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Integrating weather model & Remote sensing indices for wheat yield prediction in Haryana, India

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ABSTRACT

Wheat is a major food grain crop of main agricultural region *i.e.* northern plain of India. Haryana state holds a premium position in wheat production (*Rabi* Season) in the country. Pre-harvest yield estimation of wheat has key role in policy framing. In Haryana, Agriculture is a big support to its economy which continues to occupy a prominent position in State GDP. In present research, Agromet-Spectrals models have been developed for this purpose *i.e.*yield estimation in Haryana with the help of input data such as meteorological indices and satellite based NDVI(NASA's-MODIS) from 2000-2017. Empirical models were developed for predicting wheat yield for Hisar and Karnal districts representation the two agro-climatic zone of state in Haryana, India.The models were developed used weather variable (Temperature (Minimum and Maximum), Relative Humidity (Morning and Evening) and Rainfall) and spectral indices Normalized Difference Vegetative Index viz. Agromet- model(weather model) and Agromet-spectral model (MODIS-NDVI). Weather or Agromet model was integrated with NDVI values for both location to enhanced the accuracy of models. Regression models were developed using significant weather variables and NDVI data for wheat yield prediction at both location. The result revealed that the models when integrated with remote sensing data (NDVI) gave better prediction as compared to agromet model that depends only on weather variables. Agromet-models (adjusted R^2 = 0.38 to 0.78) whereas satellite data based NDVI i.e. MODIS-NDVI for both stationgave best result (Adjusted R^2 = 0.61-0.86) as compared to weather models. MODIS-NDVI pixel based values observed to be more effective for wheat yield predication in integrated with weather parameters.This study could help the provincial government of Haryana as well as in northern plains in estimation of yield prior harvest at first week of April by using weather spectral (NDVI-MODIS) models.

Introduction

Wheat (*Triticumaestivum* L.) is a major Cereal crop of the world in terms of production. In India, wheat is the second important food crop being next to rice (Ranjan *et al*., 2012) and contributes to the total food grain production of the country to the extent of about 35 per cent. (Anonymous, 2019).Yield prediction is a major step for various policy decisions related to distribution and export-import of food grain. In Haryana, Agriculture is a big support to its economy which continues to occupy a prominent position in State GDP. Despite the decline in the share of agriculture sector in the Gross State Domestic Product to 18 percent (2017-18) about two third population of the state still

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depends upon agriculture for their livelihood. The growing population in agrarian countries like India posing a great pressure on food-grain production. Therefore, for proper planning and management of products, various models and techniques have been developed for accurately prediction of production especially in wheat being main food grain. Mostly, all models use meteorological parameters as input for yield prediction.

Besides meteorological data, remote sensing data have also proved helpful to increase accuracy and timely forecast of yield. A prominent crop weather model was developed by Fisher *et al.,* (1924) and experimentally applied by Agarwal *et al.* (2007) on the basis of different weather parameter combination for forecasting yield. Weather plays a dominated role on growth and overall condition of a crop. Different weather parameters affect differently on different stages of crop growth. The present study is an effort to find out the weather element or their combination that are responsible for crop yield prediction. Correlation and regression analysis was carried out using Excel spread sheet and SPSS package. A regression correlation analysis was carried out between weather parameters and yield of wheat crop. To carry out this task, sum and sum product values (Agarwal *et al.,* 2007) were taken as input independent factor and yield data as dependent factor in SPSS software to find out those parameters or their combination which were most affecting wheat yield. Sisodia *et al.* (2014) developed agromet statistical regression models based on meteorological parameter *i.e* minimum and maximum temperature, relative humidity, wind-velocity and sunshine hours using 20 years data from (1990-91 to 2009-10), to predict wheat yield two month prior to harvest. Saeed *et al.* (2017) developed agromet-spectral model to forecast wheat yield before harvest with root mean square errors (RMSEs) less than 5%. The NDVI shows strong relationship with crop physiological attributes and high value of NDVI is associated with faster growth rate and higher biomass accumulation during the vegetative stage, and a longer grain filling period by delaying leaf senescence during the ripening phase thereby increasing yield (Babar *et al.,* 2006).The NDVI values of wheat during different phonological stages was observed 0.3 to 0.35 at emergence stage, 0.40 to 0.50 at tillering stage, 0.55 to 0.65 at milking stage, 0.35 to 0.45 at maturity and 0.25 to 0.30 at harvesting stage (Parida and Ranjan, 2019). Remotely sensed imagery give the information of crop quality and development at different growth stages but some uncertainty in soil, climatic condition, management and other input data will decrease the prediction accuracy (Jin *et al.,* 2018).

Bognnar *et al*. (2017) also used minimum and maximum temperature, rainfall and sunshine hours with MODIS derived NDVI values that gave better performance in forecasting wheat yield three weeks before harvest in Punjab province of Pakistan. A robust yield model was exercised for estimating and forecasting wheat yield in Hungary at country level in the period of 2003–2015 using MODIS-NDVI data. Keeping in view these efforts worldwide, this study was designed with the objective to develop an integrated model for yield prediction of wheat by taking meteorological data incorporation with Remote Sensing data derived from two sources IRS and MODIS-NDVI for two locations of different Agro-climatic zones of Haryana state in India.

Material and Methods

Study area

The present study was conducted for Haryana state by taking two locations *i.e.* Hisar and Karnal that represent the two agro-climatic zone of the state. Hisar and Karnal districts are located between of 29^0 09' N, 75^0 43' E and 29º 43' N latitude, 76º 58' E longitude of western and eastern part of Haryana respectively (Figure1). The climatic region lies between semi-arid to humid condition.

Data Collection

Satellite based NDVI values taken from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS, 16 days composite imageries of 250 m resolution) were used from 2000-2017. Rabi season MODIS imagery of path 147 and row 41 were downloaded for whole of growing season on fortnight basis. These composite images were spanning from first-November to April (Rabi Season) were obtained for the time period of 2000 to 2017, covering the entire wheat crop cycle at Hisar and Karnal district of Haryana. Meteorlogical parameters viz. Temperature (Maximum and Minimum), Relative Humidity (Morning and Evening) and Rainfall data were collected from

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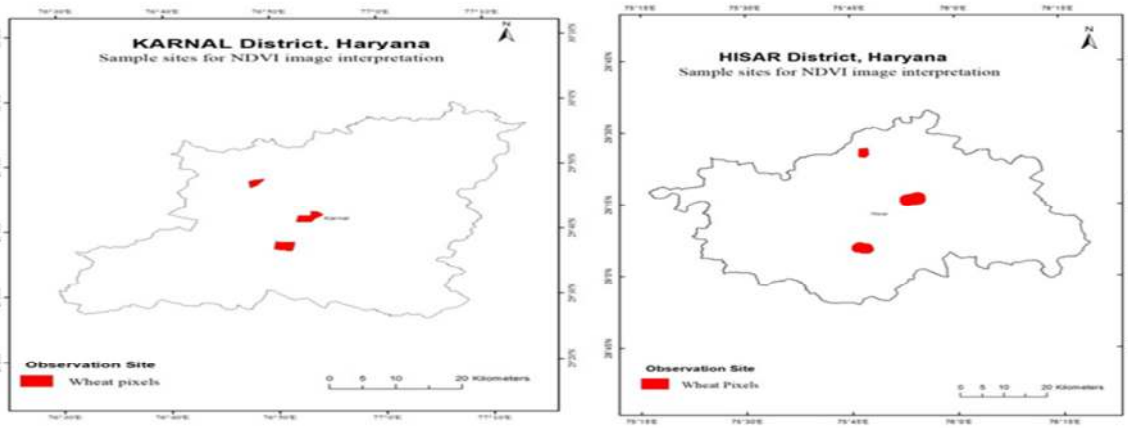

Figure 1: Wheat growing sites for NDVI image interpretation in Karnal and Hisar district

Table 1: Weather and spectral indices used in models using composite weather variables

SIMPLE WEATHER INDICES							**WEIGHTED WEATHER INDICES**					
	T_{MAX}	**T_{MIN}**	**RH 1**	**RH II**	**Rf**	**NDVI**	**T_{MAX}**	**T_{MIN}**	**RH 1**	**RH II**	**Rf**	**NDVI**
T_{MAX}	Z10						Z11					
T_{MIN}	Z120	Z20					Z121	Z21				
RH 1	Z130	Z230	Z30				Z131	Z231	Z31			
RH II	Z140	Z240	Z340	Z40			Z141	Z241	Z341	Z41		
Rf	Z150	Z250	Z350	Z450	Z50		Z151	Z251	Z351	Z451	Z51	
NDVI	Z160	Z260	Z360	Z460	Z560	Z60	Z161	Z261	Z361	Z461	Z561	Z61

University, Hisar (Haryana) and Central Soil Salinity Research Centre, Sirsa (Haryana) from 2000 to 2017. These models integrated with NDVI values from both of sources for corresponding location for above said time period (2000-2017) to enhance the accuracy of models. The statistics of the wheat yield (Kg/ha) from 2000 to 2017 for Hisar and Karnal (Haryana) were collected from the Haryana Statistical Abstract published on annual basis by Department of Economic and Statistical Analysis, Govt. of Haryana. Correlation of different combination of yield and weather parameter and then sum products (Agarwal *et al.,* 2007) were derived using M S Excel.

Coefficient of determination

R-squared also known as the coefficient of determination-is a statistical analysis tool used to predict the future output and how closely it aligns to a single measured model. The adjusted R-squared compares the descriptive power of regression models two or more variables that include a diverse number of independent variables known as a predictor. The validation of these Agromet model equations were execute for the next two consecutive years 2015-16 &2016-17. Different models were prepared viz. Agomet model, and Agromet Spectral Model (MODIS NDVI) for wheat yield estimation at regional level in Haryana and described as under.

Normalized Vegetation Index (NDVI)

Normalized vegetation index (NDVI) is calculated as (Rouse Jr *et al.*, 1974):

$$\mathbf{NDVI = (NIR\text{-}RED) / (NIR+ RED)}$$

Where, NIR and RED are the reflectance in the near- infrared and red spectral channels, respectively.

Selection of Region of Interest (ROIs):

The FCC (False Colour Composite) image of Rabi season of Hisar and Karnal districts were analyzed in different location for identification of wheat crop and polygon (region of interest) were generated. Three locations were chosen Figure 1 for both district to minimize of chance of error that may occurred to mixing of pixels with other crops. These polygons were used as a mask to obtain NDVI values of each season.

Generation of NDVl Values:

Average NDVIs of each polygon was calculated through masking the field by overlaying the ROIs with MODIS-NDVI images using Overlay option of ENVI ("Environment for Visualizing Images"). Average NDVI of each polygon was obtained and so obtained 3 NDVI values corresponding to each polygon were further analyzed to get final NDVI value of a season for a station. NDVI, which is measurement of vigour of crop plant, was calculated using following equation:

Results and Discussion

Regression analysis gave summary output that included partial regression coefficient of effective parameter and intercept value to form equation in which yield as dependent and other significant parameters are independent. Table 2 details the variables derived based on sum product-correlation of significant weather variables for developing regression models for Hisar and Karnal districts.

Where, Z131 = sum of product of maximum temperature and morning relative humidity, Z41 = Sum of product of evening relative humidity, Z230 = sum of minimum temperature and morning relative humidity, Z451 = sum of product of evening relative humidity and rainfall.

***Agromet Model*:** The Agromet model worked better for Karnal station with adjusted R^2 value of 0.78. The reason may be climatic variability which is less at Karanl as compared to Hisar where the model could not show better results (Adjusted R^2 0.38). Agromet yield model equation for Hisar and Karnal districts is present in Table 3. Further theAgromet Yield models were validated for 2015-16 & 2016-17 for wheat yield estimation for districts Hisar and Karnal as shown in Table 4.The validation of Agromet models revealed that result were better for first year 2015-16 as compared to 2016-17. The post validation test is done for the fitted model using (Percentage deviation) test. This measure the deviation (in percentage) of forecast yield from the observed yield. For the year 2015-16, percentage deviation is comes out to be 3.80%. there is only one dependent variable in the given model along with intercept term. Validity test based on a single year can't be considered since it can't be because of the changes in the trend of observed value. In order to select a good model, the model validation for multiple years. It is very clear from the 2016-17 (%deviation 16.48) data that the model is not so good to explain the forecasting.The wheat yield was higher in 2016-17 from normal, that's why the errors are on higher side.

Agromet-Spectral Model (MODIS-NDVI): In this model the Agrometmodelswereintegrated with crop specific NDVI values or real ground/pixel based NDVI(MODIS satellite data). The regression yield model developed for Hisar and Karnal districts showed considerable improvements over previous checked models (table 5). Again the model worked better for Karnal region as compared to Hisar and this time the adjusted R^2 value express its applicability for Hisar region also.

MODIS-NDVI (wheat pixel based) satellite data considerably improved the accuracy of agromet models for both of the regions as this NDVI values is pixel based or wheat grown area. Agromet models with integration of satellite based NDVI (MODIS) data can help in predicting wheat yield before two month of harvest upto 90% accuracy. The validation of model shows that prediction of yield was within acceptable limits for 2015-16. The production was exceptionally high in 2016-17 as compared to recent past due to supporting weather condition, which increase the validation errors (table 6). But in normal year the prediction were very close to real values. The R^2 values were 0.66& 0.90 for Hisar and KarnalrespectivelyThis is due to more homogeneity of wheat cropped area in Karnal as compared to Hisar.Similar result found by Singh *et al.,* (2002) estimated the wheat yield in small areas in India using IRS-NDVI and obtained very low error in the range of 1.6-6.7%. Also Nagy *et al.,* (2018) also estimated the wheat and maize yield 6-8 weeks befroe harvest at regional level in Hungary using MODIS-NDVI. Wang *et al.,* (2019) estimation the winter wheat yield with a realtive of about 6% for selected regions of China.Lopresti *et al.,* (2015) found that an empirical model was fit between NDVI and yield, to estimate wheat yield 30 days early before harvest. Ranjan *et al.,* (2012) had developed a regression model to estimate the wheat yield using different weather parameter and NDVI as input. This showed a positive relationship with predicted and observed yield.

Table 2: Effective weather parameters for Hisar and Karnal district (Sum products-correlation)

Location	Year	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14	2014-15	2015-16	2016-17
Hisar	Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Yield	4447	4283	4182	4062	4135	4162	3704	4392	3920	4829	4139	4600	5098	4477	4180	4310	4758
	Z131	-1934.95	-2363.81	-2167.82	-2282.69	-2067.37	-2791.21	-2614.77	-1770.12	-2466.38	-2039.63	-2522.52	-1940.19	-1946.65	-2120.04	-2693.18	-2018.48	-2696.40
	NDVImax (MODIS)	0.76	0.78	0.73	0.78	0.77	0.77	0.76	0.76	0.80	0.82	0.82	0.79	0.83	0.84	0.83	0.83	0.84
Karnal	Yield	4395	4635	4580	4363	4138	4183	4367	4423	4629	4601	4518	4670	5670	4912	4046	4543	5212
	Z41	9.71	8.57	34.04	10.85	-14.22	-1.05	4.02	-12.25	7.73	10.39	12.08	5.12	36.32	4.55	-11.45	-17.03	-3.80
	Z230	16053.73	17847.26	19116.87	19958.49	20369.28	18076.10	20010.13	17108.26	19894.71	18848.47	18855.91	17758.99	17925.56	18083.11	19185.72	19367.65	18480.04
	Z451	-225.09	1586.86	208.84	-341.22	-243.17	-1158.36	877.09	-322.05	486.46	225.44	-183.06	-119.54	6385.68	1413.93	-5144.58	-382.51	-1013.38
	NDVmax (MODIS)	0.82	0.84	0.84	0.83	0.82	0.83	0.8	0.8	0.86	0.82	0.85	0.83	0.86	0.85	0.85	0.85	0.86

Table 3: Agromet regression model equation for Hisar and Karnal districts

Location	Regression Equation	Adjusted R^2	R^2
Hisar	Y= 5942.17+0.73(Z131)	0.38	0.42
Karnal	Y =5237.23+6.44(Z41)-0.04(Z230) + 0.12(Z451)	0.78	0.83

Table 4: Validation of Agromet models

Location	Observed Yield (Kg/hac.)		Regression Equation	Predicted Yield (Kg/ha)			
	2015-2016	2016-2017		2015-2016	% Deviation	2016-2017	% Deviation
Hisar	4310	4758	Y=5942.17+0.73(Z131)	4474.30	3.80	3973.79	-16.48
Karnal	4543	5212	Y=5237.23+6.44(Z41)-0.04(Z230)+0.12(Z451)	4283.46	-5.70	4351.97	-16.50

Table 5: Regression yield model equation developed with addition of NDVI (MODIS) for Hisar and Karnal district

Location	Regression Equation	Adjusted R^2	R^2
Hisar	Y=1850.72 +0.77 (Z131) +5318.85 ($NDVI_{max}$)	0.61	0.66
Karnal	Y=354.78 + 1.99 (Z41)-0.05(Z230) + 0.13 (Z451) + 6155.59($NDVI_{max}$)	0.86	0.90

Table 6: Validation of Agromet-spectral (MODIS-NDVI) Yield models for wheat yield estimation for districts Hisar and Karnal during 2015-16& 2016-17

Location	Observed Yield (Kg/ha)		Regression Equation	Predicted Yield (Kg/ha)			
	2015-16	2016-17		2015-16	% Deviation	2016-17	% Deviation
Hisar	4310	4758	Y=1850.72+0.77(Z131)+5318.85($NDVI_{max}$)	4701.5	8.32	4242.3	10.84
Karnal	4543	5212	Y=354.78 + 1.99 (Z41)-0.05(Z230) + 0.13 (Z451) + 6155.59($NDVI_{max}$)	4479.2	1.42	4590.4	11.93

Conclusion

The main objective of the study was to develop a best fit regression model for early wheat yield forecasting during wheat growing season using weather parameters (viz. max. and min. temperature, morning and evening relative humidity and rainfall). The agromet models were developed on the basis of correlations of wheat yield and weather parameters of*rabi* season (October to March) for the period of fifteen years (2000-2015). The results revealed that weather model alone worked (forecast) well for yield prediction for both Hisar and Karnal regions. Further, to increase the accuracy of models remote sensing data (NDVI) was integrated in weather models that gave high coefficient of determination. The result was better for Karnal as compared to Hisar due to different climatic condition or continuous wheat growing area and high soil moisture retentation capacity. MODIS derived NDVI (exact wheat pixels in field) was tested by integrated with Agrometmodel**.**It was found that the weather model integrated with MODIS-NDVI gave more accurate model for wheat yield estimation. The result revealed that maximum temperature and morning R_H are determining factors for prediction of wheat yield at Hisar. By inclusion of NDVI as another variable the model accuracy was highest (Adjusted R^2=0.61) and error were 8% & 10% for

(2015-16 &2016-17). Similarly, minimum temperature & R_H (morning and evening) were determining factor for yield prediction at Karnal. By Integration of NDVI, the model accuracy reached to highest among all previous models (Adjusted R^2=0.86). The errors were 1.4% and 11.9% for the two year *i.e.* 2015-16 & 2016-17 for validation of wheat yield.The results also emphasis that NDVI values can be a good estimator of crop yield and used for yield estimation and prediction. Agromet models with integration of satellite based NDVI (MODIS) data can help to predict wheat yield with highest accuracy in comparison to Agromet. This study could help the provincial government of Haryana as well as in northern plains in estimation of yield prior harvest at first week of April by using weather spectral (NDVI-MODIS) models.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Agrawal, R. and Mehta, S.C.(2007). Weather based forecasting of crop yields, pests and diseases-IASRI Models. *Journal of Indian Society Agriculture statistics*., 61(2): 255-263.

Anonymous, (2019) www.business-standard.com, news article dt. February 28, 2019.

Babar, M.A., Reynolds, M.P., Van Ginkel, M., Klatt, A.R., Raun, W.R. and Stone, M.L., (2006). Spectral reflectance indices as a potential indirect selection criteria for wheat yield under irrigation. *Crop Science*, 46(2): 578-588.

Bognar, P., Kern, A., Pásztor, S., Lichtenberger, J., Koronczay, D. and Ferencz, C., (2017).Yield estimation and forecasting for winter wheat in Hungary using time series of MODIS data. *International journal of remote sensing*, 38(11): 3394-3414.

Fisher, R.A., (1924): *On a Distribution Yielding the Error Functions of Several Well Known Statistics*.

Jin, X., Kumar, L., Li, Z., Feng, H., Xu, X., Yang, G. and Wang, J., (2018). A review of data assimilation of remote sensing and crop models.*European Journal of Agronomy*, 92:141-152.

Lopresti, M. F., Di Bella, C. M. and Degioanni, A. J. (2015) 'Relationship between MODIS-NDVI data and wheat yield: A case study in Northern Buenos Aires province, Argentina', *Information Processing in Agriculture*. 2(2), pp. 73–84.

Nagy, A., Fehér, J. and Tamás, J., (2018). Wheat and maize yield forecasting for the Tisza river catchment using MODIS NDVI time series and reported crop statistics. *Computers and Electronics in Agriculture*, 151: 41-49.

Parida, B.R. and Ranjan, A.K., (2019). Wheat Acreage Mapping and Yield Prediction Using Landsat-8 OLI Satellite Data: a Case Study in Sahibganj Province, Jharkhand (India). *Remote Sensing in Earth Systems Sciences*, 2(2-3): .96-107.

Ranjan, R., Nain, A.S. and Panwar, R.(2012), Predicting yield of wheat with remote sensing and weather data. *Journal of Agrometeorology*.9(2): 158-166.

Rouse Jr, J.,Haas, R. H., Schell, J. A., & Deering, D. W. , (1974).'Monitoring vegetation systems in the Great Plains with ERTS' *NASA. Goddard Space Flight Center 3d ERTS-1 Symposium*1: 309–317.

Saeed, U.,Dempewolf, J., Becker-Reshef, I., Khan, A., Ahmad, A., & Wajid, S. A. (2017), 'Forecasting wheat yield from weather data and MODIS NDVI using Random Forests for Punjab province, Pakistan', *International journal of remote sensing*. 38(17): 4831–4854.

Singh, R.A.N.D.H.I.R., Semwal, D.P., Rai, A. and Chhikara, R.S., (2002). Small area estimation of crop yield using remote sensing satellite data. *International Journal of Remote Sensing*, 23(1), :49-56.

Sisodia, B. V. S., Yadav, R. R., Kumar, S., & Sharma, M. K (2014).'Forecasting of pre-harvest crop yield using discriminant function analysis of meteorological parameters', *Journal of Agrometeorology*. 16(1): 121-125.

Wang, Y., Xu, X., Huang, L., Yang, G., Fan, L., Wei, P. and Chen, G., (2019). An Improved CASA Model for Estimating Winter Wheat Yield from Remote Sensing Images. *Remote Sensing*, 11(9): 1-19.