THE OPTIMIZATION OF THE CROP CHLOROPHYLL CONTENT INDICES BASED ON A NEW LAI DETERMINATION INDEX [1]

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ABSTRACT

The paper presents a new modification method of chlorophyll content index based on a new LAI index-sLAIDI to solve the problem of chlorophyll content index influenced by LAI. Based on the data stimulated by PROSPECT-SAIL modal and measured data, seven chlorophyll content indices are chosen and divided by $sLAIDI^k$ to reduce the influence of LAI. Based on the stimulated dataset, the normalized standard deviation of chlorophyll content indices are used to evaluate effect of modification to determine the parameter k. Measured dataset are used and to verify result of modification. The result shows that chlorophyll content index divided by $sLAIDI^k$ can improve accuracy of estimation, and parameter k is different for different chlorophyll content indices.

Keywords: sLAIDI, Chlorophyll Content Indices, Normalized Standard Deviation, LAI

1. INTRODUCTION

The chlorophyll content is an important factor in the field of biology, ecology and agriculture for estimation of the crop health status and vigor. With the chlorophyll content of plant we can monitor the crop growth and plant diseases, and predict yield. Remote sensing which can obtain the spectrum of land cover is a fast, low-cost and wide-area method to estimate chlorophyll content. The semi-empirical relationship between the chlorophyll content and spectral feature have been studied. And several chlorophyll content indices have been described in the previous researches based on the chlorophyll absorption and shift of red_edge such as MCARI [1] (Modified Chlorophyll Absorption Ratio Index) TCARI[2](Transformed Chlorophyll Absorption Ratio Index), and so on.

However, these indexes are always sensitive to other vegetation factors changing such as leaf area index (LAI), when applied in the canopy scale [3]. That results in that the evaluation of the chlorophyll content is influenced by LAI changing: overestimation when LAI is high and underestimation when LAI is low. Some well known LAI related indices are also sensitive to chlorophyll content. However, the sLAIDI (standardized LAI Determining Index) developed by S.Delatieux [4], is insensitive to variation of leaf chlorophyll content, and can effectively measure the canopy LAI (determination coefficient is 0.83). S.Delatieux has proposed that sLAIDI can be considered as an optimization parameter to eliminate impacts of LAI on the chlorophyll content indices. Based on the above thought, the paper continues to study on the modification of chlorophyll content index by sLAIDI.

2. MATERIALS

Study area is located in the Zhangye district of the GanSu province of the China. The dataset of corn were collected on May 20 and June 29, 2008. Spectrum of corns were measured with ASD FieldSpec Pro FR spectroradiometer with a spectral range of 350-2500nm. The sampling interval across 350—1000nm is 1.4nm and across1000-2500nm is 2nm. SPAD-502 chlorophyll Meter chlorophyll was used to detect leaf chlorophyll content.

3. METHOD

3.1 Stimulated data

PROSPECT [5] modal can effectively stimulate leaf transmittance and reflectance with different biochemical and physical parameters. Leaf spectrum with range of 500-1500nm is stimulated by PROSPECT modal with Leaf mesophyll structure index value of 1.3, water content of 0.012 g/cm2, dry matter content of 0.005 g/cm^2, brown pigment content value of 0, angle degree of 59°, and

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chlorophyll content ranging from 10 to100 μg/cm^2 with interval of 10μg/cm^2.

Canopy reflectance spectra are stimulated by the SAIL (Scattering by Arbitrarily Inclined Leaves) modal [6] which can stimulate spectral reflectance of continuous canopy. The modal takes leaf at any direction as the basic unit, and calculates canopy spectrum through stimulation light scatting absorption and reflectance by leaf. Based on the stimulated leaf spectrum, canopy spectral reflectance ranging from 500 to 1500nm with interval of 1nm was stimulated by SAIL modal. Single Value model was chosen and the input parameter fraction direct solar value is 1 ,solar declination value of 0, latitude decimal of 40, view azimuth angle of 0°, view zenith angle of 0°, time of day of 10 and LAI values of 1 2 3 4 5 6 7 8 9 10.

3.2 Vegetation Indices

1) Chlorophyll content Indices

Seven chlorophyll content indices are chosen, which are MCARI [1], TCARI [2], MTCI [7] (Moderate Resolution Imaging Spectrometer Terrestrial Chlorophyll), DD [8] (Double Difference Index), R-M [9] (Red-edge Model), TCL [3] (Triangular Chlorophyll Index), GM [10] as follow:

$MCARI= [(R_{700}-R_{670})-0.2*(R_{700}-R_{550})]*(R_{700}/R_{670})$ Eq.1

$TCARI=3*[(R_{700}-R_{670})-0.2*(R_{700}-R_{550})*(R_{700}/R_{670})]$ Eq.2

$MTCI=(R_{750}-R_{710})/(R_{710}-R_{680})$ Eq.3

$DD=(R_{750}-R_{720})-(R_{700}-R_{670})$ Eq.4

$R\text{-}M = (R_{750}/R_{720})-1$ Eq.5

$TCL = 1.2*(R700-R500)-1.5*(R670-R550)*\sqrt{R_{700}/R_{670}}$ Eq.6

$GM=R_{750}/R_{550}$ Eq.7

Where R_x represents spectral reflectance in band of x nm

2) sLAIDI

Equation of sLAIDI as follow:

$$sLAIDI = S \bullet \frac{(R_{1050} - R_{1250})}{(R_{1050} + R_{1250})}$$ Eq.8

Where S is scaling factor which can adjust sLAIDI value between 0 and 1. R_{1050} and R_{1250} respectively represents spectral reflectance of 1050 and 1250nm.

3.3 Modification of chlorophyll content indices

Chlorophyll content indices are influenced by LAI: overestimation when LAI is high and underestimation when LAI is low. Meanwhile sLAIDI has little relativity with chlorophyll content, but highly correlates with LAI value. Therefore, we can divide chlorophyll content indices by sLAIDI to make the chlorophyll content indices smaller when LAI is high, and chlorophyll content indices larger when LAI is high. Because influence on different chlorophyll content indices by LAI changing is different, exponential function of sLAIDI is used so that we can adjust the coefficient k of the function to achieve optimization of every chlorophyll content index (shown in Eq. (9)).

$\text{Chlorophyll index*}=\text{Chlorophyll index}/sLAIDI^k$ Eq.9

Where Chlorophyll index* represents chlorophyll content index after modification and Chlorophyll index represents chlorophyll content index without modification. Coefficient k determines effect of modification, and is different for different indices.

3.4 Evaluation factor

3.4.1 Stimulated dataset

We stimulate canopy spectral reflectance with chlorophyll content ranging from 10 to100μg/cm^2 and LAI value from 1 to 10. From Figure 1, for the same chlorophyll content, chlorophyll content index gradually increases with increase of LAI.

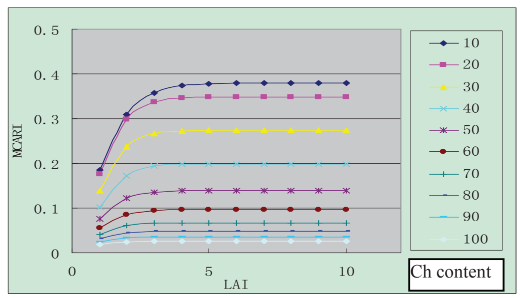


Figure 1 relationship between MCARI Value and LAI. Ch content means chlorophyll content (μg/cm^2)

For the same chlorophyll content, normalized standard deviation (Eq.10) of chlorophyll content index are calculated to estimate influence by LAI. Then mean of normalized standard deviation of chlorophyll content index for different chlorophyll content is used as evaluation factor for modification. The smaller normalized standard deviation is, the better modification is.

$$\sigma = \sqrt{\frac{1}{n}\sum_{i=1}^{n}\left(\frac{X_i - \bar{X}}{\bar{X}}\right)^2}$$ Eq.10

Where $\bar{X}$ represents mean, i means number, and X denotes index value.

3.4.2 Measured data

Because of lack enough measured data, normalized standard deviation cannot be calculated. So correlation coefficient (Equation. (11)) between chlorophyll content index and chlorophyll content can be considered as the evaluation factor. The higher correlation coefficient, better effect of modification is.

$$R=\frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2\sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad \text{Eq.11}$$

Where R denotes correlation coefficient, $\bar{x}$ and $\bar{y}$ denote mean of x and y, y_i and x_i denotes variable, and n denotes number.

4. RESULT

4.1 Normalized standard deviation of index value

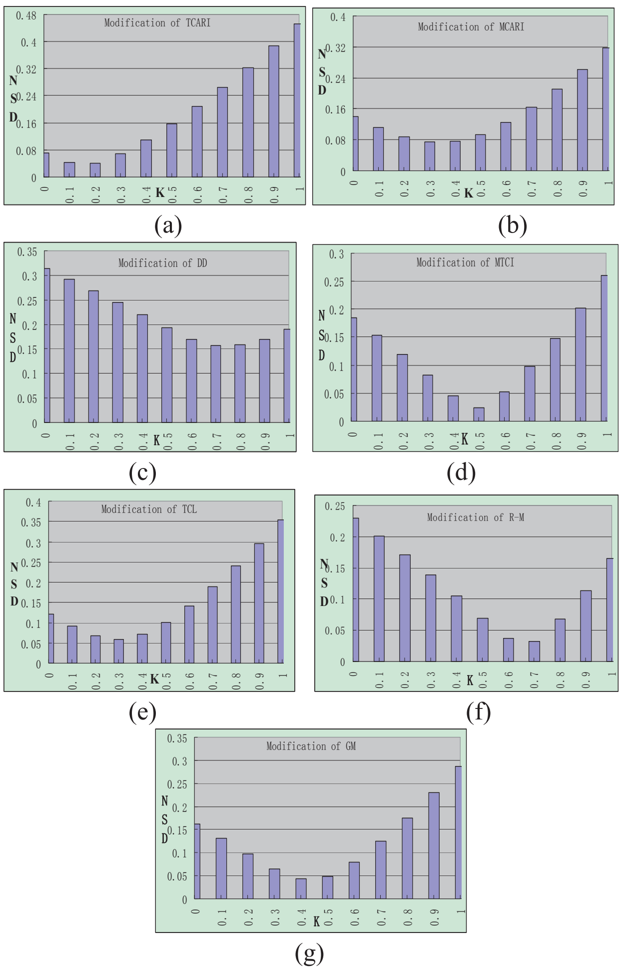


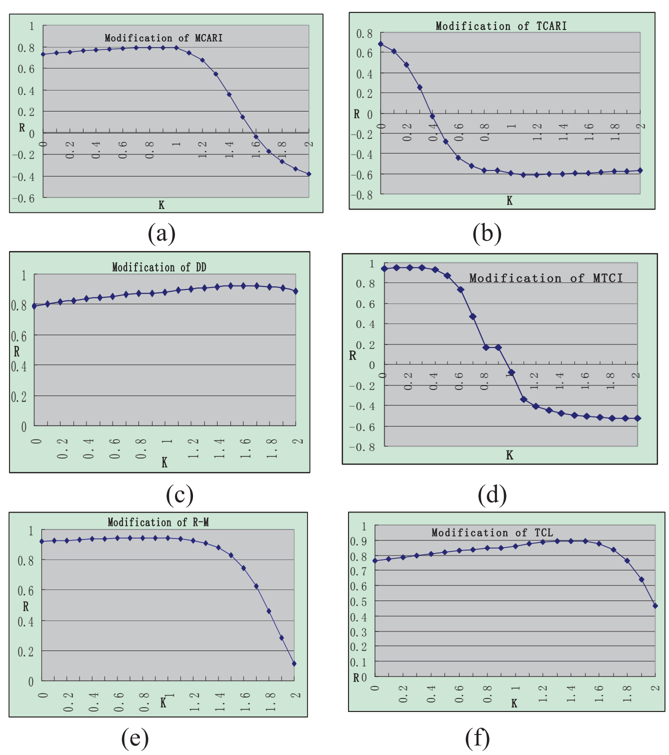
Figure 2 modifications of chlorophyll content indices based on the stimulated dataset. Figure (a) (b) (c) (d) (e) (f) (g) show the modification of chlorophyll content indices of MCARI, TCARI, MTCI, DD, R-M, TCL, GM with normalized standard deviation as abscissa and with k as ordinate. When k = 0 and $sLAIDI^0 = 1$, it means the normalized standard deviation of chlorophyll content index without modification

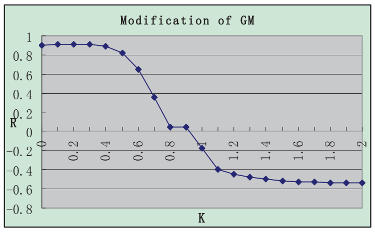
From the Figure 2, we can see that by adjusting the coefficient k of the $sLAIDI^k$ the normalized standard deviation of chlorophyll content indices can be effectively reduced. Moreover, with the k value gradually increasing from 0.1 to 1.0, normalized standard deviation firstly increases and then decreases. In other words, improper modification coefficient k may cause the normalized standard deviation of chlorophyll content index increasing, which leads to bad result of modification. The optimal normalized standard deviation and k value for each index are shown in the Table 1. Because k is discrete, only the approximation optimal result can be obtained.

Ch Index	Pre NND	NND	k
MCARI	0.139769	0.074573	0.3
TCARI	0.071696	0.041605	0.2
MTCI	0.184905	0.02355	0.5
DD	0.313584	0.156678	0.7
R-M	0.229432	0.032463	0.7
TCL	0.121279	0.058096	0.3
GM	0.162715	0.044454	0.4

Table 1 the best NND and k for different chlorophyll content indices based on stimulated data. Ch Index means chlorophyll content index. Pre NND means normalized standard deviation before modification. NND means the optimal normalized standard deviation with modification.

4.2 Correlation coefficient of index value





(g)

Figure 3 modifications of chlorophyll content indices based on measured data. Figure (a)(b)(c)(d)(e)(f)(g),respectively show the chlorophyll content indices of MCARI, TCARI, MTCI, DD, RM, TCL, GM with correlation coefficient R as abscissa and with k as ordinate When k = 0 and $sLAIDI^0 = 1$, it means correlation coefficient of the chlorophyll content index without modification.

As shown in the Figure 3, for the most chlorophyll content indices except TCARI, by adjusting the coefficient k, the correlation coefficient between chlorophyll content and chlorophyll content index can increase. In addition, with K increasing, correlation coefficient firstly increases and then decreases. It is also proved that, modification with inappropriate k value can lead to bad effect. And the correlation coefficient of TCARI does not increase and it indicates that the method of the modification still has some limitations.

Ch Index	Pre R	R	k
MCARI	0.732113	0.791266	0.8
TCARI	0.681747	*	*
MTCI	0.945106	0.953301	0.2
DD	0.79093	0.92202	1.7
R-M	0.918297	0.943128	0.8
TCL	0.762446	0.894161	1.4
GM	0.904055	0.911968	0.2

Table 2 the best R and k for different chlorophyll content indices based on measured data. Ch Index means chlorophyll content index. Pre R means correlation coefficient before modification. R means the optimal correlation coefficient with modification.* denotes no data.

By comparing modification result based on stimulated data with that based on measured data, we can conclude that modification coefficient k got by stimulated data is different with k got by measured data, and that effect of stimulated data is better than the measured data. Some reasons may explain the conclusions: the major reason may be the poor quality of the measured data. In this study, the number of spectrum reflectance and chlorophyll content is less, and range of chlorophyll content is between 30 and 50μg/cm^2. Therefore error of modification of chlorophyll content index is big. In addition, PROSPECT-SAIL physical modal which is only the approximation of real world, can cause the error. So the better verification of modification need more measured data in future study.

5. CONCLUSION

The paper purposes the modification of chlorophyll content index based on the sLAIDI methods, and verifies it with stimulated data and measured data. We choose 7 chlorophyll content indices, divide them by $sLAIDI^k$, and use normalized standard deviation and correlation coefficient to evaluate the result of modification and to determine coefficient k. Through the results, we can conclude that no matter whether they are based on stimulated data or measured data, chlorophyll content indices combined with sLAIDI can more accurately estimate chlorophyll content. Inconsistency of coefficient k for stimulated data and measured data are discussed.

6. REFERENCES

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