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Integrated Pest Management in Agriculture through Remote Sensing

Yukti Rahangdale and Jagrati Upadhyay
Department of Agriculture, Managalayatan University Jabalpur (M.P.) 483001

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Abstract

Agriculture plays a dominant role in the growth of Indian economy contributing nearly 28 per cent towards Gross Domestic Product (GDP). Insect pests (14 per cent), diseases and weeds inflict enormous losses to the potential agricultural production. The yield losses due to pest population can be suppressed to be greater extent if their incidence is known well in advance so that timely adoption of remedial measures is possible. This led to a concept of „forecasting‟ which is an important component of the IPM strategy. Forecasting methods are based on the models that utilize data on weather parameters, farmer‟s eye estimates, agrometerological conditions, remote sense crop reflectance observations *etc.* either separately or in an integrated manner. The visual detection of plant responses to biotic stresses with acceptable levels of accuracy, precision and speed is difficult. These responses affect the amount and quality of electromagnetic radiation reflected from crop canopies. Hence, remote sensing is the technique involving instruments that measure and record the changes in electromagnetic radiation and provides better means of objectively quantifying biotic stresses in comparison to visual assessment methods. In this review article, briefed the concept, principles and types of remote sensing with some case studies to augment the acquaintance on the concept of "Remote Sensing" as pest forecasting model.

Keywords: - Agrometerologycal condition, Gross domestic product, plant response.

Introduction

A sustainable approach to Remote Sensing and IPM in the context of IPM, early detection and accurate mapping of incipient disease and insect infestations can assist managers in optimizing within-field placement of agricultural practices with numerous environmental benefits. Such mapping can assist farmers in more accurately applying preventative measures such as pesticides and fungicides, matching chemical application to pest density across a field and assisting in the detection of weeds for targeted herbicide application.

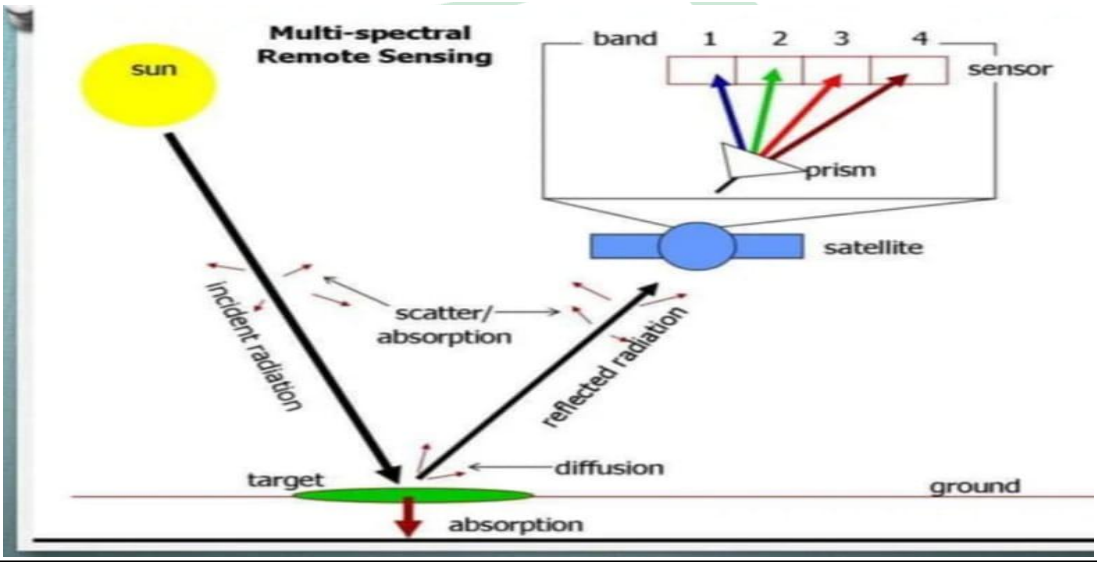
et al., 2006). Such focused applications can reduce the number of chemicals used,

Thus reducing overall costs, as well as the potential for pest resistance. Labour costs incurred for plant monitoring and removal can also be reduced There are also studies showing that the targeted application of pesticides over a field can control pests while increasing beneficial parasitoids and predators .

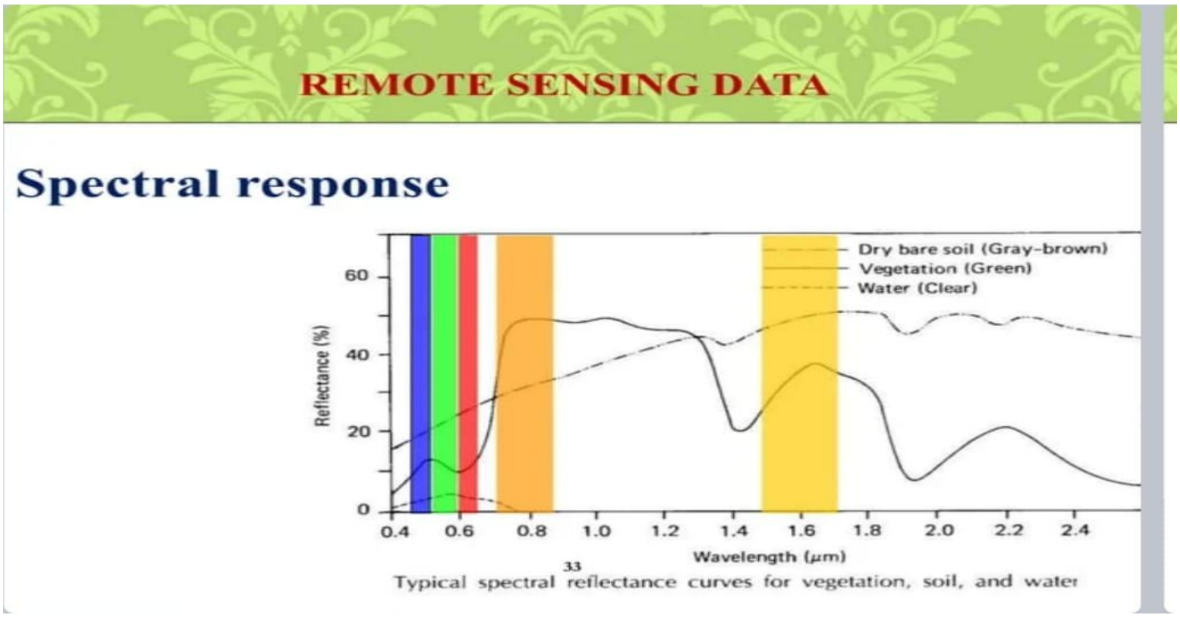
Geospatial tools are increasingly seamless in integration: GPS is used to capture precise and accurate information in the field, remote sensing imagery is used to map conditions across a broad area over time, spatial analyses are used to understand the patterns of plant stress or mortality, and all data are stored in, and in many cases analyzed within a GIS environment and integrated into the Internet .While there are examples of such comprehensive and integrated geospatial tools in the agricultural setting.

GIS and GPS use to

They describe a "high tech" category, which includes multi-nutrient variable rate application machinery, satellite and/or aerial imagery and analysis, variable seeding with GPS, all integrated through a GIS, and a "low tech" category, which includes single variable rate application with support from field mapping and soil sampling with GIS and GPS. They also describe the large numbers of farmers who use none of the geospatial tools, but still perform site-specific farm management, including manual variable rate application and variable rate seeding without GPS; and the farmers who use no site-specific management.



There are some of the advances in the comparatively lesser-used geospatial tools of RS and SA in their application to integrated agricultural pest management, and outlines some of the remaining challenges farmers face in the adoption of geospatial technologies.



What is IPM?

Integrated Pest Management (IPM) is an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices. IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. This information, in combination with available pest control methods, is used to manage pest damage by the most economical means, and with the least possible hazard to people, property, and the environment.

The IPM approach can be applied to both agricultural and non-agricultural settings, such as the home, garden, and workplace. IPM takes advantage of all appropriate pest management options including, but not limited to, the judicious use of pesticides. In contrast, *organic* food production applies many of the same concepts as IPM but limits the use of pesticides to those that are produced from natural sources, as opposed to synthetic chemicals.

How do IPM programs work?

IPM is not a single pest control method but, rather, a series of pest management evaluations, decisions and controls. In practicing IPM, growers who are aware of the potential for pest infestation follow a four-tiered approach. The four steps include:

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- **Set Action Thresholds**:- Before taking any pest control action, IPM first sets an action threshold, a point at which pest populations or environmental conditions indicate that pest control action must be taken. Sighting a single pest does not always mean control is needed. The level at which pests will become an economic threat is critical to guide future pest control decisions.
- **Monitor and Identify Pests**- :Not all insects, weeds, and other living organisms require control. Many organisms are innocuous, and some are even beneficial. IPM programs work to monitor for pests and identify them accurately, so that appropriate control decisions can be made in conjunction with action thresholds. This monitoring and identification removes the possibility that pesticides will be used when they are not really needed or that the wrong kind of pesticide will be used.
- **Prevention**:- As a first line of pest control, IPM programs work to manage the crop, lawn, or indoor space to prevent pests from becoming a threat. In an agricultural crop, this may mean using cultural methods, such as rotating between different crops, selecting pest-resistant varieties, and planting pest-free rootstock. These control methods can be very effective and cost-efficient and present little to no risk to people or the environment.
- **Control**:- Once monitoring, identification, and action thresholds indicate that pest control is required, and preventive methods are no longer effective or available, IPM programs then evaluate the proper control method both for effectiveness and risk. Effective, less risky pest controls are chosen first, including highly targeted chemicals, such as pheromones to disrupt pest mating, or mechanical control, such as trapping or weeding. If further monitoring, identifications and action thresholds indicate that less *risky* controls are not working, then additional pest control methods would be employed, such as targeted spraying of pesticides. Broadcast spraying of non-specific pesticides is a last resort.

Do most growers use IPM?

With these steps, IPM is best described as a continuum. Many, if not most, agricultural growers identify their pests before spraying. A smaller subset of growers use less risky pesticides such as pheromones. All of these growers are on the IPM continuum. The goal is to move growers further along the continuum to using all appropriate IPM techniques.

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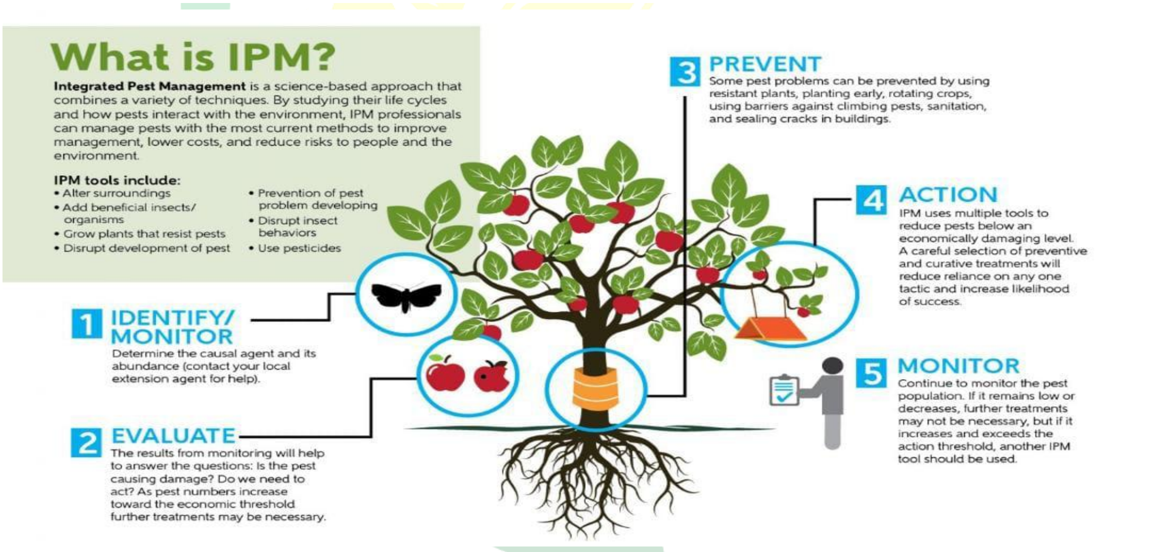
How do you know if the food you buy is grown using IPM?

In most cases, food grown using IPM practices is not identified in the marketplace like *organic* food. There is no national certification for growers using IPM, as the United States Department of Agriculture has developed for organic foods. Since IPM is a complex pest control process, not merely a series of practices, it is impossible to use one IPM definition for all foods and all areas of the country. Many individual commodity growers, for such crops as potatoes and strawberries, are working to define what IPM means for their crop and region, and IPM-labeled foods are available in limited areas. With definitions, growers could begin to market more of their products as *IPM-Grown*, giving consumers another choice in their food purchases.

If I grow my own fruits and vegetables, can I practice IPM in my garden?

Yes, the same principles used by large farms can be applied to your own garden by following the four-tiered approach outlined above. For more specific information on practicing IPM in your garden, you can contact your state Extension Services for the services of a Master Gardener.



Integrated Pest Management

Integrated Pest Management (IPM) was developed in response to steadily increasing pesticide use that resulted in pest control crises (outbreaks of secondary pests and pest resurgence following development of pesticide resistance) and increasing evidence and awareness of the full costs to human health and the environment of the intensive use of pesticides.

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IPM is the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations. It combines biological, chemical, physical and crop specific (cultural) management strategies and practices to grow healthy crops and minimize the use of pesticides, reducing or minimizing risks posed by pesticides to human health and the environment for sustainable pest management.

IPM is a dynamic process that makes use of an ecological systems approach and encourages the user or producer to consider and use the full range of best pest control options available given economic, environment and social considerations. IPM is based on ecology, the concept of ecosystems and the goal of sustaining ecosystem functions. It promotes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms.

The role of IPM in sustainable agriculture:

- **Applies sustainable pest control.** IPM builds on ecosystem services such as pest predation while protecting others, such as pollination. It also contributes to increased farm productivity and food availability by reducing pre- and post-harvest crop losses.
- **Reduces pesticide residues**. IPM contributes to food and water safety, as reducing the amount of pesticides used in turn reduces residues in food, feed and fiber, and environment.
- **Enhances ecosystem services**. IPM seeks to maintain the national crop ecosystem balance. It conserves the underlying natural resource base (i.e. soil, water and biodiversity) and enhances ecosystem services (i.e. pollination, healthy soils, diversity of species).
- **Increases income levels**. IPM reduces production costs through reduced levels of pesticide use. Higher quality crops (with less residues) can command better prices in markets and contribute to increased farmer profitability.
- **Strengthens farmer knowledge**. IPM promotes farmer stewardship, increases farmer knowledge of ecosystem functioning adapted to their local context.

Remote Sensing and IPM

In the context of IPM, early detection and accurate mapping of incipient disease

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and insect infestations can assist managers in optimizing within-field placement of agricultural practices (variable rate technology) (Pinter et al., 2003; Scotford& Miller, 2005; Weisz et al., 1995) with numerous environmental benefits. Such mapping can assist farmers to more accurately apply preventative measures such as pesticides and fungicides, matching chemical application to pest density across a field (Weisz et al., 1995; Zhang et al., 2003), and assist in the detection of weeds for targeted herbicide application (Christensen et al., 2003; Heiselet al., 1996; Langner et al., 2006). Such focused applications can reduce the amount of chemical used, reducing overall costs, as well as the potential for pest resistance Labor costs incurred for plant monitoring and removal can also be reduced . There are also studies showing that targeted application of pesticides over a field can control pests while increasing beneficial parasitoids and predators . Geospatial tools are increasingly seamless in integration: GPS are used to capture precise and accurate information in the field, remote sensing imagery are used to map conditions across a broad area over time, spatial analyses are used to understand the patterns of plant stress or mortality, and all data are stored in, and in many cases analyzed within a GIS environment and integrated into the Internet. While there are examples of such comprehensive and integrated geospatial tools in the agricultural setting and Morgan et al. (2002), all of whom describe examples of remote sensing, GIS and GPS use to answer a broad suite of farm-related questions), most PA applications rely on GPS and GIS rather than remote sensing and spatial analysis.

A recent annual report on the adoption of geospatial tools in the agricultural sector describe two levels of technology adoption in the United State which are largely distinguished by the use of remote sensing imagery and analysis. They describe a “high tech” category, which includes multi-nutrient variable rate application machinery, satellite and/or aerial imagery and analysis, variable seeding with GPS, all integrated through a GIS, and a “low tech” category, which includes single variable rate application with support from field mapping and soil sampling with GIS and GPS. They also describe the large numbers of farmers who use none of the geospatial tools, but still perform site specific farm management, including manual variable rate application and variable rate seeding without GPS; and the farmers who use no site specific management.This chapter details some of the advances in the comparatively lesser-used geospatial tools of RS and SA in their application to integrated agricultural pest management, and outlines some of the remaining challenges farmers face in the adoption of geospatial technologies.

Remote Sensing

Remote sensing and digital image analysis are methods of acquisition and interpretation of measurements from a remote target without physical contact between the measuring device and the object. The object can be analyzed many times, non-invasively and without damage. Remote sensing platforms can be field-based, or mounted on aircraft and satellites; and the data they capture is often characterized by four resolutions: (1) spatial (what the smallest resolvable unit is on the ground, also called the pixel), (2) spectral (how sensitive the spectra is sampled), (3) temporal (how often the data can be captured) and (4) radiometric (the ability to discriminate very slight differences in reflected or emitted energy). Common pixel sizes are wide-ranging: weather satellites have pixel resolutions larger than 1 km; the AVHRR sensor, an early multispectral sensor still in use has a 1km pixel size; the series of Landsat sensors have 30 m pixels, and there is a range of newer commercial satellites (e.g. Quickbird and IKONOS) that have near and under 1 m spatial resolution. Sub-meter resolution imagery is increasingly common, especially with the use of aircraft-borne sensors. The spectral information contained in imagery can include multispectral (<10 bands of spectra, covering the visible and NIR portion of the spectrum), hyperspectral (10s to 100s of bands, covering a wider range of the spectrum) and thermal spectra (covering longer wave infrared emittance spectra).

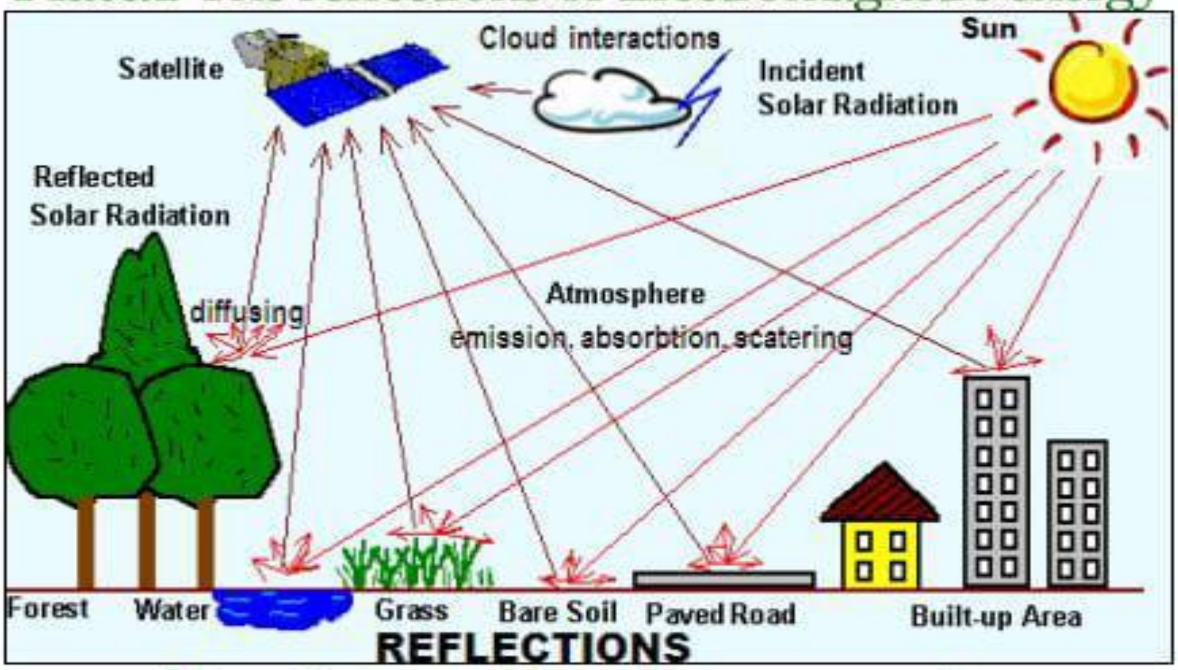
Management of crop health and detection of stress from pests, diseases and weeds can make use of remote sensing technology. Weeds can sometimes be mapped directly in imagery, and plant stress from disease or insect infestation can be expressed by a plant in many ways. Stress can influence stomata closure and transpiration rates, and impede photosynthesis. Other stress symptoms include morphological changes such as leaf curling, change in leaf angle, wilting or stunting, and chlorosis, necrosis, or premature abscission of plant parts. Detection and rapid accurate quantification of early symptoms are important in an IPM context, and efforts at remotely detecting plant stress due to disease or insect activity utilize principles of biophysical remote sensing outlined in several sources. Plants stressed by disease display changes in absorption and reflectance in visible and near-infrared (NIR) light due to decreases in chlorophyll content, changes in other pigments, and changes to the internal cellular structure of the leaves . Plant stress usually results in an increase in visible reflectance (due to a decrease in chlorophyll and a resulting decrease in absorption of visible light), and a decrease in NIR reflectance from changes in the internal leaf structure. Weed mapping relies on weed plant spectra being different from the crop target . Platforms used for vegetation mapping typically are sensitive in the following spectral regions: near-infrared (NIR) (725 – 900 nm), green (550 nm), red (650 – 690 nm) and thermal (8,000 – 12,000 nm). Utilization of these characteristic alterations in absorption and reflectance captured with aerial.

Principle of remote sensing

Every object reflects/scatters a portion of electromagnetic energy incident on it depending on its physical properties. In addition, objects emit radiation depending on their temperature and emissivity. The reflectance/emittance of any object at different wavelengths follow a pattern which is characteristic of that object, known as spectral signature .

In general the healthy plants give a higher reflectance in the near infrared region and a lower one in the visible region and opposite is the situation with the infected plants . The plant stress usually results in an increase in visible reflectance due to decrease in chlorophyll and resulting decrease in absorption of visible light.

Plate.1 The reflections of Electromagnetic energy



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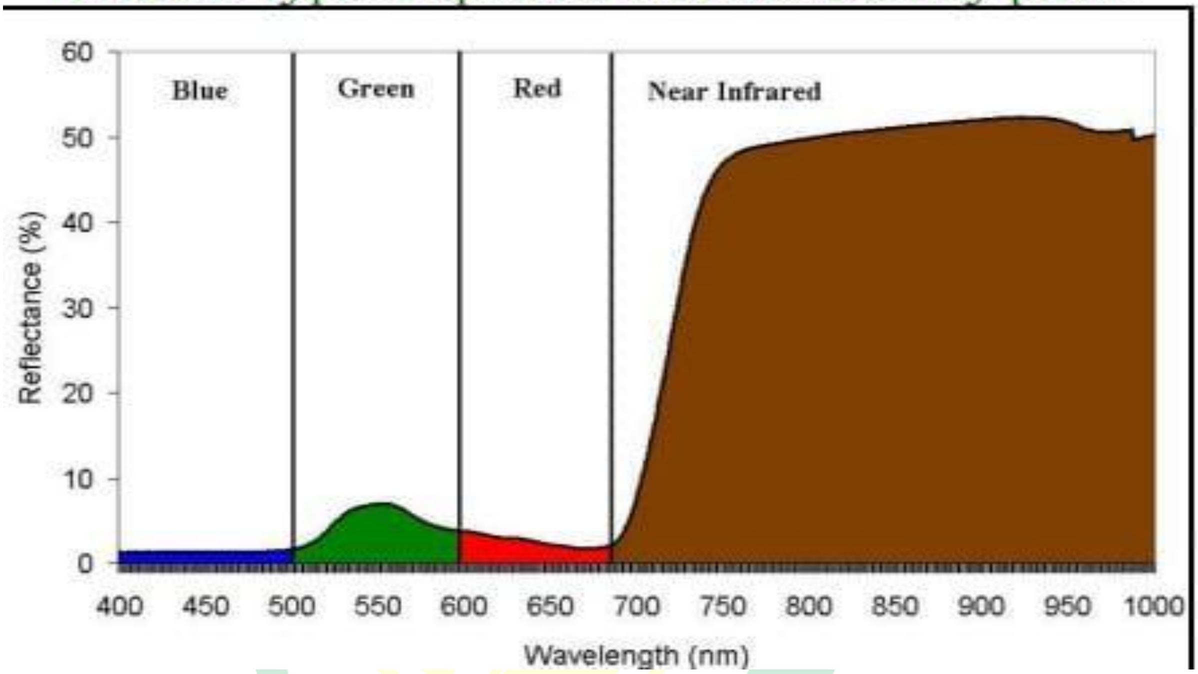
Remote sensing is the technique that measures the changes in electromagnetic radiation due to pest infestation and provides better means of objectively quantifying biotic stresses in comparison to visual assessment methods besides repeatedly used to collect sample measurements non-destructively and non-invasively.

Plate.2 Typical spectral curve of healthy plant



Types of remote sensing platforms

Three types of remote sensing platforms are basically involved to predict the plant biotic stresses.

Types of spectral scanner scan

Depending on the band width the number of bands and contiguous nature of recording spectral scanner scan be of two types (Fig. 1).

Kinds of resolution

The data the RS sensors capture is often characterized by four kinds of resolutions Spatial (the smallest resolvable unit on the ground, also called the pixel)

Applications of remote sensing in pest management

Photography and videography from aircraft and from the groundSatellite-borne multispectral scanning (MSS)Thermal imaging.Ground based and airborne radar methods (Riley, 1989)

Remote Sensing (RS) techniques in pest management

- The observation of insect themselves
- The detection of the effects that insects produce (Symptoms)
- The monitoring of environmental factors likely to influence insect occurrence/ abundance, potential damage

Studies on incidence of insects through RS

- The effect of Russian Wheat aphid and green bugs on leaf reflectance by wheat seedlings is due lower chlorophyll concentrations and displayed wavelengths of 500-525, 625-635 and 685-695 nm.
- It is possible to detect the stress caused by the BPH in rice using remote sensing. 1813-1836 nm may be most sensitive to BPHs infestation at canopy measurement level.
- Color and colour-infrared aerial photography with conventional camera have been used effectively to delineate damage caused by a number of serious pests like hemlock looper and Bark beetles . The stress caused by aphid species is detected by mapping of Mississippi river delta revealed the most probable areas where insects might attack the wheat crop is predicted through remote sensing .

Studies on distribution of insects through RS

Aerial photography was used to study distribution of host plants of tropical fruit flies in Hawaii, El Salvador and Mexico. The map areas of milkweed, a major host of monarch butterfly . SPOT and Landsat 5 high resolution imagery have been used to identify rice production areas in northern Luzon, the Philippines that could act as host for brown planthopper, *Nilaparvatalugens.*

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