PERFORMANCE EVALUATION OF SPECTRAL INDICES TO ESTIMATE EQUIVALENT WATER THICKNESS

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1. INTRODUCTION

Water is essential for plant photosynthesis, respiration and biomass. Variations of vegetation water content can be reflected in spectral reflectance, and this provides basis for us to monitor vegetation moisture status using spectral information. Currently, the spectral indices are widely used for analysis of vegetation water content, and the performance evaluation is of great importance while using spectral indices. In this paper, 5 spectral indices are selected for analysis of vegetation water content which is expressed as Equivalent Water Content. Firstly, the relationships between EWT and spectral indices are established over various vegetation types and then the estimation accuracies of different indices are compared. Next, the performance of spectral indices for estimating EWT of different within-group sample variation are examined. And then, the capabilities of spectral indices to estimate EWT in different water level are explored and evaluated.

2. DATA

To have a large water variation, the LOPEX dataset established by the JRC in 1993 is used here. And, 4 subsets of single leaf samples are selected for analysis. Data used mainly include reflectance, water content and leaf area.

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3. METHODOLOGY

3.1. Equivalent Water Thickness(EWT)

Equivalent Water Thickness (EWT) is defined as the ratio of vegetation water content (fresh weight minus dry weight) versus leaf area as formula (1) [1]:

$$EWT = \frac{FW - DW}{LA} \quad (1)$$

Where FW and DW respectively represent the fresh and dry weight of leaves, and LA is the leaf area.

3.2. Spectral Indices in Use

Many spectral indices are developed for vegetation water content estimation. Certain indices are based on only the water absorbed bands in NIR region, such as Water Index (WI) defined by Pe˜nuelas [2].

$$WI = \frac{R_{900}}{R_{970}} \quad (2)$$

Also, it has been demonstrated that reflectance of near-infrared (NIR) and shortwave-infrared (SWIR) regions is largely influenced by water and dry matter in the leaves [3-6], while photosynthetic pigments only absorb in the visible and red-edge spectral region [7-9]. Thus, the NIR-SWIR band region provides a pigment-independent quantitative estimation of vegetation water content [10]. Among these indices, the simplest one is Moisture Stress Index (MSI)[11]. Several normalized indices calculated from this region such as NDWI (NDWI based on 1240nm/1640nm/ 2130nm) have been proposed for estimating vegetation water status[3].

$$MSI = \frac{R_{1600}}{R_{820}} \quad (3)$$

$$NDWI_{1240} = \frac{R_{860} - R_{1240}}{R_{860} + R_{1240}}$$

$$NDWI_{1640} = \frac{R_{860} - R_{1640}}{R_{860} + R_{1640}} \quad (4)$$

$$NDWI_{2130} = \frac{R_{860} - R_{2130}}{R_{860} + R_{2130}}$$

3.3. Evaluation Criteria of Sample Variation and Estimation Accuracy

In this paper, coefficient of variation (CV), which is defined as the ratio of the standard deviation versus mean value of samples, is used to quantitatively represent the sample variation. Also, the coefficient of determination (R^2) and normalized RMSE (nRMSE) are chosen as the evaluation criteria of performance. nRMSE is defined as the ratio of RMSE versus range of data[12]:

4. CONCLUSIONS

Table.1. Performance of Different Spectral Indices for EWT Estimation

Index/Group	1	2	3	4
WI	0.7091(10.25%)	0.6786(12.38%)	0.6407(17.18%)	0.3845(18.04%)
MSI	0.8902(4.74%)	0.8774(7.48%)	0.8685(8.50%)	0.7470(10.96%)
$NDWI_{1240}$	0.7290(7.43%)	0.6874(12.66%)	0.6734(15.13%)	0.3114(18.87%)
$NDWI_{1640}$	0.8712(6.84%)	0.8617(8.85%)	0.8449(9.42%)	0.7298(11.60%)
$NDWI_{2130}$	0.8865(5.50%)	0.8792(7.89%)	0.8708(8.78%)	0.7858(10.36%)

Notes: The CV values of group 1-4 are respectively 68.65%, 50.72%,39.85% and 35.30%. The values outside and inside the parentheses respectively represent R^2 and nRMSE.

Table.2. Performance of Spectral Indices in Different EWT Level

Index/FMC	0-0.01	0.01-0.025	>0.025
WI	0.5884(26.20%)	0.2553(23.18%)	0.6867(24.28%)
MSI	0.8475(11.66%)	0.6025(16.94%)	0.5468(20.95%)
$NDWI_{1240}$	0.6858(19.44%)	0.2089(23.89%)	0.6024(20.07%)
$NDWI_{1640}$	0.8056(14.60%)	0.6018(16.95%)	0.5610(20.71%)
$NDWI_{2130}$	0.8295(16.02%)	0.5372(18.28%)	0.3492(24.20%)

Notes: The values outside and inside the parentheses respectively represent R^2 and nRMSE.

(1) When estimating EWT with large sample variation, all five spectral indices show good estimation accuracy of EWT. Generally, MSI and $NDWI_{2130}$ perform similarly and show better estimation accuracy than other three indices. (2) With the decrease of sample variation(CV), the estimation accuracies of all spectral indices decline, which shows that spectral indices perform better to estimate EWT within a much scattered distribution than a concentrated distribution. (3) The accuracies of spectral indices for EWT estimation are not fixed, but vary in different water level. With the increase of EWT, the estimation accuracies of spectral indices show a declining tendency. Of five indices, MSI shows the best estimation accuracy for estimating low-level (0-0.01g/cm^2) and medium-level EWT (0.01-0.025 g/cm^2), and WI performs the best for estimating high-level EWT (>0.025 g/cm^2) .

5. REFERENCES

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