*Biological Forum – An International Journal* 11(1): 131-136(2019)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

# Abiotic Stress Detection using Hyperspectral Remote Sensing

***Jonali Goswami[1], K.K. Sarma[1], Ranjan Das[2] and P.L.N. Raju[1]***

*[1]North Eastern Space Applications Centre, Umiam (Meghalaya) INDIA*
*[2]Department of Crop Physiology, Assam Agriculture University, Jorhat (Assam) INDIA*

*(Corresponding author: Jonali Goswami)*
*(Received 30 October 2018, Accepted 10 February, 2019)*
*(Published by Research Trend, Website: www.researchtrend.net)*

**ABSTRACT: Abiotic stresses are one of the major factors affecting crop production in many parts of the India. The need of the hour is to minimize the yield losses due to these abiotic stresses. Early detection can help to reduce the impact of stresses on crop growth and yield. The recent developments in hyperspectral remote sensing hold a major key in early detection of abiotic stress over a larger area with less involvement of cost, time and labour. The works relevant to abiotic stress characterization particularly nitrogen stress based on plant spectral reflectance are dealt in this paper. It was observed from the spectral data analysis that the stress indicating parameter such as Leaf area index, chlorophyll, photosynthesis can be precisely estimated using proximal hyperspectral remote sensing approach. The research work done also elucidates that hyperspectral techniques can lead to the development of real-time management of nutrient stress, thereby reducing the yield losses due these stresses.**

**Keywords:** Abiotic stress, Nitrogen, Hyperspectral Remote Sensing, Spectroradiometer

**How to cite this article:** Goswami, Jonali; Sarma, K.K.; Das, Ranjan and Raju, P.L.N. (2019). Abiotic Stress Detection using Hyperspectral Remote Sensing. *Biological Forum – An International Journal*, **11**(1): 131-136.

## INTRODUCTION

Monitoring of crop conditions at regular intervals is fundamental for implementing sustainable agriculture. It is axiomatic that high yields can only be obtained if plant stress is kept to a minimum. Abiotic stress such as nutrient, cold, drought, salt, and heavy metals largely influences plant development and crop productivity. Abiotic stress has been becoming a important threat to food security due to the constant changes of climate and worsening of environment caused by human activity. To survive with abiotic stress, plants can initiate a number of molecular, cellular, and physiological changes to respond and adapt to such stresses.

Remote sensing techniques have been shown to be timely, non-destructive and provide spatial estimates for quantifying and monitoring these vegetation characteristics as compared to direct field techniques. However, multispectral broadband-based remote sensing has limitation for quantitative estimation of biochemical properties primarily because of the low spectral resolution. A major limitation of broadband remote sensing is that it uses average spectral information over broadband widths resulting in loss of critical information available in specific narrow bands, e.g. absorption features (Blackburn, 1998 and Thenkabail *et al*., 2000). Hyperspectral remote sensing in large continuous narrow wavebands provides significant advancement in understanding the subtle changes in biochemical and biophysical attributes of the crop plants and their different physiological processes, which otherwise are indistinct in multispectral remote sensing. Recent advances in hyperspectral remote sensing demonstrate great utility for a variety of crop monitoring applications (Sahoo *et al.,* 2015). The reflectance and absorption features in narrow bands are related to specific crop characteristics such as biochemical composition (Haboudane *et al*., 2002), physical structure, water content (Champagne *et al.*, 2003) and plant eco-physical status (Strachan *et al.*, 2002). Many studies on potential applications of hyper spectral remote sensing in agriculture to assess abiotic and biotic stresses have been carried out by different researchers in India and abroad (Shobiga and Kumar, 2015).

### *A. Spectral responses of vegetation*

Leaves represent the main surfaces of plant canopies where energy and gas are exchanged. Hence, knowledge of their optical properties is essential to understand the transport of photons within vegetation (Despan and Jacquemoud 2004). The general shape of reflectance and transmittance curves for green leaves is similar for all species.

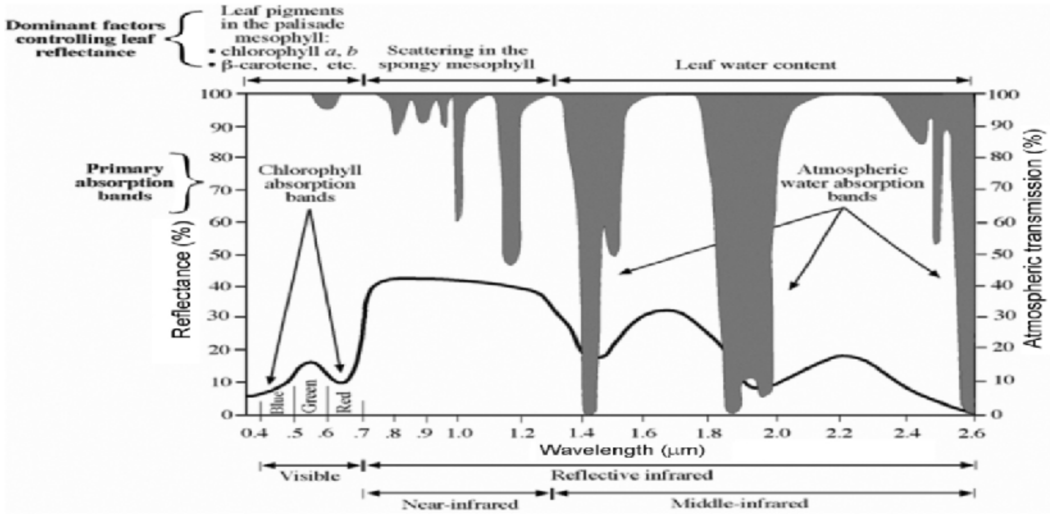


**Fig. 1.** Typical reflectance pattern of leaf (source: Jensen2000).

It is controlled by absorption features of specific molecules and the cellular structure of the leaf tissue. Three distinguished spectral domains of vegetation reflectance are defined based on the effect of biophysical and biochemical attributes on reflectance properties of vegetation.

In the visible domain (400-700 nm), absorption by leaf pigments is the most important process leading to low reflectance and transmittance values. The main light-absorbing pigments are chlorophyll *a* and *b*, carotenoids, xanthophylls and polyphenols and all pigments have overlapping absorption features. In the near-infrared domain (near-IR: 700-1300 nm) leaf pigments and cellulose are almost transparent, so that absorption is very low and reflectance and transmittance reach their maximum values. This is caused by internal scattering at the air–cell–water interfaces within the leaves (Hunt, 1989). In the midinfrared domain (mid-IR: 1300-2500 nm), also called shortwave-infrared (SWIR), leaf optical properties are mainly affected by water and other foliar constituents. Water largely influences the overall reflectance in the mid-IR domain effectively trapping the radiation, resulting in absorption that exceeds scattering processes and also has an indirect effect on the visible and near-IR reflectances. Protein, cellulose, lignin and starch also influence leaf reflectance in the mid-IR. Absorption features of different foliar chemical parameters are listed in Curran1989.

*B. Hyperspectral remote sensing for crop stress detection*

Plants respond to abiotic stresses in a number of ways, including leaf curling, wilting, chlorosis or necrosis of photosynthetically active parts, stunted growth, or in some cases reduction in leaf area due to severe defoliation. However, these responses also affect the amount and quality of electromagnetic radiation reflected from plant canopies. Based on the assumption that stresses interfere with photosynthesis and physical structure of the plants and affect absorption of light energy and reflectance spectrum of plants, hyperspectral remote sensing was found to be able to identify different stresses (Riley, 1989). Besides, this technique provides a better means to objectively quantify crop stress than visual methods, as it can be repeatedly used to collect sample measurements non-destructively (Nilsson, 1995). However, spectral characteristics and damage symptoms need to be aptly correlated based on ground truth prior to development of stress management schemes.

An experiment has been conducted by NESAC at department of crop physiology, Assam Agricultural University, Jorhat on spectral response of rice genotype to varying level of nitrogen fertilization using handheld spectroradiometer. The growth, productivity, physiological and biochemical processes of four genotype i.e. IET 22238, Inglongkiri, Banglami and Bash has been observed under varying level of nitrogen fertilization viz. N1 (0kg/hac), N2 (20kg/hac) and N3 (40kg/hac). It was observed from the spectral data analysis the stress indicating parameter such as Leaf area index, chlorophyll, photosynthesis can be precisely estimated from field spectroradiometer at leaf level irrespective of treatment and genotype. Leaf Area Index (LAI) is functionally linked to the canopy spectral reflectance and narrow band indices perform better than broadband indices for LAI estimation (Elvidge 1988, Broge and Leblanc 2000).

Similarly in the present investigation, different levels of nitrogen fertilization brought about significant difference in the LAI in irrespective of genotype. Percent reduction in leaf area index was recorded in N1 *i.e.* without Nitrogen fertilization as compared to N3 with recommended dose of fertilizer (RDF about 25.53% to 27.20% in the second and first year respectively (Fig. 1). Different hyperspectral vegetation indices were computed to estimate LAI. Spectral derived, NDVI is the widely used classic indicator of crop status, plant vigour and stress condition. In the present investigation, there was significant correlation between spectral derived NDVI and LAI. (Fig. 2).

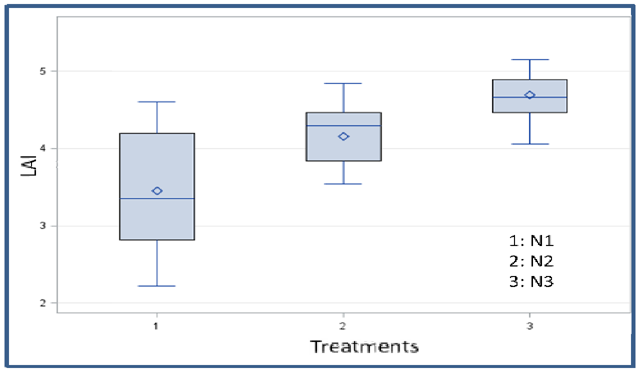


**Fig. 1.** Distribution of LAI (a) under different treatment irrespective of genotype.

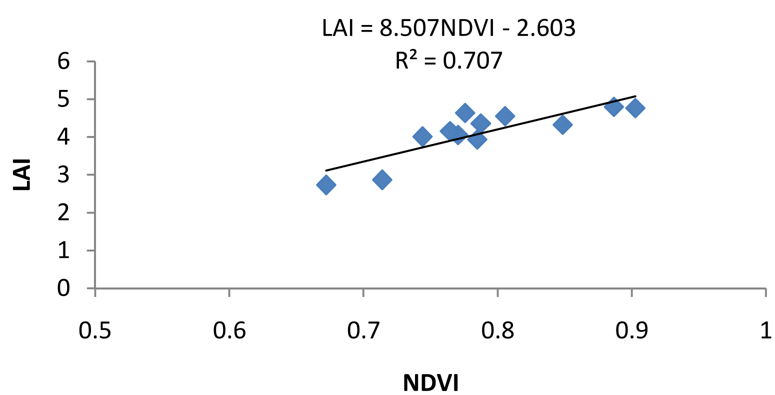


**Fig. 2.** Relation between LAI and spectral derived index, Normalized Difference Vegetation Index (NDVI).

Photosynthesis is the most large-scale vital process on earth. Light absorbed by chlorophyll provokes electrons in the molecules, enabling them to be transferred to other molecules for glucose production and thus enabling growth of vegetation. As leaves dehydrate or vegetation undergoes water stress, leaf water potential becomes increasingly negative and the rate of photosynthesis is reduced because water deficit can cause chlorophyll abasement and thus significantly reduces foliar chlorophyll concentration and disables the photochemical reaction furthermore leaves decrease the absorption of blue and red light while increasing the reflectance at the corresponding wavelength bands. The ability to accurate estimation of plant chlorophyll content and concentration may give growers useful information to allow estimation of crop yield potential and to make decisions in stress management (Rahul *et al*., 2014).

In present investigation has also shown that nitrogen stress brought about significant difference in photosynthesis. The reduction in rate of photosynthesis in N1 over N3 ranged from 32% and 34% in both the experimental year respectively. In N2 reduction of photosynthesis rate was less as compared to N1. Increase in N availability results in higher leaf photosynthesis rate (Fig. 3). The lower rates of photosynthesis under conditions of N limitation are attributed to reduction in chlorophyll content. There was significant relationship between leaf chlorophyll and canopy reflectance in the visible and near infrared regions.

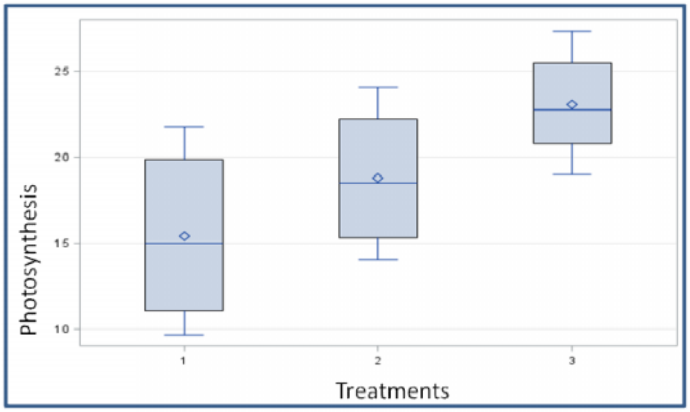


**Fig. 3.** Distribution of LAI (a) under different treatment irrespective of genotype.

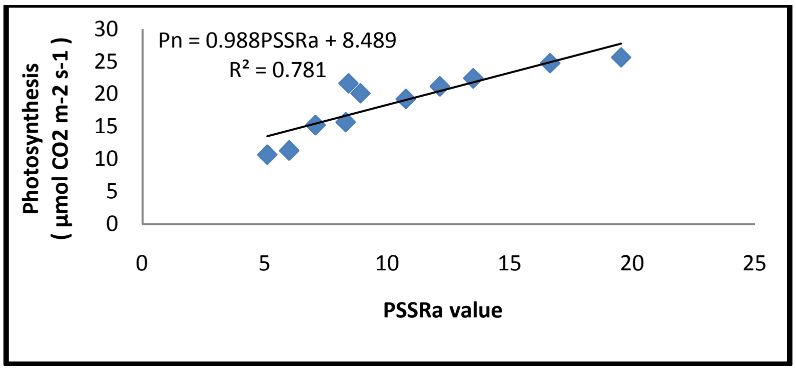


**Fig. 4.** Relation between photosynthesis and spectral derived index, pigment specific simple ration (PSSRa) for chlorophyll a.

NDVI like index, pigment specific simple ration (PSSRa) for chlorophyll a has shown similar trend with rate of photosynthesis under different levels of nitrogen and was recorded good correlation with photosynthesis (Fig. 4).

Hyperspectral remote sensing is an automatic, quick and non-destructive method of assessing plant growth parameters and nutrient levels in crop plants (Hansen and Schjoerring 2003). The principle involved in the use of remote sensing to determine crop nutrient stress is the changes caused in photosynthetic activity, cell structure, stretch and first overtone of chemical bonds such as N–H bonding (Curran 1989) which alters spectral reflectance of plants in the visible (VIS), near infrared (NIR) and shortwave infrared (SWIR) region of the spectrum, respectively. N monitoring using remote sensing is very well developed but only a few attempts have been made in selected crops to monitor nutrients other than N. Ferwerda and Skidmore (2007) have demonstrated the potential of hyperspectral remote sensing in predicting concentration of essential nutrients such as N, P, Ca, K, Na and Mg in four wood plants. They also observed a differential shift in the red edge position towards shorter wavelengths for different nutrient elements under study.

Furthermore, the increase in yield owing to the application of N-fertilizers may also be attributed to the fact that these nutrients being important constituents of nucleotides, proteins, chlorophyll and enzymes, involve in various metabolic processes which have direct impact on vegetative and reproductive phases of plants. This variability among the genotypes can easily monitored using spectral responses at red edge position. Collins (1978) had shown that transition region of red-NIR, commonly known as Red Edge brings out sudden change in vegetation reflectance between 680 to 780 nm. Experimental and theoretical studies show that it shifts according to changes of chlorophyll content (Belanger *et al.*,1995), LAI (Danson and Plummer, 1995) biomass and hydric status (Filella and Peñuelas, 1994), age (Niemann, 1995), plant health levels (Vane and Goetz, 1988) and seasonal patterns (Miller *et al.*, 1995). When a plant is healthy with high chlorophyll content and high LAI, the red edge position shifts toward the longer wavelengths; when it suffers from disease or chlorosis and low LAI, it shifts toward the shorter wavelengths (Ruiliang *et al.*, 2003).

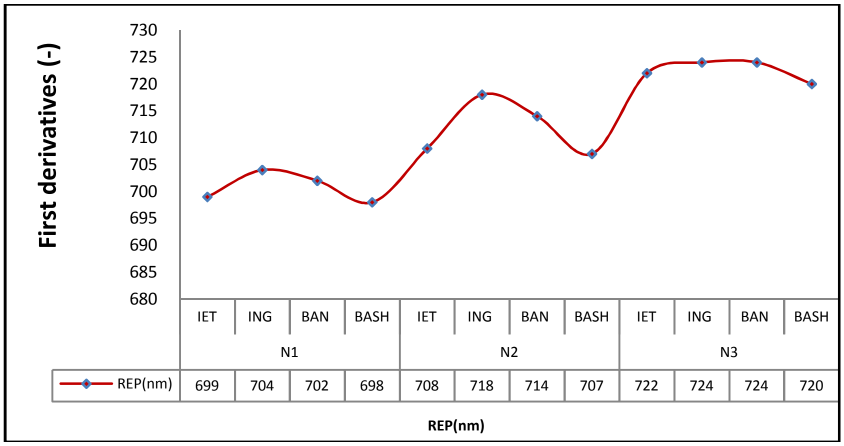


**Fig. 5.** Red edge position (REP) obtained for different rice genotype under different nitrogen treatment (N1=0, N2=20, N3=40kg ha).

In present investigation REP in tolerant genotypes (Inglongkiri, ING; Banglami, BAN) and Bash was found in comparatively longer wavelength at RDF than susceptible genotypes ( IET 22238, IET; and BASH) which is strongly correlated with foliar chlorophyll content and leaf N content as shown in Fig. 5.

## CONCLUSIONS

Recent advances in Hyperspectral remote sensing demonstrate great utility for a variety of crop stress detection. However, any stresses interfere with photosynthesis and physical structure of the plants and affect absorption of light energy and reflectance spectrum of plants, hyperspectral remote sensing was effectively used in identifying different stresses. However, as we know, remote sensing is not a standalone system, it has to be validated through proper ground truth and integrated with other collateral information for facilitating decision support.

## REFERENCES

Belanger, M.J.; Miller, J.R. and Boyer, M.G. (1995). "Comparative relationships between some red edge parameters and seasonal leaf chlorophyll concentrations," *Can. J. Remote Sens*., **21**(1): 16-21.

Blackburn, G.A. (1998). Quantifying chlorophylls and caroteniods at leaf and canopy scales: an evaluation of some hyperspectral approaches. *Remote Sensing Environ*., **66**: 273-285.

Broge, N.H. and Leblanc, E. (2000). Comparing prediction power and stability of broadband and hyperspectral vegetation indices for estimation of green leaf area index and canopy chlorophyll density. *Remote Sensing Environ.*, **76**: 156-172.

Champagne, C.M.; Staenz, K.; Bannari, A.; Mcnairn, H. and Deguise, J.C. (2003). Validation of a hyperspectral curve-fitting model for the estimation of plant water content of agricultural canopies *Remote Sensing Environ.*, **87**, 148-160.

Collins, W. (1978). Remote sensing of crop type and maturity. Photogrammetric

Curran, P.J. (1989). Remote sensing of foliar chemistry. *Remote Sensing of Environment*, **30**(3): 271-278.

Danson, F. M. and Plummer, S. E. (1995). "Red-edge response to forest leaf area index," *Int. J. Remote Sens*., **16**(1): 183-188.

Despan, D. and Jacquemoud, S. (2004). Optical properties of soil and leaf: necessity and problems of modeling. In *Reflection Properties of Vegetation and Soil* (eds von Schönermark, M. Geiger, B. and Röser, H. P.), *Wissenschaft und Technik Verlag, Berlin*, pp. 39-70.

Ferwerda, J.G. and Skidmore, A.K. (2007). Can nutrient status of four woody plant species be predicted using field spectrometry? ISPRS *Journal of Photogrammetry and Remote Sensing*, **62**: 406-414.

Filella, I. and Peñuelas, J. (1994). "The red edge position and shape as indicators of plant chlorophyll content, biomass and hydric status," *Int. J. Remote Sens*., **15**(7): 1459-1470.

Haboudane, D.; Miller, J. R.; Trembley, N.; Zarco-Tejada, P. J. and Dextraze, L. (2002). Integrated narrow-band vegetation indices for prediction of crop chlorophyll content for application to precision agriculture. *Remote Sensing Environ.*, **81**: 416-426.

Hunt, J.; Ramond, E. and Rock, B.N. (1989). Detection in changes in leaf water content using near and mid-infrared reflectance. *Remote Sensing Environ*., **30**: 45-54.

Hansen, P.M. and Schjoerring, J.K. (2003). Reflectance measurement of canopy biomass and nitrogen status in wheat crops using normalized difference vegetation indices and partial least squares regression. *Remote Sensing Environ.*, **86**: 542-553.

Niemann, K.O. (1995). "Remote sensing of forest stand age using airborne spectrometer data," *Photogramm. Eng. Remote Sens*., **61**(9): 1119-1127.

Nilsson, H.E. (1995). Remote sensing and image analysis in plant pathology. *Annu. Rev. Phytopathol.*, **15**: 489-527.

Rahul, T.; Naharkar and Dr. Ratnadeep R. Deshmukh, (2016). "Analysis and Estimation of Chlorophyll Using Non-Destructive Methods", *International Journal of Innovative Research in Computer and Communication Engineering*, **4**: 6900-6905.

Sahoo R.N.; Ray, S.S. and Manjunath K.R. (2015). Hyperspectral remote sensing of agriculture, *Current Science*, **108**(5): 848-859.

Shobiga, R. and Kumar, J.S. (2015). Analysis of Biochemical And Biophysical Attributes of Plants Using Hyperspectral Imaging; *Karpagam Journal of Engineering Research* (KJER), **III**: 2393-994.

Strachan, I.B.; Pattey, E. and Boisvert, J.B. (2002). Impact of nitrogen and environmental conditions on corn as detected by hyperspectral reflectance. *Remote Sens. Environ.*, **80**: 213-214.

Thenkabail, P.S.; Smith, R.B. and Pauw, E.D. (2000). Hyperspectral vegetation indices and their relationships with agricultural crop characteristics. *Remote Sensing Environ.*, **71**: 158-182.