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Analysis of Canopy Spectral Sensitivity on Representative Campus Vegetation in Different Growth Periods

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Abstract: The spectral reflectance data and canopy leaf area index (LAI) of some representative campus vegetation was measured at their beginning and the end of growth period, which was carried under the natural condition in Chengdu University of Technology. Based on analysis of canopy spectral reflectance curve of different cumulative sample capacity, the distinct and sensitive point or wave on the curves of various types of vegetation at their different growth stages was determined by the method of differential spectrum, characteristic bands extraction and correlation analysis, etc. And then the ratio vegetation index (RVI) and difference vegetation index (DVI) was extracted from canopy hyperspectral data collected to analyze the correlation between LAI and vegetation index. The results show that RVI has good relation with LAI. The research had got the correlation between the spectrum characteristics of campus vegetations and the correlation between vegetation spectrum and vegetation index, which supplies a reference for the research of other vegetation Spectral reflectance characteristic, and also provides theoretical basis for vegetation remote sensing dynamic monitoring.

Keywords: *Canopy spectral reflectance; Leaf area index; Vegetation index; Different growth period*

1. Introduction

Vegetation is an important influence factor of human living environment. Identifying vegetation characteristics correctly is the basis work of ecological research. At present, the methods for recognizing vegetation characteristics mainly include field survey, image interpretation and digital remote sensing. Traditional field survey needs manpower, material, financial resources and time to identify vegetation and its cover changes[1]. Moreover, the limitation of this approach is very large, and it is also difficult to meet the needs of vegetation study[2].

In the remote sensing study of vegetation, the images acquisition from traditional remote sensing and multispectral remote sensing are often only have a few discrete band of space information, radiation information and spectral information, besides, the amount of information is discontinuous and not rich enough, and it will also lose lots of useful information, all of the problem are influenced and constrained by band width, the number of bands and wavelength position. However, hyperspectral remote sensing, which had broken this bottleneck, greatly reduced the difficulty in identifying vegetation characteristics and classifying imprecisely[3-4] It provides vast amounts of data for identifying vegetation characteristics and vegetation growth dynamic monitoring technology, and it also benefits the monitoring of plant growth and grasps the characteristics of plant growth[5-7].

At present, many scholars, at home or abroad, did lots of research on hyperspectral data and achieved good results, such as the large area crop yield estimates [8-9], crop pest monitoring and forecasting[10-11], dynamic change monitoring of the growth status [12-13], large-scale vegetation interpretation[14-16] and so on. But the research on artificial vegetation canopy spectral characteristics by hyperspectral remote sensing is relative vacancy. This paper used the existing vegetation and instruments, selected typical artificial vegetation in Chengdu University of Technology, determined spectral information of vegetation and the corresponding leaf area index in the natural condition, and then analyzed vegetation canopy spectral characteristic curve and the relationship between vegetation index and leaf area index to provide theoretical and data basis for remote sensing image interpretation.

2. Data

2.1. Acquisition and Processing of Spectral Data

The acquisition of spectral data in this study was carried out in indoor and outdoor, respectively. The typical green vegetation measured were 22 species in total, 11 of which were selected according to the data quality and divided into three kinds: arbor, bush and herb. The sample classification is shown in Table 1. When measured indoors, the researcher made the sample of vegetation leaves that was collected in advance measured under the condition of artificial light source, and got the leaves spectral reflectance curves of different vegetation types. When measured outdoors, the researchers used the ASD Field Spec

Pro, whose effective band is between 350~2500nm. The field experiment is done from October 2013 to April 2014. To avoid the errors of vegetation spectrum due to the different environmental conditions, it is necessary to make the following operation: Firstly, each sampling point must do the white correction in the process of the spectral measurement; Secondly, reflective spectra were measured between 10:00-14:00 on the clear day, in order to reduce the influence of different solar zenith angle on the reflectivity; Thirdly, some spectral band, which is serious influenced by water vapor absorption, were removed to remove the impact of water vapor, which was facilitate the following analysis of spectral curves; Fourthly, in order to remove the random noise, each sample was measured 9 times, and then the average value is taken as the final value of the spectrum, complete with ENVI, at the same time smoothing effect is shown in Figure 1.

Table 1: *sample vegetation classification*

Vegetation type	Selected vegetation
Arbor	Willow, Ligustrum, Ginkgo, Cedar
Bush	Pittosporum, Wintersweet Lobular privet
Herbaceous	Ophiopogon japonicus, Fern, Bamboo, Agrostis,

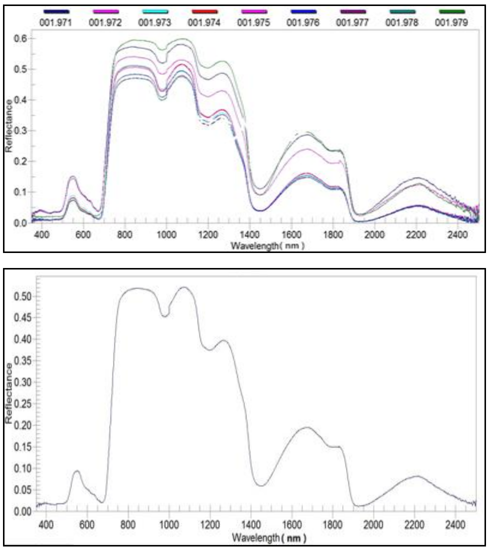


Figure 1: *The Ophiopogon japonicas spectral curves of nine measurements (upper) and their mean value(lower)*

2.2 Determination of Leaf Area Index

Leaf area index (LAI) refers to the ratio of the total area per unit of land plants and land area, which is one of the important parameters in ecosystem research[17] In the spectral sample area, the researcher utilized SUNSCAN2000 canopy analyzer to measure corresponding LAI for each sample. Because the leaf layer depth is different, the value of LAI is different, so keeping the same height every time when measured is necessary, by this way, it is conducive to analyze and comprise observation data that measures at different observations in different time.

3. Method

3.1. Differential derivative spectra method

The spectral line of vegetation is similar, the peaks and valleys appear in the similar band, but there are differences in part of reflectance peaks and troughs, which are the characteristics of vegetation spectral curve. Vegetation canopy spectral reflectance characteristics usually contain reflection or absorption intensity characteristics, waveform characteristics, index characteristics and so on. For the effective spectral analysis, we need enhance the spectral characteristics; the main methods are including spectral derivative method, spectral differential method, normalization method and continuum removal method.

Various linear and nonlinear transformations can be used for the plant spectrum. And its first order differential transformation can reduce the difference of the nonsensitive spectral bands of vegetation, and distinguish the difference of the sensitive band. It is beneficial to extract the different vegetation band. Therefore, first order differential method was used to extract the different band from hyperspectral data samples data and to analyze its feature. By comparing spectral reflectance characteristics and its differences between the original and the first-order differential spectrum curve, the characteristic spectral curve of arbor, bush and herb can be analyzed in the same growth period of the same plant type or in the same kind of different growth periods, the parameter information of the red edge slope and the position of red edge can also be analyzed.

3.2. The vegetation index model method

The vegetation index is often used to estimate biophysical and other biochemical parameters such as vegetation leaf area index, etc. The paper mainly dealed with each canopy spectral band of the campus typical vegetation based on hyperspectral technology, and then generated two common vegetation indexes, respectively ratio vegetation index (RVI) and difference vegetation index (DVI). Red band that has strong absorption in the vegetation and the near infrared that has high reflectance on the vegetation was selected to analyze the correlation between vegetation index and leaf area index, and then determined the best vegetation index which was sensitive to the LAI. RVI is the reflectance ratio between in near infrared region and the red region. It can be formulized as the following equation:

$$RVI = \rho_{\lambda 1} / \rho_{\lambda 2} \tag{1}$$

where $\rho_{\lambda 1}$ is near infrared reflectance, $\rho_{\lambda 2}$ is red band reflectance.

DVI is the reflectance difference in near infrared region and the red region, the formula is as follows:

$$DVI = \rho_{\lambda 1} - \rho_{\lambda 2} \quad (2)$$

where $\rho_{\lambda 1}$ is near infrared reflectance, $\rho_{\lambda 2}$ is red band reflectance.

4. Analysis of canopy spectral sensitivity characteristics

4.1. Analysis of arbor canopy spectral sensitivity characteristics

4.1.1. The Different Arbor Canopy Spectral Characteristics in Same Growth Period

Four kinds of arbor, namely, Ligustrum, Willow, Cedar and Gingko, were selected to research their canopy spectral reflectance characteristics. Their canopy spectral reflectance curves and the first order differential spectral curves of canopy spectral reflectance curves in the same growth period were shown in Figure 2. From the figure, it can be seen that the canopy spectral reflectance curves of four arbors formed a reflection peak near 550 nm and an absorption trough near 675 nm. What's more, the first order differential spectral curves formed reflection peaks both in near 500 nm and 700 nm to 750 nm, its red edge feature were obvious.

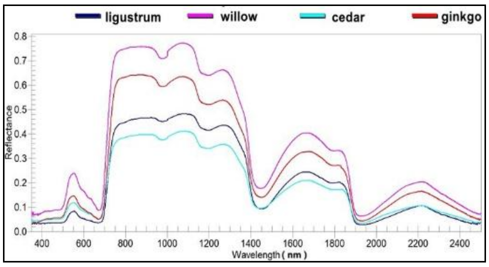


Figure 2: *The different arbor canopy spectral reflectance curves in the same period (upper), and the first order differential spectral curves of canopy spectral reflectance curves (lower).*

4.1.2. The Same Arbor Canopy Spectral Characteristics in Different Growth Period

Ginkgo's canopy spectral reflectance characteristics and the first order differential spectral curves of canopy spectral reflectance curves in the beginning and the end of growth period were shown in Figure 3. By comparing the spectral reflectance in different growth periods, it can be found that Ginkgo's red edge slope peak in the end of growth period is higher than that in the beginning. This was due to the canopy spectral reflectance characteristics of vegetation, which was not only related with the chlorophyll content, but also associated with the water in the vegetation, the content of water and chlorophyll in vegetation reduced in the end of growth period. It can be seen from the first order differential curves, there was large difference between two growth seasons of red edge slope, and red edge of Ginkgo moved to short wave, appear blue shift.

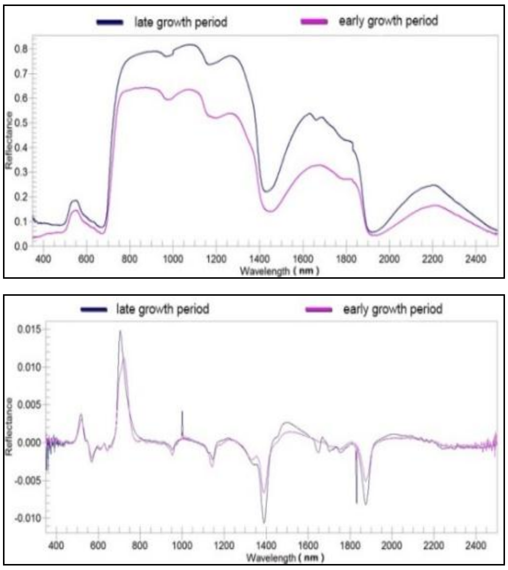
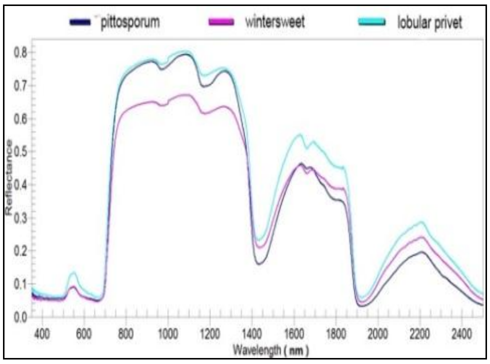


Figure 3: *The canopy spectral reflectance curves of Ginkgo in the different growth periods (upper), and the first order differential spectral curves of Ginkgo in the different growth periods (lower).*

4.2. Analysis of bush canopy spectral Sensitivity characteristics

4.2.1. The different kinds of bush canopy spectral characteristics in same growth period

Three kinds of bush like Pittosporum, Winter Sweet and Lobular Privet were selected to analyze the canopy spectral reflectance characteristics of bushes. Their canopy spectral reflectance curves and the first order differential spectral curves of canopy spectral reflectance curves in the same growth period were shown in Figure 4. The canopy spectral reflectance curves of them were similar, and all of them formed a reflection peak near 550 nm and an absorption trough near 675 nm, on account of the impact of chlorophyll a, b, carotenoids and lutein content on visible band canopy reflectance; From the first order differential curves, which formed reflection peaks at 520 nm, 710 nm and an absorption trough at 570 nm, it can be seen that the red edge features of three bushes were obvious,



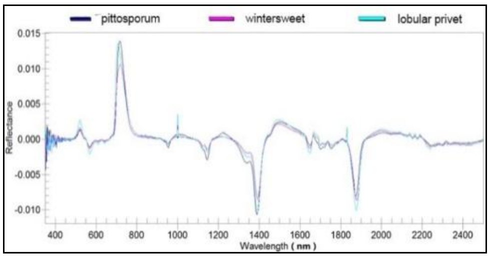


Figure 4: *The different kinds of bush canopy spectral reflectance curves in the late growth period (upper), and the first order differential spectral curves of canopy spectral reflectance curves in the late growth period (lower).*

4.2.2. The Same Kind of Bush Canopy Spectral Characteristics in Different Growth Periods

Lobular Privet was selected to analyze canopy spectral reflectance characteristics of the same kind of bush in different growth periods. The canopy spectral reflectance curve and the first order differential curves of canopy spectral reflectance curves of Lobular Privet in the beginning and the end of growth period were shown in Figure 5. It showed that in the visible band, the canopy spectral reflectance in the beginning of growth period was greater than that in the end, and the reflectivity in the beginning was almost close to 2 times than that in the end, but it was opposite after 740nm, where formed a reflection peak at 550 nm both in the two periods. From the first order differential curve, the canopy spectral reflectance in the end of growth period changed more than it in the beginning, and appeared blue shift.

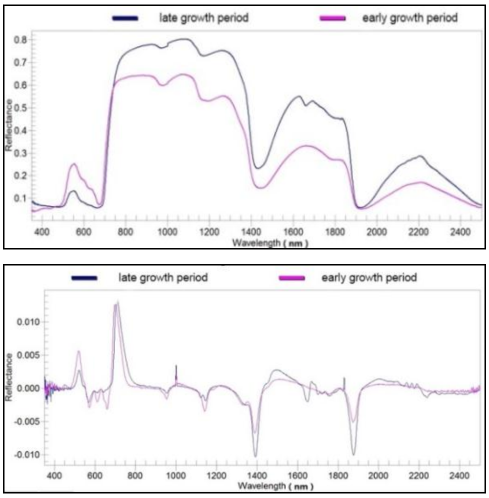


Figure 5: *The canopy spectral reflectance curves of Lobular Privet in the different growth periods (upper), and the first order differential curves of Lobular Privet in the different growth periods (lowert).*

4.3. Analysis of Herb Canopy Spectral Sensitivity Characteristics

4.3.1. The Different Kinds of Herb Canopy Spectral Characteristics in Same Growth Period

Four kinds of herb like Agrostis, Ophiopogon, Fern and Bamboo were selected to analyze the canopy spectral reflectance curve and the first order differential spectral curve of canopy spectral reflectance curves in the same growth period (Figure 6). In visible band, there are some differences in the spectral curves of four kinds of herb, formed a reflection peak at 550nm and an absorption trough near 675nm. Similarly, one order differential spectral curve of these four kinds of herb shows some characteristics in the visible band, and the red edge slope of them formed reflection peaks at 520 nm.

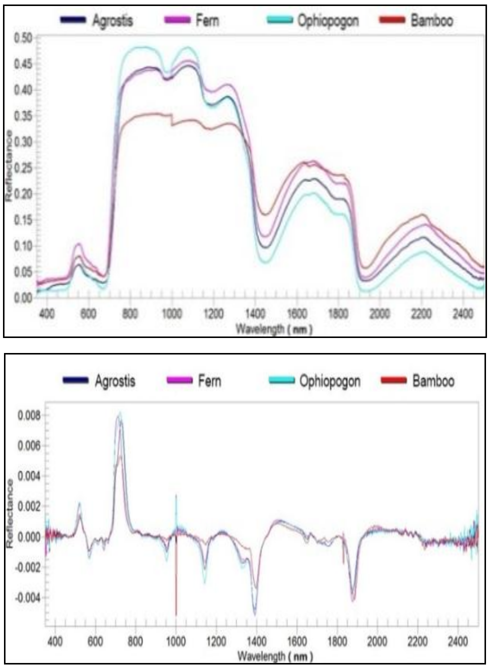


Figure 6: *The different kinds of herb canopy spectral reflectance curves in the same period (left), and the first order differential curves of canopy spectral reflectance curves (right)*

4.3.2. The Same Kind of Herb Canopy Spectral characteristics in different growth periods

Taking bamboo as an example to analyze the spectral reflectance of herb canopy in different growth periods, the canopy spectral reflectance curves and their first order differential curves of canopy spectral reflectance curves of bamboo in different growth periods were shown in Figure 7. It can be seen from the canopy spectral reflectance curves that the canopy spectral reflectance of bamboo in the end of growth period was highest, and in the near infrared band, the reflection in early growth period did not reach 50% of the late. From the first differential curve shows that the red edge slope peak of bamboo in different growth periods didn’t have any significant change, the phenomenon of blue shift is obvious; the content of chlorophyll and water were decreased and the spectral reflectance of bamboo leaves were enhanced.

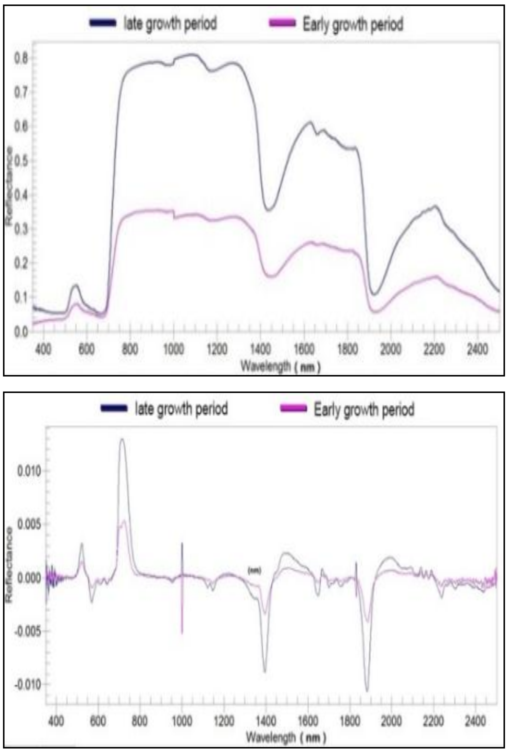


__Figure 7:__ The canopy spectral reflectance curves of bamboo in the different growth periods (upper), and the first order differential curves of canopy spectral reflectance curves (lower).

5. The relationship between vegetation index and leaf area index

The linear and nonlinear models was built and drawn with each vegetation index and its corresponding LAI measured in the field. The vegetation index was calculated with 810nm of near-infrared band and 670nm of red band from the testing hyperspectral data of campus representative vegetation. It can be seen from Figure 8-12:

(1) There is a high correlation between RVI and LAI, The relationship may be linear and the linear model is y=0.195x+0.580, the coefficients of determination is good (R^2=0.657) (Figure 8). The relationship may be exponential and the exponential model is $y=1.287e^{0.063x}$, the coefficients of determination is good (R^2=0.618) (Figure 9). The relationship may be second order linear and the second order linear model is y=0. $y=-0.007x^2+0.448x-1.290$, the coefficients of determination is good (R^2=0.698) (in Figure 10).

(2) There may be a certain relationship between DVI and LAI by comparing the DVI and LAI. If there is a certain linear relationship, the formula is y = 6.777 + 0.594 x, the coefficient of determination is R^2 = 0.560, as shown in Figure 11; If there is a exponential relationship between DVI and LAI, the formula is $y = 1.226\ e^{2.306\ x}$, the coefficient of determination R^2 = 0.595. As shown in Figure 12.

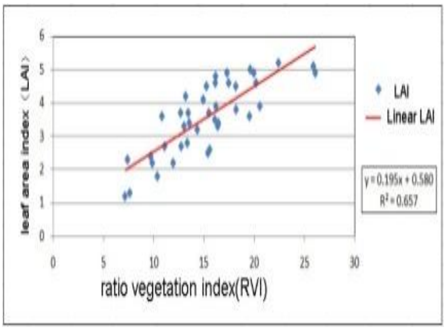


__Figure 8:__ The linear relationship between LAI and RVI (810, 670)

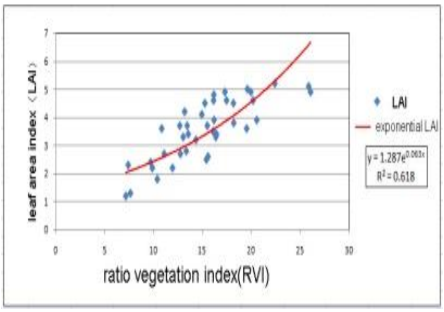


__Figure 9:__ The exponential relationship between LAI and RVI (810, 670)

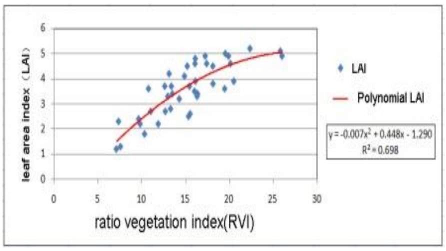


__Figure 10:__ The second order linear relationship between LAI and RVI (810, 670)

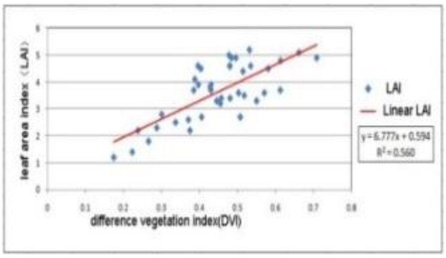


__Figure 11:__ The linear relationship between LAI and DVI (810, 670)

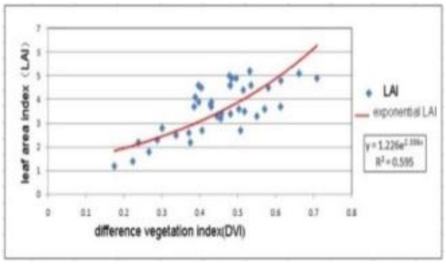


__Figure 12:__ The exponential relationship between LAI and DVI (810, 670)

6. Conclusion

By analyzing the original vegetation spectral characteristics of different types in different growth periods, the characteristics of the first-order differential curve and the relationship between the vegetation index and corresponding LAI, the following conclusions can be drawn:

(1) The band where the red edge slope peak appeared in the end of growth peiriod is is less than that in the beginning of growth period, so that the maximum red edge slope of the band can be taken as a sensitive point to distinguish the same vegetation growth final period from the beginning period.

(2) The spectral characteristics of vegetation are affected not only by the types of vegetation, but also by the growth period of itself. In different growth period, the different content of chlorophyll and moisture in the leaves result in different reflectance spectra not only among the the same vegetation in different growing period but also among the different vegetation in the same growing period.

(3) The correlation analysis between LAI and RVI, DVI,which were caculated from the band needed by extracing hyperspectral data, presents that the correlation between RVI and RVI is good.

This study has certain reference significance for the research of vegetation recognition, classification, the dynamic monitoring of vegetation growth and the establishment of remote sensing inversion model.

Because of the various objective factors limit, especially influenced by the weather, the experimental days are not enough and the number of collected samples is insufficient, moreover, spectral data and leaf area index data are limited, and they all have certain influence on the spectral data analysis. Therefore, we need a further study to remove the objective factors to improve the accuracy of the use of spectral data, and get wider application.

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