International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Using GIS for Precision Agriculture: Monitoring Crop and Soil Health

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Submitted: 20/08/2023 **Revised:** 12/10/2023 **Accepted:** 25/10/2023

Abstract: Precision Agriculture, also known as Precision Farming, uses modern technology and field data to take the right measures at the right time. This manufacturing process calls for site-specific management changes. This approach uses modern technology-enabled tools and information. GPS, GIS, yield monitoring equipment, soil, plant, and pest sensors, remote sensing (RS), and variable rate input applicator technologies are examples (Santosh et al. 2003). Remote sensing is essential for crop health and yield predictions, crop acreage estimates, crop pests and diseases identification, disaster location and mapping, wildlife management, water supply information, weather forecasting, rangeland management, and livestock surveys (Patil and Chetan 2017). Remote sensing can automate and impartially assess plant diseases (Mahlein et al. 2012). Huang et al. (2012) found that plant diseases have cost global agriculture productivity. PA applications often employ the Normalized Difference Vegetation indicator (NDVI) to measure green content. The NDVI index is calculated using R and NIR channels. Healthy plants absorb more NIR light but little red light (Shafi et al. 2019). Precision agronomic and economic decisions may benefit from remote sensing. Precision agriculture, largely from Western countries, is underutilized in India owing to farmer ignorance.

Keywords: *Precision, Agriculture, application, farmers*

Introduction

The global population, now nearing six billion, is projected to rise by an additional three billion over the next fifty years, significantly altering the world's food landscape. The scarcity of arable land resources has intensified the demand on currently productive land. In 2000, the per capita arable land was estimated at 0.23 hectares, which is expected to decline to around 0.15 hectares by 2050 (Lal, 1991) [10]. The worldwide demand for food is anticipated to rise by 1.5 to 2 times (Daily et al., 1998) [3] as a result of a growing population and an enhanced diet for those advancing economically. Consequently, to sustain the growing population, there is an imperative necessity to implement modern technologies that enhance crop yield, furnish information for improved in-field management decisions, decrease chemical and fertilizer expenses through more efficient application, facilitate precise farm record-keeping, augment profit margins, and mitigate pollution. In this context, remote sensing may be a superior alternative. The agricultural industry is most adversely impacted by drought due to its heavy dependence on weather, climate, and soil moisture. Agricultural drought refers to the reduction in agricultural production resulting from unpredictable rainfall patterns, elevated temperatures, and other factors that lead to diminished soil moisture. The significance of remote sensing and GIS in the detection, assessment, and management of agricultural drought is increasingly vital, as they offer current information across various spatial and temporal scales, a process that is laborious and time-consuming when conducted through traditional methods such as field surveys and sampling questionnaires. Thenkabail et al. (2004) [17], Arshad et al. (2008) [2], Hasan and Saiful (2011) [5], Brian et al. (2012).

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Components of Precision Agriculture

Geographic information systems (GIS): This system includes hardware, software, and protocols intended to facilitate the compilation, storage, retrieval, and analysis of feature characteristics and location data for map production. Computerized GIS maps vary from traditional maps and include many layers of information, such as yield data, soil survey maps, precipitation, crop types, soil nutrient levels, and insect distribution. GIS is a kind of computerized mapping that primarily use statistical and spatial methodologies to assess characteristics and geography. A agricultural GIS database may provide data on field topography, soil classifications, surface drainage, subsurface drainage, soil analysis, irrigation practices, chemical application rates, and crop yields.

Global Positioning System (GPS): The Global Positioning System is a network of satellites that continually delivers encoded information. It measures latitude, longitude, and elevation at every location on Earth. Access to accurate location data at all times facilitates the mapping of soil and crop measurements. GPS devices, whether transported to the field or affixed to equipment, enable users to revisit precise locations for sampling or treatment. Uncorrected GPS signals possess an accuracy of around 300 feet.

Variable Rate Technology (VRT): The equipment used for controlling the application rates of fertilizer, lime, pesticides, and seeds as an applicator traverses a field is based on a decision support system and management plan. The application of materials is determined by data received from sensors, maps, and GPS. These materials include fertilizers, chemicals, and seeds, all of which enhance agricultural production efficiency.

Fig 1: Variable rate technology

Yield Monitoring (YM): Yield monitoring is a component of precision agriculture that provides farmers with essential information for informed decision-making about their farms. Yield monitors are a relatively new innovation that enable agricultural machinery, such as combine harvesters and tractors, to collect extensive data, including grain yield, moisture content, soil characteristics, and more parameters. Yield monitors provide farmers with extensive information, enabling them to evaluate optimal times for harvesting, fertilizing, sowing seeds, and understanding weather impacts, among other factors. Yield monitors operate in three straightforward steps: the grain is harvested and sent into the grain elevator, which is equipped with sensors that measure the moisture content of the grain.

Remote Sensing (RS): Remote sensing is the discipline of acquiring information about items or areas in the real world at a distance, without direct physical interaction with the subject of investigation. The notion of remote sensing involves using the electromagnetic spectrum (visible, infrared, and microwaves) to evaluate the Earth's characteristics.

Electromagnetic Spectrum

The wavelengths used in the majority of agricultural remote sensing applications include just a limited segment of the electromagnetic spectrum. The near infrared (NIR) area is the infrared spectrum closest to the visible zone. The visible and infrared spectra are used in agricultural remote sensing.

Interaction of EMR with Atmosphere

Atmospheric particles and gases may influence incoming light and radiation. The effects result from the processes of scattering and absorption. Ozone, carbon dioxide, and water vapor are the three primary atmospheric components that absorb radiation. The portions of the spectrum little affected by atmospheric absorption, and hence advantageous for distant sensing, are referred to as atmospheric windows (highlighted in green).

Interaction of EMR with earth surface

- Reflection
- Transmission
- Absorption

Spectral signature

The spectral signature $\rho(\lambda)$ represents the ratio of reflected energy to incident energy as a function of wavelength. The correlation among reflected, absorbed, and transmitted energy is used to ascertain the spectral signature of plants. Spectral signature refers to a distinctive spectral reaction. It is distinctive among plant species.

Resolution

Ability of an entire remote sensing system including lance antennae camera etc to provide a sharply defined image

Type of Resolution: there are four type of remote sensing

Spatial Resolution: The minimum distance between two objects that a sensor can clearly identify is contingent upon the instantaneous field of view (IFOV), which is the angular cone of sight of the sensor, determining the region on the Earth's surface observable from a certain height at any given moment. For example, 10 x 10 meters.

Radiometric Resolution: Define the capability of a sensor to quantify signal strength or luminosity, referred to as contrast.

Temporal Resolution: Duration required to capture a photograph of the same item at the same position.

Satellite-based Agro-advisory Service: Data sets from several satellites have created significant opportunities for retrieving diverse information. This information is provided or made available in a timely manner enabling the user to interpret and use these warnings effectively in the management process.

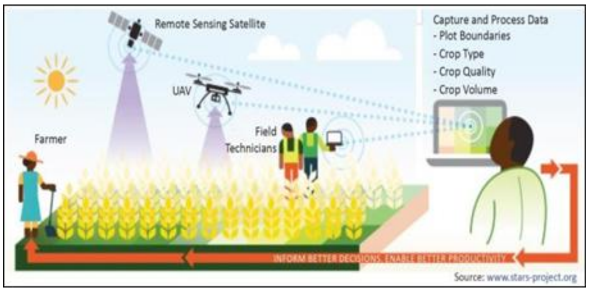

Fig 5: Satellite based Agro-advisory service

Pest Management: Integrated pest control is a crucial element of sustainable agriculture. Methodologies must be optimized for the detection of locust breeding grounds based on vegetation or moisture conditions. Formulating techniques to inhibit their proliferation and implementing effective control measures.

Assessment and Monitoring Drought: The integration of NDVI and LST yields valuable insights for drought monitoring and early warning systems for farmers. The district-level drought assessment and monitoring with NDVI derived from NOAA-AVHRR data enables prompt preventative and corrective actions to mitigate drought effects.

Soil site suitability assessment: ISRO is providing GIS and Remote Sensing services for tea plantations in Assam and West Bengal. It would provide access to precise and prompt information necessary for tea gardens to implement pest management and other measures to enhance productivity. In 2010, ISRO, in collaboration with the Tea Board, initiated a pilot project named “Tea Area Development and Management Using RS and GIS.”

Soil Moisture Estimation: The sensor captures signals in the 8-14 μm wavebands, directly measuring surface temperature. What is a function of energy balance, evaporation, and transpiration? The moisture content identified in this manner pertains to a superficial layer of soil.

Assessment and Monitoring Flood: The hydrodynamic model is mostly used for flood monitoring. It assesses the strength, velocity, and propagation of the precipitation system to ascertain the quantity, timing, and location of heavy precipitation for the next zero to three hours (termed NOWCASTING).

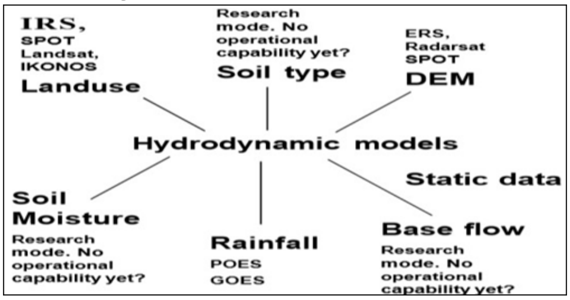

Fig 6: Remote sensing capabilities in Hydrodynamic models of flood

Case Studies Stress Monitoring

In 2003, Santhosh et al. conducted a study on stress detection and the monitoring of field conditions. To use high-resolution picture data obtained from two successful Systems flights in 1999

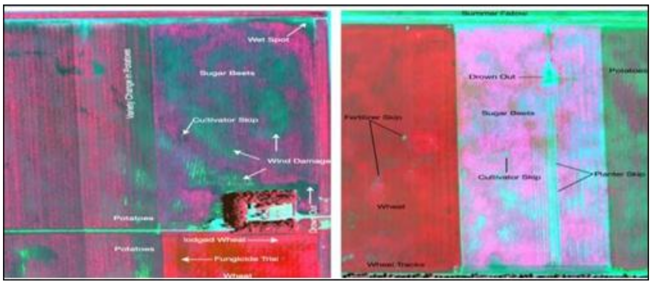

Fig 7: Stress detection and monitoring field condition (Santhosh *et al.* 2003) [14]

They identified regions of stress resulting from wind damage, crop destruction owing to floods, fertilizer omissions, cultivator blights, planter omissions, disease, and lodging. High-resolution imagery was used to ascertain locations requiring ground investigation and to delineate boundaries of problematic regions. The little irregularities undetectable on the ground were readily discernible in the images. The observed planter's skips happened because to the planter turning too near to the saturated region (shown as drowned out). The incident occurred due to the planter being obstructed by muck, of which the operator was unaware. The images illustrated the severity of the issue and enabled the farmer to circumvent the saturated region in the following year. The graphic depicting wind damage underscored the need of using cover crops to mitigate sugar beet stand loss caused by wind.

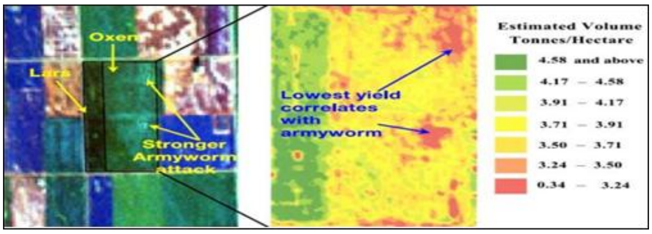

Fig 8: Detection of insect infestation (Santhosh *et al.*2003) [14]

Utilized Landsat images to verify damage inflicted by armyworms on two wheat cultivars, Oxen and Lars. The farmer saw an armyworm infestation in sections of his field during a standard inspection. Due to the challenge of identifying the specific locations of infestation, he subsequently applied insecticide uniformly throughout the whole field. Subsequent to the harvest, the conclusive yield map was juxtaposed with two Landsat images: one captured in June before to the detection of the bug infestation, and the other in late July, many weeks post-application of the pesticide. The very low reflectance regions in the July photograph indicated areas affected by armyworm infestation.

Land use planning

Kumar D. (2017) conducted a research on the monitoring and evaluation of land use and land cover changes in the northeastern area of India, using Landsat MSS, TM, and ETM+ remotely sensed images to analyze spatial and temporal variations from 1977 to 2010. LULC maps of six primary categories—dense forest, open forest, agricultural land, urban settlement, water body, and sand—were produced with a supervised classification method.

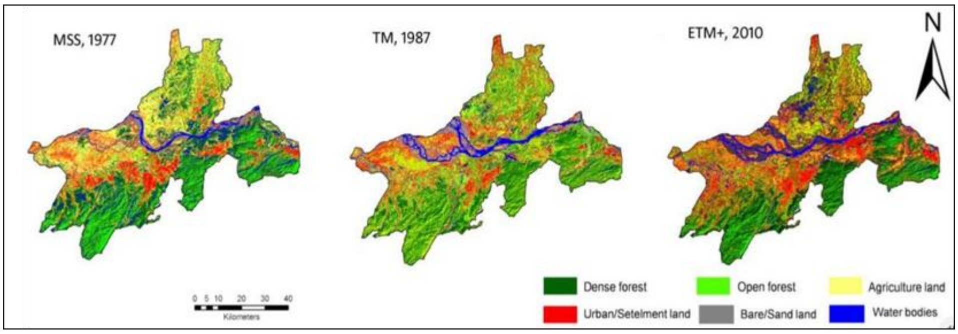

Fig 9: Class map of Vegetation and land cover of the study area in 1977 to 2010

Table 1: Percentage area covered in different land use categories and SHDI during 1977-2010

Year	**Area covered (%)**					
	Dense Forest	**Open Forest**	**Agriculture Land**	**Urban Settlement**	**Sand**	**Water bodies**
1977	29.08	14.75	32.23	12.18	2.22	9.54
1987	23.83	19.42	24.13	21.48	3.54	8.37
2010	22.34	20.06	21.68	24.57	3.23	8.11

(Kumar, D. 2017) [9]

Table 2: Comparison of Satellite Estimated yield of year 2007 with that of field derived yield in the years in 2005 & 2006

Districts	**Yield (kg/ha) 2005**	**Yield(kg/ha) 2006**	**Yield(kg/ha) 2007**
Ujjain	920	930	943
Dewas	910	830	842
Sahajahanpur	930	890	903
Bhopal	650	730	740
Sehore	770	720	730
Raisen	850	810	822
Vidisha	830	670	680
Rajgarh	850	870	883
Indore	780	950	964
Sagar	790	890	903
Guna	850	870	883
Average yield	830	832	844

(Maurya 2008) [12]

Conclusions

It is concluded that remote sensing can furnish precise information to inform agronomic and economic decision-making. Remote sensing is pivotal in identifying and managing various crop challenges, even on small landholdings, with high resolution. Crop yield forecasting is also a crucial element in decision-making and can be achieved through both ground and satellite-based remote sensing. While precision agriculture is predominantly utilized in developed nations, its adoption in India remains limited due to a lack of knowledge and awareness among farmers. Remote sensing is a robust technique for surveying, mapping, and monitoring, and its efficacy can be maximized when integrated with GIS. Crop discrimination and area estimation can be facilitated through Digital Image Processing Classification Algorithms.

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