

# Spectral Estimation of Nitrogen Status in Wheat Crops Using Remote Sensing

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**Abstract:** Remote sensing is the method of acquiring and recording of information about an object without the direct contact. Hyper spectral imaging is the technique to collect and process the information in a narrow and continuous spectral band that was obtained over the electromagnetic spectrum. Hyper spectral satellite data of wheat crop was taken for this study from Airborne Visible Infrared Imaging Spectrometer (AVIRIS) sensor with appropriate longitudes and latitudes from earth explorer site. The vegetation indices used for this study are Normalized Difference Vegetation Index (NDVI) and Vegetation Index Green (VIG). The estimation of these indices has been done on the first derivative of the reflectance obtained from the field. The Protein and Nitrogen values were calculated using satellite data and these values were correlated with experimental analysis using Kjeldahl method.

**Keywords:** AVIRIS, Hyperspectral satellite data, Kjeldahl method, NDVI, VIG.

## I. INTRODUCTION

The data obtained from remote sensing can provide the property of ground targets without any destruction [1-2]. Remote sensing collects spatially dense information that may contribute to nitrogen variable rate within the precision farming concept. Nitrogen (N) is one of the essential elements in plants apart from carbon, hydrogen and oxygen due to its key role in chlorophyll production, various enzymatic proteins, plant-growth processes, chemical components that protect against parasites, plant diseases, crop yield and biomass [3-5]. The spectral properties of plant reflect crop nitrogen status and can be used for spectral estimation of nitrogen content. The NDVI is a widely used vegetative index [6] which was developed and implemented in the late 1970's [7]. NDVI has been associated to nitrogen status, chlorophyll content, green leaf biomass, and grain yield [8]. VIG is another index which significantly correlates to leaf nitrogen and grain protein content [9-10]. The relationship between chlorophyll and reflectance measurements makes remote evaluation of nitrogen status a logical choice. Choosing the proper wavelengths for investigation when considering growth

related to plant nitrogen concentration is significant. Hansen *et al.* [11] concluded that NDVI was a useful tool in evaluating small grain growth and development. They noted that using different wavelengths to calculate the vegetative index changed the coefficients of determination for different levels of nitrogen concentration. An accurate approach for estimating nitrogen uptake has been the identification of Red Edge Inflection Point (REIP). The REIP has been shown to have a straight response to nitrogen uptake ( $r^2 = 0.90$ ) in wheat [12]. The satellite images were used for finding the percentage of nitrogen in vegetation area with the help of algorithms and formulas [13]. Satellite image is utilized instead of cameras because cameras can capture only visible band whilst the satellite image with the help of remote sensors captures data on specific scene and also gathers the moment information.

The aim of this study is to analyze the relationship between spectral reflectance measurements and nitrogen content of wheat crops. The method of evaluating the amount of incident light absorbed and reflected at different wavelengths (530,600,700,800 nm) has been utilized. The nitrogen content determined by satellite data as well as experimental analysis using Kjhedahl's method was correlated. The present study provides a foundation for using the proposed algorithm to evaluate the nitrogen status of wheat crop.

## II. MATERIALS AND METHODS

### A. Data Flow of the Proposed System

The Hyper spectral satellite data was taken for the study from AVIRIS sensor. Pre-processing of the image was done using filters. Then the image was clustered into two parts that is one of vegetation & water and another of land using K-means algorithm. The vegetation part of the image (the wheat crop near agricultural college) was cropped which was further used for feature extraction. The Bilinear Unmixing feature extraction method was used to obtain the reflectance values. The spectral indices like NDVI, VIG were calculated from the reflectance values. The Protein & Nitrogen values were calculated from the formulas. The nitrogen value was obtained from the experimental data using Kjhedahl's method. The values were

further correlated by taking the average value of all the bands with the experimental results. The data flow of the proposed work is as shown in Fig. 1.

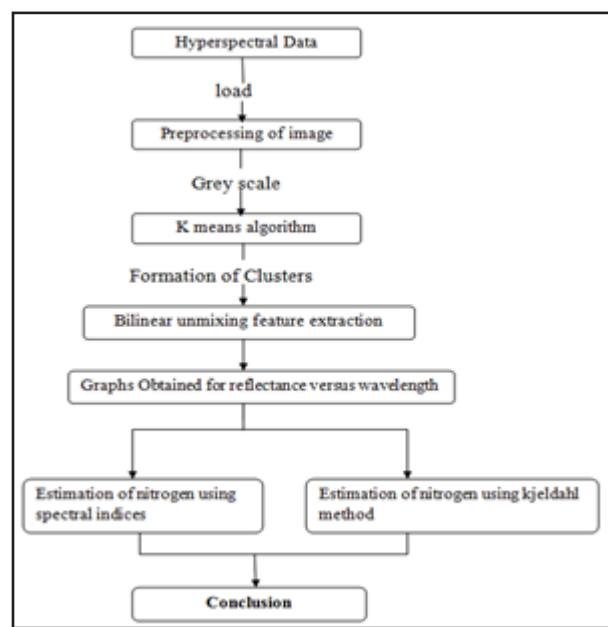


Fig. 1

### B. Loading the Input Data

The proposed system makes use of the hyper spectral satellite image as input image which is as shown in Fig. 2.

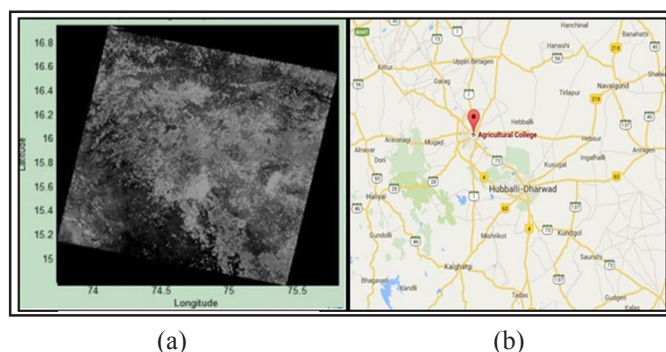


Fig. 2: Study Area Showing (a) Satellite Image and (b) Map

The image considered for the study is from the spot near Dharwad District, Karnataka State, India. The latitude and longitude considered are  $15.3500^\circ$  north,  $75.0833^\circ$  east. The Hyper spectral data contains around 220 bands that are taken from AVIRIS sensor. The considered wavelength ranges from 400 nm to 2500 nm which covers all the domains reaching from visible to infrared radiations. The brighter area indicates the land and darker range exhibits the vegetation.

### C. Pre-Processing

In this phase, the preprocessing of the given image is carried out. Filtering is the process where the satellite image that is acquired as color image is converted to its grey scale image. To do this

process the standard Gaussian filters are used on the image, for the next level of processing. The grey scale image gives better results as the filtering of grey scale image is simpler and effective.

### D. Clustering

Clustering is a strategy of obtaining data patterns and distributions in hidden data. The principal point of clustering is to find both the scanty and thick areas in information set to be clustered. One of the clustering methods chosen here is the K-means algorithm. This method is chosen as this is one of the least complex iterative techniques and straightforward to implement [14-16].

### E. K-Means Algorithm

Using K means algorithm, the first step is the selection of the number of clusters. At this point the algorithm randomly chooses centroids beginning with K, where K is indicated by the researcher. In the second stage each point is then allotted to a closest centroid and the group of pixels close to the centroid forms a cluster. The centroid is upgraded according to the points in the group and this procedure is repeated until there is no change of points in the clusters.

### F. Feature Extraction and Output Graph

Once the clustering of the input image is concluded, then it acts as the input for the bilinear un-mixing feature extraction algorithm. Here the percentage of the nitrogen in the vegetation cluster is detected [17-19]. This stage gives the graphical representation of result. A graph for reflectance versus wavelength is plotted. As nitrogen is not the only component in the crop, along with nitrogen different components like energy, protein are likewise identified. Calculations are carried out to get the nitrogen level in vegetation area. Furthermore, laboratory experiment is carried out to correlate the result obtained for spectral image.

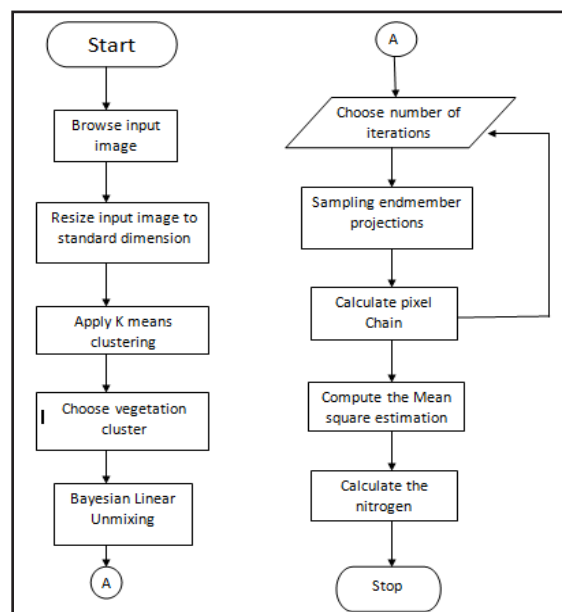


Fig. 3: Flow Chart of Bilinear Un-Mixing Algorithm

The bilinear model is as shown in Fig. 3. It takes input from the K-means and focuses only on the pixels of vegetation cluster. The pixels of interest which are scattered are collected using Nfindr (Nitrogen finder) and then the measured spectra can be expressed as the combination of the spectral signature. Calculations are carried using spectral indices to find the nitrogen level present in the vegetation area.

### III. RESULTS AND DISCUSSION

#### A. Nitrogen Value Estimated from Satellite Data

The platform used for the execution of proposed system is the MATLAB 2010A [20]. MATLAB is universally known as “Matrix Laboratory” which is a visualization and numerical computation. The data element is used in terms of matrix and if one needs to manipulate array-based datasets then it is fast to write and execute in MATLAB. The output of K-means algorithm is shown in the screen shot of Fig. 4. Here the clusters formed are clearly shown. Two clusters are observed: one is land and other is vegetation and water. The vegetation and water cluster obtained is taken as the input for bilinear un-mixing feature extracting algorithm.

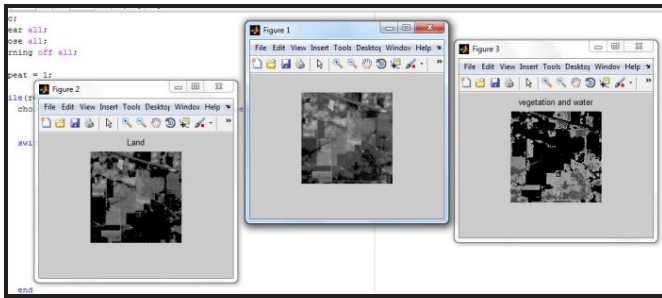


Fig. 4: Output of K-Means Algorithm

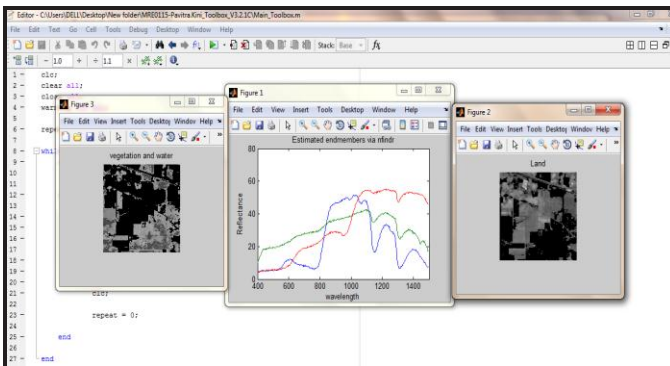


Fig. 5: Graph Obtained for Calculation of Nitrogen

In Fig. 5 the N-Findr algorithm [21-22] is used to obtain the graph for reflectance versus wave length (nm). This graph obtained helps in the calculation of nitrogen (%) present in wheat crops. The reflectance values are taken from this graph at the specified points. These reflectance values are then substituted in the formulas of spectral indices as given in Equations (1) - (4) to obtain the Nitrogen value. The algorithm checks for

the set of pixels that has largest volume by considering the end members which are the vertices for building up a simplex inside the data. The procedure starts with random initial selection of pixels. Every pixel in the image is evaluated in order to filter the estimate of endmembers, checking out for the group of pixels that increases the volume of the simplex chosen by selected endmembers. The volume is calculated for every pixel for every endmembers position by replacing that particular endmember and finding the resulting maximum volume. If the replacement results show increase in the volume, then the end member is replaced by the pixel [23]. Thus the process is repeated until there are no more endmember replacements.

The paper discusses about the outcome of the proposed system. Here the estimation of nitrogen content in the vegetation area is made. A graph is plotted for reflectance versus wavelength which indicates green, red and blue curve. The nitrogen calculated is 0.68598. The following formulas are used for the estimation of nitrogen.

$$VIG = \frac{R_{Green} - R_{Red}}{R_{Green} + R_{Red}} \quad (1)$$

Where, VIG is Vegetation Index Green. VIG varies with total nitrogen concentration and is associated with the Plant Physiological state [24]. Wavelengths used are  $R_{Green} = 530$  nm and  $R_{red} = 600$  nm.

$$NDVI = \frac{R_{NIR} - R_{VIS}}{R_{NIR} + R_{VIS}} \quad (2)$$

Where, NDVI is normalized difference vegetation index, NDVI prioritize the density to green vegetation density [25-27]. Wavelengths used are  $R_{NIR} = 800$  nm and  $R_{VIS} = 700$  nm. The protein value [28] is given by equation (3)

$$\text{Protein value} = -18.384 \times VIG + 19.370 \quad (3)$$

From protein value, Nitrogen value [29] is obtained by using equation (4),

$$\text{Nitrogen value} = \frac{\text{Protein value} - 2.6304}{2.483} \quad (4)$$

Table I consists of the values calculated as per the 1-210 bands chosen. The average value is calculated which gives the percentage of nitrogen obtained.

Based on the values of the R2 the best correlation of R2 = 0.864 was found between VIG and Protein values as plotted in Fig. 6 (b). The plots in Fig. 6 (a) and 6 (c) shows VIG versus Nitrogen values and Nitrogen values versus Protein values with R2 of 0.716 and 0.628 respectively.

TABLE I: CALCULATED VALUES OF NDVI, VIG, PROTEIN AND NITROGEN FROM 1-210 BANDS

Image Plane	NDVI	VIG	Protein Value	Nitrogen Value
1-15	0.1011	0.9028	2.7771	0.0591
15-30	-0.5156	0.9021	2.7855	0.0625
30-45	0.1896	0.9020	2.7858	0.0626
45-60	0.2514	0.9010	2.8052	0.0704

Image Plane	NDVI	VIG	Protein Value	Nitrogen Value
60-75	0.5205	0.9007	2.8104	0.0725
75-90	0.4254	0.9005	2.8138	0.0739
90-105	-0.6283	0.9014	2.7975	0.0673
105-120	0.2296	0.9011	2.8032	0.0696
120-135	0.2941	0.9010	2.8044	0.0701
135-150	0.2868	0.9011	2.8032	0.0696
150-165	0.3461	0.9002	2.8203	0.0765
165-180	0.3692	0.9011	2.8027	0.0694
180-195	0.2419	0.9000	2.8228	0.0775
195-210	0.4197	0.9011	2.8032	0.0696
Average value of Nitrogen				0.0693
Average value of Nitrogen in %				6.930

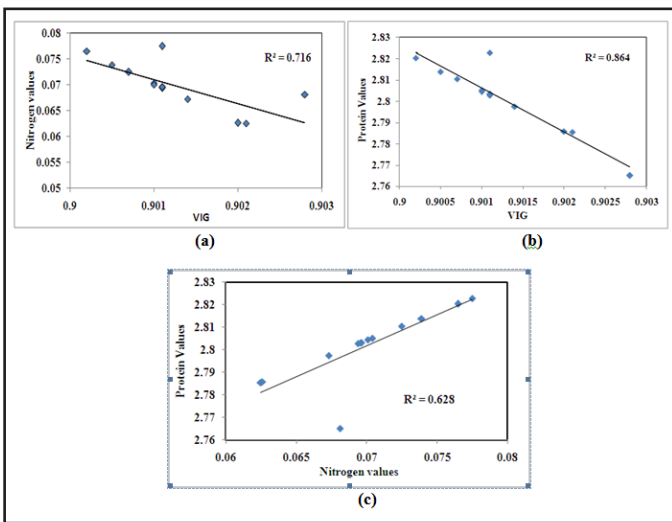


Fig. 6: Relationship Between (a) VIG Versus Nitrogen Values, (b) VIG Versus Protein Values and (c) Nitrogen Versus Protein Values

### B. Ground Truth Data

Ground truth refers to collection of information on location. Ground truth allows image data to be related to real features and materials on the ground. The set of ground truth data enables calibration of remote sensing data and analysis of the data collected. More specifically, ground truth may refer to a process in which a pixel on a satellite image is compared to what is there in reality (at the present time) in order to verify the contents of the pixel on the image. The ground truth data in this study is carried with the help of Experimental analysis of Nitrogen content using Kjeldahl Method.

#### Steps to Estimate Plant Nitrogen Content Using Kjeldahl Method

The Kjeldahl method was used for quantitative determination of nitrogen [30-35] as shown in Fig. 7. The Kjeldahl method is divided into three stages. The steps carried out are as follows:

**Wet Digestion-** Initially a sample is mixed with a proportional amount of a concentrated sulfuric acid in a Kjeldahl flask. The mixture is heated up till it clarifies as  $\text{CO}_2$ . Heated input must be as high as necessary to bring 250 ml of water at 25 °C to a rising and falling boil in 5 min. The solution obtained is an ammonium sulfate solution.

**Distillation-** In the second step, the Kjeldahl flask is attached to a water condenser. An amount of NaOH is added to the resultant digestion solution to turn ammonium ions into ammonia. Ammonia gas is released when the solution is heated, which passes through the condenser, and then it is trapped in a receiving solution (boric acid, standard acid (HCl) or sulfuric acid) contained in a flask.

**Ammonium Estimation-** Due to the fact that ammonia concentration is proportional to nitrogen content in the sample, good ammonia determination is important. The most popular method is titration.

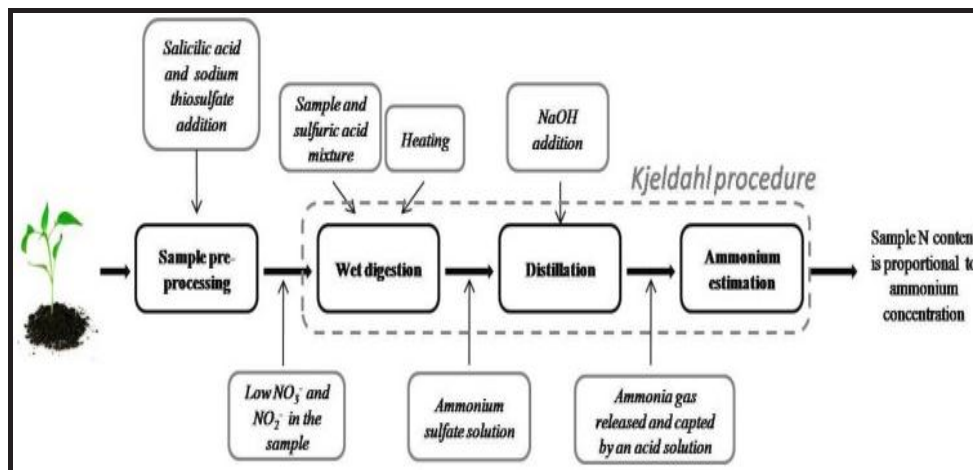


Fig. 7: Block Diagram of Kjeldahl Method [30]

The solution was distilled with sodium hydroxide. The amount of ammonia present was determined by back titration. The end

of the condenser was dipped into a solution of sulfuric acid of precisely known concentration. The ammonia reacted with the

acid and the remainder of the acid was then titrated with a sodium carbonate solution using methyl orange as indicator. Percentage of Nitrogen was calculated using the following formula.

$$\begin{aligned} & \text{Nitrogen value} \\ &= \frac{0.14 \times \text{volume of H}_2\text{SO}_4 \text{ required (ml)} \times \text{Normality of H}_2\text{SO}_4}{\text{Sample weight of the collected leaves (gm)}} \\ &= \frac{(0.14 \times 15 \times 0.05)}{2} \\ &= 0.0525 \end{aligned}$$

The Estimated Nitrogen content in laboratory by Kjeldahl method is 0.0525. The nitrogen content values calculated in the present study obtained from satellite data and the experimental data were 0.0693 and 0.0525 respectively. Both the values match well with each other. The Nitrogen value obtained from this study is in good agreement with the earlier work [36]. A good estimation of the nitrogen content is obtained from the algorithms used in this work. The value calculated concludes that the nitrogen level in crop is fair and wheat crops are healthy.

#### IV. CONCLUSIONS

The satellite images obtained are widely used in the field of research nowadays. The proposed work can be applied to predict the crop health status in the field. The nitrogen content calculated in the present study obtained from satellite data and the experimental values were 0.0693 and 0.0525 respectively. Thus, the results obtained would have an important significance for crop health status.

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