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Crop Yield Estimation Based on Landsat-NDVI
A Case Study of Sitapur District, Uttar Pradesh, India

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Abstract

The paper deals with calculation of the rice yield in Sitapur district, Uttar Pradesh using remote sensing data.Landsat-8 satellite data and CASA Model were used with raster based Geographical Information technology in calculating AGB and harvested index(HI). NDVI during grain filling is recognized as one parameter which related to the yield formation, the AGB was estimated by the available NDVI , and final HI was calculated from the accumulated NDVI before and after the rice heading period. For the calculation of accurate crop yield at development block level we have cross checked the estimated Rice yield with Crop cutting Experiments (CCE) yields of government department and found 93% accuracy. Hence the final result from satellite data represents good relationships with the data of agriculture department of Uttar Pradesh.

Keywords: *Landsat; AGB; Harvest Index; NDVI; FAPAR; LUE.*

1. Introduction

Estimation of agricultural yield at gram panchayat(GP) & block level is more and more common nowadays in India. In particular, agricultural yield estimation may play a great role in supporting policy formulation and decision-making in agriculture, and also affecting financial statistics of a region .

Remote sensing is capable of capturing changes in plant growth throughout the crop calendar season, whether relating to changes in chlorophyll content or structural changes of the crop.

Spectral data of crop canopy from remote sensing can provide qualitative and quantitative timely information on changes of plant biophysical parameters as indicatives of crop [1].

It is a most useful method, used as source of information for "real-time" model driving, it can providing spatial-temporal distributed

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information map with different level of resolution, and is frequently required when parameters simulating in crop yield forecasting[2]. The important information extracted from remote sensing data can then be used for many agricultural production processes, such as growth planning, stress management and policy making [3, 4, 5, 6, 7]. Traditional crop yield estimation methods based on remote sensing data use the statistic and semi- empirical relationships between Above Ground Biomass(AGB) and vegetation index, which are combinations of different bands. The most popular method in present time is NDVI, which can be derived from various satellite data[8].

Vegetation indices (VIs), many of which are documented indicators of the relative abundance of numerous biophysical characteristics of vegetation, including biomass, are based on the spectral reflectance of healthy green vegetation are used as proxies for biomass [9, 10].

NDVI, which can be directly calculated from satellite data, is related to vegetation canopy characteristics such as biomass and percentage of vegetation cover and is representative of plant photosynthetic efficiency, and fluctuations due to changes in meteorological and environmental parameters. NDVI images allow agricultural managers to analyse vegetation conditions for all season from NDVI/vegetation maps, NDVI curves and figures that anticipate major variations in productivity and potential harvest [1].

It has been well known that variation in yield of a crop may be related to nutrient balance, weed and pest control, and water management[11]. For rice, LAI increases with tillering and leaf expansion as plants develop. It generally reaches the peak value before heading, and decreases in senescence toward maturity [12, 13, 14, 15]. [16]pointed out that rice yield was positively correlated with total biomass and LAI near heading, and keeping larger leaf area duration (LAD) before heading until harvest would improve grain yield.

A harvest index (HI) was proposed and applied in the simulating of HI dynamic change in various weather conditions, and also applied in wheat yield estimation couple with NPP model[17]. Combination of remote sensing data with crop simulation models has been making yield estimation methods more tough and easily exportable. The direct use of a driving variable is normally difficult because the temporal resolution of remote sensing data does not match the crop models requirement. The availability of crop canopy characteristics is the fundamental factor in the application of the other methods in regional level yield estimation. The objective of this paper is to develope a practical method of crop yield estimation can be promoted in regional level mapping. This methodology is based on the relationship between the AGB & NDVI which retrieval from remote sensing data.

2. Data & Methods

2.1. Material Used

Satellite Image : Landsat - 8

Data ground resolution : 30m

Software's Packages : QGIS, Microsoft Excel

2.2 Methodology:

In accordance with the objectives of the study satellite image of Landsat - 8 has been collected for 2015. For digital data processing, analysis and integration of spatial and non-spatial data PC based raster GIS package QGIS has been used in this study. Then, using NDVI algorithm NDVI image has been generated and the study area extracted from the NDVI image. Accumulated NDVI from emergence to Heading date(average NDVI Pre) and

Accumulated NDVI from Heading date to Maturity (average NDVI Post) have been calculated. Detailed flow chart of methodology is given below in **Fig. 1**:

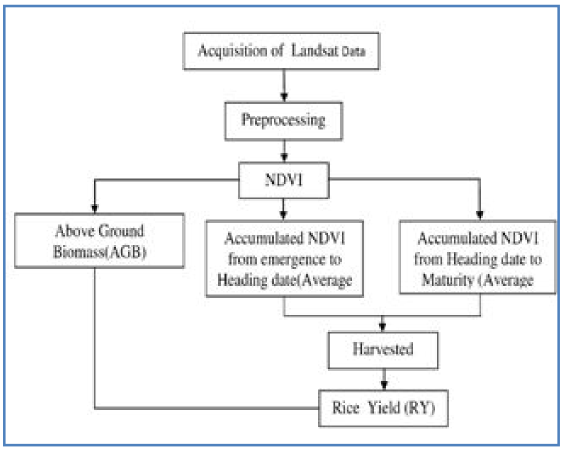

Fig. 1 Flow chart of methodology for Rice yield estimation.

3. Results and Discussion

The NDVI was retrieved in Study area with QGIS, and Above Ground Biomass was calculating with the help of NDVI. As we know, the rice growth rate is faster and faster after the stage of emergence, so both of the AGB and NDVI showing faster growth rate before the stage of Heading-date. After then, the NDVI is decreased gradually, but the Biomass is continue increased. So, The method of accumulation of NDVI data has been adopted in research, and the relationship is significant between AGB & NDVI. Above ground biomass has been calculated from Remote sensing data using CASA Model.

3.1. Calculation of biomass from vegetation index:

3.1.1.PAR (Photo synthetically Active Radiation)

PAR is calculated as 1/2 the total solar surface irradiance.

(PAR)= ½ Total solar Radiation ($MJm^{-2}yr^{-1}$) (1)

From calculation PAR(Photosynthetically Active Radiation) = 3053.39 $MJm^{-2}yr^{-1}$

3.1.2.Calculation of FAPAR (Fraction of Absorb Photo synthetically Active Radiation)

$FAPAR=(NDVI-NDVI_{MIN})/ (NDVI_{MAX}-NDVI_{MIN})$ (2)

or

$FAPAR=(SR-SR_{MIN})/ (SR_{MAX}-SR_{MIN})$ (3)

$SR=(1+NDVI)/ (1-NDVI)$ (4)

where, SR is simple ratio

FAPAR the fraction of absorbed PAR, which could be estimated form the simple ratio (SR) or NDVI by linear functions. Here FAPAR was calculated as a linear function of SR(Table. 1).

Table 1. Fraction of Photosynthetically Active Radiation.

DISTRICT	BLOCK	FAPAR
SITAPUR	AILIA	0.49
	BEHTA	0.44
	BISWAN	0.50
	GONDLAMAU	0.49
	HARGAON	0.50
	KASMANDA	0.52
	KHAIRABAD	0.48
	LAHARPUR	0.49
	MACHHREHTA	0.48
	MAHMOODABAD	0.48
	MAHOLI	0.49
	MISRIKH	0.48
	PAHALA	0.51
	PARSENDI	0.50
	PISAWAN	0.47
	RAMPUR MATHURA	0.40
	REUSA	0.45
	SAKRAN	0.48
	SIDHAULI	0.49

3.1.3. Total above ground biomass

The CASA (for Carnegie-Ames-Stanford Approach) model, introduced by Potter et al. (1993) and expanded here, is structured so that, for a given area, the amount of photosynthetically active radiation absorbed by green vegetation (APAR) multiplied by the efficiency by which that radiation is converted to plant biomass incrementequals to Above ground biomass.The CASA is a simple terrestrial ecosystem model that combines satellite and field observations in estimating annual net primary production and decomposition. The modification was the incorporation of a structure that allows ε to vary seasonally and within biomes without recourse to ecosystem-specific ε values (Field et al., 1995). This structure is as depicted in the model below:

$\varepsilon(x,t) = \varepsilon^{\circ}(x,t)*T1(x,t)*T2(x,t)*W$ (g MJ-1)

where ε is a corrected calculated variable in time and space; ε˚, the globally uniform maximum value; T1, and T2 are temperatures depicting temperature suitability and W, the availability of water. According to (Field et al., 1995) CASA assumes that each grid cell (pixel) is well drained thus not limiting productivity by anaerobic conditions in supersaturated soils. They also found out that CASA's ability to track variation in crop yield was strongly dependent on NDVI data. For present study the AGB are given in Table. 2.

Above Ground Biomass(AGB) =ε∑ FAPAR X PAR (5)

or

Above Ground Biomass(AGB) =ε∑APAR(6)

The values of ε vary from 0.354 g C /MJ PAR for broadleaf evergreen trees to 0.135 g C/MJ PAR for bare soil and desert for cropland Light Use Efficiency (ε) = 0.242 [18]

Table 2. Above Ground Biomass (Kg/ha)

DISTRICT	BLOCK NAME	AGB(g/m^2)	AGB(Kg/Ha)
SITAPUR	AILIA	362.24	3622.43
	BEHTA	327.47	3274.73
	BISWAN	368.12	3681.17
	GONDLAMAU	361.70	3616.96
	HARGAON	367.20	3671.95
	KASMANDA	384.99	3849.89
	KHAIRABAD	351.90	3519.03
	LAHARPUR	365.36	3653.56
	MACHHREHTA	356.38	3563.80
	MAHMOODABAD	357.15	3571.55
	MAHOLI	359.35	3593.48
	MISRIKH	353.12	3531.22
	PAHALA	374.78	3747.83
	PARSENDI	369.15	3691.46
	PISAWAN	343.96	3439.58
	RAMPUR MATHURA	297.27	2972.68
	REUSA	330.65	3306.47
	SAKRAN	354.05	3540.48
	SIDHAULI	365.21	3652.10

3.2 Estimation of Harvest Index(HI)

NDVI in the period of grain filling is recognized as one parameters which related to the yield formation, the Above Ground Biomass(AGB) was simulated by the available NDVI values, and final Harvest Index(HI) can be calculated from the NDVI. The negative environmental effects on the efficiency of nutrient transfer (e.g. water stress and temperature stress) was considered to affect the optimal Harvest Index(HImax). The final Harvest Index(HI) was expressed as below:

Harvested Index(HI) = HImax - HIrange{(NDVIpre - NDVIpost)/NDVIpre} (7)

NDVIpre is the average value of NDVI form emergence to heading date, and NDVIpost is the average value of NDVI from heading date to maturity. The default value of HImax and HIrange is 0.48 and 0.18 [19]

Table 3. Harvested Index from Remote Sensing Data.

DISTRICT	BLOCK	HI_{NDVI}
SITAPUR	AILIA	0.46
	BEHTA	0.47
	BISWAN	0.47
	GONDLAMAU	0.44
	HARGAON	0.45
	KASMANDA	0.46
	KHAIRABAD	0.45
	LAHARPUR	0.46
	MACHHREHTA	0.44
	MAHMOODABAD	0.46
	MAHOLI	0.45
	MISRIKH	0.44
	PAHALA	0.47
	PARSENDI	0.46
	PISAWAN	0.44
	RAMPUR MATHURA	0.48
	REUSA	0.47
	SAKRAN	0.47
	SIDHAULI	0.45

3.3 Final estimation of Rice yield

Using the computed AGB and HI_{NDVI} final Rice Yield (WY) was calculated as:

Rice Yield = HI X BiomassAGB (8)

Table 4. Development Block wise Rice Yield.

DISTRCT	BLOCK NAME	Rice Yield (Kg/ha)
SITAPUR	AILIA	1652.95
	BEHTA	1537.37
	BISWAN	1721.89
	GONDLAMAU	1577.38
	HARGAON	1669.13
	KASMANDA	1776.12
	KHAIRABAD	1600.89
	LAHARPUR	1692.35
	MACHHREHTA	1572.28
	MAHMOODABAD	1652.98
	MAHOLI	1630.87
	MISRIKH	1545.26
	PAHALA	1764.23
	PARSENDI	1711.02
	PISAWAN	1514.39
	RAMPUR MATHURA	1425.25
	REUSA	1545.57
	SAKRAN	1648.17
	SIDHAULI	1638.06

Table 5. Comparison of Estimate yield and Govt. Agency Yield.

District	Govt. Agency Yield(Kg/ha)2014	Predicted Yield(Kg/ha)2015	Difference (Kg/ha)	Deference Percentage
Sitapur	1734	1625	109	6.28

4. Conclusions

The research was conducted based on the remote sensing data which combines the all major weather factors such as rain, temperature, humidity and wind. The NDVI, which being related to crop production processes directly, is one of the best driving factor in crop status analysis and Yield calculation. In this study, we analysed NDVI imagery from the Landsat satellite to monitor the development of biomass of rice crop in the Sitapur District for the year 2015.

The image acquisition was carried twice a month during cropping season and the time of peak growth or end of growing period and beginning of flowering is the period of maximum greenness or maximum photosynthesis and is called peak decadal. Peak decadal has the highest NDVI value of the cycle which is used for calculation of AGB. Harvested Index were calculated with the help of accumulated NDVI and implemented in yield calculation. The result from satellite and agriculture statistics of Uttar Pradesh were compared and found 93.72% accuracy.

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