Geo-spatial Technology for Agriculture

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It is an honour and a privilege to have this opportunity to address the members of the Hyderabad Chapter of the Indian Society of Soil Science (ISSS) on the occasion of the fifth Dr TD Biswas Memorial Lecture. My thanks are also due to the national council of the ISSS, New Delhi. Dr TD Biswas was an eminent Soil Physicist with a very open mind towards application of emerging techniques and technologies that are of significance to the agriculture. In my student days at the Indian Agricultural Research Institute, New Delhi, though our interactions had been very limited, we used to feel proud to be in their association in many an occasion and get many valuable suggestions, directly or indirectly. On this occasion, I thought that it would be appropriate to deliver the lecture on one of the emerging technologies viz., the Geo-spatial technology for agriculture.

During the recent past 5 years, the performance of agricultural sector has been phenomenal (fig. 1). These achievements are closely associated with the decisions taken at micro and macro levels represented, respectively, by the farming community and the administrators. Though yield gaps do exist for different crops at domestic as well as the international levels, our experience gives an optimistic future trend to meet the projected national targets. All the stakeholders of relevance to agriculture and food security, have been using the advance cutting edge technologies to different degrees based on their conviction and affordability. Natural resources management, resilience to disasters, including that of climate change, from the perspective of sustainable agriculture, form the foundation for effective decision making. In this context, the Geospatial technology, that essentially uses the remote sensing, GIS, GPS, mobile and wireless communications, etc. has become very important in objectively generating information in an accurate, timely and reliable manner. Considering the vast scope of the Geo-spatial technology, I have restricted the presentation to those that are of prime importance to agriculture. The myriad applications of this technology are upto one's own imagination. As the in situ observations are most essential for the decision making, the presentation is more directed towards space based observations that have the capability to provide synoptic observations, across different scales, at a regular periodicity.

Geospatial technologies:

In addition to satellite remote sensing and GIS technologies, of late the instrumentation technology led to the plethora of instrumentation for collection, dissemination and utilization of geospatial information for rational decision making by all the stakeholders of relevance to agricultural development (fig.2). Global Positioning System is useful for knowing the precise location in terms of latitude, longitude and altitude. This technology is of specific importance in site specific or precision farming. The LIDAR (LIght Detection And Radar) enabled generation of high resolution DEMs (Digital Elevation Models). Doppler weather radar technology facilitated monitoring larger areas for assessing cyclone progress and tracking, etc. Among the various applications developed using cell phones, their utilization for uploading ground information, geo-tagging and receiving the feedback or advisories have become feasible for effective agricultural extension.

Crop Inventorying:

RS technology has been used for inventorying of crops at different spatial levels due to its multi-spectral, large area and repetitive coverage. Pre-harvest estimation of crop acreage and production enables better decision making with regard to ascertaining the surplus / deficit situation of major agricultural products and strategically plan for export / import, public distribution and market intervention operations. During the past about three decades, Indian Remote Sensing (IRS) satellites with different multi-spectral sensors varying in their spatial resolution, swath and re-visit are being successfully utilized in this endeavour. RISAT-1 with C-band Synthetic Aperture Radar (SAR) has been launched mainly to overcome the cloud problem. Currently, this satellite is being used to generate rice and jute area estimates on an operational basis, while the efforts are in [progress to inventory other crops as well. For horticultural crops also, satellite remote sensing data is being used for suitability assessment and analysing the scope for expansion. Further studies are being carried out to carry out cropping system studies, retrieval of crop canopy parameters and generation of spatialized crop models to explore the spatio-temporal variability of the crop growth responses.

Soil Moisture Monitoring:

Soil moisture plays a key role in the success of the crop. Hence, monitoring of soil moisture is very important for the success of agricultural drought monitoring. In order to capture the surface soil moisture status, passive microwave AMSR-E sensor derived soil moisture products were used in the project (Chakraborty et al., 2012). To effectively monitor crop throughout the season, knowledge on top 30 cm and root zone soil moisture is very important to assess the performance of the crop. Passive microware data provides surface soil moisture upto a depth of 5 cm which is adequate during early part of the season. This information is useful in the assessment of the soil moisture status during the sowing window and monitor the progression of agricultural areas favourable for sowing.

Dielectric constant of soils varies as a function of wetness. However, the backscatter which is functionally related to dielectric constant is influenced by the system parameters such as frequency, polarization and incidence angle and other target parameters such as roughness, geometry and orientation. India has launched a state-of-art active microwave satellite, operating in C-band and providing data in multiple modes. Availability of multi-dimensional information is being explored to retrieve the soil moisture in the root zone of the crops to aid in agricultural water management.

Soil Water Balance (SWB) Model

Soil water balance, by mass balance or by partitioning of the incident net radiation can be depicted spatially and the spatio-temporal variations help in utilization of this input both for agricultural water management and climatic water balance studies, as well. A soil water balance model was developed under NADAMS which was run on a daily basis to provide the top 30 cm soil moisture and root zone soil moisture for some selected crop throughout the kharif season. The top soil moisture is very useful input in deriving the Area Favorable for Crop Sowing during early part of the season. The root zone soil moisture for the selected crops is helpful in identifying the exact period and duration of stress in a particular region. The soil water balance model has been a very important input in the assessment and monitoring of agricultural drought during the season. Active research is being carried out to estimate the evapo-transpiration fraction by partitioning the satellite derived incident net radiation into sensible and latent heat.

Area Favourable for Crop Sowing / Crop Sown Area:

In addition to passive radiometry, which provides information on a coarse scale, indices that provide information on relatively larger scale are also being explored. E.g., using multiple parameters viz., the Short wave Angle Slope Index (SASI), soil texture, rice/non-rice areas and soil water balance, a procedure was evolved to generate a geo-spatial product on crop sowing favourable area or already cropped area in the season. This product called Area Favourable for Crop Sowing / Crop Sown Area (AFCS), has been generated on fortnightly or monthly scale from June-September. The cloud covered pixels in SASI images are resolved with the support of rainfall and water balance derived soil moisture index. After validation with state level crop sown area statistics reported by respective agriculture departments, the product is generated and used operationally from kharif 2010. Extending SASI for rabi season monitoring, Murthy et al 2012, mapped spatial patterns of surface wetness and rice transplantation in rabi season of recent 10 years (2002-03 to 2011-12) in a rice dominant irrigated command area.

Soil Resources:

For efficient management of soils, we must have an in-depth knowledge about their morphology, physical and chemical properties, behaviour, kind and degree of problems and their extent and distribution on the landscape, which can be achieved through soil survey and mapping. The role remote sensing was proved to be a powerful tool to study soil in spatial domain, on different scales, in a time and cost effective manner. In India, initial attempts were made with aerial photos to map soil resources. Satellite data from IRS sensors are being used to generate soil maps through monoscopic (non-stereoscopic) visual interpretation and computer-assisted digital analysis approaches. In visual interpretation approach, the intimate relationship between physiography (landform) of the terrain and soils occurring therein is exploited.

Similarly, the land degradation processes such as water erosion, wind erosion, water logging, salinization / alkalization, acidification, frost heaving / shattering, mass movement and shifting cultivation, etc. are amenable form remote sensing. Research emphasis currently lays on automatic / semi-automatic feature extraction methods for land cover analysis and quantifying the role of the land use land cover drivers.

Water resources:

Managing water resources is a major challenge for the country.. The temporal and spatial analysis of satellite data has indicated problem pockets of poor performance within the irrigation commands. Diagnostic analysis supported by farmer surveys has identified causative factors for corrective management. Satellite data has helped in these projects in identifying cropping pattern, the extent of unauthorised irrigation and poor recovery of water rates, thus providing inputs for changes in policies and operational plans. Spatial analysis of crop sowing periods, crop condition assessment are useful in irrigation scheduling. Data from AWiFS (Advanced Wide Filed Sensor) on Resourcesat, with a re-visit period of 5 days, has the potential for development of real-time decision support systems for irrigation water management. High resolution satellite imagery can provide a rapid, high quality data source for capturing existing irrigation network and associated infrastructure details. Inventory of glacial lakes and snow clad areas feasible using satellite data is of immense importance in the context of climate change and estimation of snow-melt run off, especially for the agricultural sector in the entire Indo-Gangetic alluvium. Information on Geology, Geomorphology, drainage, Lithology, landform, structural, slope, soil and land use generated from satellite data, are essential in identifying the groundwater prospect zones. Remote sensing data helps in delineating the potential groundwater occurrence zone in less time and cost effective manner than the conventional methods.

Land use land cover:

Land use / cover (LULC) is one of the major inputs to any resource planning and is very dynamic both seasonally as well as annually. Realizing the need for an up-to-date nationwide LULC maps by several departments in the country, a LULC classification system with 24 categories up to Level-II, suitable for mapping on 1:250K scale, was developed. Rapid Assessment of Land Use / Land Cover on 1: 250K scale was initiated annually in 2004-05 time frame using multi-temporal IRS AWiFS data for entire country. In this project the cropped areas during *kharif*, *rabi* and *zaid* seasons are assessed along with area under double/ triple crops and at the end of the year net sown area is estimated. So far, eight cycles have been completed and the data is made available to users through Bhuvan, the geo-portal of ISRO. Under Space based Information System for Decentralized Planning (SIS-DP) project, LULC information on 1:10K scale is being generated using IRS-LISS-IV Resourcesat-1/2 and Cartosat-1 data where broad LULC classes amenable to Panchayat Raj level planning.

Watershed:

Watershed management has been defined as 'the integrated use of land, vegetation, and water in a geographically discrete drainage area for the benefit of the people, with the objective of protecting or conserving the hydrologic services which the watershed provides and of reducing or avoiding negative downstream or groundwater impacts' (World Bank, 2007). It consists of delineation, selection, characterization, prioritization, analysis of natural resources, identification of constraints, development of action plan, implementation of action plan, monitoring, and impact assessment, etc. LISS-I, II, III, IV and Cartosat-1 from Indian Remote Sensing Satellites is being used to generate information in the watershed management for various national watershed programmes of the country.

Precision farming:

Precision farming helps in enhancing the use efficiency of the externally applied inputs as well as augmenting the realization of the natural resources' potential. Optimization of the externally applied inputs is accomplished through ascertaining the information on the intra-field variability. Field data collection e.g., soil sampling for fertility, which is geo-tagged using using Global Positioning System (GPS) (fig. 3) significantly helps in creation of the geospatial point data, which would be subjected to geo-statistical analysis for generation of surfaces. Such surfaces representing different fertility parameters could be conjunctively utilized for a better decision making in the precision or smart farm management. Delineation of homogeneous zones for appropriate crop management also call for spatial data that could be generated by following a standard framework catering to the variability of the parameters in reference. However, precision farming is confronted by the small farm sizes in Inida.

Floods :

In India, about 40 Mha is the estimated flood prone area. The Ganga and the Brahmaputra river basins are the most vulnerable, chronically causing enormous damage to agriculture, loss of lives and property. On account of frequent changes in river courses and braiding of channels, erosion of riverbanks also assumes importance as one of the major problems associated with floods. Currently, all the major floods in the country are being monitored and the near real time information is being provided to the concerned for immediate actions. In addition to the monitoring, hazard zonation, based on the historical database, and river bank erosion monitoring are also being carried out (Navalgund et al., 2007).

Agricultural Drought:

About two-third of the agricultural land being rainfed, our agriculture is profoundly subjected to the vagaries of the monsoon. The National Agricultural Drought Assessment & Monitoring System (NADAMS) has been conceptualized and materialized during 1987-1989 to assess the prevalence, spatial extent and intensity of agricultural drought. Over a period of time, the NADAMS had undergone many methodological changes over time, keeping pace with developments in remote sensing technology and user needs and showcased an integrated agricultural drought monitoring mechanism in the country. The utilization of WiFS data of the second generation satellite, IRS-1C during 1996, followed by IRS 1D WiFS data had brought a significant change in the drought assessment perspective of the NADAMS leading to sub-district level assessment. Availability of Resourcesat-1 AWiFS data resulted in the combined use of NDVI and NDWI for improved agricultural drought assessment and monitoring. The spectral indices and their anomalies derived from WiFS and AWiFS datasets are found to be synergistic to those derived from other sensors like MODIS and enabled the synergistic use of IRS datasets with other global satellite datasets and products for drought monitoring. Drought impact assessment, early warning, exploration of new indices, development of new bio-physical products are some of the issues to be addressed to take the drought monitoring endeavor to next level and to achieve resilient rainfed agriculture in India (Sesha Sai et al., 2013).

Climate Change:

Agricultural ecosystems will be highly affected by the climate change / variability either directly or indirectly. Droughts, floods and extreme weather events are to affect the sustainable agriculture. Observational data and model simulations form the foundation of understanding the climate system. Satellite remote sensing allows for continuous monitoring on the global scale. It provides an independent source of observations to validate climate models and climate theories. Data from these satellites vary in spatial and temporal resolutions often serve as complementary sets and augment the scientific analyses.

Observations from satellites enable deriving information on land, ocean and atmosphere at various spatial and temporal scales. Spatio-temporal changes of land cover have been studied by the research community in a variety of situations to understand the drivers that are responsible for such changes and use such information towards developing mitigation measures to cope up with the adverse impacts, if any. Satellite data on land, water and atmosphere are integrated towards generating products for re-analysis of the data for studying a wide range of climate research towards better comprehension of the processes and their interactions. The Global Climate Observation System has listed 26 out of 50 essential climate variables (ECVs) as significantly dependent on satellite observations. An information system, called the NICES (National Information System for Climate and Environmental Studies) using Indian Remote Sensing and geostationary satellites data and others is being developed by the Indian Space Research Organization (ISRO) at the National Remote Sensing Centre. These inputs are being used towards building a climate resilient agriculture.

BHUVAN:

In India, over the past 3 decades satellite data are being used to generate information on natural resources, including infrastructure, and disaster management support with its own as well as international satellites. Bhuvan, the geo-portal of the Indian Space Research Organisation, showcases the Indian imaging capabilities in multi-sensor, multi-platform and multi-temporal domain. Bhuvan provides a range of services enabling visualization of various thematic data generated from the national missions and projects carried out by NRSC. This Earth browser of Bhuvan gives a gateway to explore and discover virtual Earth in 3D space with specific emphasis on Indian Region.

Futuristic perspective

Knowledgeable agricultural decision making and policy formulation are critical to sustainable agricultural development, food security and economic prosperity. Farming decisions are becoming more complex due to the internationalization of agricultural product markets, global climate change, and the need for farmers to adopt sustainable farming practices. Geo-tagged observations from multiple platforms enabled generation of integrated information on various scales exploring synergy. Efforts are in progress to develop techniques for extraction of meaningful information and disseminate for near real time for decision making. Agro-geoinformation, the agricultural-related geo-information, has the substantial role in the agricultural decision making and policy formulation processes. The academia, including the scientific societies, as well as the industry need to pay special attention to harness the best out of the geo-spatial technology for agricultural development.

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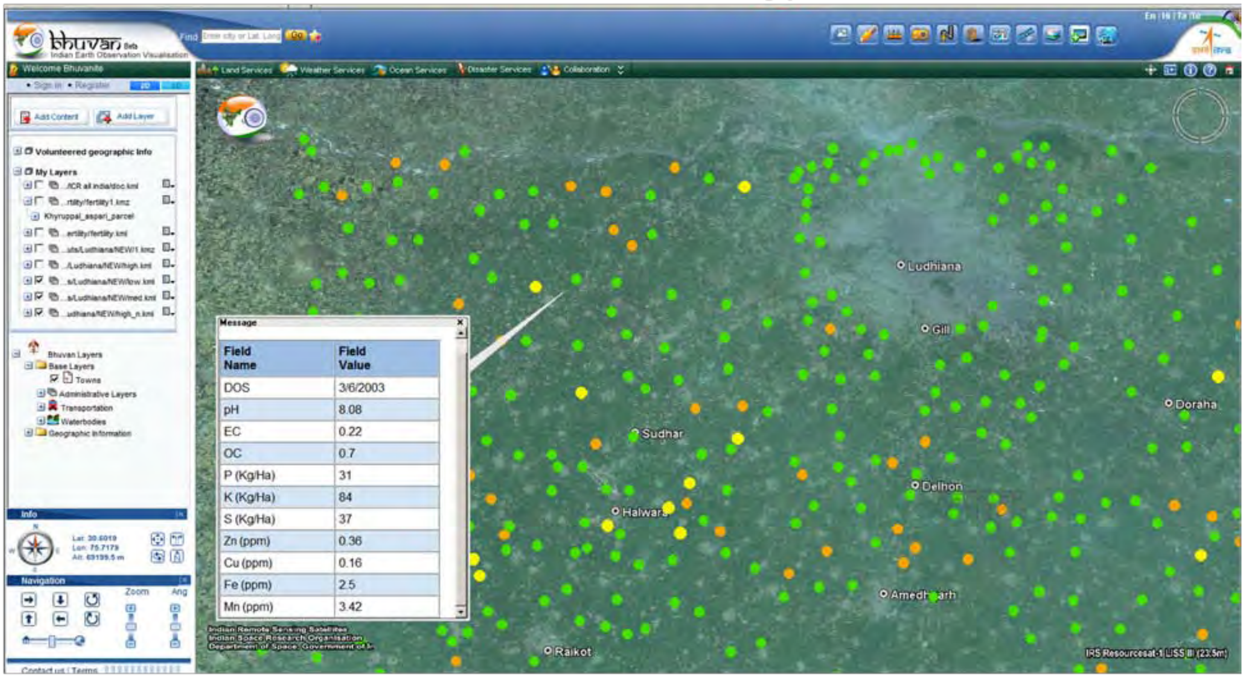
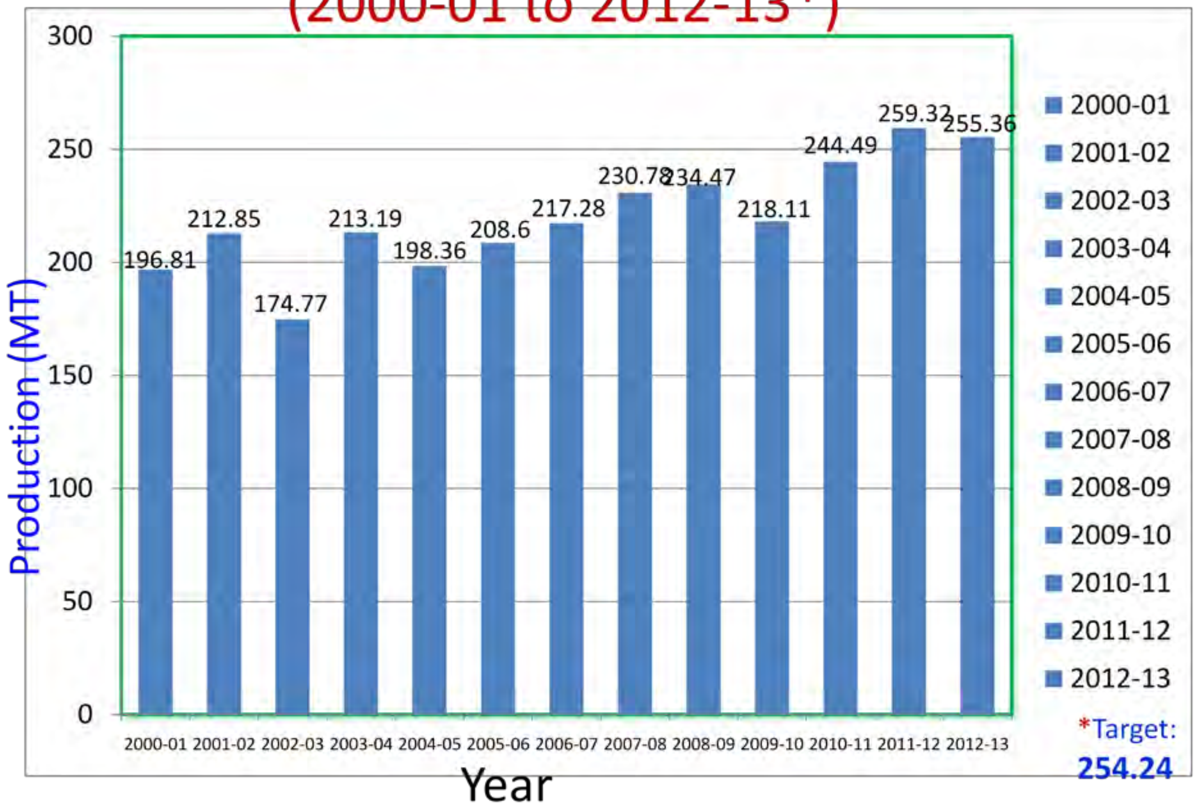
Fig. 3: Real time field data collection for soil fertility using mobile technology



High Medium Low

Fig. 2: Convergence of Geospatial Technologies Inclusive, participatory, coordinated local area development

Fig. 1: Food grain production (MT) of India (2000-01 to 2012-13*)



Crop Intensity: 137; NSA: 140 M ha, GSA:192 M ha, GIA: 86 M ha; NIA: 63.26 M ha

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