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Research Article

ESTIMATION OF BIOMASS YIELD OF WHEAT USING CANOPY REFLECTANCE AT DIFFERENT GROWTH STAGE

BAGHEL R.[1], PYASI S.K.[2] AND SHARMA R.[3]

[1]Department of Soil and Water Engineering, College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Adhartal, Jabalpur, 482004, India
[2]Professor of Soil and Water Engineering, College of Agricultural Engineering, Jawaharlal Nehru Krishi Vishwa Vidyalaya, Adhartal, Jabalpur, 482004, India
[3]Principal Scientist Agriculture & Soil Division, RSAC, Madhya Pradesh Council of Science and Technology, Bhopal, 462003, Madhya Pradesh, India
*Corresponding Author: Email - rachnabjnkvv@gmail.com

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Abstract: The study was planned in village Halali of district Raisen to determine the vegetative canopy of wheat at different growth stages, to compare canopy reflectance/ radiance of wheat crop using radiometer observation, remote sensing data and recommendation of best method to examine the utility of hyperspectral remote sensing in predicting canopy characteristics such as LAI and canopy chlorophyll content in a crop. The study area belongs to eastern part of the fertile Vindyanchal Plateau. This study has been done for the data collected during humid subtropical climate with cool, dry winter's a hot summer and a humid monsoon season. Reflectance observations available at very high (56m) spatial resplution from Advanced Wide- Field Sensore (AWiFS) sensore onboard Indian Remote Sensing, Resourcesat-2 satellite was used in this study. Forward simulation of canopy reflectance in four AWiFS band *viz.* GREEN (0.52um), RED(0.62-0.68um),NIR(0.77-0.86um),SWIR(1.55-1.70um)were carried out to generate the look up table using CRT model PROSIAL from all combinations of canopy intrinsic variable. An inversion technique based on minimization of cost function was used to retrieval LAI from LUT and observed AWiFS surface reflectance. The plant bio physical parameter of wheat was measured in different stage and reported as maximum plant height 79 cm, No. of leaf/plant 17, leaf length 42.68cm, leaf width 1.90cm, leaf area 64.20cm², chlorophyll content 73.25 micro gram /cm² LAI, 4.52, leaf water equivalent thickness 0.18 g/cm² and wheat yield 4300 kg ha^{-1}. The plant bio physical parameters were taken from LAI meter, Chlorophyll meter and Spectroradiometer. These parameters were taken as input parameters for PROSIAL model. The simulated data & ground data were used to get R^2 by linear correlation. The linear correlation between simulated and ground data during the wheat growing season gave high coefficient of determination (R^2= 0.99) in SWIR band. Relationships between wave length and spectral response were drawn by relative spectral response (RSR) for 2nm intervals using Lagrange's interpolation scheme. The empirical regression models were developed for the study area by using in situ field observation and LAI was calculated during growing to harvesting crop season 2015-2016. A spatial yield maps of the study area were generated using LAI values and yield data, LAI values and NDVI values of crop season 2015-2016. The LAI Vs yield regression model showed positive correlation with equation (Y = 11.70x - 2.041) and (R^2 = 0.94). The LAI Vs NDVI regression model also gave higher coefficient of determination equation (Y = 643.3x + 1108.86) (R^2 = 0.93) as well as lowest standard error 0.02.

Keywords: *LAI meter, Chlorophyll meter, Spectrometer*

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important widely grown cereal grain crop occupying 17 % of the total cultivated land in the world. It is a major staple food for 35% of the world population and provides more calories and protein in the world's diet than any other crop [1]. Global wheat production in 2013-14 was 717 million tones and forecast to around 718.5 million tonnes in 2014-15 [2]. India is one of the main wheat producing and consuming countries of the world. In India, wheat is grown over 30 million ha (58% of the net cropped area during Rabi) with a production of 94 million tons and contributing about 43% to the country's granary [3]. India's second rank in global wheat production after China and it share about 13.1% in global wheat production and about 3.16 % share for global wheat export in the year 2013-14 [4] In 2013-14 Madhya Pradesh wheat production was 13.93 million tonnes on 5.79 million ha with a productivity of 2405 Kg per ha. In Madhya Pradesh, wheat acreage increased by 9.28 % but decline in the crop yield by 2.96 per cent in 2013-14 over 2012-13 [5].

Crop growth studies require quantification and monitoring of biochemical and biophysical attributes. Estimates of foliar biochemical's such as the levels of chlorophyll and nitrogen provide us indicators of plant productivity, stress and the availability of nutrients. Compared to direct field techniques, remote sensing techniques have been shown to be timely, non-destructive and provide spatial estimates for quantifying and monitoring these vegetation attributes.

Hyperspectral (narrow band) indices have been shown to be crucial for providing additional information with significant improvements over broad bands, in characterizing, mapping and quantifying biophysical and biochemical parameters of agricultural crops. Recent advances in hyperspectral remote sensing demonstrate great utility for a variety of crop monitoring applications. There are many studies supporting this, conducted on a wide array of crops and their biophysical and biochemical variables such as yield [6,7], chlorophyll content [8], nitrogen content [9,10] carotenoid pigment1, plant biotic stress [11,12], plant moisture [13] and other biophysical variables [14]. The development of spectral library using hyperspectral data is another emerging component [15]. This fairly detailed list, though not exhaustive, gives a measure of the current, proven experimental capabilities and operational applications, and stimulates investigations of new and ambitious applications. The empirical relationship of vegetation indices and biophysical parameters is sensitive to vegetation type and soil background. Among all PROSAIL model is popular and widely applied and it describes both the spectral and directional variations of canopy reflectance as a function of leaf biochemistry and canopy architecture [16].

Material and Methods

Leaf area index (LAI)

LAI was measured using a plant canopy analyzer LAI-2000.

Which determines effectives LAI using measurements of diffuse solar radiation above and below the grass canopy? The LAI was measured under overcast sky conditions between 10:00 and 16:00 using a view restrictor of 900 the average LAI was calculated in each subplot based on one above canopy measurement and five below canopy measurement.

LAI= leaf area m² / ground area m²

In broad leaf canopies. In conifers, three definitions for LAI have been used:

1. Half of the total needle surface area per unit ground surface area.
2. Projected (or one-sided, in accordance the definition for broadleaf canopies) needle area per unit ground area.
3. Total needle surface area per unit ground area.

Leaf chlorophyll content

Chlorophyll is an extremely important bimolecular, critical in photosynthesis, which allows plants to absorb energy from light.

A Portable SPAD-502 Chlorophyll meter was used for the measurement of LCC (Leaf Chlorophyll Content). The SPAD measures a unit less value which is highly correlated with leaf chlorophyll content. For each subplot the SPAD reading was calculated based on the average of 30 randomly selected leaf readings within the subplot in order to convert the unit less SPAD reading in to LCC (μg cm²), in accordance with Markwell's formulation [17], an exponential equation (Cab=84.8*exp (0.00702*SPAD)-82.01 was found to best describe the relationship between the calculated LCC (μg cm²) and the SPAD reading.

Leaf Chlorophyll Content (Cab) = 84.8*exp (0.00702*SPAD)-82.01

Leaf Chlorophyll Content (micro g/cm²) = Leaf Chlorophyll Content X Leaf Length

Leaf weight

One plant per plot were selected randomly and tagged for taking the periodic observation on leaf weight. The leaf weight was measured on selected leaf are collected on different filed and measured the weight of leaf on moist condition and then after shifted to hot air oven for 50°C in 24 hours and take weight of simples in zero moisture content condition. These observations were taken at different date in all the field.

Leaf tilt angle

The leaf has a complex structure and is not flat, it may be necessary to approximate the actual leaf by a set of small plates, in which case there may be a number of leaf normal's and associated angles. The LAD describes the statistical distribution of these angles.

Ground reflectance

Reflectance on the surface of material is effectiveness in the reflecting radiant energy. It is the fraction of incident electromagnetic power that is reflected at an interface. The reflectance spectrum or spectral reflectance curve is the plot of the reflectance as a function of wavelength.

Zenith angle

The solar zenith angle is the angle measured from directly overhead to the geometric centre of the sun's disc, as described using a horizontal coordinate system. The solar elevation angle is the altitude of the sun, the angle between the horizon and the centre of the sun's disc. If we write θs for the solar zenith angle, then the solar elevation angle $\alpha s = 90° - \theta s$

Azimuth angle

The azimuth angle is the compass direction from which the sunlight is coming. At solar noon, the sun is always directly south in the northern hemisphere and directly north in the southern hemisphere.

Leaf water content

Water content is a slight misnomer; it is really a water ratio. It is the amount of water in the leaf relative to its dry weight.

WC (g/g) = (FW-DW)/DW

WC=Leaf Water Content

FW=Leaf Fresh Weight

DW=Leaf Dry Weight

Plant height

The height of plant was measured on the main Culm from the ground level to the base of well emerged last or flag with the help of meter scale in cm at different growth stage.

Post Harvest Observation:

At harvest, the earlier tagged plants were harvested for the purpose of recording observation on yield attributing parameters.

Number of tillers

Total number of tillers per meter row length at different dates and at harvest was recorded by counting from five marked row (one meter length) in each plot and the mean values were calculated.

Number of grains/panicle

Randomly selected five panicle were crushed by hand manually then remove the straw and count the total number of grains. Finally total number of grains counted and divided by five which give number of grains/panicle.

Straw yield (kg/ha)

The straw yield of each plot was determined by subtracting the grain yield from the biological yield of the respective plot. The values so obtained were converted into straw yield per ha by multiplying with net plot yield by the converting factor (10,000 dividing by net area (m) of plot). The yield was expressed in Kg per hectare.

Analysis Method

PROSAIL method

The combined PROSPECT leaf optical properties model and SAIL canopy bidirectional reflectance model, also referred to as PROSAIL, have been used for about sixteen years to study plant canopy spectral and directional reflectance in the solar domain. PROSAIL has also been used to develop new methods for retrieval of vegetation biophysical properties. It links the spectral variation of canopy reflectance, which is mainly related to leaf biochemical contents, with its directional variation, which is primarily related to canopy architecture and soil/ vegetation contrast. This link is key to simultaneous estimation of canopy biophysical/structural variables for applications in agriculture, plant physiology, and ecology at different scales. PROSAIL has become one of the most popular radiative transfer tools due to its ease of use, general robustness, and consistent validation by lab/field/ space experiments over the years.

Methods

Using the Radiative Transfer Model, the canopy is described as a layer consisting of leaves and the spaces between them in the model [18) in this study, the PROSAIL1 model was used [19]. The PROSPECT-5 model [20] was used for the leaf level and 4-SAIL [21,22] for the canopy level. The input parameters to both models are presented in [Table-1].

The PROSPECT and SAIL models are quite rarely used for heterogeneous communities; these models were used to simulate spectral reflectance in the different kinds of meadows, mainly on flat areas [23].

The field measurements performed to model PROSAIL were conducted on village Halali district Raisen on December 2015 to March 2016. The following information was collected during the field measurements: chlorophyll content using a chlorophyll content meter, fresh biomass, dry matter amount, information about the canopy structure such as LAI using a LAI-2000 Plant Canopy Analyzer, Average Leaf Angle, canopy height, and date and time of measurement.

Field measurements were used to calculate input parameters for each polygon separately. Chlorophyll and carotenoid content in μg/cm² were calculated using CCI and LAI. Brown pigment content was recalculated from the dry matter amount. Dry matter and water content were calculated using the LAI and the amount of water.

Table-1 Input Parameters to Run PROSAIL Model

Model	Units	Symbol	Range or Fixed value
PROSPECT			
Leaf structure parameter	-	N	01-Mar
Chlorophyll a + b content	μg cm-²	C_{ab}	30-70
Leaf equivalent water thickness	cm	C_w	0.01-0.06
Leaf dry matter content	gcm-²	C_m	0.008-0.025
Leaf size to crop height	-	SI	0.1-0.5
SAIL			
Leaf area index	-	LAI	01-Jul
Leaf inclination angle	-	LAI	20-60
Hot spot parameter	-	S_L	0.5/LAI
Horizontal visibility	m	VIS	50
Sun zenith angle	º	θs	-20 to +80
View zenith angle	º	θv	0-55
Relative azimuth angle	º	φsv	-120 to+120
Soil albedo	-	ρs	

The structural parameters for each polygon were estimated empirically and from the literature [24]. One of the hot spot size parameters was calculated using leaf average, leaf length, and canopy height. The Solar zenith angle was estimated from the coordinates, time, and date of the measurements. Other parameters (soil brightness parameter, ratio of diffuse to total incident radiation, second hot spot size parameter, observer zenith, and azimuth observer angle) were fixed based on previous studies [25].

For each polygon using the PROSAIL model, the reflectance was calculated from 400 to 2500 nm with 1 nm spectral resolution. Then, the acquired results were compared with the spectrum collected during field measurements. The Root Mean Square Error (RMSE) for the whole range 400-1000 nm and for specific ranges 400-555, 500-650, 600-700,730-910,680-780 and 800-900 nm was calculated to estimate the accuracy.

Results and Discussion

Crop Bio- Physical Parameter

Plant height (cm)

The data on plant height recorded at different dates are presented in [Table-2]. The plant height is also graphically depicted and presented in [Fig-1]. It is observed from [Table-2] there was a progressive increase in the height of the plant from 15 days after sowing to maturity. The mean plant height of all fields was found to be highest on 1/3/2016 and after that it remains constant *i.e.*, 76.44cm. On 10/12/2016 the SD *i.e.*,3.23 with CV *i.e.*, 8.01 were also found to be highest.

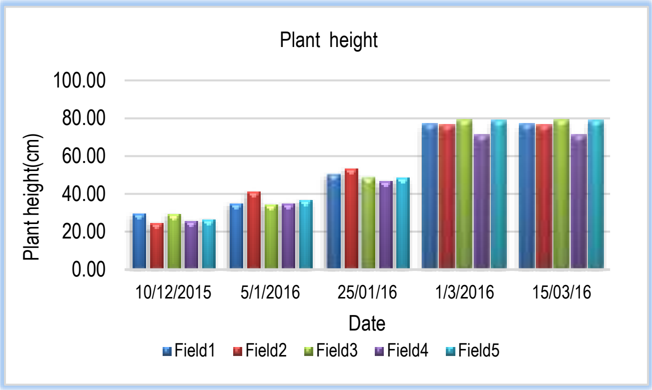

Fig-1 Plant Height at Different Dates.

Table-2 Plant Height on Different Dates at Crop Growth Stage

	Plant Height				
Field No.	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	30.20	35.40	51.00	76.80	76.80
F2	25.20	41.80	54.00	76.40	76.40
F3	29.80	35.00	49.60	79.00	79.00
F4	26.20	35.40	47.40	71.00	71.00
F5	27.00	37.20	49.00	78.80	78.80
Mean	27.68	36.96	50.20	76.40	76.40
SD	2.22	2.84	2.49	3.23	3.23
CV%	8.01	7.68	4.95	4.23	4.23
Median	27.00	35.40	49.60	76.80	76.80

Number of Leaf/plant

The number of leaf/plant recorded at different dates and fields are presented in [Table-3] The data are also graphically depicted and presented [Fig-2]. It is observed from [Table-3]. That the average number of leaf/plant of all field is highest on 25/1/2016 *i.e.*, 14.4 and SD and CV is highest on 1/3/2016 *i.e.*, 3.35, 23.57.

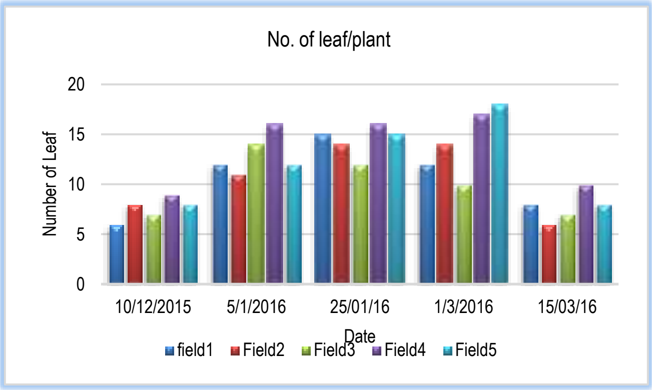

Fig-2 No. of Leaf/Plant at Different Dates.

Table-3 Number of Leaf/Plant on Different Dates During Crop Growth

	Number of Leaf				
Field	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	6	12	15	12	8
F2	8	11	14	14	6
F3	7	14	12	10	7
F4	9	16	16	17	10
F5	8	12	15	18	8
Mean	7.6	13	14.4	14.2	7.8
SD	1.14	2	1.52	3.35	1.48
CV%	15	15.38	10.53	23.57	19.02
Median	8	12	15	14	8

Dry weight of leaf /plant

The data on dry weight of leaf/plant recorded at different dates and field are presented in [Table-4] The dry weight of leaf/plant are also graphically depicted and presented [Fig-3]. That the dry weight of leaf/plant at all the stages of plant growth. Maximum dry weight of leaf recoded; is tillering stage and minimum dry weight of leaf in milking stage.

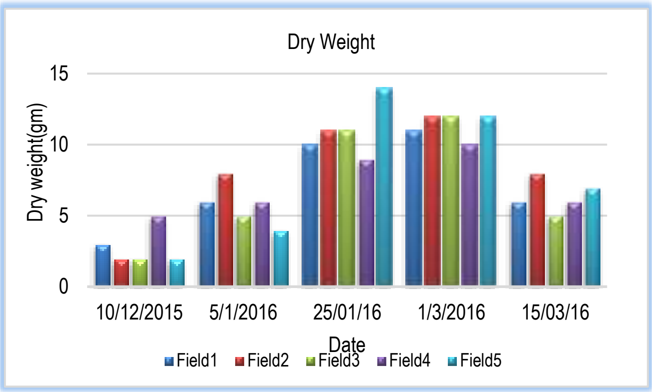

Fig-3 Dry Weight at Different Dates.

Table-4 Dry Weight on Different Dates During Crop Growth

	Dry Weight of leaf/ plant				
Field no.	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	3	6	10	11	6
F2	2	8	11	12	8
F3	2	5	11	12	5
F4	5	6	9	10	6
F5	2	4	14	12	7
Mean	2.80	5.80	11.00	11.40	6.40
SD	2.76	5.76	11.20	11.48	6.48
CV%	2.91	5.31	11.24	11.37	6.17
Median	3.09	5.37	11.28	11.25	6.41

Leaf length (cm)

The leaf length curve depicted that leaf length was found to be increase with the advancement in the age and stage of crop plant different date and interval up to 15 days stage to 90 DAS [Fig-4]. The data pertaining to the leaf length per plant recorded at different dates of crop growth were statistically analyzed and the overall effects of different dates and field are included in [Table-5]. The results revealed that leaf length was influenced appreciably by the various dates and field at all the stages of crop growth. Significant higher leaf length was recorded to 1/3/2016 and 15/03/2016 dates and field. F5 42.68cm and the lowest leaf length was found in initial stage 10/12/02015 in the field of F3 11.20cm was recorded. Where are maximum leaf length reduced at 1/3/2016 and 15/03/2016

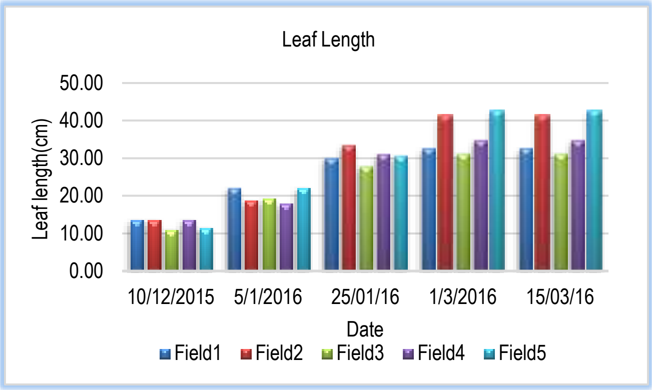

Fig-4 Leaf Length at Different Dates.

Table-5 Leaf Length on Different Dates during Crop Growth

Leaf Length					
Field	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	13.80	22.40	30.40	32.90	32.90
F2	13.80	19.08	33.80	41.40	41.40
F3	11.20	19.50	28.16	31.60	31.60
F4	13.80	18.18	31.40	35.10	35.10
F5	11.70	22.40	31.00	42.68	42.68
Mean	12.86	20.31	30.95	36.74	36.74
SD	1.30	1.96	2.03	5.02	5.02
CV%	10.10	9.67	6.54	13.67	13.67
Median	13.80	19.50	31.00	35.10	35.10

Leaf width (cm)

The leaf width curve depicted that leaf width was found to be increase with the advancement in the age and stage of crop plant different date and interval up to 15 days stage to 90 DAS [Fig-5]. The data pertaining to the leaf width per plant recorded at different dates of crop growth were statistically analyzed and the overall effects of different dates and field are included in [Table-6]. The results revealed that leaf width was influenced appreciably by the various dates and field at all the stages of crop growth. Significant higher leaf width was recorded to 1/3/2016 and 15/03/2016 dates and field F4 1.90. and the lowest leaf width was found in initial stage 10/12/02016 in the field of F1 0.80. Where are maximum leaf width reduced at 1/3/2016 and15/03/2016.

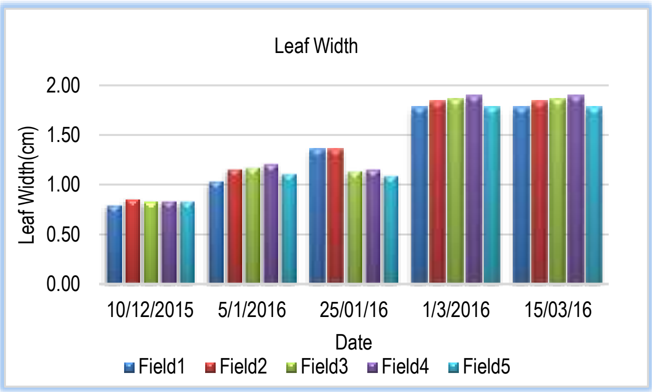

Fig-5 Leaf width at Different Dates

Table-6 Leaf Width on Different Dates During Crop Growth

Leaf Width					
Field	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	0.80	1.04	1.36	1.78	1.78
F2	0.86	1.16	1.36	1.84	1.84
F3	0.84	1.18	1.14	1.86	1.86
F4	0.84	1.22	1.16	1.90	1.90
F5	0.84	1.12	1.10	1.78	1.78
Mean	0.84	1.14	1.22	1.83	1.83
SD	0.02	0.07	0.13	0.05	0.05
CV%	2.62	5.98	10.30	2.85	2.85
Median	0.84	1.16	1.16	1.84	1.84

Leaf area (cm²/plant)

The leaf area curve depicted that leaf area was found to be increase with the advancement in the age and stage of crop plant different date and interval up to 15 days stage to 90 DAS [Fig-6].

The data pertaining to the leaf area per plant recorded at different dates of crop growth were statistically analyzed and the overall effects of different dates and field are included in [Table-7]. The results revealed that leaf area was influenced appreciably by the various dates and field at all the stages of crop growth. Significant higher leaf area was recorded to 1/3/2016 and 15/03/2016 dates and field F2 and F5 64.32 and 64.20. And the lowest leaf area was found in initial stage 10/12/02016 in the field of F3 9.30 was recorded. Where are maximum leaf area reduced at 15/03/2016.

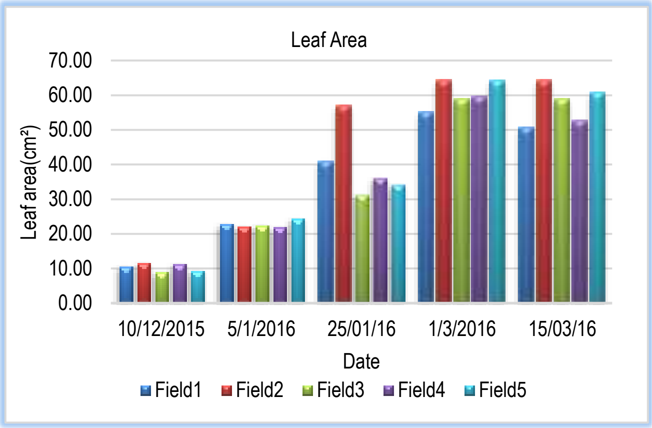

Fig-6 Leaf Area at Different Dates.

Table-7 Leaf Area on Different Dates During Crop Growth

Leaf Area					
Field	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	10.92	23.20	40.94	55.14	50.66
F2	11.83	22.38	57.10	64.32	64.32
F3	9.30	22.72	31.53	58.90	58.90
F4	11.66	22.26	36.34	59.62	52.62
F5	9.57	24.64	34.50	64.20	60.76
Mean	10.66	23.04	40.08	60.44	57.45
SD	1.17	0.97	10.11	3.88	5.69
CV%	10.97	4.20	25.22	6.43	9.91
Median	10.92	22.72	36.34	59.62	58.90

Chlorophyll content (micro gram /cm²)

The data on chlorophyll content recorded at different dates and fields are presented in [Table-8]. The data are also graphically depicted and presented [Fig-7]. It is observed for [Table-8] that the average chlorophyll content of all field is maximum on 10/12/2016 *i.e.*, 63.44, SD 7.72 and CV is maximum on 5/1/2016 16.46, and the average chlorophyll content of all field is minimum on 1/3/2016 *i.e.*, 26.10, SD 25/1/2016 2.61 and CV 8.79. The chlorophyll content is highest in tillering to booting stage and lowest chlorophyll content is milking to maturity stage.

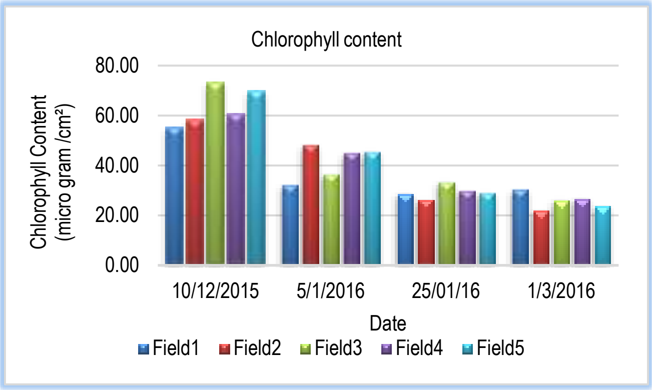

Fig-7 Chlorophyll Content at Different Dates.

Table-8 Chlorophyll Content on Different Dates During Crop Growth

Chlorophyll content (micro gram /cm²)				
Field	10/12/2015	5/1/2016	25/01/16	1/3/2016
F1	55.13	32.49	29.01	30.65
F2	58.43	48.69	26.42	22.33
F3	73.25	36.75	33.65	26.40
F4	60.63	45.49	30.25	26.98
F5	69.77	45.89	29.29	24.14
Mean	63.44	41.86	29.73	26.10
SD	7.72	6.89	2.61	3.15
CV%	12.17	16.46	8.79	12.06
Median	60.63	45.49	29.29	26.40

Leaf area index

The data on leaf area index recorded at different dates and fields are presented in [Table-9]. The data are also graphically depicted and presented in [Fig-8]. It is observed for [Table-9] that the leaf area index higher so crop is healthy condition. Average leaf area index of all field is maximum on 25/1/2016 *i.e.*, 3.67, SD 0.71 and CV is maximum on 5/1/2016 45.94, and the average leaf area index of all field is minimum on 10/12/2015 *i.e.*, 1.50, and SD, CV on 15/3/2016 *i.e.*, 0.11, 6.17.

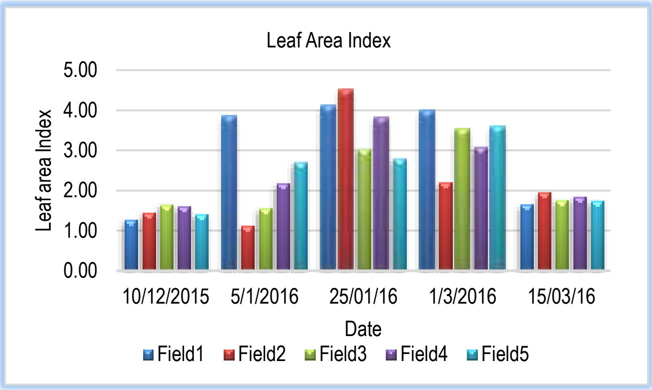

Fig-8 Leaf Area Index at Different Dates.

Table-9 Leaf Area Index on Different Dates During Crop Growth

Leaf Area Index					
Field No.	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	1.30	3.85	4.12	4.00	1.68
F2	1.48	1.14	4.52	2.23	1.98
F3	1.67	1.58	3.07	3.54	1.78
F4	1.63	2.21	3.83	3.11	1.87
F5	1.43	2.74	2.82	3.59	1.76
Mean	1.50	2.30	3.67	3.29	1.81
SD	0.15	1.06	0.71	0.68	0.11
CV%	10.06	45.94	19.41	20.51	6.17
Median	1.48	2.21	3.83	3.54	1.78

Leaf water equivalent thickness (g/cm²)

The data onleaf water equivalent thickness found at different dates and field are presented in [Table-10]. The data are also graphically depicted and presented in [Fig-9]. Maximum leaf water equivalent thickness is 10/12/2015 field F1 0.18 and minimum leaf water equivalent thickness is 1/3/2016 field F2 and F5 0.2.

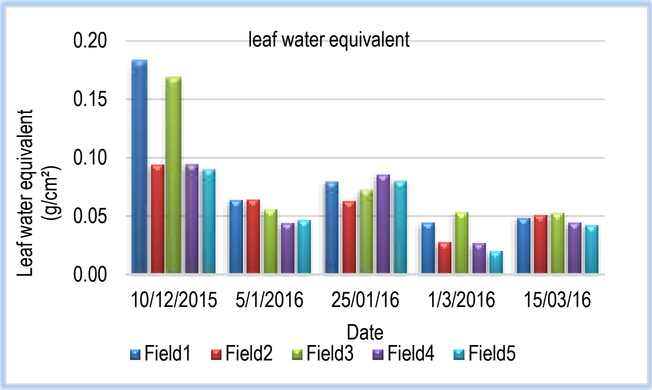

Fig-9 Leaf Water Equivalent at Different Dates.

Table-10 Leaf Water Equivalent Thickness on Different Dates During Crop Growth

Leaf Water Equivalent Thickness					
Field	10/12/2015	5/1/2016	25/01/16	1/3/2016	15/03/16
F1	0.18	0.06	0.08	0.05	0.05
F2	0.1	0.06	0.06	0.03	0.05
F3	0.17	0.06	0.07	0.05	0.05
F4	0.1	0.04	0.09	0.03	0.05
F5	0.09	0.05	0.08	0.02	0.04
Mean	0.13	0.06	0.08	0.04	0.05
SD	0.12	0.05	0.08	0.03	0.05
CV%	0.12	0.05	0.08	0.03	0.05
Median	0.11	0.05	0.08	0.03	0.05

Number of tillers

The data on number of effective and non-effective tillers recorded at harvest are presented in [Table-11]. Different dates exert their significant effect on effective number of tillers and remained at par among them selves. Maximum number of effective tillers was observed F2 46, and the lowest number of effective tillers are recoded in the F4 42.33.

Among different field, field F2 3.31 gave significantly lower non-effective tillers and other field gives significantly more number of non-effective tillers. The maximum number of non- effective tillers is found in the field of F4 4.72.

Straw yield (Kg/ha)

The data pertaining on straw yield of wheat are presented in [Table-12]. The data are also graphically depicted and presented in [Fig-10]. Straw Yield of wheat is found maximum in field F2 (4896kg ha^{-1}) and minimum in field F4 (3679 kg ha^{-1}).

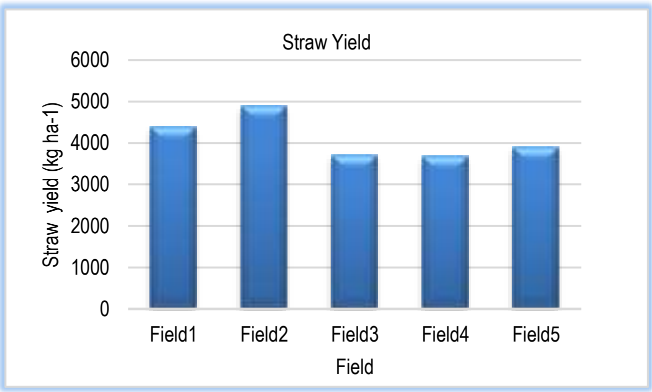

Fig-10 Straw Yield on Different Field.

Table-11 Effective and Non Effective Tillers per 0.5 Meter Row Length on Different field

Field	Number of Tillers/0.5 m row	
	Effective	Non Effective
F1	45.87	4.53
F2	46.93	3.31
F3	42.61	4.57
F4	42.33	4.72
F5	44.63	4.43
Mean	44.47	4.31
SD	2.01	0.57
CV%	4.51	13.21
Median	44.63	4.53

Biological yield (kg ha^{-1})

The data pertaining on biological yield of wheat are presented in [Table-13]. The data are also graphically depicted and presented [Fig-11]. In present study the highest biological yield is obtained in field F2 that is (9036 kg/ ha^{-1}) and lowest biological yield is obtained in field F5 that is 6411 kg/ ha^{-1} respectively [Table-13].

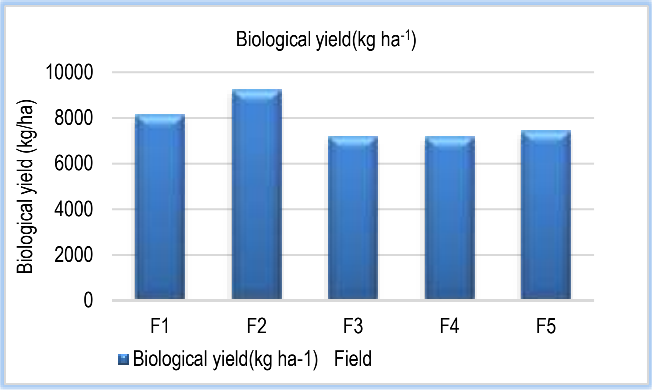

Fig-11 Biological Yield on Different Field.

Table-12 Straw Yield on Different Field

Field	Straw yield (kg ha^{-1})	straw yield/Field (kg)	Straw yield/plant(gm)
F1	4386	43.86	6.95
F2	4896	48.96	7.68
F3	3704	37.04	5.79
F4	3679	36.79	5.73
F5	3891	38.91	6.26
Mean	4111.20	41.11	6.48
SD	522.62	5.23	0.83
CV%	12.71	12.71	12.79
Median	3891.00	38.91	6.26

Use of RS for Crop Monitoring.

Development of NDVI – based empirical models

The empirical regression models have been developed for the study site by using in situ field LAI measurement during growing to harvesting crop season 2015-16. The NDVI were computed from surface reflectance from AWiFS (as per section "pre – processing of satellite data and wheat map generation"). Linear fits were found to be the best for NDVI, respectively to predict LAI. The LAI - NDVI models showed higher value R^2 0.93 as well as lowest standard error 0.02 [Table-14]. The NDVI is commonly preferred index as compared to other for extracting biophysical properties of the vegetation, because it is relatively insensitive to background soil reflectance, reduces the effects of atmospheric condition and topographical variation. There is a relative advantage of NDVI as it saturates at higher LAI (smith et al., 2005) the empirical model, LAI- NDVI model showed the least equation of $y= 11.70x – 2.041$,($R^2= 0.93$), (Multiple R=0.96), (Adjusted R square = 0.92), (standard error 0.02), (n = 15). It was also showed by Gonsama, (2011) that sensitivity of NDVI decreases as LAI approaches above 4 with various soil backgrounds. The present study showed that better accuracy of NDVI based model in the prediction of LAI spatial distribution.

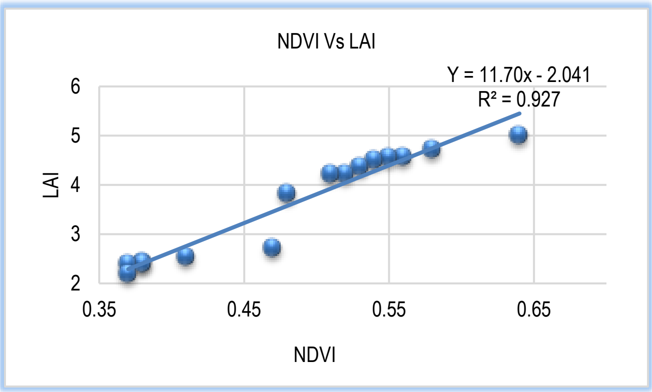

Fig-12 Validation of LAI with NDVI

Table-13 Biological yield on Different Field

Field	Biological yield(kg ha-1)	Biological yield/Field(kg)	Biological yield/plant(gm)
F1	8686	86.86	12.85
F2	9036	90.36	14.45
F3	7424	74.24	11.24
F4	6819	68.19	11.14
F5	6411	64.11	11.93
Mean	7675.20	76.75	12.32
SD	1147.59	11.48	1.37
CV%	14.95	14.95	11.13
Median	7424.00	74.24	11.93

LAI and yield relationship

The yield data were collected from the study fields corresponds to the LAI observation and these locations were recorded using GPS for the future analysis using NDVI Vs LAI statistical relationship a regression model. Developed and using the LAI model spatial map of LAI is generated and presented [Fig-12] using the crop cutting data of the study fields & LAI data LAI Vs yield regression model is formed to generate spatial yield map of the study area, using LAI, NDVI images of the study area. The LAI Vs yield regression shows positive correlation with R^2 0.94 using the above mentioned approach field distribution map generated and presented [Fig-12].

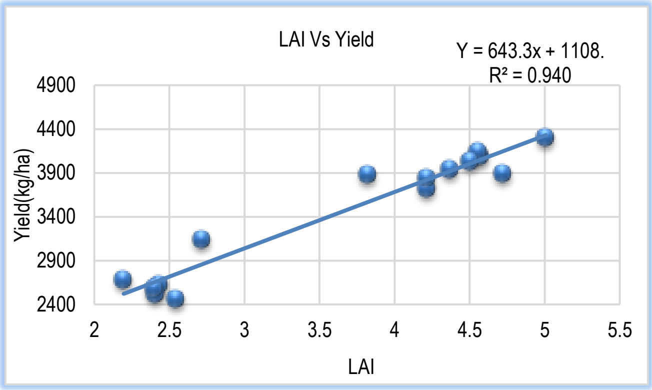

Fig-13 Validation of YIELD with LAI

Pre – processing of satellite data and FCC map, NDVI map, wheat map, LAI map, yield map generation.

Supervised hierarchical decision rule classifier was used to generate FCC, NDVI, wheat, LAI, yield maps. Using 27th January 2016. The wheat area has been estimated using sample segment approach using radiometric normalization of data for clear day.

Conclusion

The physical parameter of wheat was measured in different stage and reported as maximum plant height 79 cm, No. of leaf/plant 17, leaf length 42.68cm, leaf width 1.90cm, leaf area 64.20cm², chlorophyll content 73.25 micro gram /cm² LAI, 4.52, leaf water thickness 0.18 g/cm² and wheat yield 4300 kg ha^{-1}.

All AWiFS spectral bands were able to capture the temporal gradient of LAI throughout the wheat season. The superiority of NDVI over other listed indices for the estimation of LAI produced no surprise as its mathematical formulation reduces maximum soil background and atmospheric perturbations as compared to other. But retrieval of LAI from simulation approach outperformed NDVI based LAI estimation at all LAI range and the most striking outcome was no 'saturation' of retrieved LAI for more than 3. The LAI - NDVI models showed higher R^2 value 0.93 and lowest standard error 0.02. ($Y = 11.70x - 2.041$) The LAI Vs yield regression shows positive correlation with $R^2 = 0.94$ ($Y = 643.3x + 1108.86$).

Application of research: This study is very helpful for forecasting crop coverage area for the whole region as well as forecasting of major crop diseases and their control in time. It is also helpful in forecasting of crop biomass yield of the entire region and its subsequent management.

Research Category: Crop science

Table-14 Regression Equation and Coefficient of NDVI Vs LAI relation

Parameter	Equation	R^2	Multiple R	Adjusted R Square	Standard Error	Observation
LAI Vs NDVI	Y = 11.70x - 2.041	0.93	0.96	0.92	0.02	15

Table-15 Statistical Analysis for LAI and Grain Yield

Parameter	Equation	R^2	Multiple R	Adjusted R Square	Standard Error	Observation
LAI Vs yield	Y = 643.3x + 1108.86	0.94	0.97	0.94	175.81	15

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****Principal Investigator or Chairperson of research: Professor Dr. S K Pyasi**
University: Jawaharlal Nehru Krishi Vishwa Vidyalaya, Adhartal, Jabalpur, 482004, Madhya Pradesh, India
Research project name or number: Research station study

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Halali of district Raisen

Cultivar / Variety / Breed name: Wheat

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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