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EVALUATING CROP BIOMETRICS BY REMOTE SENSING TECHNIQUES

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ABSTRACT

Assessing and monitoring crop growth, identifying the stress conditions are extremely important to develop strategies for yield forecast. Field experiment was conducted in the research farm of Indian Agricultural Research Institute (IARI), New Delhi in the year 1999 and 2001 for puddling and unpuddling rice. Statistical correlations were developed between NDVI (Normalized Difference Vegetation Index) and RVI (Ratio Vegetation Index) with LAI (Leaf Area Index), DM (Dry matter) production and total leaf chlorophyll content. Second order polynomial equations were developed to correlate remotely sensed data with crop biometrics. Polynomial second order equations of Band Ratio were found to be better fitted than NDVI with crop biometrics.

Key words : *Dry matter, LAI, Leaf Chlorophyll, NDVI, RVI and Rice.*

India attained not only self-sufficiency in food but surplus food production, an important step towards achieving food security. However, Rao (1982) observed that potential yield of food crops in India, even when growing improved varieties, still remain at about 20% because of stresses such as nutrient, water and disease. The need for early detection and identification of stress and its causes can never be over emphasized. Irrigation and fertilizers are vital and costly inputs in agricultural production and are used to increase the productivity of the crop. This necessitates understanding the specific requirement of the crop and strategies for their better management. Monitoring and assessing crop growth, identifying the stress conditions are extremely important to develop strategies. Remote sensing technique can be used on large scale to monitor the crop under different stress condition. Spectral reflectance forms the basis for remote sensing.

Crop N status and shoot growth rate of rice were found directly related to the formation of crop components. However, N uptake rate per second was not a reliable variable to relate to production. Until flowering, the N use efficiency for leaf biomass and specific leaf weight were constant (Stutterheim and Barbier, 1995). The sum of LAI of rice crop at the panicle differentiation stage, heading stage and 20 days after heading was positively correlated with the Nitrogen rates (Lin *et al,* 1990).

Chlorophyll contents, yield and seed quality of rice are affected by nitrogen fertilizer. Nitrogen application results in an increment in chlorophyll content (Gopal et al, 1999; Jago *et al*., 1995; Jain *et al.,* 1999). However, Sader *et al* (1990) concluded that leaf chlorophyll content measured after 30 days growth was unaffected by N rate.

Plant stress, which reduces chlorophyll production in leaves, will cause leaves to absorb less in the chlorophyll absorption bands; such leaf will appear yellowish or chlorotic and will have a higher reflectance, particularly in the red region. Other pigments contributing to spectral reflectance characteristics of a plant leaf are carotenes, xanthophylls (yellow pigments) and anthocyanins (red pigments). Chlorophyll masks the colour of these other pigment except during senescence when the leaf chlorophyll content is at the minimum. At the NIR, leaves typically reflect 40-50% and absorb less than 5% of the incident energy (Srivastava *et al.,* 1998). The high reflectance, as well as transmittance in the NIR "plateau" between 700 and 1300 nm are explained by multiple reflections in the internal mesophyll structure, caused by differences in the reflective indices of the cell wall and intracellular cavity. Since internal structure of leaves often differ considerably among species, reflectance differences are frequently greater in the NIR than in the visible wavelengths. Because of multiple transmittance and reflectance, there is an increase in NIR reflectance through layers of leaves with the maximum of 70-80% reflectance at about eight leaves layer (Allen and Richardson, 1986).

Wang *et al.* (1998) carried out research on effect of nitrogen nutrition on the spectral reflectance characterization of rice leaf and canopy. Differential nutrient treatments were applied and spectral and agronomic measurements were carried out. Reflected radiation at 400-1100 nm was measured with PIS-B spectroradiometer and Licor-1800 spectroradiometer. The effects of nitrogen were apparent across the entire wavelength interval measured and results showed that 540, 680 and 740-1070 nm were most sensitive to N.

MATERIALS AND METHODS

Field experiments were conducted in the research farm of Indian Agricultural Research Institute (IARI), New Delhi, popularly known as Pusa Institute, which lies between latitude 280 37' to 280 39' N and longitude 770 9' to 770

Table-1 : Spectral equations developed during peak growth stage of rice (1999) between crop biometrics and vegetation indices.

No.	Condition	Variables	Equations
1.	Puddled	X = LAI, Y = NDVI	Y = 0.031X2-0.1401X+0.7829
2.	Unpuddled	X = LAI, Y = NDVI	Y = 0.1218 X2-0.5349X+1.1593
3.	Puddled	X = LAI, Y = RVI	Y = -0.2218 X2-5.2961X-5.4765
4.	Unpuddled	X = LAI, Y = RVI	Y = 0.7511 X2-2.0257X+10.099
5.	Puddled	X = DM, Y = NDVI	y = -0.0002 X2 + 0.028 X - 0.3113
6.	Unpuddled	X = DM, Y = NDVI	y = 0.0001 X2 - 0.0111 X + 0.7919
7.	Puddled	X = DM, Y = RVI	y = -0.0072 X2 + 1.0835 X - 27.761
8.	Unpuddled	X = DM, Y = RVI	y = -0.0048 X2 + 0.6653 X - 11.51
9.	Puddled	X = Chl., Y = NDVI	y = 0.1178 X2 - 0.7935 X + 1.9644
10.	Unpuddled	X = Chl., Y = NDVI	y = 0.6039 X2 - 4.6068 X + 9.3854
11.	Puddled	X = Chl., Y = RVI	y = 0.6701 X2 + 0.4357 X - 1.706
12.	Unpuddled	X = Chl., Y = RVI	y = -3.9945 X2 + 35.372 X - 66.736

Table-2 : Spectral equations developed during peak growth stage of rice (2001) between crop biometrics and vegetation indices.

No.	Condition	Variables	Equations
1.	Puddled	X = LAI, Y = NDVI	y = -0.0973 X2 + 0.8554 X - 1.1201
2.	Unpuddled	X = LAI, Y = NDVI	y = -0.1383 X2 + 1.0684 X - 1.2938
3.	Puddled	X = LAI, Y = RVI	y = -2.4116 X2 + 20.085 X - 30.512
4.	Unpuddled	X = LAI, Y = RVI	y = -4.2067 X2 + 28.592 X - 39.312
5.	Puddled	X = DM, Y = NDVI	y = 3E-05 X2 + 0.0041 X + 0.3388
6	Unpuddled	X = DM, Y = NDVI	$y = -0.000 X^2 + 0.06 X - 1.2615$
7.	Puddled	X = DM, Y = RVI	$y = -0.0023 X^2 + 0.3936 X - 4.7287$
8.	Unpuddled	X = DM, Y = RVI	$y = -0.0039 X^2 + 0.599 X - 12.622$
9.	Puddled	X = Chl., Y = NDVI	$y = -0.0963 X^2 + 0.926 X - 1.4379$
10.	Unpuddled	X = Chl., Y = NDVI	$y = -0.1774 X^2 + 1.5806 X - 2.7848$
11.	Puddled	X = Chl., Y = RVI	$y = -3.0854 X^2 + 27.6 X - 49.692$
12.	Unpuddled	X = Chl., Y = RVI	$y = -5.3212 X^2 + 44.087 X - 82.103$

11' E at an altitude of 228.7m above mean sea level. The climate is sub-tropical and semi-arid. Forty year maximum temperature is 45°C and minimum temperature ranges from 2 to 30C. May and June are the hottest months and January is the coldest month of the year. The mean annual rainfall is 710 mm (30 years average) of which substantial part (about 75%) is received during the period from July to September by south-west monsoon rains. Occasional showers are received in the months of December, January and February.

The soil belongs to the major groups of Indo-Gangetic alluvium : The field experiments were designed for two years (1999 and 2001) Rice was grown following Split Plot Design consists of main and sub-plot. Tillage treatment was considered as main factor (puddled and unpuddled) and sub-factor was fertilizer with nitrogen, phosphorus and potash with three replications.

Vegetation Indices : Different vegetation indices (NDVI-Normalized Difference Vegetation Index, RVI-Ratio Vegetation Index) were calculated by spectral data which was taken by spectroradiometer. The crop spectral reflectance, expressed in percentage, was calculated by taking ratio of measured canopy reflectance (numerator) to the incoming solar radiation. Incident radiation (standard) measurements were taken by holding the sensor horizontally with focusing it above which provided the standard value. The standard readings were taken at the beginning and at the end of each observation. Then it was averaged to get a mean value. The reflectance measurement of crop canopy was taken at 5 nm band intervals from 330 nm to 1100 nm on clear sky conditions at around solar noon local time. The sensor was held at a height of 1 m above the crop canopy with the sensor facing the crop and oriented perpendicular to the crop canopy. Precautionary measures were taken to prevent any shadow cast on the sensor element.

Crop Biometrics : The different crop biometrics was measured to correlate with the NDVI and BR. These indices were well correlated with green biomass, and have been used to indirectly estimate photosynthetic capacity and net primary productivity (Goward *et al.,* 1985; Sellers, 1987; Field *et al.,* 1993) of crops. The different crop biometrics at different growth stages (phonological stages) were measured here for correlation with the spectral indices.

Dry Biomass : Dry biomass was determined during each 10 days of the crop growth period for rice and wheat crops in all the replicated treatments. The sample of leaves collected in 1 m^2 of ground area was used to determine the dry matter production at different growth stages of the crop for different treatment combinations. The samples were dried in the oven at 70°C for 72 hours and then weighed on an automatic digital balance.

Leaf Area Index (LAI) : The sample of leaves collected in 1 m^2 of ground area for dry matter production was used to determine the Leaf Area Index at each 10 days interval of crop growth period for all treatment combinations. For measuring the leaf area all the plants of a given area were cut and wrapped in paper at field itself and immediately

Table-3 : Comparison of coefficient of determination (R^2) of the crop biometrics with vegetation indices for the rice crop.

Parameters	Puddled rice				Unpuddled rice			
	NDVI		Band Ratio		NDVI		Band Ratio	
	1999	2001	1999	2001	1999	2001	1999	2001
Total chlorophyll	0.79	0.78	0.84	0.83	0.78	0.77	0.79	0.82
Dry matter	0.73	0.67	0.75	0.68	0.70	0.71	0.74	0.66
LAI	0.75	0.70	0.78	0.78	0.75	0.68	0.78	0.77

brought to laboratory. The leaf area was measured using Leaf Areameter (Model-LICOR-3100). Leaves were placed between the guides on the lower transparent belt and allowed to pass through the conveyor. Then leaf area index was obtained by dividing green leaf area by the ground area from where the leaves were cut.

Total Leaf Chlorophyll : DMSO (Dimethyl Sulphoxide) method (Hiscox and Israelstam, 1979) was used for the measurement of total leaf chlorophyll content in rice and wheat crops. 50 mg of leaf tissue was cut from the leaves of the upper portion of the plant leaving about 2 cm from the petiole and kept in a test tube containing 20 ml DMSO. Three samples from each plot were taken. The samples were kept in an oven at a temperature of 65°C for 24 hours along with a blank chlorophyll extraction from tube. The concentration of the chlorophyll (mg per gm of fresh leaf weight) of leaf tissue was determined specro-photometrically by Spectronic-20. The leaf sample used was the flag leaf collected from the plot of respective treatment combinations. The pigment absorbance was read in spectrophotometer at 663 nm and 645 nm wavelength. The total chlorophyll content of leaf was calculated using formula which is given below:

Total chlorophyll content

$$= \frac{(20.2 X A_{645} + 8.02 \ X \ A_{663}) \quad V}{100 \quad W}$$

Where,

A_{645} = Absorbance at 645 nm wavelength

A_{663} = Absorbance at 663 nm wavelength

V = Final volume of chlorophyll extract in DMSO

W = Weight of chlorophyll extract in DMSO

RESULTS AND DISCUSSION

NDVI and RVI correlated with LAI, DM and leaf Chlorophyll content of rice crop for both, puddle and unpuddled rice (Table 1 and 2). Second order correlation equation have developed for these parameters and depicted in Table 1 for the year 1999 and Table 2 for the year 2001. Coefficient of determination (Table 3) showed highest value (0.84) for Band ratio verses chlorophyll content. In general, Band ratio showed more value than NDVI if correlated with LAI, DM and chlorophyll content. Same trend of increasing or decreasing value was followed for both the indices irrespective of years of crop growth.

Polynomial second order equations of Band Ratio were found to be better fitted than NDVI with crop biometrics.

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