ISSN: 2347-2723 IMPACT FACTOR : 2.0260(UIF) VOLUME - 4 | ISSUE - 9 | APRIL - 2017

REVIEW OF LITERATURE

REMOTE SENSING FOR DETECTION OF PLANT STRESS

Prof. Kamble S. B.

ABSTRACT

Remote sensing (RS) of biotic stress is based on the assumption that stress interferes with photosynthesis and physical structure of the plant at tissue and canopy level, and thus affects the absorption of light energy and alters the reflectance spectrum. Research into vegetative spectral reflectance can help us gain a better understanding of the physical, physiological and chemical rocesses in plants due to pest and disease attack and to detect the resulting biotic stress. This has important implications to effective pest management. This review provides an overview of detection of various biotic stresses in different crops using various RS platforms. Previous work pertaining to the use of RS technique for assessing pest and disease severity using different RS techniques is briefly summerized.

The available sources of ground based, airborne and satellite sensors are presented along with various narrow band vegetation indices that could be used for characterizing biotic stress. Using relevant examples, the merits and demerits of various RS sensors and platforms for detection of pests and diseases are discussed. Pest surveillance programs such as field scoutings are often expensive, time consuming, laborious and prone to error. As remote sensing gives a synoptic view of the area in a non-destructive and non- invasive way, this technology could be effective and provide timely information on spatial variability of pest damage over a large area. Thus remote sensing can

guide scouting efforts and crop protection advisory in a more precise and effective manner. With the recent advancements in the communication, aviation and space technology, there is a lot of potential for application of remote sensing technology in the field of pest management.

KEYWORDS : *Remote sensing (RS) , physical, physiological and chemical rocesses .*

INTRODUCTION

Plant stress is defined as a significant deviation from the optimal conditions for plant growth that could cause harmful effects when the limit of plants' ability to adjust is reached (Larcher 1995) . Plant stress can affect almost every part of a plant, although typically one or few plant structures are influenced depending on the age and the source of stress. In case of biotic stress, the mechanism of damage by the pest largely influences the physiological response of plants, which is in turn gets manifested into typical symptoms. Plants may respond to pest and disease stress in a number of ways, including leaf curling, wilting, chlorosis or necrosis of photosynthetic plant parts, stunted growth, or in some cases reduction in leaf area due to severe defoliation.

Major types of pest damage mechanisms are classified as germination reduction, stand reduction, light stealing, assimilation rate reduction, assimilation sapping, tissue consumption and turgor reduction (Boote et al. 1983 ; Aggarwal et al. 2006) . While many of these responses are difficult to visually quantify with acceptable levels of accuracy, precision, and speed, these same plant responses will also affect the amount and quality of electromagnetic radiation reflected from plant canopies. Thus, remote sensing instruments that measure and record changes in electromagnetic radiation may provide a better means to objec-tively quantify disease stress than visual assessment methods. Furthermore, the effects of many pest/disease infestations are often not noticeable to the human eye, until it reaches an advanced stage when it becomes too late to control the outbreak. Remote sensing provides an alternative cost effective method to obtain detailed spatial information for entire crop fields at frequent intervals during the cropping season (Datt et al. 2006) . Additionally, remote sensing can be used repeatedly to collect sample measurements non-destructively and non-invasively (Nilsson 1995 ; Nutter et al. 1990 ; Nutter and Litterell 1996) .

PRINCIPLE OF OPERATION

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in con-tact with the object under investigation. When electromagnetic energy is incident on any feature on the earth surface, three energy reactions with the feature are possible: reflection, absorption and/or transmission (Lillesand et al. 2004) . The portion of energy reflected, absorbed or transmitted will vary for different earth features depending on their material type and condition. Even within a given feature type, the portion of reflected, absorbed and transmitted energy will vary at different wave-lengths. Thus, two features may be distinguishable in one spectral range and be very different in another wavelength band. Because many remote sensing systems operate in the wavelength regions in which reflected energy predominates, the reflectance properties of earth surface are very important. The reflectance characteristics of earth surface features may be quantified by measuring the portion of incident energy that is reflected (Panda 2005) . Reflectance is measured as a function of wavelength and is called spectral reflectance. A graph of the spectral reflectance of an object as a function of wavelength is termed as 'spectral reflectance curve' (Fig. 16.1).

The configuration of spectral reflectance curve gives us the insights into the spectral characteristics of an object and has a strong influence on the choice of wavelength regions in which remote sensing data need to be acquired for particular application.

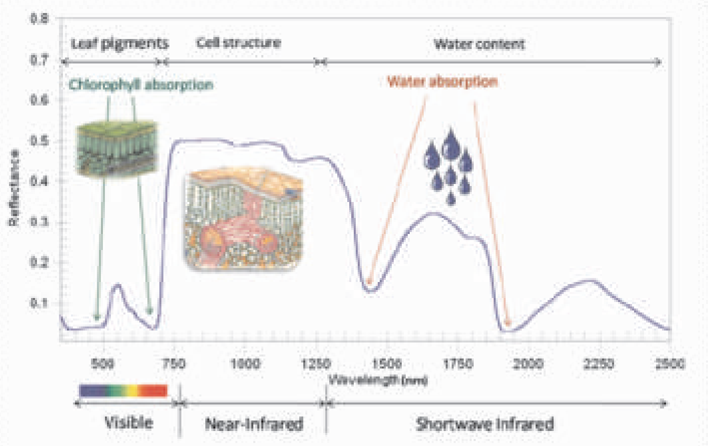

Fig. 16.1 Typical spectral reflectance curve of healthy vegetation depicting different absorption peaks

Physical and physiological basis for the reflectance of visible and near infrared radiation from vegetation has been extensively studied (Knipling 1970 ; Zhang et al. 2003) . Reflectance spectra of crop canopies are known to be a function of canopy optical properties with contributions from biophysical and biochemical attributes of vegetation, viewing geometry of detector, illumination conditions of the surroundings, and background effects (Asner 1998 ; Barrett and Curtis 1992 ; Goel 1998 ; Myneni et al. 1989) . The three dimensional orientation of biophysical attributes of vegetation provides a better architecture for photon reception from incident radiation, yet creates variation in the spectral characteristics. The biochemical components of the plant parts also influence plant reflectance spectra (Buschman and Nagel 1993 ; Baret et al. 1994 ; Kupiec and Curran 1995) .

TYPES OF REMOTE SENSING PLATFORMS

Remote sensing platforms can be field-based (ground based), or mounted on aircraft (airborne) or satellites (space borne). Ground-based platform, such as handheld spectroradiometer, is typically used for ground truth study. Airborne RS is flexible and able to achieve different spatial resolutions with different flight altitudes. Satellite RS is generally for small scale (large area) study but it often times cannot meet the requirement of spatial resolution in applications. However, with recent advent of high resolution sensors, there is lot of potential for large scale (small area) field applications.

CONCEPT OF SPECTRAL VEGETATION INDEX

A vegetation index (VI) can be defined as a dimensionless, radiation based measurement computed from the spectral combination of remotely sensed data. Numerous vegetation indices, broadband as well as narrowband, have been developed to detect plant stress (Carter 1994) . Single wavebands are often good indicators of biochemical constituents, but are subject to variability caused by environmental factors such as illumination differences including solar angle and background scattering. Vegetation indices also lead to data dimensionality reduction and therefore might be helpful in terms of data processing and analysis. Such indices are also able to overcome the limitations of single band applications by minimizing external factors, and therefore correlate more closely with vegetative biochemical constituents (Delalieux et al. 2009) . VIs also enhances sensitivities to green vegetation spectral signals and reduces external effects such as noise related to soil and atmospheric influences (Zhao et al. 2005). Ratios can be simple two band ratios or can include a combination of bands. Several researchers have proposed several ratios for different applications (Tables 16.2 and 16.3). These VIs can be divided into four broad groups (Mirik 2001) .

GROUND BASED REMOTE SENSING OF BIOTIC STRESS

Spectroradiometry is the technique of measuring the spectrum of radiation emitted by a source. In order to do this the radiation must be separated into its component wavebands and each band measured separately. It is achieved by diffraction grating technique within the spectroradiometers to split the radiation entering the system into its constituent wavebands. A suitable detector is then used to quantify the radiation of each wavelength (ASD 1999) . The field spectroscopy concerns in situ measurement of the reflectance of composite surfaces. Increasingly, spectral data are being incorporated into process-based models of the Earth's surface and atmosphere, and it is therefore necessary to acquire data from terrain surfaces, both to provide the data to parameterise models and to assist in scaling-up data from the leaf scale to that of the pixel (Milton et al. 2009).

GROUND BASED – MULTISPECTRAL

There are number of studies on use of multispectral radiometers for pest and disease detection. Maize leaves infected with dwarf mosaic virus showed significantly lower reflection even before visible symptoms could be noted, when compared to healthy leaves (Ausmus and Hilty 1971) . Such a change in reflectance characteristics was used to make an early diagnosis of disease symptoms. Changes in citrus soft scale infestation levels were detectable because the honeydew excreted by the scale insects was an excellent growth medium for a sooty mold fungus that showed very low reflectance in both the visible and NIR wavelength regions and tended to accu-mulate as the season progressed (Gausman and Hart 1974) . Infection of Sclerotina stem rot in oil seed rape, net blotch disease in barley and barley stripe disease (Nilsson 1991) were studied using ground based radiometry. The highest correla-tions with disease severity were found in the NIR bands, while some effects were traced to the visible bands. High correlations were also reported between disease incidence and the NIR to red and the green-to-red reflectance ratios.

AIRBORNE REMOTE SENSING OF BIOTIC STRESS

Studies on the use of airborne remote sensing for crop disease assessment started long time ago. For example, in the late 1920s, aerial photography was used in detecting cotton root rot (Taubenhaus et al. 1929). The use of infrared photographs was first reported in determining the prevalence of certain cereal crop diseases (Colwell 1956). William Collins and Sheng-Huei Chang, along with Hong Yee Chiu developed the first airborne spectrometer for vegetation stress applications based on variations in the wavelength position of the red-edge (Chiu and Collins 1978) .

AIRBORNE – MULTISPECTRAL

Hart and Meyers (1968) used colour-infrared (CIR) photography and hyperspectral reflectance data to identify citrus trees infected with brown soft scale insects (Coccus hesperidum). Airborne RS technology has been employed for detecting crop disease and assessing its impact on productivity (Heald et al. 1972 ; Henneberry et al. 1979; Schneider and Safir 1975). Wheat disease severity assessment has been advocated using airborne remote sensing (Kanemasu et al. 1974). Detection of coconut wilt disease is one of the earliest applications on use of airborne RS for pest detection from India (Dakshinamurti 1971) . The recent advent of high spatial reso-lution aircraft-borne imaging instrumentation has demonstrated several applications in pest management. Such multispectral instruments typically capture reflectance in three visible and the NIR band, and thus their imagery is often used to map vegetation.

AIRBORNE – HYPERSPECTRAL

Hyperspectral data recorded from low attitude flights usually have high spectral and spatial resolution, which can be very useful in detecting stress in green vegetation. An airborne visible infrared imaging spectrometer (AVRIS) image with 224 bands with the wavelength range of 0.4–2.5 m was used to detect stress in tomatoes induced by late blight disease in California, USA (Zhang et al. 2003) and strawberry spider mite (Tetranychus turkesni U.N.) in cotton (Fitzgerald et al. 2004). Williams et al. (2004) developed hyper spectral signatures using airborne data that charac-terised individual tree species and health class which in turn may be used to classify hyperspectral images to produce maps of emerald ash borer host trees.

SPACE BORNE – HYPERSPECTRAL

Satellite based imaging sensors, equipped with improved spatial, spectral and radiometric resolutions offer enhanced capabilities over those of previous systems. The Hyperion sensor, on board the EO-1 satellite provides continuation of broad spatial coverage with increased spectral sensitivity (over 200 bands from 0.4 – 2.5 nm) that can help in plant disease or pest damage discrimination.

CONCLUSIONS

Over the years lot of information has been generated on characterizing biotic stress using hand held multi spectral radiometry. With the advent of hyperspectral radiom-etry, it has been possible to have insights into more details and better understanding of the crop stress induced by insect pests and diseases. It was also feasible to differentiate between biotic and abiotic stresses with reasonable accuracy using hyperspectral radiometry. Reflectance data obtained by ground based remote RS provides vital information to understand spectral interactions between pests damage on the host plants and also to collect fundamental ground-truth information required for interpretation of remote sensing data obtained from space borne and airborne platforms. Satellite remote sensing provides sufficient data for large scale studies, but it has limitations such as temporal and spatial resolution, and more importantly, availability of cloud free data. On the other hand, airborne systems have a higher resolution and time flexibility and provide sufficient lead time for dissemination of crop protection advisory. Though application of airborne RS for biotic stress has been in vogue in several developed countries, it is yet to find wide usage in many of the developing countries. One of the main reasons could be the high cost involved, availability of suitable sensors, small farm holdings and diverse cropping systems.

REFERENCES

1. Aggarwal PK, Kalra N, Chander S, Pathak H (2006) InfoCrop A generic simulation model for assessment of crop yields, losses due to pests and environmental impact of agro-ecosystems in tropical environments 1 Model description. Agric Syst 89:1–25.
2. Apan A, Held A, Phinn S, Markley J (2004) Detecting sugarcane orange rust disease using EO-1 Hyperion hyperspectral imagery. Int J Remote Sens 25:489–498.
3. Apan A, Dutt B, Kelly R (2005) Detection of pests and disease in vegetable crops using hyperspectral sensing: a comparison of reflectance data for differential sets of symptoms. In: Proceedings of Biennial Conference of the Spatial Sciences Institute September 2005 Melbourne Spatial Sciences Institute, ISBN 0-9581366-2-9.
4. Aquino VM, Shokes FM, Berger RD, Gorber DW, Kucarek TA (1992) Relationships among late leaf spot healthy leaf area duration canopy reflectance and pod yield of peanut. Phytopathology 82:546–552.