

# A Simple VIS–NIR LED-Based Model for Estimation of Plant Chlorophyll



Wesheü Mero and Subra Mukherjee

**Abstract** Estimation of chlorophyll content often involves destructive analysis and lengthy procedures. Several sensors systems have been developed that measure and monitor plant health status; however, most of these methods are destructive or they involve posh devices. We intended for a cost-effective and noninvasive method for the estimation of chlorophyll content of tulsi (*Ocimum tenuiflorum*) leaves. The proposed sensor system works for diffused transmittance method using VIS–NIR sources kept in the near target area of different conditions of the leaves. Leaves can be sensed under different sensing conditions and their outcome is analyzed. The transmittance values obtained are measured using a detector. Based on the transmittance values, Simple Ratio Vegetation Index (SRVI) is computed and the result is correlated to the chlorophyll content of the leaves. Also, the proposed sensor system has been compared with three different standard laboratory methods and the results obtained are satisfactory. The performance of the proposed sensor system is statistically analyzed using indicators such as RMSE and  $R^2$ . The RMSE obtained is 0.004 and  $R^2$  is found to be greater than 0.9 in almost all the cases. The proposed methodology aims to produce a nondestructive, reliable, convenient, and cost-effective way of estimating chlorophyll content of leaves and thereby aid the agri-tech industry. Further, this work has the potential of providing information for use in remote sensing and energy balance studies.

**Keywords** Chlorophyll · Transmittance · Spectroscopy · Optical sensor · Plant nutrients · Vegetation index

---

W. Mero (✉) · S. Mukherjee  
Department of Electronics & Communication Engineering, Assam Don Bosco University,  
Guwahati, India  
e-mail: [ashelemerowk@gmail.com](mailto:ashelemerowk@gmail.com)

S. Mukherjee  
e-mail: [subra.mukherjee@dbuniversity.ac.in](mailto:subra.mukherjee@dbuniversity.ac.in)

© Springer Nature Singapore Pte Ltd. 2019  
R. Bera et al. (eds.), *Advances in Communication, Devices and Networking*,  
Lecture Notes in Electrical Engineering 537,  
[https://doi.org/10.1007/978-981-13-3450-4\\_1](https://doi.org/10.1007/978-981-13-3450-4_1)

## 1 Introduction

Generally, chlorophyll is a green pigment comprising of tetrapyrrole ring and a central magnesium ion. It is found mostly in plants and algae. A long hydrophobic phytol chain is present in the structure of chlorophyll [1]. Chlorophyll is the most important pigment and is necessary for the conversion of light energy to the stored chemical energy. Chlorophyll absorbs light generally in the red (650–700 nm) and the blue-violet (400–500 nm) regions of the visible spectrum. Green region (~550 nm) is reflected giving chlorophyll its specific color. Chlorophyll aids the body in a unique and distinctive way by detoxifying harmful toxins and fights infection from the body [2]. Two important chlorophyll present are chlorophyll a and b, where chlorophyll a holds a green-blue color, and chlorophyll b holds a green-yellow color [3]. In tumor therapy, chlorophyll or chlorophyll results can be employed such as a photodynamic agent [4]. It can also be further studied, amended, and produced in disciplines like chemistry and physics for different uses comprising of electronic, photophysics, optoelectronic, and electrochemistry [5]. By the color of leaf, one can specify the proportion and amount of chlorophyll in leaves, which are related to the health status of the particular plant based on different conditions. Hence, chlorophyll content can be used as a key to detecting nutrient status. Various kinds of color chart and chlorophyll meters have been developed to estimate leaf color or chlorophyll content which are helpful in agro-industry but may lead to certain limitations [6]. Spectral signature characteristics are closely related to leaf chlorophyll content and depend on the interaction that occurs when light emits plant tissue, where some of the signals will be absorbed, transmitted, and reflected from the leaf surface [7]. Readings from the chlorophyll meter are basically a measure of the greenness of leaf and in general shows the linear relationship with extractable chlorophyll concentrations for a wide variety of crops. However, environmental conditions may affect the relationship between plant species [8]. The usability of Soil Plant Analysis Development (SPAD) meter transforms the indices to interpretable data. Before the readings are measured for a particular species, calibration is required as the sensor changes the signal into indices that could cause variation [9]. However, spectral signatures are useful in sensing plant stress only if one single factor is involved. It may be challenging when different stress factors affect a plant at the same time. This is due to the fact that some stressors may affect the physiology of the plant species in a similar way, as in the case of nutrient deficiency and varies in pigment, moisture, and canopy of plant species [10]. In paper [11–14], estimation of chlorophyll content was mostly performed by chlorophyll meters and digital cameras using reflectance measurement, in different types of leaves. Extraction and different types of vegetative indices were also obtained with the measurement data. Different techniques were employed but show the nonlinear relationship with the chlorophyll content.

In this paper, optical properties for detection, monitoring, and estimation of chlorophyll content are considered. In a nutshell, the transmittance measurement has been currently employed in designing of the sensor system. The system uses transmittance measurement in such a way that the light transmitted by the sample, i.e., based on

different conditions of leaves, is collected by the detector and gives the correlate output voltage. Several VIS–IR sources were used. But further, it was preceded with IR and red sources, because it gives a better correlation with the chlorophyll content. So, we intended to produce a simple cost-effective sensor system for detection and monitoring of factor(s) related to plant health status.

## 2 Materials and Methods

### 2.1 *Single-Leaf Method*

Leaves were collected from different conditions of tulsi (*Ocimum tenuiflorum*) leaves. Transmittance measurement was performed. Several experiments were carried out and the transmittance readings were obtained for different conditions of tulsi (*Ocimum tenuiflorum*) leaves. Analysis of the experiments was performed in a dark room at room temperature. The two sources red (650 nm) and IR (930 nm) were used during the experiment. So, for transmittance response, it was converted into Simple Ratio Vegetative Index (SRVI) and statistical analysis was carried out.

### 2.2 *Spectrophotometer Method*

Leaves of tulsi (*Ocimum tenuiflorum*) plant under different conditions, i.e., healthy, early stress, slightly stress, and fully stress, were collected. Separate sample solutions were prepared and the absorbance and transmittance values were obtained using a spectrophotometer. The values obtained were converted into Chlorophyll Concentration Index (CCI) and chlorophyll concentration for the validation of further analysis.

### 2.3 *Design of the System*

Generally, the design of the sensor system shows the use of devices like LEDs for measuring chlorophyll content. The properties of diffuse transmittance were used in order to check the transmitted light from the samples. The system consists of the sensing part which has two sources—IR (930 nm) and red (650 nm)—and detector along with the sample to be examined. It has a control unit for estimating and monitoring the chlorophyll of leaves based on different conditions, and finally display unit, where the result will be displayed based on the decision. Figure 1 shows the block diagram and Fig. 2 shows the flowchart of the proposed methodology.

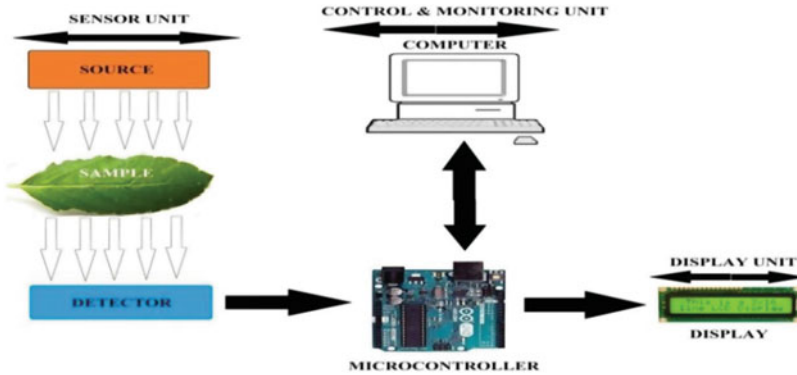


Fig. 1 Block diagram of the proposed sensor system

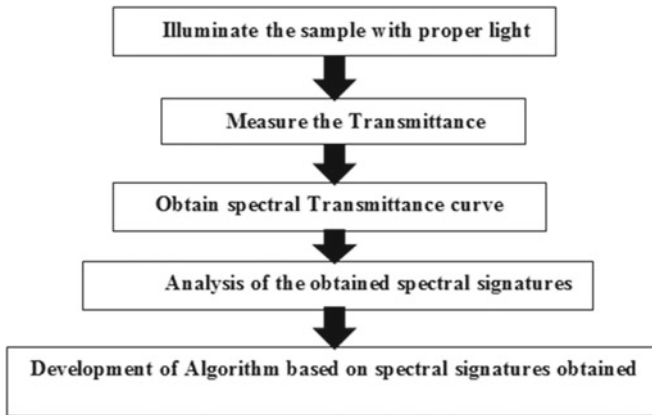


Fig. 2 Flowchart for the proposed methodology

### 3 Results and Discussion

Greens are highly useful for the maintenance of health and prevention of diseases and also considered important sources of protective food [2]. To study this, we considered an important parameter known as **Simple Ratio Vegetation Index (SRVI)** which measures the greenness of leaf.

Figure 3 shows the comparison done for SRVI obtained for different conditions of tulsi leaves. Several experiments were carried out to analyze the relation of red and infrared wavelengths to the chlorophyll content. Different conditions, i.e., healthy, early stress, slightly stress, and fully stress of tulsi (*Ocimum tenuiflorum*) leaves, were used for estimating the chlorophyll content and it was observed that SRVI value varies for different conditions of tulsi (*Ocimum tenuiflorum*) leaves.

Simple Ratio Vegetation Index (SRVI) is a simple indicator employed to check the greenness of a target area. It is given by

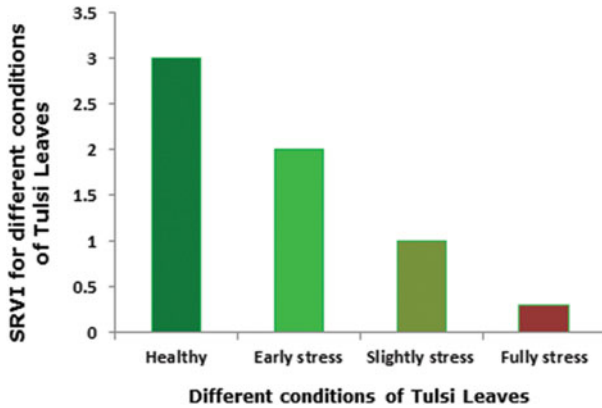


Fig. 3 SRVI for different conditions of tulsi (*Ocimum tenuiflorum*) leaves

$$SRVI = \frac{\text{Transmitted or reflected light from the leaf in IR region}}{\text{Transmitted or reflected light from the leaf in Red region}}$$

### 3.1 Comparison of SRVI for Different Methods

Comparing reported data collected from tulsi (*Ocimum tenuiflorum*) plant from different conditions, i.e., healthy, early stress, slightly stress, and fully stress, different methods were employed, i.e., SRVI of single-leaf method, SRVI from the Spectrophotometric method (SPH), chlorophyll concentration (Theoretical), and Chlorophyll Concentration Index (CCI) based on spectrophotometric method. These four methods showed the strong relationship and were correlated with different conditions of the plant (Fig. 4).

In CCI of tulsi (*Ocimum tenuiflorum*) leaves, the values correlated linearly to SRVI with  $R^2$  of 0.90. The chlorophyll concentration affects the plants of various species including the photosynthetic rate. So from several analyses obtained, the concentration relates well with SRVI.

The SRVI (SPH) was also linearly correlated with SRVI and has an  $R^2$  of 0.96. These further confirm the need of developing a definite relationship from the obtained results. Higher  $R^2$  obtained furthermore check the strength of the sensor system for use in other plant species (Fig. 5).

In Fig. 6, the chlorophyll concentration (SPH) was linearly correlated with SRVI and has an  $R^2$  of 0.94. Table 1 also shows the performance of the proposed sensor system when compared with different methods, i.e., Spectrophotometer, Theoretical chlorophyll concentration, and Chlorophyll Concentration Index (CCI). The error performance was best observed in spectrophotometer for the different conditions of

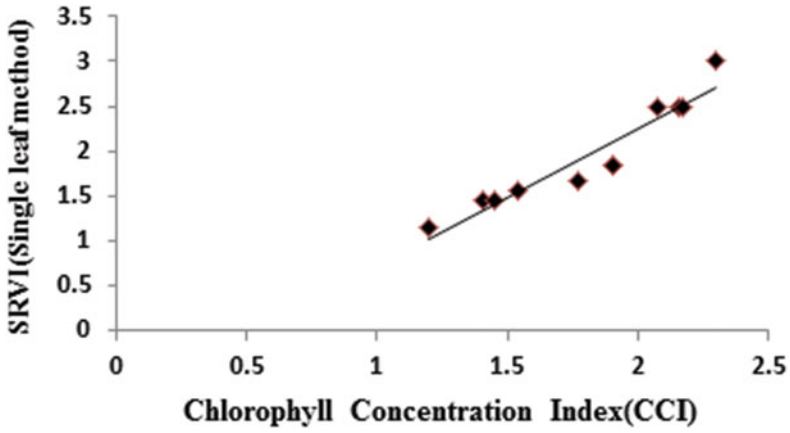


Fig. 4 Relationship between SRVI of single-leaf method with Chlorophyll Concentration Index (CCI)

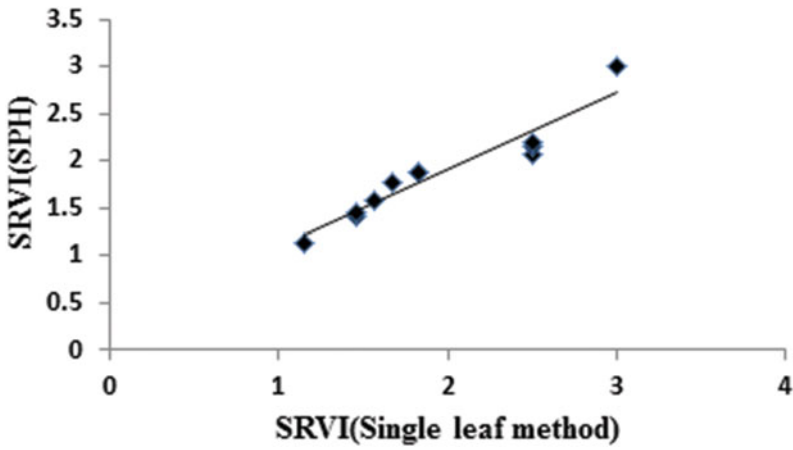
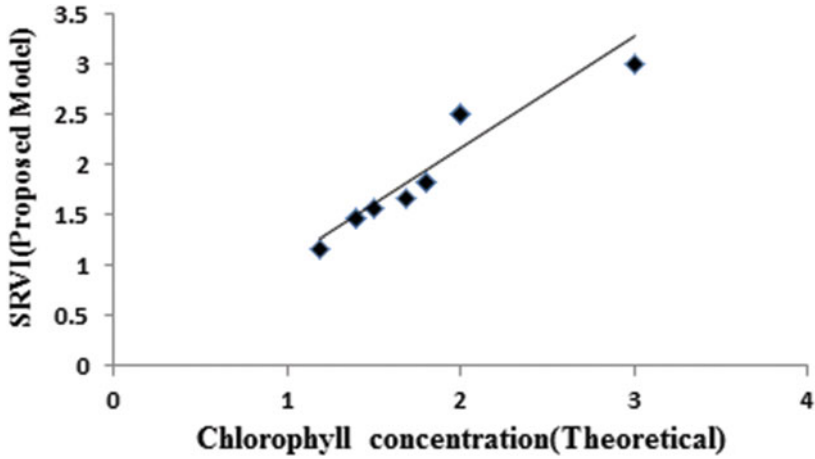


Fig. 5 Relationship between SRVI of single-leaf method with SRVI (SPH)

tulsi (*Ocimum tenuiflorum*) plant obtaining  $R^2$  value of 0.997 and RMSE value of 0.004.



**Fig. 6** Relationship between SRVI of single-leaf method with chlorophyll concentration (theoretical)

**Table 1** Performance analysis of different methods

Conditions of leaves	SRVI of proposed sensor system	SRVI of spectrophotometer	SSE	SST	R <sup>2</sup>	RMSE
Healthy	2.99	3	0.0122	4.0074	0.99	0.045
Early stress	1.4	1.5	0.0001	0.008	0.99	0.004
Slightly stress	0.877	0.9	0.012	4.0074	0.99	0.0447
Fully stress	0.2	0.1	0.012	4.0074	0.99	0.0447
		SRVI of theoretical chlorophyll concentration				
Healthy	3.89	4	0.05	1.479	0.94	0.0912
Early stress	12	1.3	0.0025	0.003	0.96	0.02
Slightly stress	0.78	0.37	0.002	0.008	0.97	0.0183
Fully stress	0.288	0.3	0.002	0.008	0.97	0.0183
		SRVI of chlorophyll concentration index (CCI)				
Healthy	1.887	2	0.025	1.479	0.98	0.0645
Early stress	1.25	1.267	0.001	0.005	0.98	0.0129
Slightly stress	0.49	0.5	0.018	0.007	0.94	0.0547
Fully stress	0.373	0.4	0.018	0.007	0.94	0.0547

## 4 Conclusion

A simple method based on VIS–NIR LED for estimation of chlorophyll content/nitrogen content in tulsi (*Ocimum tenuiflorum*) leaves has been reported. Estimation of chlorophyll content of leaves has been employed from the red and IR wavelength region. An indicator called SRVI was calculated for the different conditions of tulsi (*Ocimum tenuiflorum*) leaves. The SRVI value varies based on the status of the leaves. The SRVI is greater than 1 for high chlorophyll content indicating healthy leaf and less than 1 for leaves having low chlorophyll content. Different standard laboratory methods were also performed and compared to validate the performance of the proposed sensor system and it showed satisfactory results. RMSE and  $R^2$  were also obtained for healthy, early stress, slightly stress, and fully stress leaves. The success rate from the proposed sensor system was found to be 93%. Further studies will continue with estimation of nitrogen content in different types of leaves. Also, other features of the leaves can be explored and evaluated for their improved representation of nitrogen content in leaves. All different plant species have different concentrations of chlorophyll. So for a specific plant, the content also varies due to different regions. Based on different conditions of the leaves, the content of the chlorophyll may differ.

## References

1. Aminot A, Rey F (2000) Standard procedure for the determination of chlorophyll a by spectroscopic methods. International council for the exploration of the sea. ISSN 0903-260
2. Rajalakshmi K, Banu N (2013) Extraction and estimation of chlorophyll from medicinal plants. Int J Sci Res (IJSR) 4(11). ISSN (Online): 2319-7064, Index Copernicus Value (2013): 6.14, Impact Factor (2014): 5.611
3. Aron D (1949) Copper enzymes isolated chloroplasts, polyphenoloxidase in *Beta vulgaris*. Plant Physiol 24:1–15
4. Brandis AS, Salomon Y, Scherz A (2006) Chlorophyll sensitizers in photodynamic therapy. Adv Photosynth Respir 25:461–483
5. Nurhayati N, Suendo V (2011) Isolation of chlorophyll a from spinach leaves and modification of center ion with  $Zn^{2+}$ : study on its optical stability. J Mat Sains 16(Nomor 2)
6. Kawashima S, Nakatani M (1997) An algorithm for estimating chlorophyll content in leaves using a video camera. National Institute of Agro-Environmental Sciences, Tsukuba, and Kyushu National Agriculture Experiment Station, Miyakonojo, Annals of Botany Company, 9 Sept 1997
7. Liew OW, Jenny Chong PC, Li B, Asundi AK.(2008) Signature optical cues: emerging technologies for monitoring plant health. Sensors
8. Wood CW, Reeves DW, Himelrick DG (1993) Relationships between chlorophyll meter readings and leaf chlorophyll concentration, N status, and crop yield: a review. Proc Agron Soc N Z 23:1–9
9. Marquard, RD, Tipton JL (1987) Relationship between extractable chlorophyll and an in situ method to estimate leaf greenness. HortScience 22:1327–1327
10. Li X, Zhao X, Fang Y, Jiang X, Duong T, Fan C, Huang C-C, Kain SR (1998) Generation of destabilized green fluorescent protein as a transcription reporter. J Biol Chem Am Soc Biochem Mol Biol Inc 273(52):34970–34975



11. Mark S, Gitelson AA, Rundquist D (2008) Non-destructive estimation of leaf chlorophyll content in grapes. *Pap Nat Resour* 282
12. Liang Y, Urano D, Liao K-L, Hedrick TL, Gao Y, Jones AM (2017) A non-destructive method to estimate the chlorophyll content of *Arabidopsis* seedlings
13. Pal K, Singh RD, Prasad R (2012) Non-destructive estimation of chlorophyll and nitrogen content in leaf of *Rosa damascena*
14. Lichtenthaler HK, Gitelson A, Lang M (1996) Non-destructive determination of chlorophyll content of leaves of a green and aurea mutant of tobacco by reflectance measurements