



Source: <https://eos.com/>

#### 5. Components of Remote Sensing System

A remote sensing system consists of various elements that are related in such a manner that they function in unison in order to gather or analyze crop-related information. This starts with the source of energy, which could be solar energy in the case of passive remote sensing or artificial sources in active remote sensing, like radar. Then, it travels through the atmosphere, where it could scatter or even absorb before arriving at the Earth's surface. Here, the target could be the crop canopy, which could reflect, absorb, or even transmit various forms of electromagnetic waves depending on the crops, their growth stage, as well as their condition.

The reflected or emitted energy sensed by the sensors is recorded in the form of data in different bands of the spectrum. The sensors are placed on platforms, which are in the form of satellites, aircraft, or drones. The data obtained in raw form is sent to the system of data processing, and finally, the information obtained from the data is sent to the end users, who are farmers, scientists, and planners.



Source: <https://www.xyonix.com/>

#### 6. Platforms Used for Crop Monitoring

There are numerous platforms used in the field of remote sensing to carry out crop monitoring effectively, and they vary in spatial resolution and period of coverage and usage. The satellite platforms, like Landsat and Sentinel, are regularly used in the field of crop monitoring at the regional and global levels due to their period of coverage and the availability of data recorded over the years. The platforms are suitable for crops and yield estimation. The use of aerial platforms and their higher spatial resolution are helpful in conducting specific studies of certain agricultural areas through manned aircraft.

Unmanned Aerial Vehicles (UAVs), or drones in short, have gained popularity for use in the fields due to the very high resolution images they can capture. It is highly effective in detecting crop stresses, pests, or nutrient deficiencies in the crops. Sensors used in the ground help in the site-specific monitoring of crops, including soil conditions like moisture or temperatures. They have distinct uses for each situation, making them interchangeable in the monitoring of crops.

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#### INTRODUCTION

Agriculture largely depends on timely and accurate information dealing with crops, soils, and weather. There are traditional methods of crop monitoring, such as field surveys, which are extremely time-consuming, labor-intensive, and expensive. To overcome these limitations, remote-sensing technology emerged recently as a powerful technology for crop monitoring and management.

It is the science of acquiring information about objects or areas by means of distant and no direct physical contact with the object being observed. It plays a crucial role in observing crop growth, health, stress, and productivity over large areas in agriculture.

#### 2. Remote Sensing Defined

Remote sensing has been defined as the acquisition of information about the Earth's surface, by sensors mounted on satellites, aircraft, drones, and other platforms that record reflected or emitted electromagnetic radiation.

In this respect, remote sensing methodology presents a continuous, non-destructive, and wide-scale observation in agricultural field monitoring.

#### 3. Importance of Remote Sensing in Agriculture

Remote sensing has been observed to play a vital role in modern farming as it gathers timely and accurate information regarding crop status. Remote sensing technology has been of great use as a crop monitoring technique, as crop status, growth, and variability can be quickly assessed over a wide coverage that would be nearly impossible to conduct using conventional crop surveys. Remote sensing is incredibly good at monitoring extensive and inaccessible regions of agricultural areas, saving valuable time and labor. Remote sensing also helps to identify any crop stress due to lack of moisture, nutrient deficiencies, or crop diseases and pests at an early stage, allowing timely interventions to correct the crop conditions. Remote sensing greatly reduces the monitoring cost as repeated visits to the crop fields are eliminated.

#### 4. Principles of Remote Sensing

The concept of using RS technology is based on the interaction between EMR and the surface of the Earth, especially crop canopies for agriculture fields. However, RS technology starts with the source of energy, whether it is artificial or natural, particularly solar energy, which is involved in RS technology, especially passive RS technology, whereas other RS technologies, like radar sensors, have artificial source energy. Then, the EMR passes through the atmosphere, where it has the tendency to be absorbed or scattered by some gases, dust, and water vapor, and then it reaches the surface, interacting with crops, being absorbed, reflected, or transmitted according to the crop type and its growing status and health condition.

The reflected or emitted energy can then be detected by sensors installed on satellites, aircraft, or drones. The sensors receive the intensity of the radiations in various bands. The collected data is then processed and interpreted, and digital images are analyzed to extract useful information about crop conditions and performance.

Healthy crops tend to strongly reflect red light due to chlorophyll content, and there is also strong reflection in the near-infrared region due to the leaf structure. Additionally, crops that are stressed or otherwise unhealthy tend to exhibit weak reflection in the near-infrared region but higher reflection in the red region. This phenomenon provides the basis for the calculation of various vegetation indices. This, in turn, has applications for crop health, growth, and productivities.

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कोटा, राजस्थान



## REMOTE SENSING FOR CROP MONITORING

संकलन

Smriti Hansda<sup>1</sup>, Anil Kumar<sup>2</sup>, Manjul Jain<sup>3</sup>,  
Shiv Narayan Dhaker<sup>4</sup>

<sup>1</sup>Assistant Professor (SWCE), College of Agriculture, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

<sup>2,3</sup>Assistant Professor, Department of Agronomy, School of Agriculture, Eklavya University Damoh, Madhya Pradesh-470661

<sup>4</sup>Ph.D., Scholar, Division of Vegetable Science, ICAR-Indian Agricultural Research Institute New Delhi

## 7. Types of Remote Sensing

Remote sensing techniques are broadly classified into two types based on the source of energy used in the process of remote sensing. This has significant importance in the field of agricultural and crop monitoring techniques.

### 7.1 Passive Remote Sensing

Passive remote sensing employs natural sources of energy, mostly solar power, to sense the Earth's surface. Here, the detectors measure the reflected or emitted energy produced by objects such as crop canopies. Most images obtained by satellites and utilized for agricultural purposes belong to this category. Generally, passive remote sensing is greatly utilized for crop recognition, crop growth estimation, and plant health assessment through the NDVI index. But the efficiency of passive remote sensing can sometimes be hampered by the appearance of clouds and atmospheric disorders.

### 7.2 Active Remote Sensing

Active remote sensing systems have their own energy sources for illumination. They also transmit energy towards the target being sensed. After transmitting the energy, they receive reflected energy from the target surface. Some examples of active remote sensing systems include Radar and LIDAR systems. They have the ability to work both during the day and night, making them less affected by weather conditions, clouds, or haze.

## 8. Types of Sensors Used in Crop Monitoring

Various sensors work in remote sensing to gather specific information about crop conditions. Passive optical sensors operate by measuring reflected energy in both the visible and infrared parts of the electromagnetic spectrum. They find wide applications for assessing crop growth, vegetation cover, chlorophyll content, and overall health of crops. Thermal sensors record the temperature emitted from the surface of crops and are useful for detecting water stress, efficiency in irrigation, and plant transpiration rates.

Microwave sensors have longer wavelengths, which can pass through clouds, light rain, and even the top of the soil surface. Thus, they are useful in assessing soil moisture, surface roughness, and crop structure irrespective of weather conditions. Hyperspectral sensors undertake data acquisition in a large number of narrow and continuous spectral bands, offering detailed spectral information. This high spectral resolution makes one precisely recognize different crop species, offer early detection stress, nutrient deficiencies, and diseased symptoms of crops, making hyperspectral sensing highly useful for advanced crop monitoring and precision agriculture.

### 9. Spatial, Spectral and Temporal resolution

These are the three major types of resolution governing the level of detail and usefulness of remote-sensing data for crop monitoring; spatial resolution refers to the size of the smallest feature that can be detected on the ground. High spatial resolution enables precise monitoring of small fields, individual plants, or in-field variability. Spectral resolution refers to the number and width of spectral bands captured by a sensor. Increasing the spectral resolution increases the capacity to identify subtle differences in crop health, nutritional status, or stress conditions. Temporal resolution is the frequency with which data are captured over the same area. Frequent observation is important for crop growth stage monitoring, early detection of crop stress, and planning for appropriate timings of interventions. High spatial, spectral, and temporal resolution will add more value to the accuracy and effectiveness of crop monitoring.

## 10. Crop Identification and Area Estimation

It is a strong tool for the identification of crop types and mapping of the agricultural landscapes. From the satellite or aerial imagery, detailed mapping of the cropping pattern and crop distribution can be performed. It helps in the estimation of crop acreage at regional and national levels to support government planning, policy formulation, and resource allocation. Reliable crop area estimates also help in forecasting production and monitoring food security.

### 11. Crop Growth and Development Monitoring

This is all possible because, through remote sensing, the growth of a crop is monitored at every stage of the season. Satellite images taken during the season track crop phenology, biomass accumulation, and canopy cover. Quantitative information on crop vigor and health is derived from vegetation indices such as NDVI. Such analysis on temporal variations in such indices enables farmers and scientists to identify performance indicators of crops, detect growth anomalies, and make informed decisions regarding nutrient management and irrigation scheduling.

### 12 Crop Health and Stress Detection

Remote sensing is an effective method in the early detection of crop health problems. Remote sensing methods are capable of detecting problems like nutrient deficiency, water stress, and pest/disease infection before the appearance of symptoms. For instance, changes in the color of leaves or the reduction in near-infrared reflectance from leaves can help in the early detection of chlorotic deficiency that is related to water stress. Remote sensing is an effective means for the early detection of crop problems, which in turn enables the implementation of remedial actions in time to avoid loss of economic productivity.

### 13. Crop Yield Estimation

The data obtained through remote sensing technology, along with crop growth and historical data, helps in predicting crop yields more efficiently. This technology helps in estimating crop yields prior to harvesting seasons. This helps farmers to plan crop storage and distribution better. In order to maintain food security and to enable government and other organizations to plan better import, export, and disaster scenarios, it is important to forecast crop yields more efficiently. The uncertainty associated with crop yields can be reduced through crop growth monitoring.

### 14. Role in Precision Agriculture

One of the integral aspects of precision agriculture is remote sensing, a scientific tool that helps in optimizing the production of crops across the agricultural fields. On one hand, remote sensing helps in identifying the variations in agricultural fields, thus enabling specific action in these fields. Farmers may even use variable input applications, including fertilizers, water, or even pesticides, in the agricultural fields, thus avoiding wastage and curtailing costs, which in turn increases efficiency. The combination of GPS, GIS, and remote sensing technologies increases the sustainability of agriculture and thus increases crop production.

### 15. Irrigation and Water Management

In fact, remote sensing, especially thermal and optical imagery, plays a vital role in irrigation and water management of crops in agriculture. Thermal sensors sense different temperatures of crops and soils, an indication of water stress in plants. From this observation, farmers schedule irrigation when necessary to provide water to specific areas where crops need it most, hence a better mode of water use efficiency, thereby conserving this precious commodity called water. Additionally, remote sensing facilitates the monitoring of drought conditions over vast agricultural regions, thus enabling timely intervention and planning. Overall, remote sensing supports precision irrigation practices that enhance crop yield while minimizing water wastage.

## 16. Advantages and Limitations

Advantages from remote sensing in agricultural monitoring include the following:

- Non-contact and fast evaluation of the state of crops in a non-destructive manner
- Large area cover, including regions that may be inaccessible or very remote
- More frequent monitoring allows for timely detection of stress and alterations.
- Cost-effective in the long run, since it cuts down labor and field survey costs.

### 17. Limitations of Remote Sensing

Despite its advantages, there are certain limitations of remote sensing:

- Cloud cover and atmospheric conditions may impact data obtained from an optical sensor.
- High initial investment in sensors, platforms, and software
- It requires technical expertise for data processing and interpretation.
- Has limited accuracy if not validated with field-based ground truth data

### 18. Integration with GIS and GPS

Moreover, the usage of remote sensing gets considerably enhanced with the integration of GIS (Geographic Information System) and GPS (Global Positioning System) technology. With this integration, farmers become capable of carrying out intense analysis of the crops. This integration also provides field-level accuracy using GPS technology. Overall, using this integration of technologies aids farmers in making favorable decisions. It ensures effective implementation of precision agriculture. This integration is also advantageous in carrying out large-scale agricultural planning, which enhances the accuracy of the crop monitoring process.

### 19. Emerging Trends in Crop Monitoring

The technology in RS systems is always improving and allows for new opportunities in the monitoring of crops.

- Artificial Intelligence (AI) and Machine Learning: Automated analysis of crop data.
- High-definition drone images for field-level monitoring
- Real-time crop monitoring for instant decisions
- Smart farming system consisting of intelligent sensors, IoT technology, and data analytics
- Planning in climate-resilient agriculture, which helps in adaptive management in a changing climatic scenario

### 20. Role in Climate Change Adaptation

Remote sensing plays a key role in adapting agriculture to climate change. It helps in:

- Monitoring climate impacts on crops, such as heat stress or delayed growth
- Assessing drought and flood damage to fields and production
- Planning adaptive farming strategies, including crop selection, irrigation scheduling, and resource allocation

## CONCLUSION

"Remote Sensing has revolutionized the monitoring of crops, providing timely, accurate, and extensive information, which enhances the assessment of crop health, prediction of yields, management of water and nutrient resources, and precision agriculture." With the development of technology, remote sensing will remain a vital force in promoting food security globally. In the future, advances in technology will rely on remote sensing for modern agriculture.