Secretariat Director, GEO
• GEOGLAM Team

• Mr. A.S. Kiran Kumar, Director, SAC, ISRO
• Dr. J.S. Parihar, Dy. Director, SAC
• My Colleagues at SAC, ISRO
Water Resources

- Inventory of surface water bodies (tanks, reservoirs)
- Performance evaluation of irrigation commands
- Ground water prospecting/recharge structures
- Glacier inventory, retreat
- Snowmelt run-off, snow physics
Financial Sector

Data Portal to satisfy vast Meteorological & Oceanographic data needs, products from ISRO science missions.

24, 48 & 72 hrs forecast of temperature, humidity, rain, cloudiness, wind speed and wind direction, at each of the locations (blue dots) on the map is available on MOSDAC

<table>
<thead>
<tr>
<th>District Name</th>
<th>Met-subdivision</th>
<th>Rain (mm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sabarkantha</td>
<td>GUJARAT-REGION</td>
<td>8.26</td>
</tr>
<tr>
<td>Mehsana</td>
<td>GUJARAT-REGION</td>
<td>10.91</td>
</tr>
<tr>
<td>GAandhinagar</td>
<td>GUJARAT-REGION</td>
<td>31.32</td>
</tr>
<tr>
<td>Kheda</td>
<td>GUJARAT-REGION</td>
<td>17.97</td>
</tr>
</tbody>
</table>