Effect of Water Background and Depth on Red and Red-Edge Reflectance Based Yield Prediction Models in Rice

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Introduction

Nitrogen (N) management based on remote sensing technology has been studied in cereal crops. In rice flooded growth condition, water background is a unique feature and may require additional investigation prior to implementing remote sensor technology. The commonly tested normalized difference vegetation index (NDVI) or simple ratio (SR) have raised concern when crop reached complete canopy closure.

Objectives

- To predict rice yield of two rice varieties using red and red-edge spectral reflectance
- To evaluate the relationship of agronomic parameters with spectral reflectance readings under undisturbed and turbid water background, and varying water depth

Materials and Methods

- Varieties x N trials were established at the LSU AgCenter Rice Research Station located in Crowley, Louisiana in 2011 and 2012.
- Canopy spectral reflectance under clear and turbid water, biomass yield, N content, plant canopy coverage, and water depth were collected each week for three consecutive weeks beginning two weeks before panicle differentiation (PD); at harvest, plot grain yield was determined.

Spectral Indices

- Spectral Ratio Based Indices

$$SR_{red} = \rho_{780}/\rho_{670} \qquad NDVI = \frac{\rho_{780} - \rho_{680}}{\rho_{780} + \rho_{680}}$$

$$SR_{red-edge} = \rho_{780}/\rho_{730} \qquad NDRE = \frac{\rho_{780} - \rho_{730}}{\rho_{780} + \rho_{730}}$$

- Red-edge Position (REP)

REP_{DF} =Fifth order polynomial fitting (Cho and Skidmore, 2006)
REP_{LI}=Linear interpolation technique (Guyot, 1988)
REP_{LE}=Linear extrapolation technique (Cho and Skidmore, 2006)
REP_{LAG}=The Lagrangian technique (Dawson and Curran, 1998)

Statistical Model

- The effect of water turbidity on spectral signatures

$$Y_i = b_0 + b_1 X_1 + b_2 X_2$$

Where
b_1= coefficient of water background
b_2 = coefficient of plant biomass
X_1= *0* if water is clear, =*1* if water is turbid
X_2=dry plant biomass kg ha^{-1}
Y_i=spectral reflectance at each wavelength

- The effect of water depth on spectral signatures

$$Y_i = b_0 + d_1 W_1 + d_2 W_2$$

Where
d_1= coefficient of water depth
d_2 = coefficient of plant biomass
W_1=water depth
W_2=dry plant biomass kg ha^{-1}
Y_i=spectral reflectance at each wavelength

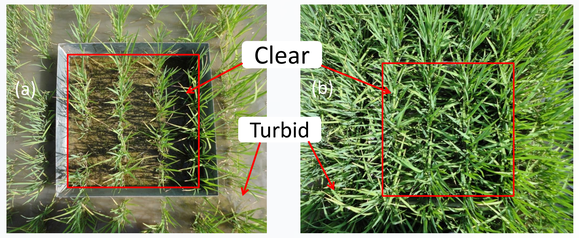

Fig 1. Rice water background (clear and turbid) from check plot (s) and pre-plant N applied plot (b) at PD.

Table 1. The correlation of between vegetation indices and each agronomic variable at different growth stages.

Vegetation Index	PD	PD +1wk	50% HD	PD	PD +1wk	50% HD
	Biomass			N uptake		
SR_{red}	0.72	0.77	0.66	0.56	0.76	0.75
$SR_{red-edge}$	0.84	0.83	0.70	0.83	0.84	0.75
$NDVI_{red}$	0.79	0.76	0.61	0.67	0.75	0.64
NDRE	0.84	0.79	0.64	0.83	0.84	0.73
REP_{DF}	0.75	0.69	0.57	0.78	0.76	0.62
REP_{LI}	0.81	0.69	0.61	0.85	0.82	0.72
REP_{LAG}	0.44	0.29	0.39	0.45	0.32	0.41
REP_{LE}	0.75	0.76	0.58	0.75	0.84	0.62
	Plant Coverage			Yield		
SR_{red}	0.48	0.67	0.65	0.72	0.83	0.83
$SR_{red-edge}$	0.77	0.84	0.76	0.82	0.85	0.89
$NDVI_{red}$	0.76	0.87	0.81	0.82	0.86	0.84
NDRE	0.83	0.88	0.78	0.85	0.88	0.90
REP_{DF}	0.91	0.94	0.81	0.71	0.81	0.85
REP_{LI}	0.82	0.86	0.74	0.78	0.78	0.84
REP_{LAG}	0.55	0.46	0.63	0.43	0.38	0.62
REP_{LE}	0.78	0.92	0.73	0.72	0.88	0.85

Table 2. Summary of regression models to determine the effect of variety on the relationship between red-edge based indices and grain yields at different growth stages.

Indices	Growth Stage	R^2	Coefficients			
			b_0	b_1	b_2	b_3
$SR_{red-edge}$	PD	0.73	-3092	6005	-2620	2050
	PD+1wk	0.74	-5310	608	7154	-
	50%HD	0.83	-4238	6432	-3058	1999
NDRE	PD	0.73	596	25639	890	-
	PD+1wk	0.76	-117	27617	573	-
	50%HD	0.82	-648	28587	508	-
REP_{DF}	PD	0.45	-124104	182	-	-
	PD+1wk	0.64	-175646	252	-	-
	50%HD	0.72	-185746	266	-	-
REP_{LI}	PD	0.63	-401254	798	563	-
	PD+1wk	0.6	-394877	544	-	-
	50%HD	0.71	-371885	522	-	-
REP_{LG}	PD	0.18	-54026	84.9	-	-
	PD+1wk	0.15	-23469	43	-	-
	50%HD	0.38	-83653	125	-	-
REP_{LE}	PD	0.52	-100169	149	-	-
	PD+1wk	0.78	-149918	216	-	-
	50%HD	0.72	-137077	199	-	-

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Influence of water background and depth on spectral reflectance

There was a significant effect of water background (turbidity) on the spectral reflectance when plant coverage was less than 50 % (Fig. 1). No significant effect of water depth on the spectral reflectance was observed except at red wavelength. The impact of water depth on the red bands can potentially affect the values of NDVI or SR_{red}. To clarify this, statistical regression model with the following equation was performed at each sampling time.

$$Y_i = b_0 + d_1 W_1 + d_2 W_2$$

where d_1= coefficient of water dep
d_2 = coefficient of plant biomass
W_1=water depth
W_2=dry plant biomass kg ha^{-1}
Y_i =NDVI or SR_{red}

According to the model, water depth had no significant effect on NDVI and SR_{red}. Therefore, we can conclude that the effect of water depth on red reflectance was not carried over when reflectance readings were transformed to vegetation indices.

The relationships between spectral indices and agronomic parameters

The red-edge based vegetation indices had better relationship with biomass, N uptake, plant coverage, and grain yield compared with red-based indices (Table 1). With regards to biomass, the degree of improvement using red-edge based indices declined as rice grows. The improvement of linear relationship with N uptake or grain yield using red-edge based indices was more evident. The relationship between $SR_{red-edge}$ had the highest *r* values with measured parameters across sampling periods.

The effect of rice variety on the yield prediction model using red-edge bamds

To determine the effect of rice variety on the relationship between yield and red-edge based indices, the following equation was performed.

$$Y_i = b_0 + b_1 I + b_2 V + b_3 V * I$$

where b_1= coefficient of vegetation indices based on red-edge reflectance
b_2 = coefficient of variety
b_3= coefficient of variety*vegetation indices
I=0 if variety is CL261 and *I=1* if variety is CL152
Y_i=grain yield kg ha^{-1},

According to the model, differences in variety were more evident when grain yield was related with using red-edge normalized or ratio-based vegetation indices (Table 2). When NDRE was used, there was no effect of I*V indicating that there was no corresponding different relationship with grain yield per unit increase of NDRE between varieties. However, there were still notable effects of variety on the model by having different intercept values. While when grain yield was regressed by red-edge position (REP_{DF}, REP_{LI}, REP_{LG}, and REP_{LE}) coefficients, b_2 and b_3, were not significant. This indicates that there was no effect of variety or interaction of variety and vegetation index on the yield regression model.

Conclusions

Our findings showed that :1) water back ground poses minimal concern when using remote sensing technology for mid-season N application in paddy rice fields, and 2) red-edge based vegetation indices were better predictors of rice grain yield compared with red based indices.

Cho, M.A., & Skidmore, A.K. (2006). A new technique for extracting the red edge position from hyperspectral data: The linear extrapolation method. *Remote Sensing of Environment*, 101, 181-193.Guyot, G., Baret, F. (1988). Utilisation de la haute résolution spectrale pour suivre l'état des couverts végétaux. Proceedings of the 4 th International Colloquium on Spectral Signatures of Objects in Remote Sensing, Aussois, France, pp.279-286. Dawson, T.P., & Curran, P.J. (1998). A new technique for interpolation the reflectance red edge position. *International Journal of Remote Sensing*, 19, 2133-2139.