ANALYSIS OF WHEAT CROP FORECASTS, IN INDIA, GENERATED USING REMOTE SENSING DATA, UNDER FASAL PROJECT

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ABSTRACT:

Wheat (*Triticum aestivum L.*) is a major cereal crop of the world, which plays an important role in global food and nutritional security. In India, wheat grown areas are more as compared to other food crops, except for rice. The total area under wheat cultivation is 30.60 million hectares with production of 98.38 million tonnes and the productivity is 3.22 tonnes /hectare (DES, 2017). The main objective of this paper is to highlight the development of satellite-based methodology, compare the relative deviations (%) at national level, RMSE (%) and correlation coefficient at state level and correlation coefficient at district level between DES and FASAL estimates from 2013 to 2017. It was observed that the area and production estimates improved with improvement in the satellite resolution and ground truth data. During the last 10 years of estimation the spatial resolution of the satellite data has gradually improved from 23.5 meter of (Reourcesat-2, LISS-III) and finally 10m of Sentinel-2, MSI, which is being currently used for acreage estimation purpose. Hooda R.S et al (2006) studied that the improvement in the spatial resolution, spectral and temporal resolution of the satellite data has also improved the crop discrimination. Both accuracy as well as precision of the estimates has improved over the years from 2013 to 2017, as reflected by relative deviation, RMSE (%) and Coefficient of correlation values at national, state and district level respectively.

1. INTRODUCTION

With growing population and increasing demands for food and security, wheat (*Triticum aestivum L.)* plays as a major role in global food and nutritional security and grown on more land area than any other food crop (220.4 million hectares, FAOSTAT 2014) and 749 million tonnes wheat is produced in 2016 (FAO, 2016), makes it the second most-produced cereal after maize. India produces 13.1% of the total wheat production of the world, occupying the second position, next to China. About 40 per cent of the total food grain reserves of the country is contributed by wheat crop. The total area under wheat cultivation is 30.60 million hectares with production of 98.38 million tonnes and the productivity being 3.22 tonnes/hectare (DES, 2017). Major wheat producing states of India include Haryana, Madhya Pradesh, Punjab, Rajasthan and Uttar Pradesh. In India, the highest area and production under wheat cultivation is in Uttar Pradesh whereas, Haryana ranks first in productivity. Goswami, S.B et al (2012) has estimated district level wheat crop acreage using single date Resourcesat-1, LISS-III data and compared the deviation found from the land record data of commissioner of Madhya Pradesh. Hooda, R.S et al (2006) has studied wheat crop area and yield estimate using remote sensing data. In the present studies wheat area, was studied at National/State level during 2013 using low resolution Resourcesat-1, AWiFS data and sample segment approach under FASALSoft 1.0 and from 2014 onwards district level and Maximum Likelihood (MXL) approach was started using complete enumeration method, medium resolution Resourcesat-2, LISS-III (23.5m) and Landsat-8, OLI (30m) and yield estimation using meteorological and remote sensing data based models. Further high-resolution Sentinel-2, MSI (10m) data was incorporated from 2016 onwards. The results obtained under FASAL were compared with DES estimates at National, State and District level.

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2. STUDY AREA

Major wheat growing states in India are Punjab, Uttar Pradesh, Madhya Pradesh, Bihar, Rajasthan, Gujarat, Haryana, Himachal Pradesh, and Uttarakhand (Figure 1). These states contribute an aggregate of 93.1 % of the total wheat area and 96.2 % of total wheat production (based on DES data of 2011-12 to 2015-16) in the country. The State-wise contribution of wheat area and production of the country are shown in Figure 2. Uttar Pradesh state covers total 32% of the wheat area, while Madhya Pradesh and Punjab cover 18% and 12% of area respectively. Uttar Pradesh also occupies the first place in terms of production accounting for 30% followed by Punjab and Madhya Pradesh contributing 18% and 15% of total production, respectively. FASAL (Forecasting Agricultural output using Space, Agro-meteorology and Land based observations) is the national level programme of Ministry of Agriculture and Farmers Welfare, under which MNCFC (Mahalanobis National Crop Forecast Centre) has been regularly generating crop forecasts at District/State/National level for major crops of the country since 2012.This programme includes multiple pre-harvest crop acreage and production estimation forecasts for 9 crops, i.e. Rice (*Kharif* & *Rabi*), Wheat, Rapeseed & Mustard, Jute, Sugarcane, Cotton, Rabi Sorghum and Pulses (Rabi).

2. DATA USED & METHODOLOGY

3.1 Satellite Data Used for Area Estimation

Present studies have been carried out using different satellite data (multiple spatial and temporal resolution) for wheat area estimation since 2013-14. The details of the satellite/(sensor) have been shown in Table 1.

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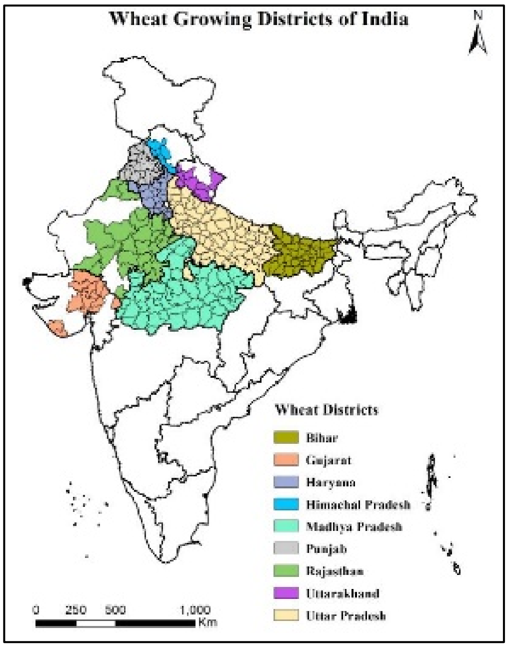
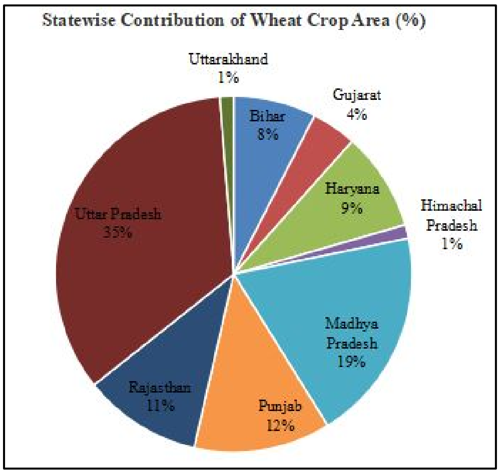
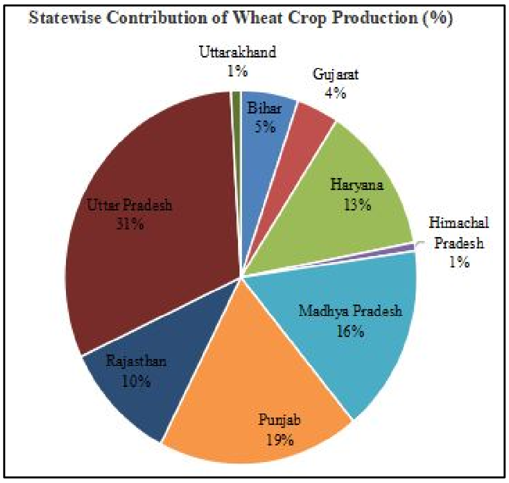


Figure 1. Major wheat growing states of India



(a)



(b)

Figure 2. The State-wise(percentage) contribution of wheat area(a) and production(b)

Remote Sensing Data/Satellite/Sensor				
2013	2014	2015	2016	2017
R2	R2	R2	R2	R2
AWiFS	AWiFS	AWiFS	AWiFS	AWiFS
LISS-III	LISS-III	LISS-III	LISS-III	LISS-III
-	-	Landsat-8(OLI)	Landsat-8(OLI)	Landsat-8(OLI)
-	-	Sentinel-2(MSI)	Sentinel-2(MSI)	Sentinel-2(MSI)

Table 1. Showing year-wise Satellite and sensor from 2013 to 2017

3.2 Satellite Data for Yield Estimation

3.2.1 MODIS NDVI Data

Moderate resolution remote sensing data of MODIS (Moderate Resolution Imaging Spectroradiometer) on-board Terra/Aqua Satellite was used for developing remote sensing based index (Vegetation Condition Index). Fortnightly MODIS Normalized Difference Vegetation Index products (250 m resolution), from 2006 were used for computing VCI, as given below.VCI can be computed as Kogan, (1997).

$$VCI = \frac{NDVI_{curr} - NDVI_{\min}}{NDVI_{\max} - NDVI_{\min}} \quad (1)$$

Where, NDVICurr, NDVIMax, NDVIMin, are the values of Normalized Difference Vegetation Index values of Current period, maximum and minimum of last 11 years’ data, for the corresponding period, respectively. The following set of data has been used in semi physical model.

Data /Product	**Satellite/ Ground**	**Sensor**	**Resolution**
Daily integrated Insolation	INSAT 3D	Imager	8 km
8-days composite FAPAR	Terra	MODIS	0.5 km
8-days composite surface reflectance	Terra	MODIS	0.5 km
Crop(Wheat) mask	Resourcesat	AWiFS	56 m
Daily Tmin and Tmax	Gridded Data of IMD	0.5 x 0.5 degree	
16 days NDVI Profile	Terra	MODIS	250 m

Table 2. Showing satellite details for Yield Data.

3.2.2 Ground Truth Data

Ground truth (GT) data is essential for the analysis of remote sensing data for differentiating various land uses/land covers and crop classes. The ground truth (GT) for wheat crop has been collected each year during rabi season with collaboration with State Agriculture Departments. The ground truth has been conducted for use of reference for the analysis of a remotely sensed image and to verify the accuracy of crop classification using remote sensing data (accuracy assessment). The GT data has been collected by the state agriculture department officials using a smartphone based Android App, called Bhuvan FASAL, developed by NRSC (ISRO). Number of GT collected and used from 2013 to 2017 has been shown graphically in the figure 3 (State wise (a), and total (b)).

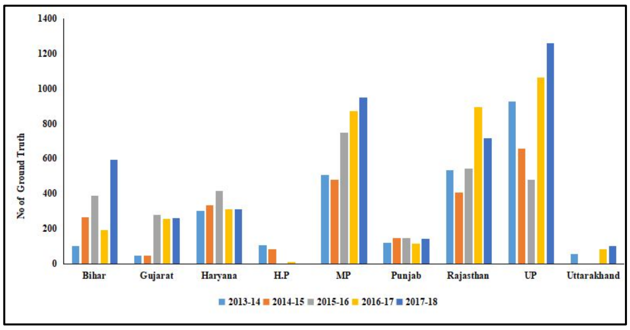


Figure 3(a). State wise GT used from 2013-14 to 2017-18

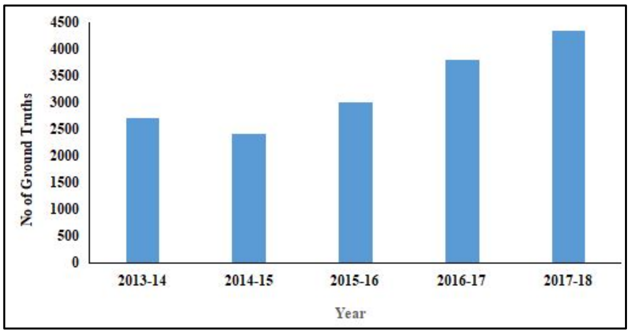


Figure 3(b). Year wise total GT used from 2013-14 to 2017-18

3.2.3 Methodology for Area estimation

During 2013-14 single date data (R2 AWiFS) and sample segment approach was used for state wise wheat crop estimation. From 2014-15 onwards, complete enumeration approach was used for district wise crop area estimation using single date high resolution data including Resourcesat-2 LISS-III and Landsat-8, OLI in 2014-15 along with Sentinel-2, MSI in 2016 and 2017. Wheat classification includes a two-step process comprising of optimum date selection and classification. K-means, ISODATA classification was carried out on the multi-spectral (3-4 bands) data set to identify the land use classes. Within crop classes, Maximum Likelihood Classification approach was followed using ground truth sites collected by state agricultural departments. Area of interest of wheat crop and other land cover features are identified using ground truth data. The maximum likelihood classifier was used which calculates the probability of a pixel belonging to a particular class. Lillesand and Kiefer, (2000). After the classification wheat crop mask was generated and wheat crop acreage was calculated by overlaying the district boundary. Finally, accuracy of the classified results was verified using ground truth. Additional data used for crop classification included agricultural crop mask, collected from LULC mapping programme of NRSC (NRSC, 2006).

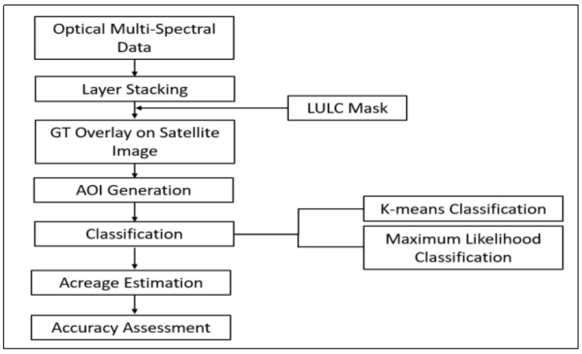


Figure 4. Shows the illustrative flow diagram of crop classification.

3.2.4 Methodology for Yield Estimation

Tripathy et al, (2014) has used Spectral yield models based on Vegetation Index (VI) and the mechanistic crop simulation models for estimating wheat yields. Yield has been estimated using Agro-meteorological regression models in 2012-13 and Semi-physical model using satellite derived input and weather based model in 2013-14. Crop simulation model included in 2015-16 for yield estimation and semi physical model also used for 2017-18 estimates. District level wheat crop yield has been estimated using four different procedures - i) Agro-meteorological regression models, ii) Crop Simulation model iii) Remote sensing index (NDVI and VCI) based empirical models, and iv) Semi physical Model. First two approaches were used by IMD (in collaboration with state agricultural universities); The third and fourth approaches were used by MNCFC to estimate wheat yield.

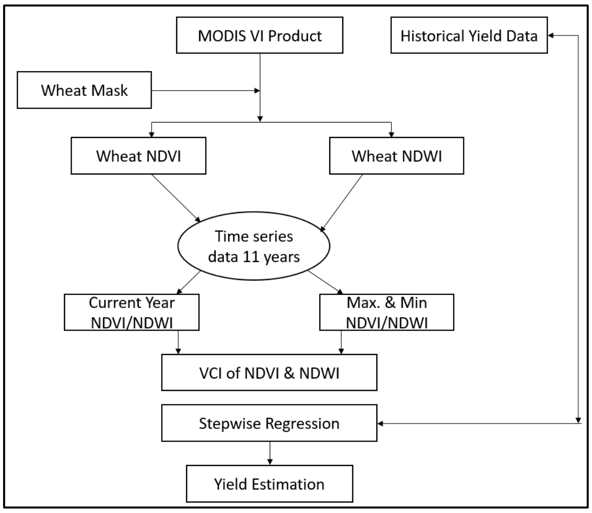


Figure 5. Flow diagram for calculation of yield using Vegetation Condition Index (VCI) (Dubey et al., 2016

4. RESULTS AND DISCUSSION

4.1 Satellite data and Classified Image

Based on area of interest (AOI) generated using ground truth sites for wheat and mustard and crop profile generated from mean values, crops were classified using maximum likelihood classifier. An example for wheat and mustard crop classified of Baran district of Rajasthan using Sentinel-2 MSI (10m) has been shown below (Figure 6).

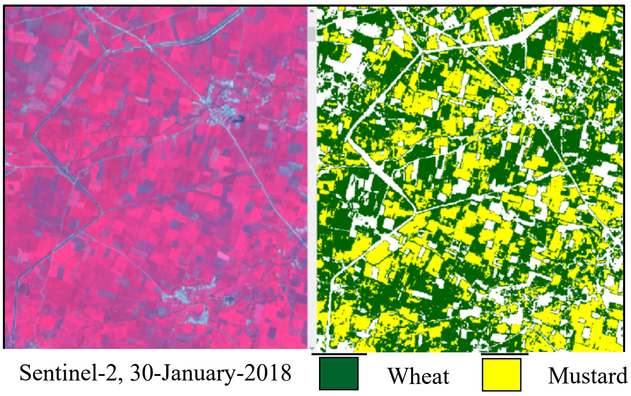


Figure 6. Showing classified image of wheat and mustard crop

4.2 Classification Accuracy

Accuracy of image classification is defined as a percentage correct on the basis of ground truth data at a number of locations within the image. The user's accuracy (UA) is computed using the number of correctly classified pixels to the total number of pixels assigned to a particular category. It takes errors of commission into account by telling the user that, for all areas identified, a certain percentage are actually correct. The producer's accuracy (PA) informs the image analyst of the number of pixels correctly classified in a particular category as a percentage of the total number of pixels actually belonging to that category in the image. Producer's accuracy measures errors of omission. Overall accuracy for wheat is 84.77% which has improved with the use of high resolution data for acreage estimation.

Accuracy Assessment

Class Name	Reference Total	Classified Total	Number Correct	Producers Accuracy	Users Accuracy
Wheat	96	100	85	88.54%	85.00%
Mustard	55	51	43	78.18%	84.31%
Totals	151	151	128		

Overall Classification Accuracy= 84.77%

Overall Kappa Statistics=0.670

Table 6. Accuracy assessment for wheat crop

4.3 Deviation (%) of wheat area and production at national level

Relative deviation (%) of DES & FASAL from 2013 to 2017 shows (-3.93%) and (-7.64%) for area and production respectively as shown in Figure 7. Singh et al, (2017) studies show low estimates for yield and production because of heavy rainfall and hailstorm events occurred in major wheat growing areas of the country during February and March 2015 that caused large scale damages to the crop.

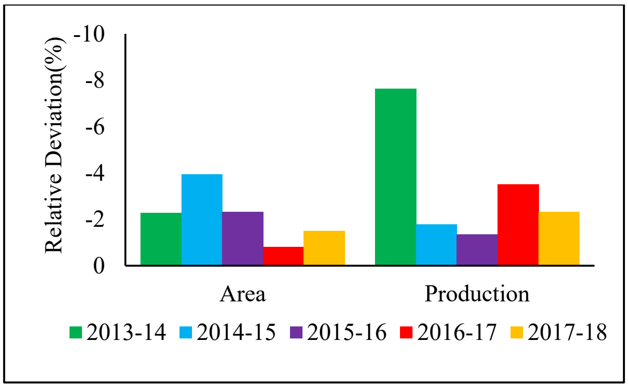


Figure 7. Showing RD (%) of area and production from 2013-2017

4.3 Comparison RMSE (%) & Correlation Coefficient(R)

RMSE (%) have improved over the years from 2015 to 2017 due to the improved satellite resolution (Sentinel-2, MSI,10m), (Table 1) and ground truth data (Figure 3b). Correlation coefficient is very high between DES and FASAL estimates of more than 0.995 (Figure 9). Similar correlation coefficient was observed for production, except for the year 2014-15 which may be because of heavy rainfall and hailstorm events occurred in major wheat growing areas of the country during February and March 2014-15 that have caused large scale damages to the crop. Singh et al, (2017).

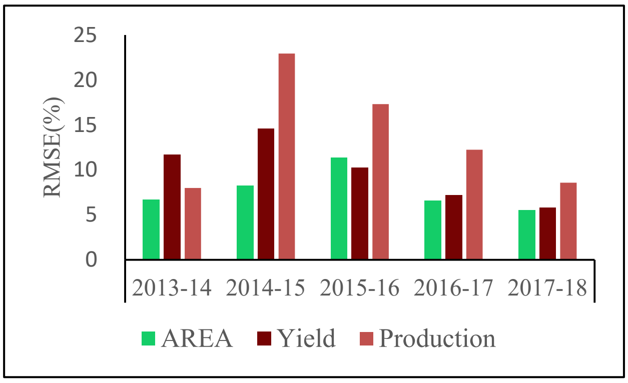


Figure 8. State-wise RMSE (%) between DES & FASAL State level Estimates (2013-2017)

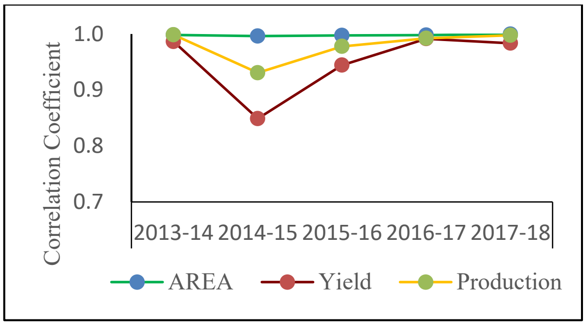


Figure 9. State-wise Correlation Coefficient between DES & FASAL Estimates (2013-2017)

4.4 Correlation Coefficient between DES & FASAL estimates

The district-wise correlation coefficients between DES & FASAL estimates for area, yield & production was 0.93,0.63 & 0.92 respectively as predicted from Figure 9, Figure 10 & Figure 11. Correlation coefficient values for yield was low may be due to heavy rainfall and hailstorm events occurred in major wheat growing areas of the country during February and March 2015.

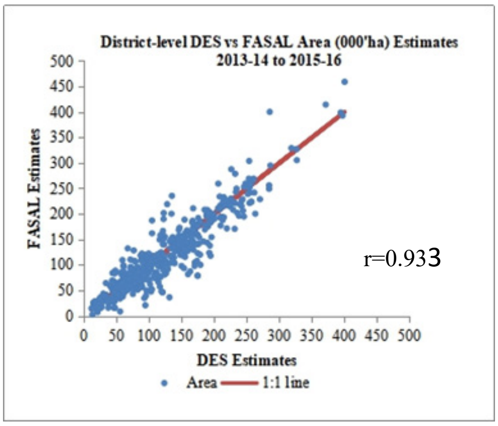


Figure 10. District-wise Area ('000 ha), DES and FASAL Estimates (2013-14 to 2015-16)

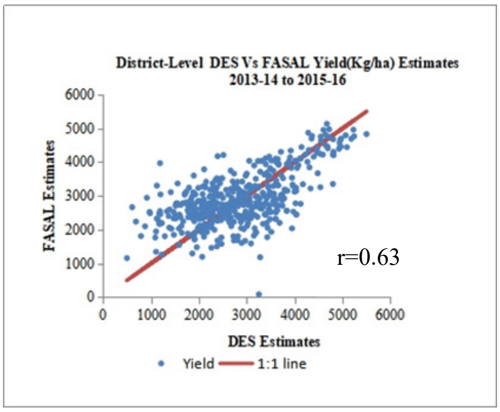


Figure 11. District-wise Yield (kg/ha), DES and FASAL Estimates (2013-14 to 2015-16)

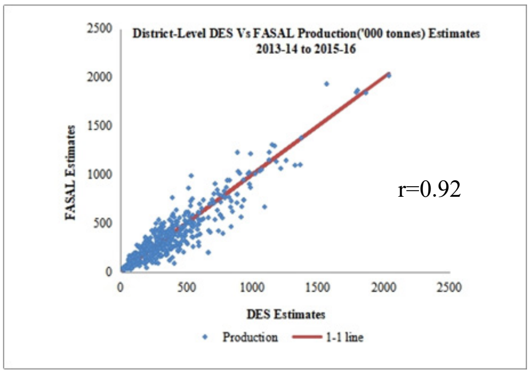


Figure 12. District-wise Production ('000 tonnes), DES and FASAL Estimates (2013-14 to 2015-16)

5. SUMMARY AND CONCLUSION

It was observed that the area and production estimates improved with improvement in the satellite resolution and number of ground truth data from 2016 onwards. It can be further improved by increasing the number of ground truth sites per district and preferred higher resolution satellite data for giving results at block and village level.

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