Geospatial Technology: the emerging global trend towards the new horizon of sustainable agriculture

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Abstract **- Agriculture has been the backbone of the growth of any civilization since ages, especially in a country like India, where the majority of the rural population is based on the agricultural and allied activities. Agriculture not only contributes to the economy of the country, but it is the most important way to feed the huge and ever growing world population. The Food and Agriculture Organization of United Nations (FAO) has given a special emphasis on the second sustainable development goal, i.e. zero hunger to be met by the year 2030. To meet such a requirement, it has become extremely important to continuously monitor agricultural changes over time at different spatial scales. The emerging geospatial technology, consisting of remote sensing, GIS and GPS, enables us to study the agricultural growth and pattern in a cost/time efficient way. While the remote sensing technology helps to portray a clear picture of the earth surface and its changing pattern over time, the Geographic Information System (GIS), on the other hand, offers the analysis, manipulation and management of the remotely sensed data in a more user friendly and easily understandable manner. This technology offers a wide range of agricultural benefits that include estimation of acreage and yield monitoring, crop identification, agricultural land use mapping, forecasting agricultural production, crop damage assessment, climatic impact on cropping system in different seasons, environmental footprint like emission of methane and carbon stock and many more. The geospatial technology has faced a great evolution in the agricultural applications in the past few decades. Starting from using low spatial resolution data in the early ages of this technology for the agricultural land use mapping, it has reached to the point of using more modernized techniques like using UAVs and high spatial resolution data for precision farming. Now-a-days, the demand of microwave remote sensing along with the optical remote sensing is increasing due to its all-weather imaging capability especially in the countries which are mainly based on monsoon rainfall dependent crops. Geospatial technology can also play a crucial role to combat climate change situation through Climate Smart Agriculture (CSA), which enables to identify crops those are more adaptable to the climate change. The geospatial technology has now become an essential component of agricultural sector worldwide which can bridge the gap between the existing farming practices and the upcoming new improved techniques, which can further be useful for planning and developing sustainable agriculture to ensure the food security globally.**

Keywords - Food security, agricultural growth, geospatial technology.

1. Introduction

The world population is continuously increasing day by day. According to the reports provided by the United Nations, the current (as of June, 2017) world population is 7.6 billion which is expected to reach 9.8 billion by 2050 and 11.2 billion by 2100 (*UN, 2017*). Now the major problem of this ever growing global population is to fulfill the hunger of this huge population and ensure the global food security. The Food and Agriculture Organization of the United Nations (FAO) has defined the food security as the regular physical and economical access to quality food to feed the billions of people and lead a healthy life. The FAO has given a special emphasis on the second goal of the seventeen Sustainable Development Goals (SDGs) set by the United Nations (UN) in 2015 which demands zero hunger worldwide to be achieved by the year 2030. To fulfill this target, the agricultural growth must be put in the focus of any kind of sustainable development planning as this particular sector contributes a major percentage of the world economy. According to the FAO, about 11% of the global land surface is used for the agriculture purpose at present (*FAO, 2017*). India, being the second largest populated country in the world too needs an extreme attention towards the agricultural growth as the majority of its rural population is engaged in agriculture and allied activities. So the continuous monitoring of agricultural growth and pattern over time and different spatial scales must be addressed. But this rigorous task has been much easier after the involvement of the geospatial technology in the agricultural sector. The geospatial technology consisting of three main components, i.e. remote sensing, GIS and GPS helps to monitor the cropping system in a more time and cost efficient way.

2. The role of geospatial technology in agriculture

The geospatial technology is a multidisciplinary tool that is being used in the modern era of science and technology for the combined studies related to the earth and space. It consists of three main component namely remote sensing, geographical information system (GIS) and the global positioning system (GPS). Each of these components is essential for this technology and plays its respective key roles. The remote sensing or more popularly known as the earth observing technology acquires the image of the earth from the space with the help of onboard camera or sensor in the satellite or spacecraft or aircraft. It started back during the World War II with balloon photography. After that it had revolutionary changes with the use of aircraft, spacecraft and the very recent Unmanned Aerial Vehicles (UAVs). The imaging process is done by sensing the reflected, emitted or backscattered energy from the earth surface. The technology works in the different wavelength region of the electromagnetic (EM) spectrum. The optical remote sensing mainly works in the visible, near infrared (NIR) and short-wave infrared (SWIR) regions, whereas, the radar remote sensing operates in the microwave region of the EM spectrum. Fig. 1a gives a clear picture of the EM spectrum based on the wavelength range.

The remote sensing technology can be categorized into two types based on the source of incoming radiation on earth, namely passing remote sensing (uses the solar radiation) and active remote sensing (the sensor itself is the radiation source!). The mechanism of the remote sensing is shown in the Fig. 1b. The GIS on the other hand, helps to analyze, manipulate, database management and display the remotely sensed data in a much user friendly manner, with the help of GPS, which enables GIS to validate the information with respect to the earth.

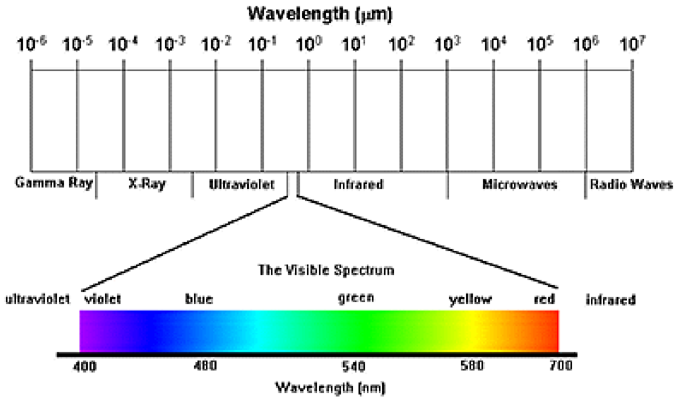

Figure 1a: Electromagnetic spectrum (Image source: http://www.crisp.nus.edu.sg/)

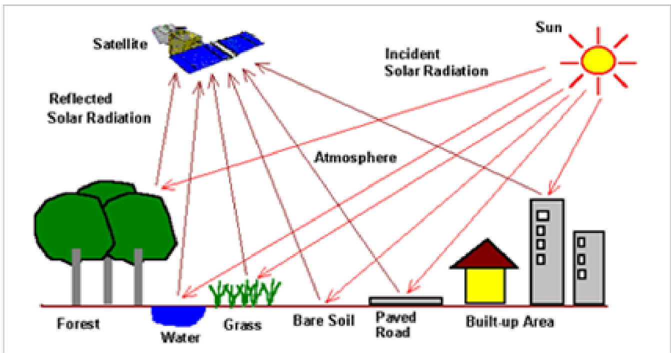

Fig. 1b: Mechanism of remote sensing (Image source: http://www.crisp.nus.edu.sg/)

2.2 Advantages of geospatial technology in agriculture

The conventional way of agriculture survey has many problems to deal with. The major ones are reliability of data, cost and benefits, measurement of area, unavailability of statistics at different administrative level, consumption of time etc. But the geospatial technology can help to overcome these issues. It provides easy data acquisition with broader spatial coverage even in inaccessible areas. The real time capability and the facility of laboratory analysis of the data reduce the effort of fieldwork and other agriculture survey as well as saving the cost. The GIS helps to manage the database more accurately and efficiently to keep a permanent data record.

2.3 Major thrust areas in agriculture

This technology is capable of working in multiple directions in the agriculture sector. It can help to prepare a proper crop inventory or crop information system by identifying and monitoring the crops, estimating the cropped area, land use mapping, modeling the yield and forecasting the production. It can also help to keep a track to the crop condition by assessing the crop health, identifying any kind of pest and disease infestation, detecting stress and nutrient deficiency and crop damage etc. the technology provides good and reliable information about the crop requirements like soil mapping, soil moisture estimation, water resources mapping and the irrigation requirement. The climate of any place is a key factor playing a major role behind the cropping system. This technology can also help to understand the climatic influence on agriculture. It can be used to identify the flood inundated crop lands, study the effect of temperatures on crops as well as for agricultural drought assessment. Now-a-days, the technology further offers precision farming and climate smart agriculture which add new degrees to the modern agriculture. Precision farming is based on the concept of 'right thing at right place and right time', i.e. it provides the information about the agricultural parameters to be taken care of at a very precise level. On the other hand, climate change and agriculture go hand-in-hand. A slight change in climate of an area can impact the agriculture system of that place to a great extent. The climate smart agriculture offers cropping those are very much adaptable to the changing climate. Geospatial technology can also help in agriculture policy making, crop planning and irrigation scheduling. Table 1 gives a brief description of the application of remote sensing technology in agriculture.

Table 1: Applications of remote sensing in agriculture

Multispectral remote sensing	Crop mapping	Crop identification
		Area and acreage estimation
		Land use mapping
		Yield modeling and estimation
		Forecasting production
	Crop health assessment	Pest and disease infestation
		Detecting stress
		Detecting nutrient deficiency
		Crop damage
Both multispectral and microwave remote sensing	Agriculture water requirements and climatic influences	Agricultural drought assessment
		Water resources mapping
		Crop water requirement
Microwave remote sensing		Soil moisture estimation
		Flood affected area
		And many more……

3. Remote Sensing satellites and data

A wide range of satellites having different spatial resolution and coverage are used for the agricultural study. Moderate Resolution Imaging Spectroradiometer (MODIS), series of Landsat satellites by NASA, series of Indian Remote Sensing satellites (IRS) by ISRO, Advanced Very High Resolution Radiometer (AVHRR) by the National Oceanic and Atmosphere Administration (NOAA), Sentinel 1 and 2, Worldview, Quickbird, Radarsat are some of the major satellites used for this purpose. Among these satellites, MODIS provide low spatial resolution data (250m, 500m and 1 km) with wide geographical coverage with good revisit time to study the agricultural growth pattern. Landsat Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), Operational Land Imager (OLI) and Thermal Infra-RedSensor (TIRS) all having spatial resolution of 30m, IRS Resourcesat 1 LISS (Linear Imaging Self Scanning) III (23.5m) and AWiFS (Advanced Wide Field Sensor) (56m) are considered to be the medium resolution satellites used for agricultural study. The recent Sentinel 2A and 2B by the European Space Agency (ESA), however, have high spatial resolution of 10m. These are all multispectral remote sensing satellites, operating is the optical and thermal region of the EM spectrum. There are also some radar satellites which operate in the microwave wavelength region. These satellites have special imaging capabilities through all-weather as well as in both day and night time. Envisat, Radarsat 1 & 2, RISAT and Sentinel 1 are two of the major radar satellites. These are not the only satellites which are being used for the agricultural study. The number of earth observing satellites to be used in agricultural research, launched by different space agencies all over the world, is increasing day by day. The optical remote sensing is used mainly for crop area and acreage estimation, land use planning, yield modeling and crop forecasting etc. while the radar satellites are used for soil moisture mapping, flood mapping etc.

Normally satellite imageries are shown in standard False Color Composite (FCC), with the Near Infra-Red (NIR) wavelengths as Red band, red wavelength as green band and the green wavelengths as blue band. Fig. 2a and 2b show the standard FCC of the LISS III image of the IRS Resourcesat-1 satellite acquired on 20th October, 2008 and 9th March, 2012 around the Ranchi Airport area. The two images from different cropping seasons in Jharkhand show the tonal variation of the crop lands. The abundance of the red tone in the croplands of the first image represents the presence of crops in the field in Kharif seasons. In the second image, however, the presence of crops is very less. Fig. 2c is image of the same place taken from the Google Earth Pro with a higher spatial resolution.

There is various vegetation indices used for the agriculture study. Most common of them are Normalized Difference Vegetation Index (NDVI), Enhanced Vegetation Index (EVI), Perpendicular Vegetation Index (PVI), Leaf Area Index (LAI) and many more. These vegetation indices give detail information about the crop growth and crop health in the growing seasons and help understanding the cropping pattern and intensity over an area. Different agricultural features and characteristics can be understood from the spectral signature curve of the EM spectrum. These indices can be derived from different wavelength bands of the satellites. But now-a-days, some satellites provide already prepared products of these indices. Fig. 3 shows the spectral signature curve of natural vegetation at different wavelengths.

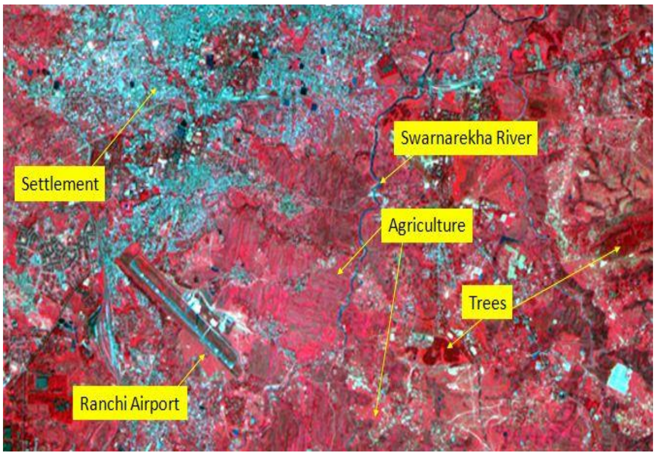

Figure 2a: IRS LISS III image of Ranchi Airport and surrounding area (acquired on 20th October, 2008)

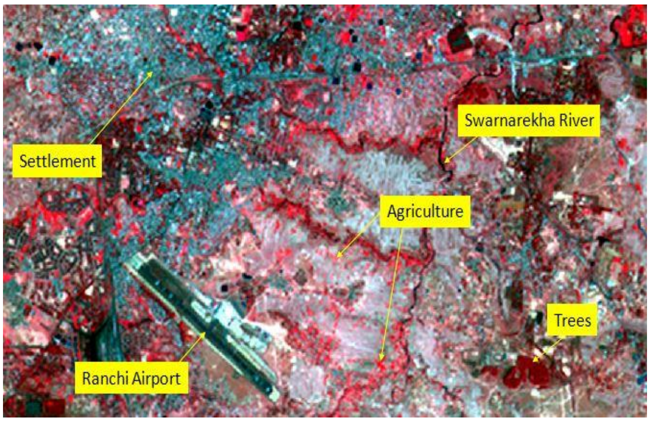

Figure 2b: IRS LISS III image of Ranchi Airport and surrounding area (acquired on 9th March, 2012)

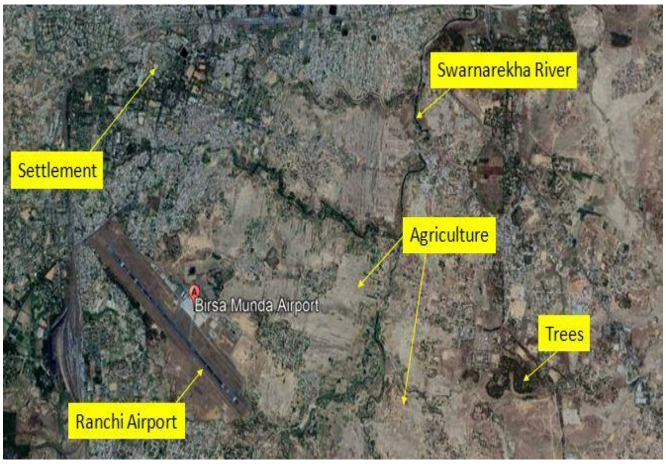

Figure 2c: Image taken from Google Earth Pro on 19th March, 2018

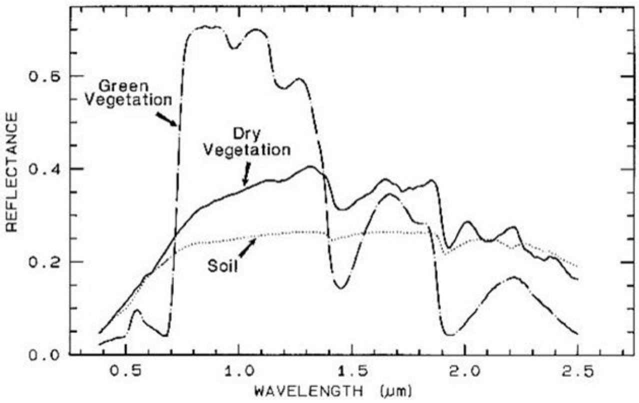

Figure 3: Spectral signature of vegetation (Image source: Clark, 1999)

4. Organizations and projects

4.1 Global initiatives

The Food and Agriculture Organization by the United Nations is the major governing body which looks after the fulfillment of the worldwide agricultural needs. The launch of the Large Area Crop Inventory Experiment in 1974 jointly by NASA, USDA and NOAA was a major initiative towards the monitoring of agriculture sector with the aid of geospatial technology (*Pinter et al., 2003; Menon, 2012; Atzberger, 2013*). The Global Agricultural Monitoring Project (GLAM) was performed jointly by NASA, USDA and the University of Maryland over the period 2012-2016 to monitor crop condition and crop production estimation. Another project namely Global Cropland Extent funded by NASA Applied Science Program and USDA was done to map the global extent of croplands over the period 2000-2008.

4.2 National Involvements

National Remote Sensing Centre (NRSC), ISRO, Hyderabad has taken major initiative towards the agricultural growth of the country involving the space technology. The Mahalanabis National Crop Forecast Centre in New Delhi was established in 2012 to look after the crop forecasting and managing the crop database repository. Crop Acreage and Production Estimation (CAPE), Forecasting Agricultural Output using Space, Agro-Meteorology and Land-based Observations (FASAL), National Agricultural Drought Assessment and Monitoring Systems (NADAMS), National Agricultural Land Use Mapping are some of the major projects completed jointly by NRSC and MNCFC. Indian Council of Agricultural Research (ICAR), Central Agricultural Research Institute (CARI), Indian Agricultural Research Institute (IARI) and Central Research Institute for Dry-land Agriculture (CRIDA) are some other major agricultural research organizations in India. There are also various space applications centers all over India which have taken initiatives towards different agricultural programs at state level. The Jharkhand Space Applications Center (JSAC) in Ranchi is also working various state level agricultural projects using the space technology which may lead to the agricultural growth of the state.

5. Conclusion

The remote sensing technology has the unique capability to provide real time data unlike the conventional agricultural methods and that too at a very low cost. Not only that, acquiring and managing those data has been so easy with the help of GIS, that it has been considered as an essential component of the modern technology to be used in agricultural researches. Not only the researches, has it also helped in decision and policy making for the farmers as well as governments, suggesting action plans and management strategies to promote sustainable agriculture to meet the food security. The remotely sensed satellite data are freely available from many of the space agencies in the world. This makes most of the researches less costly too. This paper emphasizes the importance of the geospatial technology at present age with reference to the agricultural sector for better economical growth of the country and the world as well.

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