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Remote Sensing: A Promising Strategy for Crop Pest Management

Shamik Dey*, Rahul Nandi
Corresponding Email: shamik.dey@jisuniversity.ac.in
Faculty of Agriculture, JIS University, Kolkata, West Bengal, India

ABSTRACT

An overview of the historical and contemporary approaches to remote sensing techniques and their uses, particularly for managing plant diseases and insect pests, is given in this article. The technique of measuring, logging, and analysing the electromagnetic radiation emitted and reflected from the ground target is essential to remote sensing. Applications of remote sensing rely on the spectral behaviour of living things. The detection, prediction, and control of crop pests on various fruit orchards and crops are now accomplished with the help of remote sensing. These tools' primary goals were to gather information that would aid in managing insect pests and reducing the environmental contamination caused by chemical pesticides. Through the use of multi-spectral systems that rely on colour changes in canopy semblance over time, it has also been utilised to assist farmers in the early diagnosis of mite infestation in cotton fields. By quickly and accurately predicting the presence of specific crop pests, remote sensing helps reduce pest damage and management expenses.

KEY WORDS

Remote sensing, management, spectrum, crop pest, EMR

INTRODUCTION

Insect pest detection and control have recently been made easier by the advancement of information technology such as remote sensing sensors, geographic information systems, and GPS (global position systems). The primary premise of remote sensing technologies is the acquisition and interpretation of data about the earth's surface without any physical interaction (Nilsson 1995). The primary source of electromagnetic energy that affects data gathering comprehension is remote sensing. This method uses sensor equipment to measure and record the electromagnetic radiation's emission and reflection from the target area. Digital cameras, video cameras, radio-control systems, and electro-mechanical scanners are examples of different sensing instruments. These methods rely on electromagnetic energy and the way radiation interacts with ground targets (Yang and Everitt 2011). There are two categories of electromagnetic radiation: visible and invisible (UV, gamma, X-ray, infrared microwave, and radio). The sun, of course, generates electromagnetic energy, which travels straight forward at the speed of light through millions of kilometres of empty space to reach the earth's surface and atmosphere. The earth's surface reflects some of these radiations upward, while other radiations are absorbed or released as heat energy. Two fields that are positioned at right angles to each other—the magnetic field and the electrical field—make up this electromagnetic radiation. The wavelength and frequency of electromagnetic radiations are the two primary properties that are crucial to comprehending remote sensing.

This review highlights various topics on the principles of remote sensing systems, their applications for approaches to agriculture; in particular, management of crop pests and also their advantages and limitations.

BASIC PRINCIPLE OF REMOTE SENSING

1. FUNCTIONING OF REMOTE SENSING

Electromagnetic energy is any energy that travels in a harmonic wave pattern at the speed of light. Electromagnetic energy is detectable solely in terms of its interaction with matter, but its propagation is explained by the wave idea. Electromagnetic energy acts in this interaction as if it were made up of numerous separate particles known as photons, each of which possesses qualities including momentum and energy. Through the use of various electromagnetic radiation (EMR) sensors, such as satellites and aerial photography, data can be remotely collected and analysed to provide details about the object or phenomenon being sensed. Through the use of various electromagnetic radiation (EMR) sensors, such as satellites and aerial photography, data can be remotely collected and analysed to provide details about the object or phenomenon being sensed. Data collection and analysis are included in EMR. The satellites sustain their energy by self-emission or the sun, a massive energy source that propagates through the atmosphere and experiences losses from absorption, scattering, and other processes (Acharya and Thapa, 2015).

2. PHYSICAL BASIS FOR REMOTE SENSING

According to (Holmes and MacDonald, 1969) the unique characteristics of electromagnetic radiation from both natural and artificial environments serve as the physical foundation for remote sensing. The collection of data about the earth's surface through measurements of radiated energy generated by sensors mounted on aeroplanes or spacecraft is known as remote sensing in this context. The primary goal of remote sensing is to identify, quantify, document, and examine energy in certain electromagnetic spectrum regions. Three types of electromagnetic field fluctuations can be monitored and utilised to distinguish between different objects: temporal, spatial, and spectrum. Between electric and magnetic forces, energy is transferred over space as electromagnetic radiation. Cosmic rays, gamma rays, X-rays, ultraviolet, visible, and infrared radiation, as well as microwave energy, are all included in the electromagnetic spectrum. The range of the electromagnetic spectrum employed for remote sensing is between 0.3 and 100 µm. The optical wavelengths, which range from 0.3 to 15 µm, are the most desirable electromagnetic spectrum to employ in remote sensing.

3. PHYSIOLOGICAL BASIS OF REMOTE SENSING

This includes leaf reflectance, canopy reflectance, crop canopy temperature and vegetation indices, which are outlines as follows:

- **Leaf reflectance**

When using remote sensing to analyse crop conditions, it is crucial to comprehend the physiological characteristics of plants and how they interact with incident radiation. High absorbance in the blue (0.45 µm), red (0.65 µm), and green (0.55 µm) areas of the spectrum, high reflectance in the NIR (0.75–1.2 µm), and once more extremely high absorbance in the FIR sections of the spectrum are the remarkable characteristics of leaf reflectance. Photosynthetically active radiation (PAR), which is caused by plant pigments such as carotenoids, chlorophyll a, and chlorophyll b, is what causes the absorbance in the visible portion of the EMR spectrum.The interior leaf structure and canopy geometry are to blame for the sudden increase in reflectance at 0.75 µm. The visible portion of the leaf becomes more reflective when there is any physiological disruption. Very significant absorption across the FIR region (1.3–2.5 µm) is mostly caused by leaf wetness (Acharya and Thapa, 2015).

- **Canopy reflectance**

Through various models, strong empirical correlations between ground-measured vegetation biophysical and biochemical characteristics and remotely sensed canopy reflectance have been established. In order to reduce the detrimental effects of interfering elements, such as the surrounding land cover, bare soil, or climatic/atmospheric conditions, mathematical functions of two or more spectral bands are utilised instead of raw reflectance data. These functions are known as vegetation indices (VIs), and each one is made to correlate as best as possible with a certain vegetation aspect (Malenovsky *et al.*, 2009).

- **Crop canopy temperature**
  In order to predict the sunny and shaded components for row crops, (Colaizzi *et al.*, 2010) presented a radiometer footprint model. When there is an aerodynamically rough canopy with an adequate supply of water, crop evapo-transpiration is the fundamental physiological process that controls the canopy temperature; as a result of the heat lost by transpiration, leaves are typically cooler than the surrounding air. The temperature of the canopy rises in comparison to a crop that is not under soil moisture stress, though, as evapo-transpiration falls as a result of partial stomata closure when the moisture in the root zone becomes limiting. Crop production and water status may be determined by measuring the Tc-Ta difference between canopy and air temperatures at the peak surface temperature. The thermal infrared band (8–14 µm) is the most practical wavelength range for canopy temperature detection and quantification. LANDSAT, Advanced Very High Resolution Radiometer (AVHRR), Onboard US National Oceanic and Atmospheric Administration (NOAA), and Indian National Satellite (INSAT) all currently provide data in thermal infrared channels through their thematic mappers (TM).

- **Vegetation indices**
  The greenness, or relative density and health of vegetation, of each picture element, or pixel, in a satellite image is described by an indicator called a vegetation index. (Rouse, 1973) created a transformation of the brightness values of the two opposing spectral bands, red (R) and near infrared (NIR), which he named the vegetative index (VI). An optical sensor's spectral resolution is its capacity to divide wavelengths into smaller increments and resolve characteristics within particular wavelengths of the optical spectrum. The primary goal of spectral vegetation indices is to reduce the effects of soil, atmosphere, and sun-target-sensor geometry while simultaneously enhancing the information found in spectral reflectance data by removing variability caused by vegetation features (such as vegetation cover and LAI). The photosynthesis-active biomass, as well as the health and condition of the plant canopy, can be tracked using the greenness vegetation index (GVI) and the perpendicular vegetation index (PVI), which were later established. Satellite data from programs like LANDSAT, SPOT, IRS-IA, NOAA, and AVHRR is used to create the VI. For worldwide vegetation state monitoring, the AVHRR sensor's normalized difference vegetation index (NDVI) is most frequently utilized. The NDVI is calculated by dividing the difference between the visible and NIR spectrums' luminosity levels by their sum.

TYPE OF REMOTE SENSING PLATFORM

Remote-sensing platforms can be field-based (ground-based) or mounted on aircraft (airborne) and satellites (space-borne).

- **Ground-Based Remote Sensing**
  Ground truth studies usually employ a ground-based platform, like a handheld spectroradiometer. The method of measuring the radiation spectrum that a source emits is called spectroradiometry. This requires that the radiation be divided into its individual wavebands and that each band be monitored independently. It is accomplished in spectroradiometers by dividing the incoming radiation into its component wavebands using a diffraction grating. After that, the radiation of each wavelength is measured using an appropriate detector. Measurement of composite surface reflectance in situ is the focus of field spectroscopy. Process-based models of the Earth's surface and atmosphere are increasingly incorporating spectral data. As a result, in order to help scale up data from the leaf scale to the pixel scale and to provide the data needed to

parameterize models, it is necessary to collect data from terrain surfaces. Reflectance is typically expressed as a "reflectance factor" for a soil surface or vegetation canopy.

According to Prabhakar *et al.*, 2013, reflectance data collected by handheld devices over small areas offers essential ground-truth for interpreting RS data recorded from satellites and aeroplanes, as well as information on the spectral interactions between insect pests and their host plants.

- **Airborne Remote Sensing**
  To capture photographs of the earth's surface, sensors that view down or sideways are installed on aeroplanes. With varying flying heights, Airborne RS can obtain a variety of spatial resolutions, making it versatile. The reflected electromagnetic energy was captured by aerial cameras and recorded on analog films that span wide spectral regions. Digital imaging can be used as a reference database to track changes in the future and the evolution of insect infestation throughout time. A potential disadvantage of aerial systems is the issue of spectral pixel mixing, which is the blending of signals from many sources, including soil, both healthy and diseased plants or vegetation, species, and the variable amounts of cover that are now prevalent in developing countries.

- **Space-Borne Remote Sensing**
  In space-borne remote sensing, sensors are installed aboard a satellite or space shuttle that circles the planet. Weather satellites at a high altitude of 36,000 kilometres frequently employ geostationary orbits. Typically employed for extensive research, satellite RS frequently falls short of the spatial resolution needed for pest management applications.
  The benefits of space-borne remote sensing include: quantitative measurement of ground features using radiometrically calibrated sensors; semi-automated computerized processing and analysis; large area coverage; frequent and repetitive coverage of an area of interest; and comparatively low cost per unit area of coverage.

APPLICATION OF REMOTE SENSING IN CROP PEST MANAGEMENT

Over the past several decades, remote-sensing technology has been widely tested and used for several crop pests in many countries. Here are some examples of insect pests which are controlled by using remote sensing

- **Colorado Potato Beetle**
  Small unmanned aircraft systems (sUAS) and remote sensing have the ability to identify Colorado potato beetles (CPBs) since low flight altitudes enable the capture of images with extremely high spatial resolution. The visual rating of damage showed a strong correlation with the area of CPB damage measured using object-based image processing. Early detection using object-based image processing based on high spatial resolution sUAS remote sensing is possible. Early identification of Colorado potato beetle (CPB) damage opens up more alternatives for precision integrated pest management, which lowers the quantity of insecticides used in a field (Hunt & Rondon, 2017).

- **Mustard Aphid**
  The proliferation of aphids (*Lipaphis erysimi*) in Indian mustard has been modelled at the regional level using satellite-based remote sensing data by Dutta *et al.*, 2008. They used near-surface meteorological characteristics obtained from field observations of pest infestation and data from the National Oceanic and Atmospheric Administration's (NOAA) Television and Infrared Operational Satellites (TIROS) and Operational Vertical Sounder (TOVS). At two test sites in India, Bharatpur and Kalyani, second-order polynomials were found to fit the relationship between the peak aphid count and the TOVS cumulative air temperature at peak. In order to demonstrate the spatial distribution of aphid growing severity zones

(population density) and forecast the dates of severe aphid infestation (peak population) at each grid level in the region, the regional level model was validated over a sizable area of a mustard-growing region for a range of sowing dates, surface air temperature, and specific humidity.

- **Chilli Thrips**
  In the multispectral satellite images, an effort has been made to distinguish between pest-affected and healthy chilli crops using a number of multispectral vegetation indices (Prabhakar *et al.*, 2019). The LSWI and NDWI indices were determined to be the two most significant of the spectral vegetation indices. It was discovered that LSWI outperformed NDWI. Therefore, using satellite data in the Kurnool District of Andhra Pradesh State, India, the LSWI was utilised to estimate the area damaged by thrips and the extent of their infestation.

- **Silver Whitefly**
  The combination of remote sensing, GPS, and GIS gave resource managers useful tools and made it possible to create maps that depicted the distribution of B. *tabaci* bug infestations over wide regions. Insect infestations can be tracked throughout time by using the digital picture as a permanent database (Everitt *et al.*, 2003). Using computerized area estimating techniques and photographic improvements, photographs were collected from a distance of 2000 metres, and various levels and regions of infestation were successfully measured. Photographs taken at 2000 metres showed clear growth patterns of the whitefly-induced sooty mould, which was visible on cotton at 300 metres.

- **Rice Brown Plant Hopper**
  Using remote sensing, it is possible to identify the stress that the BPH causes in rice. According to Zhou *et al.*, 2010, the wavelengths that are most susceptible to BPH infestation at the canopy measurement level are those between 1813 and 1836 nm. Hyperspectral remote sensing was utilised in India to identify *Nilaparvata lugens*, brown planthoppers (BPH), and stress on rice plants in both glasshouse and outdoor settings. The difference in plant reflectance caused by BPH damage was less pronounced at shorter wavelengths (350–730 nm) and more pronounced at longer wavelengths, such as NIR (740–925 nm) and mid-infrared (MIR) (926–1800 nm). This suggested that BPH stress on rice could be detected and stakeholders could be promptly warned.

- **Solenopsis Mealybug**
  Reflectance was measured with a hyperspectral radiometer in the 350–2500 nm spectral region. Green, near-infrared, and shortwave infrared spectral regions showed significant changes for plants with early stages of mealybug *Phenacoccus solenopsis* infestation, and all but blue regions showed the same variations for plants with higher grades of infection. The optimal planning of management is made possible by the potential use of remote sensing to monitor the spatial and temporal distribution of P. *solenopsis* (Prabhakar *et al.*, 2013).

ADVANTAGES OF REMOTE SENSING TECHNOLOGY

1. In comparison to traditional manual scouting techniques, remote-sensing devices can identify pests and direct scouting efforts more quickly.
2. By using remote sensing to detect pest infestations early, variable rate application technology may be able to use fewer pesticides overall.

3. It is possible to examine the spatial population dynamics of pests over time by using non-invasive geospatial approaches to map pest complexes inside fields.
4. To help explain changes brought on by pest infestation, digital imaging offers access to many observations of a field during the growing season.
5. Crop maps for polyphagous insects that infest large agricultural systems can be constructed using satellite remote-sensing data.
6. We can identify how plants react to extremely low levels of pest infestation thanks to sophisticated imaging technologies and reliable processes for calibrating and correcting the leaf reflectance data.
7. Factors such as intensive cultivation, cropping system, crop density all influence pest outbreak. The Earth observing systems are useful in monitoring such ecological conditions favourable for crop pests.

LIMITATIONS OF REMOTE SENSING TECHNOLOGY

1. Large measurement uncertainty, challenging data interpretation, and the requirement to comprehend theoretically how the equipment is performing the measurements are all possible.
2. The crop systems maps that are obtained by remote sensing platforms and utilised to power the models are frequently intricate and challenging to create.
3. In-field heterogeneities of crop vigour and damage assessment are currently detected using high-resolution multispectral data, however these data are frequently unsuitable for early crop pest identification.
4. When supplying basic baseline data, mismatched picture pixels on the ground can negatively impact high-resolution airborne RS.
5. The issue of spectral pixel mixing, which occurs when signals from many objects, including soil and both healthy and infected vegetation, mix, may have an impact on the outcome.
6. Satellite platforms' availability of cloud-free data, especially during the kharif season.

CONCLUSION

In conclusion, new developments in remote sensing technology have led to an increase in the number of applications in many agricultural approaches, particularly in the management of crop pests. The information technology revolution, as well as the interpretation and data analysis of such high-tech applications, offer significant benefits in expanding and bolstering the input knowledge that aids in the advancement of numerous research domains. In recent years, remote sensing has been seen as general-purpose data for a wide range of consumers with somewhat different needs. By enabling the examination of various environmental factors and accessible natural sources as a whole, remote sensing has emerged as one of the most promising technologies for crop pest management. However, there is a need for advancements in the design and operation of remote sensing systems to lower costs and improve output imaging quality.

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