Food and Agriculture Organization of the United Nations

ADB

CROP MONITORING FOR IMPROVED FOOD SECURITY

Proceedings of the Expert Meeting

Vientiane, Lao People's Democratic Republic

17 February 2014

Use of remote sensing in crop forecasting and assessment of impact of natural disasters: operational approaches in India

Shibendu Shankar Ray[1], Mamatha Neetu, S. and Sanjeev Gupta
[1] Director
Mahalanobis National Crop Forecast Centre, Department of Agriculture & Cooperation, Ministry of Agriculture, India
Pusa Campus, New Delhi -110 012, India
E-mail: [1] shibendu.ncfc@nic.in

Key words: FASAL, NADAMS, Crop Forecasting, Drought Assessment, Remote Sensing

ABSTRACT

Use of remote sensing data for pre-harvest crop production forecast has been operationalized in India under a national-level programme called Forecasting Agricultural output using Space, Agro-meteorology and Land-based observations (FASAL). The FASAL programme, funded by the Ministry of Agriculture, envisages multiple production forecasts of major crops of the country at National/State/District levels. Similarly, under the National Agricultural Drought Assessment and Monitoring System (NADAMS) project, remote sensing data from multiple sources are integrated with ground and meteorological information for district/sub-district level drought assessment for 13 states of India. The methodology for both of these programmes was developed by the Indian Space Research Organization and later on transferred to a centre (Mahalanobis National Crop Forecast Centre) specifically created under the Ministry of Agriculture to operationalize space technology applications in agriculture.

1. Introduction

In India, agriculture is one of the major application areas of remote sensing technology. Various-national level agricultural applications have been developed which showcases the use of remote sensing data provided by the sensors/satellites launched by the country's space agency, Indian Space Research Organisation (ISRO). Some of these applications include crop acreage and production estimation, cropping system analysis, agricultural water management, drought assessment and monitoring, horticultural development, precision farming, soil resources mapping, potential fishing zone forecast, watershed development, climate impact on agriculture and so on (Navalgund and Ray 2000; Panigrahy and Ray 2006; Navalgund *et al.* 2007). A few of these applications, after reaching operational level, have been transferred to the user departments. This has resulted in the institutionalization of the remote sensing applications in the country (Parihar and Manjunath 2013). One recent example of operationalization/institutionalization of remote sensing application is the creation of a centre called Mahalanobis National Crop Forecast Centre (MNCFC) under the Department of Agriculture & Cooperation, Ministry of Agriculture. The centre operationalizes two major programmes developed by ISRO on crop forecasting and drought assessment apart from various other activities related to agricultural assessment. This article describes these operational approaches.

2. Crop forecasting

Crop forecasting is essential for various agricultural planning purposes, including pricing, export/import, contingency measures, etc. Crop forecasting using remote sensing data, in India, started in the late 1980s in the Space Applications Centre of ISRO under the Department of Agriculture and Cooperation's (DAC) sponsored project CAPE (Crop Acreage and Production Estimation). This later on developed into a national level programme, called FASAL (Forecasting Agriculture output using Space, Agro-meteorology and Land-based observations), which has been in operation since August, 2006. The FASAL project aims at providing multiple pre-harvest production forecasts of crops at National/State/District levels (Parihar and Oza 2006). Remote sensing data, both optical and microwave form the core of crop area enumeration, crop condition assessment and production forecasting. Crop yield is estimated using agro-meteorological/spectral yield models and also crop growth simulation models. The FASAL approach also involves using econometric models to forecast the area and production before the crop sowing operations. FASAL is a multi-institutional programme, which integrates the activity from many organizations. The list of such organizations is given in Table 1. MNCFC has started providing crop forecasts under the FASAL programme from the kharif (rainy) season of 2012.

Table 1. Organizations involved in FASAL programme and their responsibilities

S.N.	Name of the Organisation	Responsibility
1	Directorate of Economics & Statistics, Ministry of Agriculture	Overall Coordination
2	Mahalanobis National Crop Forecast Centre, Ministry of Agriculture	Operational Crop Assessment
3	Space Applications Centre, Indian Space Research Organisation	Techniques Development
4	India Meteorological Department	Crop Yield Forecasting
5	Institute of Economic Growth	Econometric Modelling for pre-season forecast
6	State Agricultural Departments	Ground truth collection
7	State Remote Sensing Application Centres	Support for Techniques Development Activities

Currently, under the FASAL project, national and state level multiple forecasts are being issued for 5 crops: rice (kharif and rabi), jute, rapeseed and mustard, winter potato and wheat. From 2013-2014 onwards, state and district level forecasts are generated for cotton, sugarcane and rabi (winter season) sorghum. While multi-date SAR (Synthetic Aperture Radar) data of Indian SAR satellite RISAT-1 is used for rice (kharif and rabi) (Figure 2) and jute, multi-date Resourcesat-2 AWiFS (Advanced Wide Field Sensor) data, with 56 m spatial resolution, are used for other crops. LISS III data, with 23.5 m resolution, is being used for district-level assessments. A stratified random sampling approach is followed for crop area estimation. All those states, which together contribute more than 90 percent of the particular crop's area in the country, are considered for area and production assessment. A hierarchical/logical classification approach is followed for classifying multi-date SAR data. A hybrid (combination of supervised and unsupervised) classification method is followed for multi-date optical data, while maximum likelihood (MXL) is followed for single date optical data. Indigenously-developed software, called FASALSoft (Manthira Moorthi *et al.* 2014) is used for carrying out the digital analysis of remote sensing data. The yield forecasts are generated under the FASAL programme by the India Meteorological Department, correlation weighted empirical agro-meteorological models. For rice and wheat crops the final yield forecasts are being given using physical models with inputs from remote sensing data (Chakraborty *et al.* 2005; Tripathy *et al.* 2013). The details of the crop forecasts given in 2013-2014 are presented in Table 2. Typically, in an agricultural year, 16 crop forecasts are generated. A comparison with the official estimates of the Ministry of Agriculture showed that the remote sensing-based area estimates at the national level are within -0.5 to -8.8 percent, while differences in production estimates ranged between -11.2 to 5.6 percent.

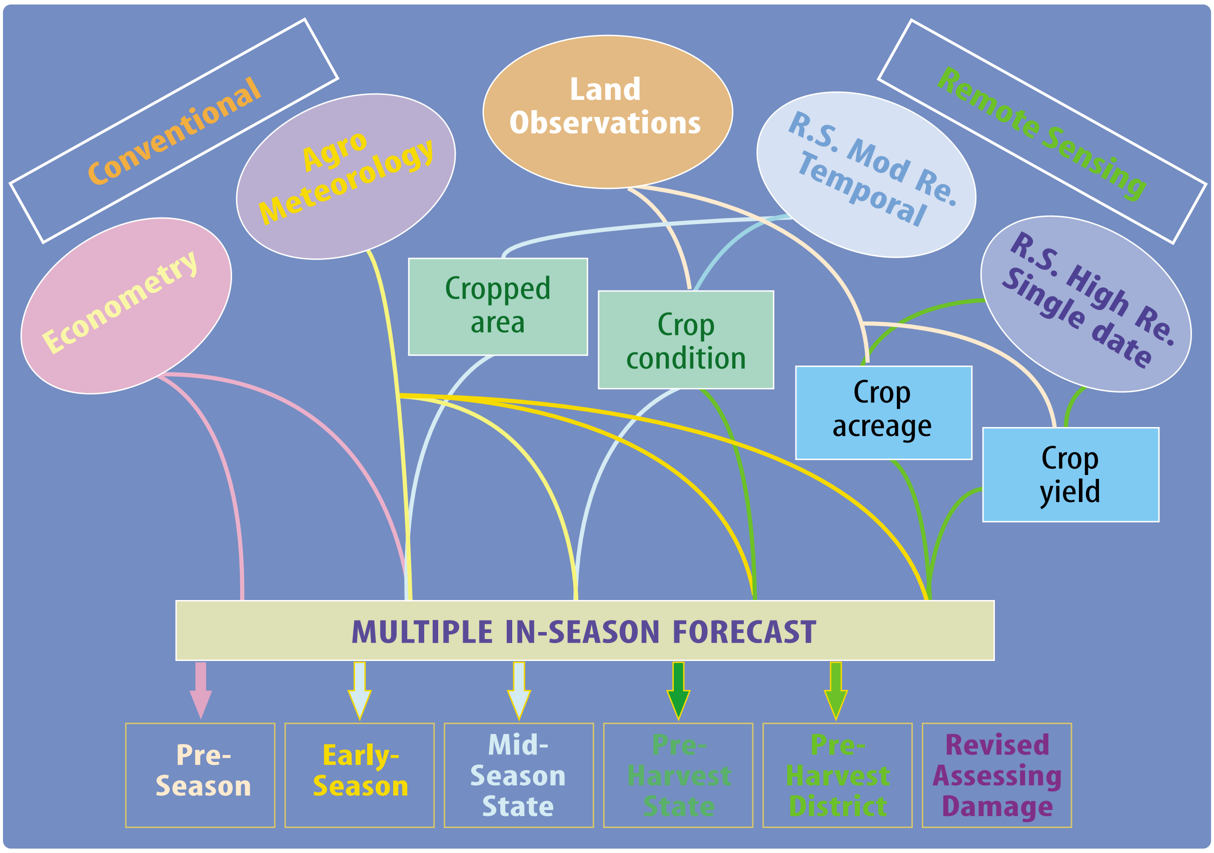


Figure 1. Approaches followed for multiple forecasts under FASAL programme (Source: SAC, ISRO)

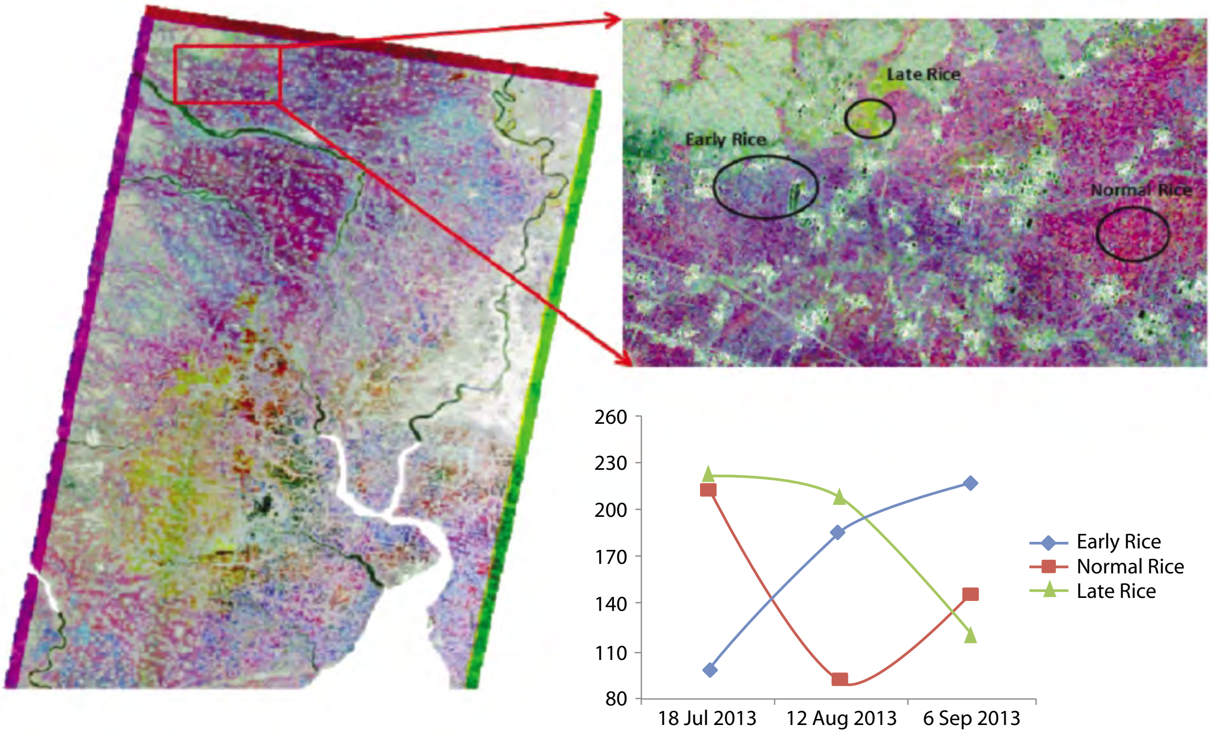


Figure 2. A typical 3-date RISAT-1 colour composite showing rice crop of different transplanting time

Table 2. Summary of crop forecasts generated under FASAL project during 2013-2014

Crop	No. of States	Forecasts	Dates of Forecasts	Satellite Data Used
Jute	3	F1	Jul. 24, 2013	RISAT-1 SAR
Rice (Kharif)	13	F1 F2 F3	Aug. 31, 2013 Sep. 30, 2013 Jan. 22, 2014	RISAT-1 SAR RISAT-1 SAR RISAT-1 SAR
Sugarcane	3	F1	Dec. 18, 2013	R2 LISS III
Cotton	7	F1	Dec. 18, 2013	R2 LISS III
Rapeseed & Mustard	5 5 6	F1 F2 F3	Dec. 31, 2013 Jan. 31, 2014 Feb. 28, 2014	R2AWiFS R2 AWiFS R2 LISS III
Winter Potato	4 5	F1 F2	Jan. 31, 2014 Mar. 04, 2014	R2 AWiFS R2 LISS III
Wheat	9	F1 F2 F3	Feb. 15, 2014 Mar. 11, 2014 Apr. 04, 2014	R2AWiFS R2 AWiFS R2 LISS III
Sorghum (Rabi)	2	F1	Feb. 15, 2014	R2 LISS III
Rabi Rice	4	F1	Apr. 04, 2014	RISAT-1 SAR

R2 – Resourcesat-2 satellite

2.1 Ground Truth collection using smart phone

Ground Truth (GT) is an essential component for remote sensing data analysis. Ground Truth includes collection of GPS readings, photographs, preparing a sketch of the field layout and filling up the GT form. Earlier, GT was being collected using a GPS, a camera and filling up a form. A recent initiative was made for smart phone-based GT collection. An Android-based application was developed by the National Remote Sensing Centre of ISRO (Figure 3a). State Agriculture Department officials collected GT using smart phones provided by MNCFC. The GT information directly comes to the Bhuvan server (ISRO's Geoportal), which can be downloaded and used real-time (Figure 3b). During the kharif and rabi season of 2013-2014 more than 5 800 GT points were collected from 16 states using the smart phones.

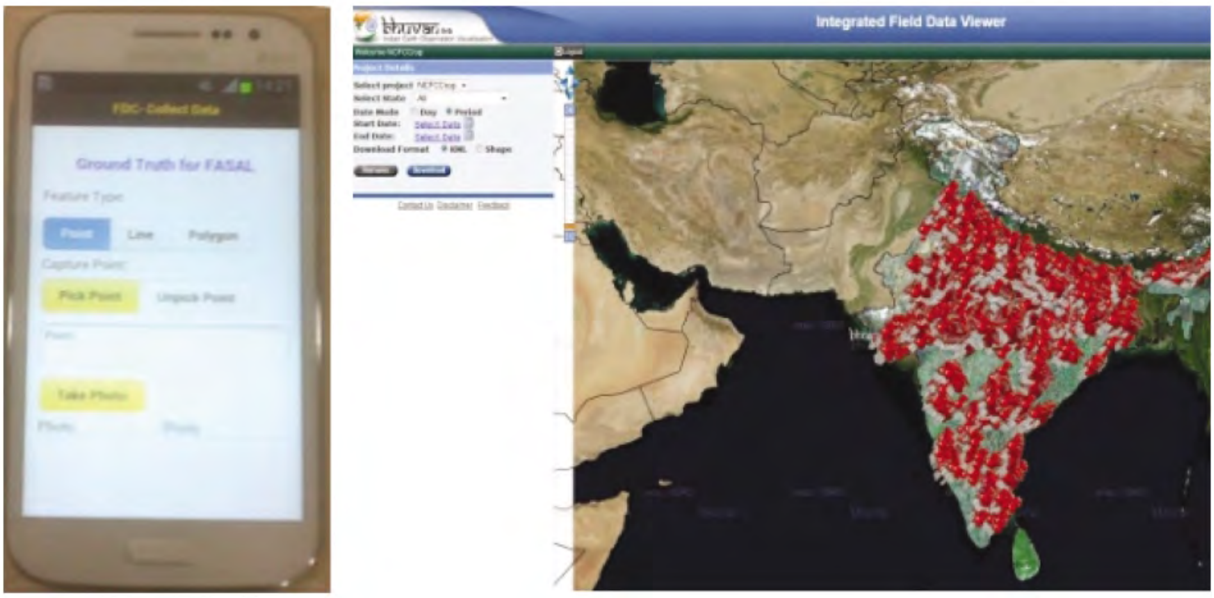
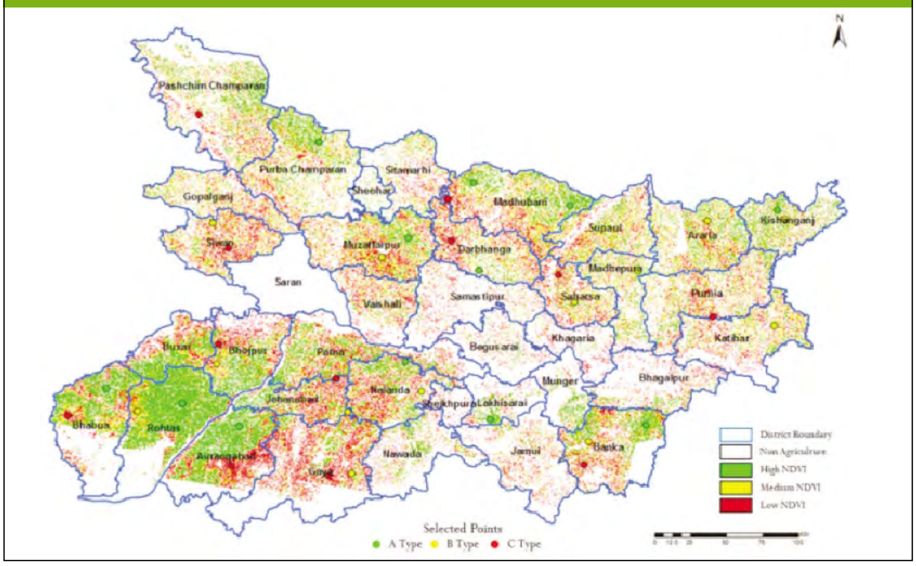


Figure 3. Real time ground truth collection using smart phone, a) Android app developed by NRSC, b) Ground Truth sites available on Bhuvan server

2.2 Remote sensing-based crop cutting experiments

Crop cutting experiments (CCE) are carried out for each crop to estimate crop yield at district and state levels. The conventional method CCE planning does not consider the current crop condition, which may result in errors in sampling. To overcome this, remote sensing-driven crop cutting experiments (CCE) planning was carried out in Bihar State for the rice crop during the kharif season of 2013. The work was carried out jointly with the Bihar Agriculture Department. A rice crop map was generated using RISAT-1 MRS data. Resourcesat-2 AWiFS time composite NDVI during September 2nd Fortnight to October 1st Fortnight was extracted for the rice area. Three classes (A, B, C) were defined based on frequency distribution of NDVI values. Thirty-seven points were randomly selected in 22 districts of Bihar (Figure 4a). A crop cutting experiment was carried out under the supervision of MNCFC. Yield models were developed between NDVI and yield and a yield map was generated (Figure 4b). The study showed a highly efficient stratified sampling plan generated for CCE based on NDVI values.

37 Crop Cutting Exeriment sites in Bihar State



Kharif Rice Yield Map of Bihar State (kg/ha)

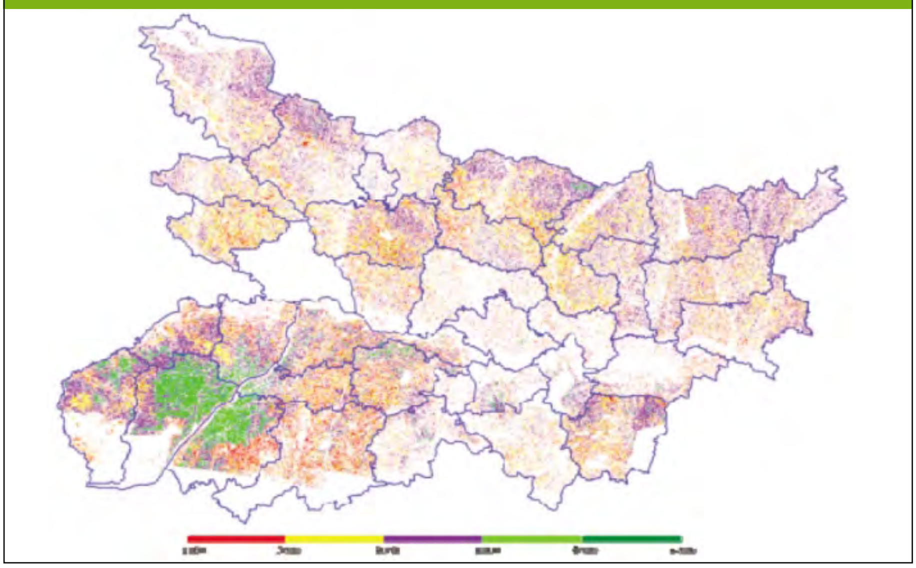


Figure 4. Use of remote sensing data for a) selecting sites for Crop Cutting Experiments for rice crop in Bihar and b) generating a yield map

2.3 Crop emergence progression

The NDVI (Normalized Difference Vegetation Index) product derived from the Indian geostationary satellite INSAT-3A-based CCD camera is extremely useful for vegetation monitoring, because of its high temporal frequency (half an hour) (Nigam *et al.* 2011). The spatial resolution of the data is 1 km. The 10-day NDVI product was used to monitor the rabi season crop emergence based on a methodology developed by the Space Applications Centre, ISRO (Vyas *et al.* 2011). Since satellite data sees the crop only after spectral emergence (i.e. the time when crops are big enough to start registering a spectral signature) this was called emergence area progression. The analysis was carried out for 6 states (Punjab, Haryana, Rajasthan, UP, MP and Bihar) at 10-day intervals during December 2013 to February 2014 (Figure 5).

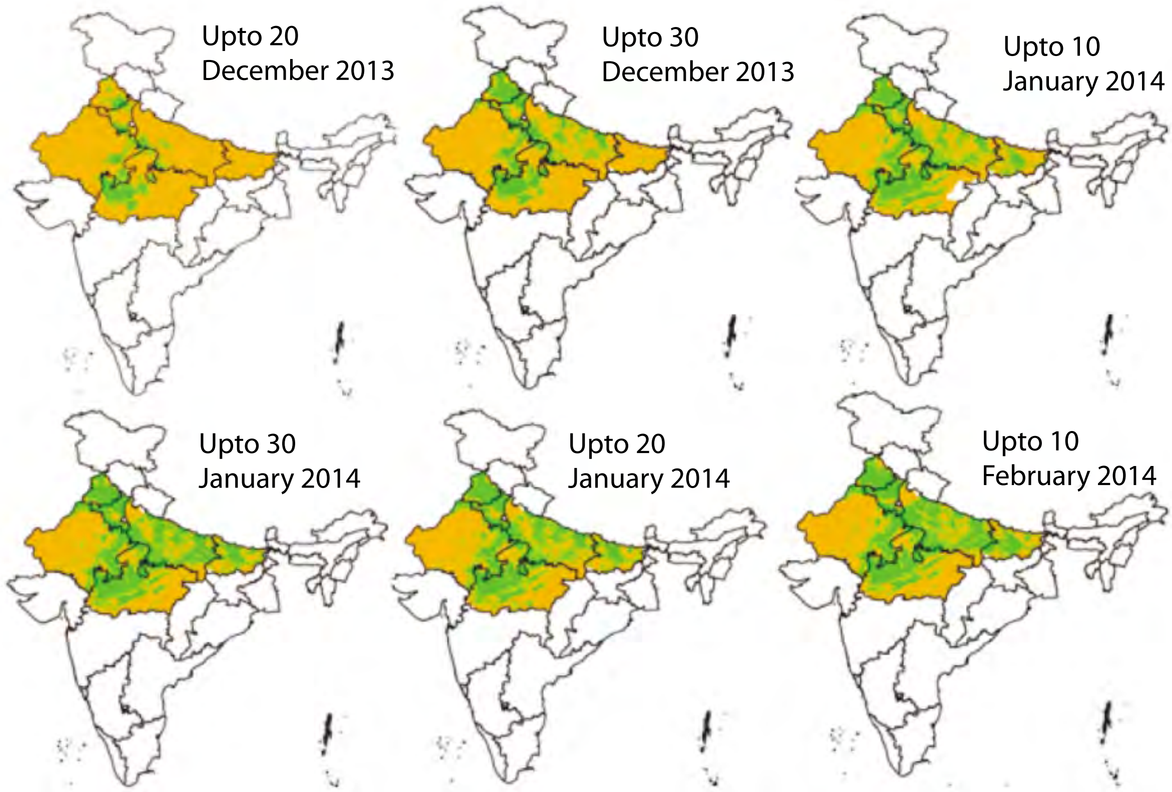


Figure 5. Map of Rabi season crop emergence area progression in 6 States of India

3. Drought and flood impact assessment on agriculture

Agriculture in India is strongly affected by two major hydro-meteorological disasters, namely droughts and floods. Droughts are a perennial feature. Sixteen percent of India's total area is drought-prone and approximately 50 million people are annually affected by droughts (DAC 2009). Over 68-70 percent of the total sown area in India is vulnerable to drought. Similarly, around 40 million hectares of land in India is prone to floods as per a National Flood Commission report.

Assessment of agricultural conditions during droughts or floods is essential for taking various relief and rehabilitation measures. Since both these disasters impact large areas, satellite-based monitoring is extremely useful.

3.1 Agricultural drought assessment

In India, operational agricultural drought assessments using remote sensing data is carried out under a major programme called the National Agricultural Drought Assessment and Monitoring System (NADAMS). The NADAMS project, developed by the National Remote Sensing Centre, provides near real-time information on prevalence, severity level and persistence of agricultural drought at state/district/sub-district levels (Murthy and Sesha Sai 2011). Currently, it covers 13 states of India (Andhra Pradesh, Bihar, Chhattisgart, Gujarat, Haryana, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, and Uttar Pradesh), which are predominantly agriculture-based and prone to drought situations. In four states (Andhra Pradesh, Karnataka, Haryana and Maharashtra), the assessment is carried out at sub-district level. The remote sensing data of NOAA AVHRR (for district level), MODIS and Resourcesat-2 Advanced Wide Field Sensor, AWiFS (for sub-district level) along with rainfall data are used for drought assessment (Choudhary *et al.* 2011). Various spectral indices, such as Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI) and Shortwave Angle Slope Index (SASI) are computed and integrated with the Soil Moisture Index and District Level Rainfall to assess the drought condition (Figure 6). Agricultural conditions are monitored at state/district levels using daily NOAA AVHRR/MODIS data. Fortnightly/monthly reports of drought conditions are provided to all the concerned central and state government agencies under NADAMS. MNCFC has started providing periodic Drought Assessment Reports from the kharif season of 2012 (Ray *et al.* 2014).

The district level drought assessment map for September 2013 is presented in Figure 7, which shows that in the 13 states, 11 districts were in moderate drought condition and 43 districts were in mild drought condition. Every month, similar maps are generated and circulated along with all satellite-derived products. Recently a drought geo-portal has been created (www.ncfc.gov.in), where users can access the images, maps, assessments and NDVI profiles.

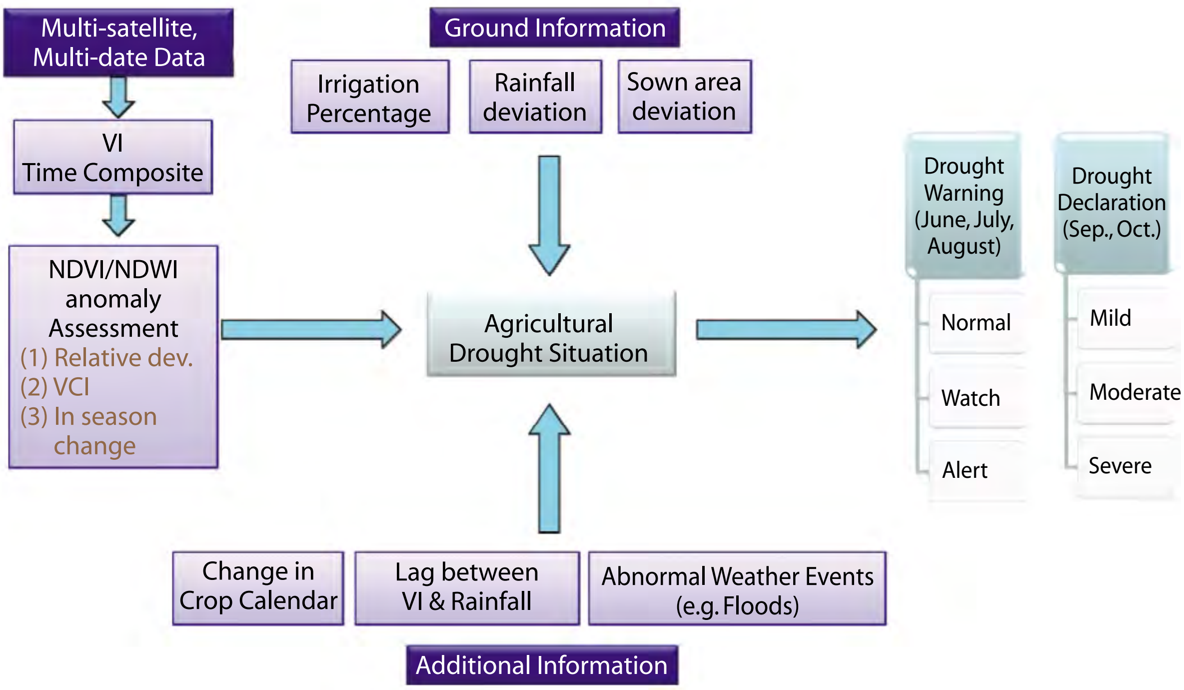
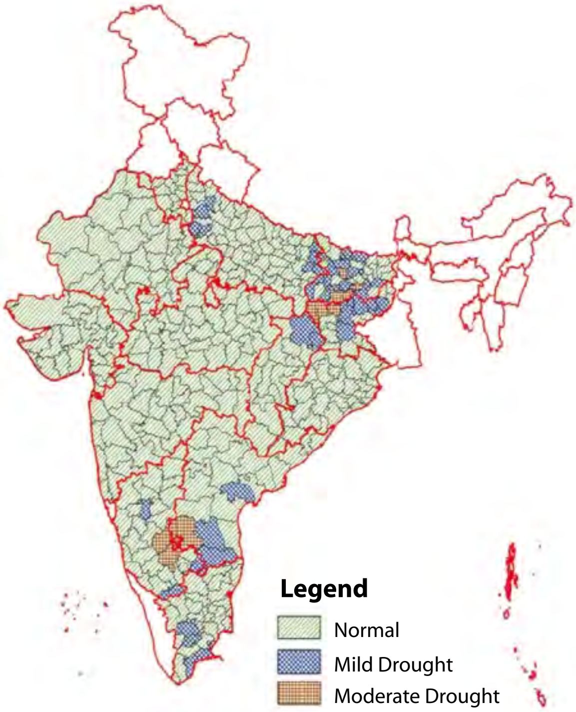


Figure 6. Methodology for drought assessment under NADAMS project

Agricultural Drought Assessment for September 2013



(No. of Districts)

State	Normal	Mild	Moderate
Andhra Pradesh	18	3	1
Bihar	16	16	5
Chhattisgart	13	2	0
Gujarat	25	0	0
Haryana	20	0	0
Jharkhand	12	7	3
Karnataka	25	3	2
Maharashtra	34	0	0
Madhya Pradesh	45	0	0
Odisha	30	0	0
Rajasthan	32	0	0
Tamil Nadu	26	4	0
Uttar Pradesh	61	8	0
Total	357	43	11

Figure 7. District level drought assessment during September, 2013 under NADAMS project

3.2 Rice flooded area mapping

Another study was carried out to assess the impact of floods on the rice crop in Odisha State of India, post-Phailin cyclone of 12 October 2013. A RISAT SAR-derived rice map was integrated with a flood inundation map developed by the National Remote Sensing Centre to map the areas of rice crop under flood. A total ten districts were affected by cyclone and rice inundation; more than 4 percent of the rice area. In four districts, namely Baleshwar, Bhadrak, Kendrapara and Jajpur, more than 15 percent of the rice was severely affected by cyclone. A post-analysis ground truth was conducted which showed the accuracy of the rice flooded area mapping was 89 percent.

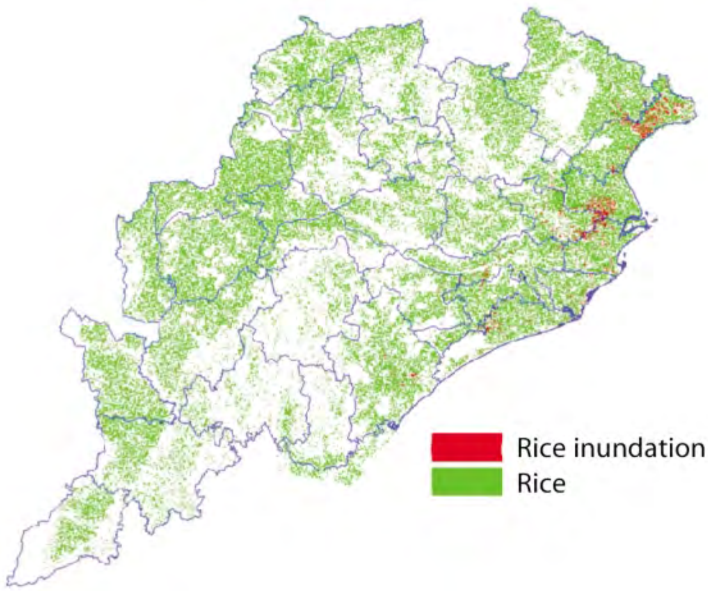


Figure 8. Flooded rice area mapping in Odisha state of Indian post-Phailin cyclone

3.3 Rabi season crop alert

As mentioned earlier, the drought assessment is generally carried out during the kharif (rainy) season. Though the majority of the crop growing area in the rabi (winter) season is irrigated, it is essential to monitor the agricultural conditions to identify any alert situation for necessary intervention measures. The crop condition was assessed using MODIS Vegetation Indices 16-Day Composite data and MODIS Land Surface Temperature 8-day Composite data. Vegetation Condition Index of NDVI and NDWI and Temperature Condition Index (Kogan, 1995) were derived using the past ten years' satellite data. Based on the above three mentioned parameters, and by using a logical modeling approach, the districts were divided into normal, watch and alert. This exercise was carried out for 8 states namely Bihar, Haryana, Punjab, Rajasthan, Uttar Pradesh, Madhya Pradesh and West Bengal (Figure 9). The analysis showed that the crop situation was normal during the rabi season of 2013-2014.

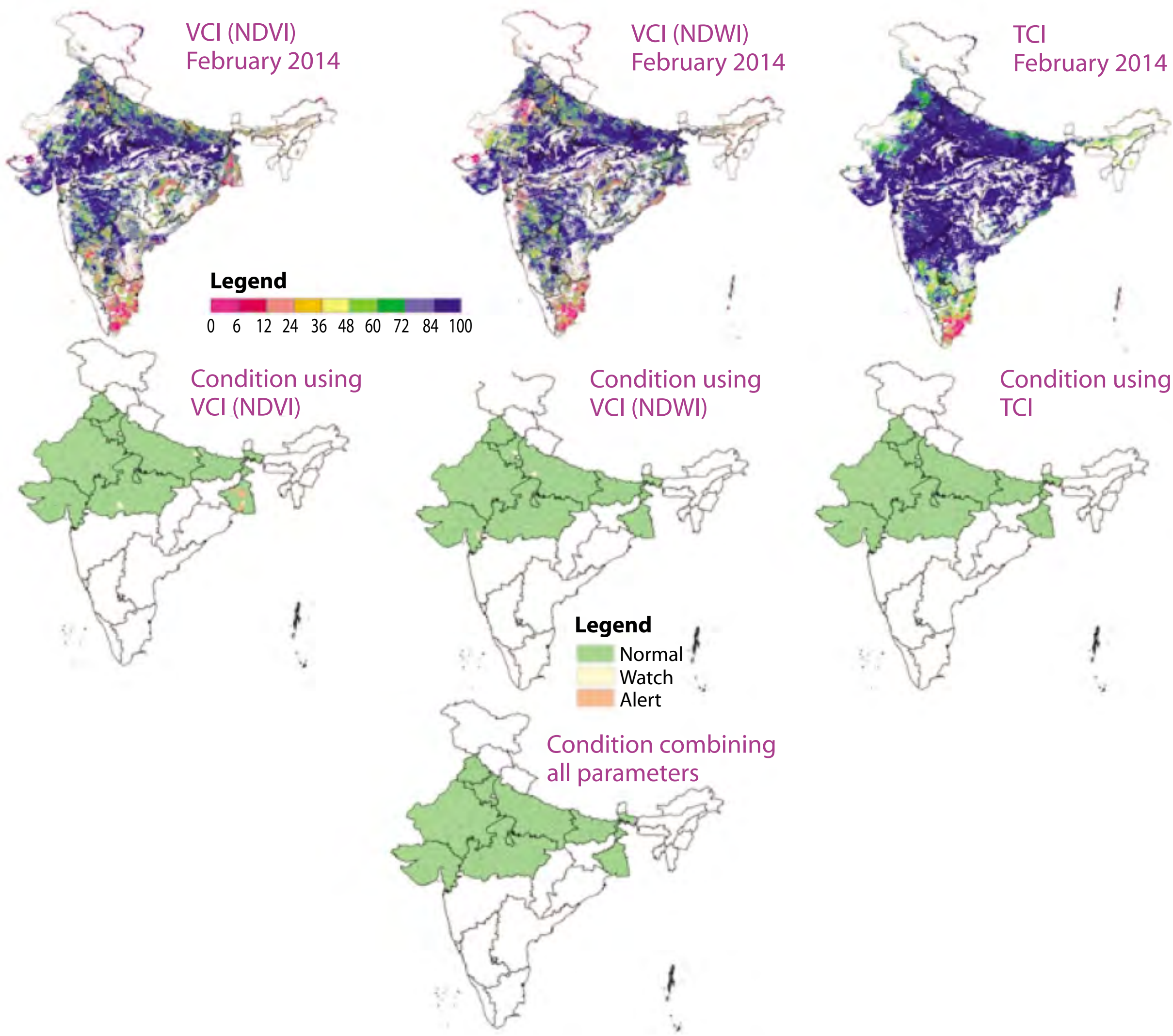


Figure 9. Rabi season crop alert assessment for 8 states of India during February, 2014

4. Conclusions

The examples presented in this article have showed how remote sensing data from various sources, in combination with other ancillary data, have been successfully used for operational assessment of agriculture in the country. However, there is a need to further extend the area of activity. The following future developments are envisaged in this field: i) taking up more crops and covering more States; ii) developing spectral yield models for all crops; iii) assessing biotic and abiotic disaster impacts on agriculture; iv) monitoring the impact of agricultural development programmes of the country; v) horticultural assessment; and vii) agricultural resources management.

Acknowledgements

The authors are grateful to the scientists of the Indian Space Research Organization for developing the procedures for the FASAL and NADAMS Projects and transferring the technology to the Mahalanobis National Crop Forecast Centre for their operationalization. The Ministry of Agriculture has not only funded this activity, but also has been responsible for the growth remote sensing applications in the country by pro-actively adopting the technology. The authors are also grateful to Sh. Ashish Bahuguna, the Secretary, DAC, for his guidance. Thanks are due to Dr. J.S. Parihar, Outstanding Scientist, Space Applications Centre and Dr. Dalip Singh, Additional Statistical Adviser, DES for their strong support to these activities.

References

Chakraborty, M., Manjunath, K.R, Panigrahy, S., Kundu, N. and Parihar, J.S. 2005. Rice crop parameter retrieval using multi-temporal, multi-incidence angle Radarsat SAR data. *ISPRS Journal of Photogrammetry and Remote Sensing*. 59(5): 310–322.

Choudhary, K., Goel, Inka, Bisen, P.K., Mamatha, S., Ray, S.S., Chandrasekar, K., Murthy, C.S. and Sesha Sai, M.V.R. 2014. Use of remote sensing data for drought assessment: a case study for Bihar State of India during kharif, 2013. In: *High Impact Weather Events over the SAARC Region* (Eds. Kamaljit Ray, M. Mohapatra, B.K. Bandyopadhyay & L.S. Rathore). Capital Publishers & Springer India, New Delhi. pp. 378–385.

DAC. 2009. *Manual for drought management*. Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India, New Delhi, 192 p.

Dadhwal, V.K., Singh, R.P., Dutta, S. & Parihar, J.S. 2002. Remote sensing-based crop inventory: A review of Indian experience. *Tropical Ecology* 43(1): 107–122.

Kogan, F.N. 1995. Application of vegetation index and brightness temperature for drought detection. *Advances in space research*. 15(11): 91–100.

Manthira Moorthi, S., Oza, M.P., Misra, Indranil, Gambhir, Rajdeep K., Darji, N.P., Sharma, Shikha, Jain, D.K., Dhar, D., Padia, Kirti, Ramakrishnan, R., Chowdhury, S. & Parihar, J.S. 2014. FASALSoft – An ISRO software framework for crop production forecast using remote sensing data analysis. *Journal of Geomatics.* 8(1): 27–33.

Murthy, C.S. & Sesha Sai, M.V.R. 2011. Agricultural drought monitoring and assessment. In: *Remote Sensing Applications* (Eds.) P.S. Roy, R.S. Dwivedi and D. Vijayan, NRSC, Hyderabad.

Navalgund, R.R, Jayaraman, V., Roy, P.S. 2007. Remote sensing applications: An overview. *Current Science*, 93(12): 1747–1766.

Navalgund, R.R. & Ray, S.S. 2000. *Geomatics in natural resources management*. In Proceedings of Geomatics-2000. 21-22 January, 2000, Pune, pp. NR1-NR14.

Nigam, R., Bhattacharya, B.K., Gunjal, K.R., Padmanabhan, N. & Patel, N.K. 2011. Continental scale vegetation index from Indian geostationary satellite: algorithm definition and validation. *Current Science*, 100(8): 1184–1192.

Panigrahy, S. & Ray, S.S. 2006. *Remote Sensing*. In: Environment and Agriculture. (Eds. K.L. Chadha & M.S. Swaminathan). Malhotra Publishing House, New Delhi. pp. 361–375.

Parihar, J.S. & Dadhwal, V.K. 2002. *Crop production forecasting using remote sensing data: Indian experience.* Proceedings of the ISPRS Comm. VII Symposium "Resource and Environmental Monitoring" held at Hyderabad, India. during Dec. 3–6, 2002, IAPRS & GIS, vol. 34, Part 7, pp. 1–6.

Parihar, J.S. & Manjunath, K.R. 2013. Agricultural Applications: Evolution during last 25 Years. *NNRMS Bulletin*. March, 2013, pp. 58–75.

Parihar, J.S. & Oza, M.P. 2006. *FASAL: an integrated approach for crop assessment and production forecasting.* Proc. of SPIE Vol. 6411641101 Agriculture and Hydrology Applications of Remote Sensing, edited by Kuligowski, R.J., Parihar, J.S. and Saito, G. (doi: 10.1117/12.713157).

Ray, S.S., Sesha Sai, M.V.R, & Chattopadhyay, N. 2014. *Agricultural drought assessment: operational approaches in India with special emphasis on 2012.* In: High Impact Weather Events over the SAARC Region (Eds. Kamaljit Ray, M. Mohapatra, B.K. Bandyopadhyay & L.S. Rathore). Capital Publishers & Springer India, New Delhi. pp. 331–345.

Tripathy, R. Chaudhari, K.N., Mukherjee, J., Ray, S.S., Patel, N.K., Panigrahy, S. & Parihar, J.S. 2013. Forecasting wheat yield in Punjab state of India by combining crop simulation model WOFOST and remotely sensed inputs. *Remote Sensing Letters* 4(1), 19–28.

Vyas Swapnil, Nigam, Rahul, Patel, N.K., Panigrahy, S. and Parihar, J.S. 2011. *Monitoring of rabi crop progress using geostationary satellite INSAT 3A CCD data.* SAC, Scientific note: ABHG/SAC/SN/03/2011. Space Applications Centre, Ahmedabad.

The research agenda of the Global Strategy to Improve Agricultural and Rural Statistics foresees the potential of alternative methods and opportunities such as advances in satellite-based technology for improving crop estimation and monitoring.

Many institutions in Asia and the Pacific region are using remotely sensed data in conjunction with conventional statistical methodologies to estimate the crop area and to forecast yields. The applications of these methods have achieved diverse degree of success, depending upon the nature of agriculture and/or access to advanced satellite imagery.

The Expert Meeting on Crop Monitoring for Improved Food Security provided an occasion for over 50 experts from Asia and other regions to deliberate on best practices and methodological issues, and to identify challenges for future research work.

This publication summarizes the outcomes of the deliberations in the meeting and presents a collection of technical papers on the subject. A comparative study of the methods presented in the book will be useful to the countries which are planning to integrate these new technologies in their statistical programme.

IMPROVING AGRICULTURAL STATISTICS
Global Strategy

FAO Regional Office for Asia and the Pacific
39 Phra Atit Road
Bangkok 10200, Thailand

GlobalStrategy-AP@fao.org
www.gsars.org

Asian Development Bank
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines

ISBN 978-92-5-108678-0
9 789251 086780
I4273E1/12.14