Monitoring leaf area index after heading stage using hyperspectral remote sensing data in rice

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Introduction

Leaf area index (LAI) is functionally linked to the canopy spectral reflectance. A major problem in the use of vegetation indices arises from the fact that canopy reflectance, it is strongly dependent on both structural and biochemical properties of the canopy. Because the impact of panicles on the canopy reflectance is still unclear, the estimation accuracy of LAI still needs to be improved in the late period of crop growth.

The main objectives in this study were as follows: (1) to assess the impact of panicles on the estimation accuracy of LAI and (2) to propose a convenient method to remove the effects of panicles on canopy reflectance and (3) to enhance the prediction accuracy of LAI after heading stage of rice.

Materials & methods

◆ *Experimental design*

Table. 1 Detailed information of the field treatments adopted in this study.

	Cultivar	Nitrogen Fertilization Rate (kg ha^{-1})	Plant Density (cm*cm)	Sampling Date (DAT[a])
Exp.1 (2014)	Wuyunjing24	150	20 * 15	28, 40,
			30 * 15	50, 68,
	Eryou728	300	40 * 15	79, 86, 102, 119
Exp.2 (2015)	Wuyunjing24	100	30 * 15	37, 43, 50, 58,
			40 * 15	71, 86, 95, 96[b],
	Eryou728	300	50 * 15	101, 102[b], 117, 118[b]

[a] DAT means days after transplanting

[b] In these days, we remove the panicle layers of the rice canopy.

Figure 1. Overview of the study area

◆ *Data collection*

The spectral reflectance data of the entire canopies ($R_{entire\ canopy}$) were first collected. Then, all the panicles were carefully removed and the spectral reflectance of the canopy without the panicles ($R_{canopy\ without\ panicles}$) was measured. Calculation of difference index (DI) and $DI_{modified}$ using $R_{entire\ canopy}$ and $R_{canopy\ without\ panicles}$, respectively.

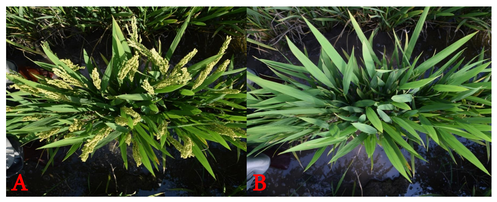

Figure 2. The entire canopy of rice (A) and the rice canopy without panicles (B)

Figure 3. FieldSpec® 4, Analytical Spectral Devices, Inc. Boulder, CO, USA

◆ *Vegetation index modification*

$$DI = R_{nir} - R_{red\ edge}$$

$$DI_{modified} = a * \theta * DI + b$$

Table. 3 Different agronomic parameters (θ) used in this study.

θ	Unit
1.$DW_{above\ ground}$*	g/m^2
2.$DW_{panicles}$	g/m^2
3.Leaf nitrogen content (LNC)	mg/g
4.LNC/PNC	-
5.$DW_{panicles}$ / DW_{leaf}	-
6.$DW_{panicles}$ / $DW_{above\ ground}$	-
7.DW_{leaf} / $DW_{above\ ground}$	-

*DW means dry weight

Results

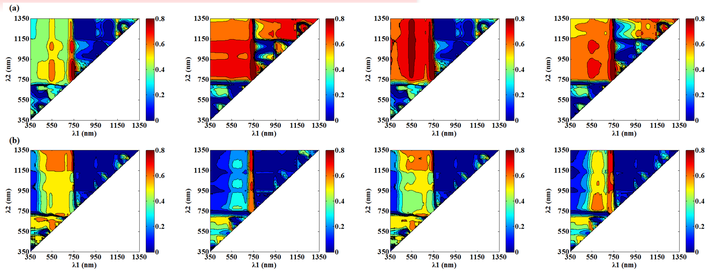

Figure 4. Correlations between normalized difference vegetation index (NDVI), difference index (DI), simple ratio (SR), or optimizing soil adjusted vegetation index (OSAVI)and leaf area index for rice canopies by using the reflectance of rice canopy before heading stage (a) and after heading stage (b) in 2014.

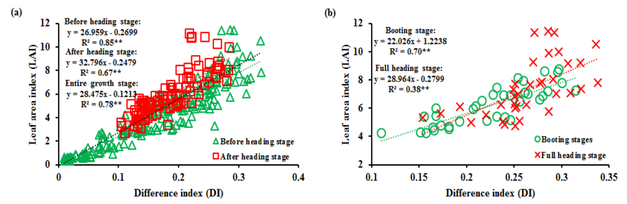

Figure 5. Using difference index (DI) in estimating leaf area index in different growth stages in 2014. (a) is before and after heading stage; (b) is booting stage and full heading stages.

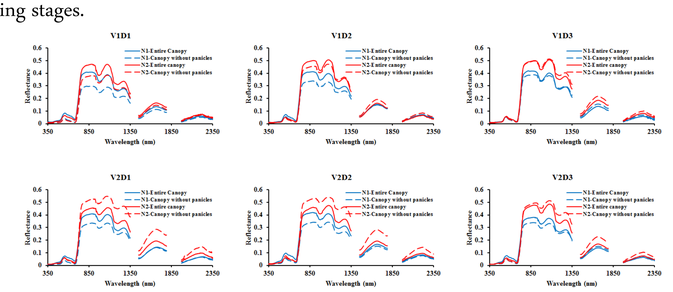

Figure 6. Variations in spectral reflectance characteristics of rice canopies before and after removal panicles for different treatments.

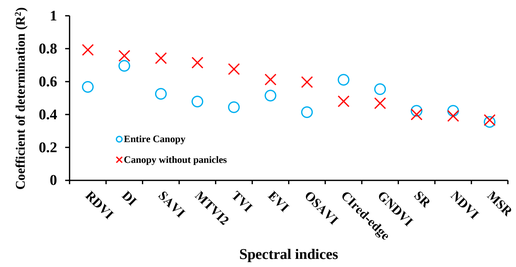

Figure 7. R^2 (Coefficient of determination) of leaf area index to different spectral indices which were calculated by using the spectral data of entire canopy and canopy without panicles, respectively.

Table 4. Linear fitting results using different agronomic parameters.

θ	a	b	R^2	RMSE
$DW_{above\ ground}$	0.0023	0.0546	0.6592	0.0316
$DW_{panicles}$	0.0008	0.0668	0.3462	0.0438
LNC	0.3878	0.0504	0.9636	0.0145
LNC/PNC	0.4744	0.0371	0.8697	0.0195
$DW_{panicles}$ / DW_{leaf}	-0.0898	0.2159	0.0854	0.0965
$DW_{panicles}$ / $DW_{above\ ground}$	2.1661	-0.0022	0.4827	0.0389
DW_{leaf} / $DW_{above\ ground}$	3.8826	0.0741	0.8568	0.0205

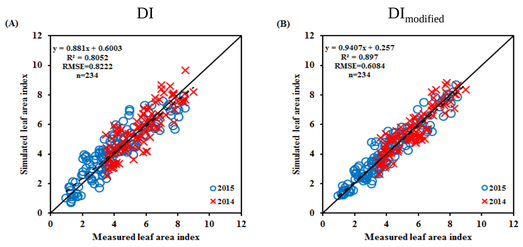

Figure 8. Comparison of simulated with measured leaf area index in rice. (A) is simulated by DI and (B) is simulated by $DI_{modified}$.

Conclusion

During the late growth stages of rice, the panicles layers had a strong influence on canopy reflectance. Vegetation indices could simulate LAI better by using the canopy reflectance that being measured after removal of panicles. $DI_{modified}$ could significantly increases the predictive power in estimating the LAI of rice compared with common VIs.