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Hyperspectral Analysis of Wheat Leaf Rust (WLR) Disease: A Review

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Abstract— Remote Sensing has wide range of applications in many different fields. Remote Sensing has been found to be a valuable tool in evaluation, monitoring, and management of land, water and crop resources. The applications of remote sensing techniques in the field of agriculture are wide and varied ranging from crop identification, detection of disease on different crops & predicting grain yield of crops. Many remote sensing applications are devoted to the agricultural sector. The selected applications are put in the context of the global challenges the agricultural sector is facing: minimizing the environmental impact, while increasing production and productivity. The application of remote sensing in agriculture typically involves measuring reflectance of electromagnetic radiation in the visible (390 to 770 nm), near-infrared (NIR, 770 to 1,300 nm), or middle-infrared (1,300 to 2,500 nm) ranges using spectrometers. This paper reviews the concept of hyperspectral remote sensing, use of remote sensing in terms of agriculture field, study of diseased wheat leaves using hyperspectral remote sensing.

Keywords—Remote Sensing, Wheat Leaf Rust, Vegetation Indices, ASD Fieldspec4 Spectroradiometer.

I. Introduction

Remote sensing refers to the activities of recording/observing/perceiving (sensing) objects or events at far away (remote) places. Remote sensing is a sub-field of geography. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals (e.g. electromagnetic radiation) [1]. The electromagnetic radiation is normally used as an information carrier in remote sensing. The reflection of that energy by earth surface materials is then measured to produce an image of the area sensed. Generally, Remote sensing can be done on two types of data namely imagery and non imagery. It can be done using different kinds of remote sensing devices like ASD fieldspec Spectroradiometer. Remote sensing have wide range of applications in various fields, among which Agriculture plays important role in our day to day life as not only in india but in many countries agriculture is their primary source of income and all human beings, animals and many industries are dependent on agriculture field. agriculture plays key macroeconomic roles in the industrialization of developing countries by relieving saving, aggregate demand, fiscal, and foreign exchange constraints on the industrial sector [2].

In agriculture field winter wheat is one of the highest yielding crops on the farm [3]. Different climatic factors and disease symptoms affects the plant growth and it directly results in yield of crop. Rust are among the most important fungal diseases of wheat worldwide [4]. There are three types of rust diseases in wheat crop: Strip Rust, Leaf Rust, Stem Rust.

Wheat rusts are caused by three related fungi [5]:

- Stripe rust is caused by Puccinia striiformis f. sp. tritici.
- Leaf rust is caused by Puccinia triticina.
- Stem rust is caused by Puccinia graminis f. sp. tritici.

This paper reviews the study of wheat leaf rust (WLR) disease using hyperspectral analysis, different vegetation indices and spectral signatures can be used to estimate the features of diseased and healthy crop. In this review paper ASD Fieldspec4 Spectroradiometer is used for data collection of diseased wheat leaves and healthy wheat leaves. Using different vegetation indices (VIs) biophysical and biochemical properties of crop can be estimated.

II. Basics of Remote Sensing

Hyperspectral remote sensing is used for over 100 years for analysis of various objects and their chemical as well as biological composition. But hyperspectral sensor offers an alternate and nondestructive technique for analysis of physical and chemical properties of material. Remote sensing of vegetation is mainly performed by obtaining the electromagnetic wave reflectance information from canopies using passive sensors. It is well known that the reflectance of light spectra from plants changes with plant type, water content within tissues, and other intrinsic factors [6].

The reflectance from vegetation to the electromagnetic spectrum (spectral reflectance or emission characteristics of vegetation) is determined by chemical and morphological characteristics of the surface of organs or leaves [7].

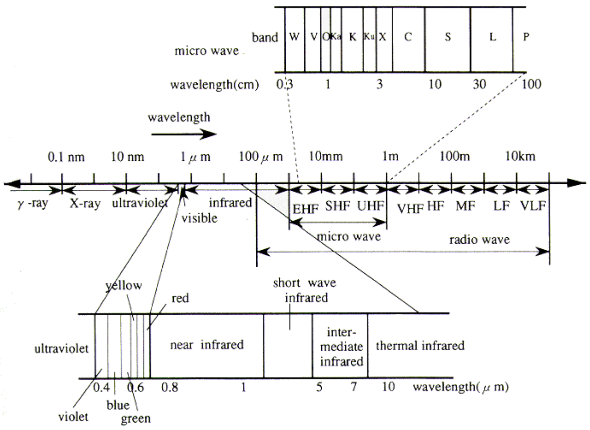

Figure 1. Bands used in Remote Sensing [8]

The main applications for remote sensing of vegetation are based on the following light spectra: (i) the ultraviolet region (UV), which goes from 10 to 380 nm; (ii) the visible spectra, which are composed of the blue (450–495 nm), green (495−570 nm), and red (620–750 nm) wavelength regions; and (iii) the near and mid infrared band (850–1700 nm) [9,10].

III. HYPERSPECTRAL REMOTE SENSING IN AGRICULTURE

Spectral data at the leaf and canopy scales have been utilized to improve the plant disease detection techniques from remotely sensed observations [11,12], where the visible and infrared regions are more sensitive to disease development [13]. The measured spectra can be utilized to early detection of fungus disease. Moreover, the optimized narrow bands vegetation indices were employed to discriminate various disease of wheat [14].

III.I *Wheat Leaf Rust (WLR) Disease*

The wheat rust is an important crop disease which has three types, i.e., wheat yellow rust (WYR), wheat leaf rust (WLR), and wheat stem rust [15].

Figure 2. Wheat Leaf Rust causing agents: *Puccinia triticina*

WYR disease is identified by a single symptom which occurs as a narrow yellow stripes parallel to nervures on the leaf, whereas WLR disease is caused by the *Puccinia triticina* fungus and illustrates numerous symptoms simultaneously in various parts of an infected leaf [16]. The WLR symptoms vary from leaf to leaf but it presents a yellow color earlier, then its changes to orange and dark brown. Finally, the disease symptom ends with the dry leaf [17].

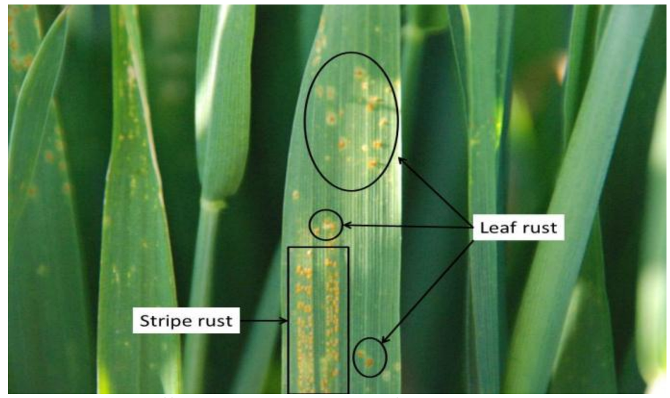

Figure 3. Difference between wheat leaf rust and wheat stripe rust

The effect of a disease on the pigments and structure of a plant and the change in their spectral responses enable spectroradiometry and remote sensing techniques to detect plant disease effectively [18].

Crop disease can cause significant yield loss and reduction of grain quality, which have a negative impact to food security around the world [19].

IV. EXPERIMENTAL SETUP

IV.I *Data Collection*

Field spec 4 spectrometer (Analytical spectral device, ASD Co. USA) shown in following figure having parameter details in Table 1. Spectrum data export in ASCII text, then it can analyze spectrum data with different software like ASD View Spec Pro. Unscramble and MATLAB/ Octave [20].

Figure 4. ASD FieldSpec4 Spectrometer

Table 1. Specifications of Fieldspec4 Spectroradiometer

Table	Specification of field spec 4 spectrometers	
No.	*Performances*	*Value*
1	Spectral Range	350-2500 nm.
2	Spectral Resolution	3 nm @ 700 nm 8 nm @ 1400/2100 nm.
3	Spectral sampling (bandwidth)	1.4 nm @ 350-1000 nm 1.1 nm @ 1001-2500 nm.
4	Scanning Time	100 milliseconds.
5	Stray light specification	VNIR 0.02%, SWIR 1 & 2 0.01%
6	Wavelength reproducibility	0.1 nm
7	Wavelength accuracy	0.5 nm
8	Maximum radiance	VNIR 2X Solar, SWIR 10X Solar
9	Channels	2151
10	Detectors	VNIR detector (350-1000 nm): 512 element silicon array SWIR 1 detector (1001-1800 nm): Graded Index InGaAs Photodiode, Two Stage TE Cooled SWIR 2 detector (1801-2500 nm): Graded Index InGaAs Photodiode, Two Stage TE Cooled.
11	Input	1.5 m fiber optic (25° field of view). Optional narrower field of view fiber optics available.
12	Noise Equivalent Radiance (NEdL)	VNIR 1.0 $X10^{-9}$ $W/cm^2/nm/sr$ @700 nm SWIR 1 1.4 $X10^{-9}$ $W/cm^2/nm/sr$ @ 1400 nm SWIR 2 2.2 $X10^{-9}$ $W/cm^2/nm/sr$ @ 2100 nm

V. VEGETATION INDICES FOR ESTIMATION OF WLR SYMPTOMS

Spectral data at different scales including leaf, canopy and landscape-level have been widely used to improve precision [21-24]. In recent years, researchers have studied various spectral vegetation indices (SVIs) to detect different vegetation diseases [24-26]. Efficient use of spectral data in detection of plant disease depends on the application. The spectral regions from 400 to 700 and 700 to 1100 are mainly influenced by leaf composition of pigments, structure, and water content [27]. The effect of a disease on the pigments and structure of a plant and the change in their spectral responses enable spectroradiometry and remote sensing techniques to detect plant disease effectively [28]. There are indices derived from reflectance values at several wavelengths that are able to detect and quantify the leaf content substances such as chlorophyll, anthocyanin, and water [29,30].

By using different types of vegetation indices estimation of biochemical and biophysical properties of crops is possible. Vegetation indices that are used by many researchers have shown in following table [31].

Table 2. Different Vegetation Indices

Index	Equation	Reference
Structure(LAI, Green Biomass, Fraction)		
EVI	2.5 * (RNIR – Rred) / (RNIR +6 Rred – 7.5 Rblue +1)	[32]
Green NDVI	(RNIR – Rgreen) / (RNIR + Rgreen)	[33]
NDVI	(RNIR – Rred) / (RNIR + Rred)	[33]
SR	RNIR/Rred	[34]
NDWI[a]	(R857- R1241) / (R857+R1241)	[35]
WBI[b]	R900 / R970	[36]
ARVI[a]	(RNIR - [Rred - γ *{Rblue - Rred}]) / (RNIR + [Rred - γ *(Rblue – Rred)])	[37]
SAVI[a]	[(RNIR – Rred) / (RNIR + Rred + L)] * (1+ L)	[38]
VARI[a]	(Rgreen - Rred) / (Rgreen + Rred - Rblue)	[39]
VIgreen[a]	(Rgreen - Rred) / (Rgreen + Rred)	[39]
Biochemical		
Pigments		
SIPI[b]	(R800 – R445) / (R800 – R680)	[40]
PSSR[b]	(R800 / R675); (R800 / R650)	[41]
PSND[b]	[(R800 – R675) / (R800 + R675)]; [(R800 – R650) / (R800 + R650)]	[42]
PSRI[b]	(R680 – R500) / R750	[43]
Chlorophyll		
CARI[b]	[(R700 – R670) – 0.2 * (R700 – R550)]	[44]
MCARI[b]	[(R700 – R670) - 0.2 * (R700 – R550)] * (R700 / R670)	[45]
CIred[b]	RNIR / Rred edge – 1	[46]
Anthocyanins		
ARI[b]	(1 / Rgreen) – (1 / Rred edge)	[47]
mARI[b]	[(1 / Rgreen) – (1 / Rred edge)] * RNIR	[48]
RGRI[b]	Rred / Rgreen	[49]
ACI[b]	Rgreen / RNIR	[50]
Carotenoids		
CRI1[b]	(1 / R510) – (1 / R550)	[51]
CRI2[b]	(1 / R510) – (1 / R700)	[52]
Water		
NDII[a]	(RNIR - RSWIR) / (RNIR + RSWIR)	[53]
NDWI[a], WBI[b]	See Above	
MSI[a]	RSWIR / RNIR	[54]
Light Use Efficiancy		

RGRI[b], SIPI[b]	See Above	
PRI[b]	(R570 – R531) / (R531 + R570)	
Stress		
MSI[a]	See Above	
REP[b]	L (max first derivative: 680-750nm)	
RVSI[b]	[(R714 + R752) / 2 – R733]	
Note: Repeated indices are used for multiple purpose a: Narrow band equivalent of a broad band index b: Strictly narrow band/ Hyperspectral band		

VI. CONCLUSION

As Remote Sensing technology growing rapidly in technological era and hyperspectral Remote sensing has wide number of applications not only in agriculture field but also in different industries which are dependent on agricultural area. With the help of different spectral characteristics like spectral signatures, vegetation indices, reflectance spectra we can use it for discrimination of crops. It can be used to study the severity of disease in crops, estimating the grain yield of crops, analysis and growth modulation of crop.

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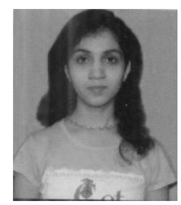

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