

ANALYSIS OF SUGARCANE ACREAGE AND YIELD ESTIMATES DERIVED FROM REMOTE SENSING DATA AND OTHER HYBRID APPROACHES UNDER FASAL PROJECT

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ABSTRACT:

Sugarcane (*Saccharum* spp.) is a most important cash crop of India. India has the largest area under sugarcane cultivation in the world and is the world's second largest producer of sugarcane next to Brazil. Uttar Pradesh stands as the leading producer of sugarcane in India followed by Maharashtra. Under FASAL project, the crop acreage and yield forecasts at National/State/District level, is issued at two levels. This study was carried out to analyze under FASAL Project at Mahalanobis National Crop Forecast Centre, New Delhi during year 2018. Five-year state and district level area, yield and production estimates were observed and analyzed using different approaches in 6 major sugarcane producing states of India. The state and district-wise sugarcane area yield and production estimates of MNCFC were compared with the DES Data of the corresponding year. Two statistical parameters were computed namely, Root Mean Square Error RMSE (%) and correlation coefficient (R). The results when compared to the DES statistics revealed that the RMSE (%) for district level analysis were 23.4%, 30% and 18.35%, while the correlation coefficient (R) between the DES and FASAL estimates was computed 0.94, 0.95 and 0.60 for area, production and yield respectively. These results revealed that RS based technique can be effectively used for state level acreage, yield and production estimation. The national level statistics revealed that the correlation of FASAL sugarcane area and production is in good agreement with the DES estimates as compared to Yield estimates.

1. INTRODUCTION

Sugarcane (*Saccharum* spp.) is a most important cash crop of India. It provides raw material for the second largest agro-based industry after textile. India occupies second position in the world, both in area and production, next to Brazil (DES, 2017). Largest sugarcane producing state of India is Uttar Pradesh, which has 47% and 44% share in overall sugarcane area and production (DES 2015-17 figures). The second and third largest states are Maharashtra and Karnataka.

It needs hot and humid climate with an average temperature of 21°C to 27°C (Das, 2007). 75-150 cm rainfall is favorable for sugarcane cultivation. Its water requirement generally ranges from 1500-2500 mm over the entire growing season. Heavy soils with good drainage are preferred for sugarcane cultivation, though it grows well on medium & light-textured soils also with assured irrigation. The crop requires about 8-10 irrigations depending upon the intensity of rainfall in that area.

Forecasting Agricultural output using Space, Agro-meteorology and Land based observations (FASAL) is a scheme of Department of Agriculture, Cooperation and Farmers' Welfare, under which satellite, meteorological and field data are used for district-state-national pre-harvest crop production forecasting (Ray, et al., 2016; Ray and Neetu, 2017). Operational forecasts are generated by Mahalanobis National Crop Forecast Centre (MNCFC), in collaboration with India Meteorological Department, State Agriculture Departments and State Remote Sensing Centres by using the procedures developed by the Space Applications Centre of ISRO (Parihar and Oza, 2006). The first forecast for sugarcane crop is given in June end, which is national and state forecast (F1) using multi-date AWiFS data (56m spatial resolution).

The second forecast is given in November end, which is State and District forecast (F2) using single date LISS III data (23m spatial resolution), Sentinel-2A MSI (10m spatial resolution) and Landsat-8 OLI (30m spatial resolution) acquired near peak vegetation growth stage. Crop yield are generated using correlation weighted Agromet modelling with weather data, i.e. rainfall, temperature maximum and minimum. Remote sensing indices-based yield is also given at district level for sugarcane.

State-wise and district-wise area, yield and production estimates of sugarcane crop (2014-18), under FASAL project, were compared statistically with Directorate of Economics and Statistics (DES) estimates. Two statistical parameters were computed namely, Root Mean Square Error RMSE (%) and correlation coefficient (R). While RMSE showed the differences between two estimates, the correlation coefficient showed the agreement between the patterns of two estimates.

2. STUDY AREA

The district level area and production estimation is carried out in 6 major sugarcane growing states of India.

The states are Gujarat, Haryana, Karnataka, Maharashtra, Uttar Pradesh and Uttarakhand (Figure 1). In each state, the major districts growing sugarcane crop are selected for the analysis. The study states receives annual rainfall more than 75-150 mm which suits the sugarcane cultivation in that area. Also, the optimum temperature requirement of 21-27°C for the crop is met satisfactorily by the study states

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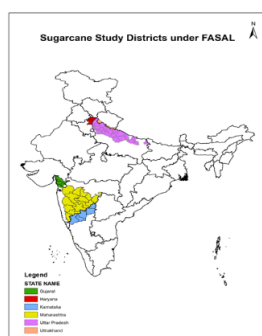


Figure 1. The states for which Sugarcane Area and Production estimation is carried out under FASAL Project

. The state-wise contribution of sugarcane area and production is shown in Figure 2.

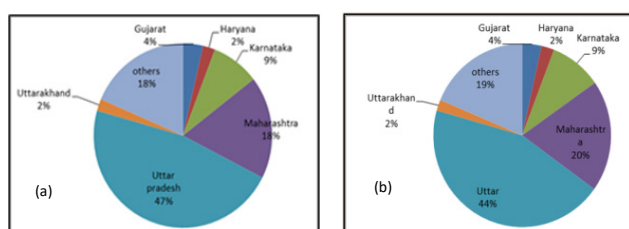


Figure 2. State-wise contribution to Sugarcane (a) Area and (b) Production in the country (Source: DES, 2015-16 to 2017-18)

3. DATA USED

3.1 Data used for Acreage Estimation

Sugarcane acreage forecast is estimated using supervised classification of multi-spectral datasets. The details of the data used over the past five years are mentioned in table 1.

Year	Satellite/sensor	Spatial Resolution	Temporal resolution	Swath
(2013-14)	AWiFS, Resourcesat-2 LISS-III	AWiFS-56 m	AWiFS-10 days	AWiFS-740 km
(2014-15)	AWiFS, Resourcesat-2 LISS-III, Landsat-8 OLI	LISS III-23.5 m	LISS III-24 days	LISS III-141km
(2015-16)	AWiFS, Resourcesat-2 LISS-III, Landsat-8 OLI	LISS III-23.5 m	LISS III-24 days	LISS III-141km
(2016-17)	AWiFS, Resourcesat-2 LISS-III, Landsat-8 OLI	LISS III-23.5 m	LISS III-24 days	LISS III-141km
(2017-18)	AWiFS, Resourcesat-2 LISS-III, Landsat-8 OLI, Sentinel 2A	LISS III-23.5 m	LISS III-24 days	LISS III-141km

Table 1: Satellite data used for acreage estimation of Sugarcane over the past 5 years

3.2 Data used for Yield Estimation

Yield estimation through meteorological models includes

weekly weather data provided from IMD over the crop growth period for the weather-based yield models. For remote sensing indices-based yield computation, moderate resolution remote sensing data of MODIS (Moderate Resolution Imaging Spectroradiometer) on-board Terra/Aqua Satellite was used for developing remote sensing-based index i.e. Normalized Difference Vegetation Index (NDVI) and Normalized Difference Water Index (NDWI). Fortnightly (from first fortnight of June to second fortnight of October) MODIS products (250 m resolution), from 2006-2017, were used for computing NDVI and NDWI.

3.3 Ground truth

MNCFC collaborates with State Agriculture Departments and State Remote Sensing Centres for collection ground information. The ground truth collected from multiple locations includes the information like crop growth stage, crop variety, date of sowing, vigour, GPS location of the field (latitude, longitude) etc. The field photographs (overview and close view), are also collected. The ground truth s collected \ using a smartphone-based Android App, called Bhuvan FASAL, developed by NRSC (ISRO). According to the GT collected for sugarcane crop in the last five years, it was revealed that there are mainly three sugarcane growing seasons in India and sowing time varies from state to state. Figure 3 reveals that highest number of Ground truth was collected in Uttar Pradesh state for sugarcane in the year 2014-15 and declined thereafter.

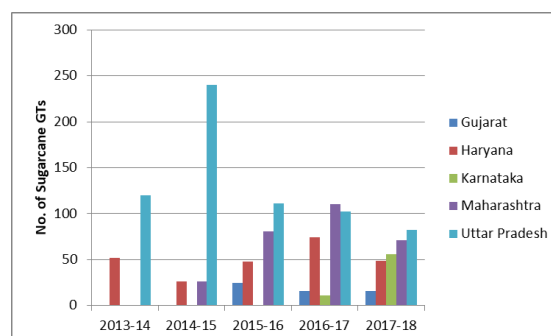


Figure 3. Number of Ground truth Points Available on Bhuvan for Sugarcane (2013-17)

4. METHODOLOGY

4.1 Area estimation methodology

This paper includes the use of satellite imagery for identifying and classifying sugarcane and providing timely and acceptably accurate information on the area under sugarcane production . (Narsico, 1999). Sugarcane classification includes a two-step process comprising of optimum date selection and classification. Unsupervised classification was carried out on the multi-spectral (3-4 bands) dataset to identify the land use classes. Within crop classes, supervised classification approach was followed using ground truth sites collected by state agricultural department officials. Signatures of sugarcane crop and other land cover features were identified using GT data, tone, texture, pattern and association from the satellite image. The maximum likelihood classifier was used, which calculates the probability of a pixel belonging to a particular class (Rao, 2002). Data from the training sets (signature) are assumed to be normally distributed, which allows the mean vector and the

covariance matrix of the spectral cluster of each category of brightness values to be calculated (Lillesand and Kiefer, 2000). Based on these concepts, the statistical probability of pixel's DN value consisting to each category of land use/cover was calculated. Each pixel was assigned to the category/class with the highest probability value.

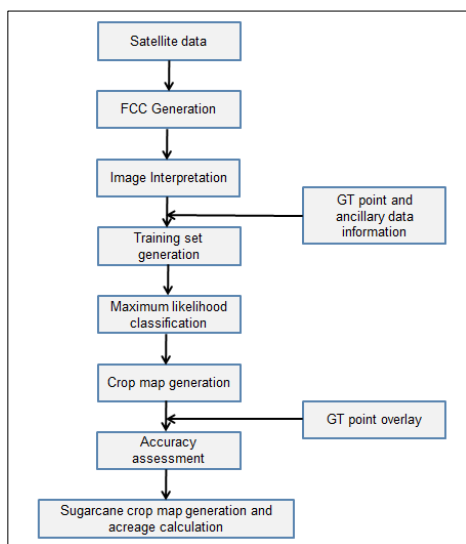


Figure 4. Classification methodology for sugarcane using multi spectral data

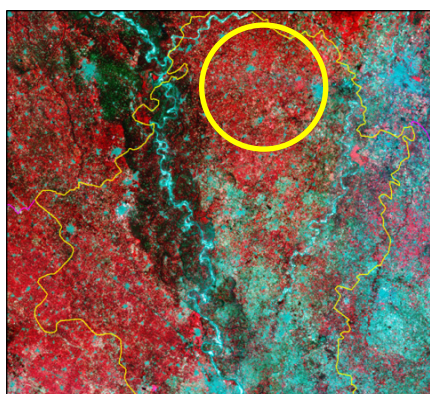


Figure 5. Satellite image (LISS-III) showing Sugarcane area in Uttar Pradesh

After the classification sugarcane crop mask was generated and accuracy of the classified results verified using GT data.

Class Name	Reference	Classified	Number Correct	Producers Accuracy	Users Accuracy
Unclassified	0	11	0		
Bajra	6	6	3	50	50
Sugarcane	50	49	41	83.7	82
Maize	10	8	7	87.5	70
Paddy	110	102	97	95.1	88.2
Total	176	176	148		
Overall Classification					
Accuracy			84.1		
Overall Kappa			0.713		

Table 2. Accuracy Assessment of sugarcane classification

The classification accuracy (%) and Kappa coefficient (Cohen, 1960) for a selected scene is presented in Table 2. Overall accuracy is computed by dividing the total number of correctly classified pixels by the total number of pixels used in the classification (Congalton, 1991). Kappa coefficient reflects the difference between actual agreement and the agreement expected by chance. Kappa of 0.713 means there is 71.3% better agreement than by chance alone.

Figure 6, elaborates the sugarcane classified image of Yamunanagar district of Haryana. Furthermore, the sugarcane classified image was used to give the acreage estimation, by overlaying the district boundary. Additional data used for crop classification include agricultural crop mask, collected from LULC mapping programme of NRSC (NRSC, 2006).

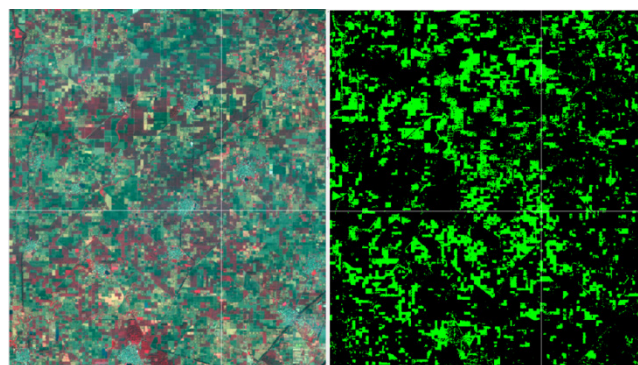


Figure 6. Satellite image showing Sugarcane FCC and Classified area in Yamunanagar district of Haryana

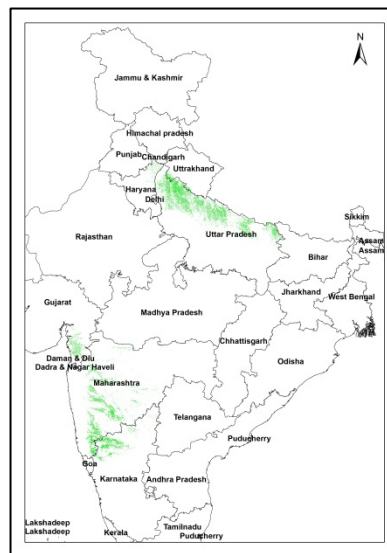


Figure 7. Crop map of the sugarcane growing states under FASAL Project

4.2 YIELD ESTIMATION METHODOLOGY

4.2.1 Agrometeorological regression models:

District level Sugarcane yield estimation is done using Agrometeorological regression models (Ghosh et al., 2014) utilizing the weekly weather data of last 20 years and using data from June to November. Daily weather data comprising of Maximum

and Minimum Temperature, Rainfall and Morning & Evening Relative Humidity were downloaded from IMD website (http://imd.grimmet.gov.in/ind_datalist/form) and pre-processed to obtain weekly observations. The historical weather data from 1995-2018 and yield data from 1995 to recent available is acquired and arranged to prepare district-wise templates. Initially, trend yield was calculated to obtain adjusted yield which is the difference of actual and trend yield. The weighted and non-weighted Z-parameters were calculated using weather data and adjusted yield. Non-weighted parameters (Z10, Z20....., Z50) were calculated taking the season-wise sum of weekly observations where 1 to 5 are parameters namely Maximum Temperature, Minimum Temperature, Rainfall, Morning RH and Evening RH respectively. Weighted parameters (Z11, Z21....., Z51) were calculated taking season-wise sum product of correlation coefficient (correlation between adjusted yield and every week's observations in all the years) and weekly observations. The weighted and non-weighted combination parameters (Z120, Z121, Z130 etc.) were calculated taking the product of two individual above mentioned weather parameters. The data was further analyzed in SPSS for yield estimation for current year. Step-wise linear regression method has been used for developing yield models at 5% level of significance.

4.2.2 Remote sensing indices (NDVI and NDWI) based empirical models:

Various techniques and remote sensing products had been used for sugarcane yield forecasting (Mulianga *et al.* 2013, Morel *et al.* 2014, Rahman and Robson, 2016). Remote sensing-based sugarcane yield was estimated using MODIS (MOD13Q1A V006, 250m resolution) vegetation index product. Vegetation Indices, such as NDVI and NDWI, were computed fortnightly (first fortnight of June to second fortnight of October) basis for the period 2006-2017. Step-wise regression was carried out between DES yield and Remote sensing indices. The flow diagram of the methodology is presented in Figure 7.

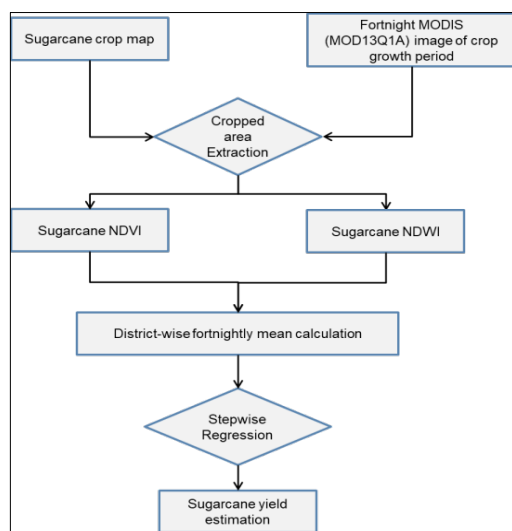


Figure 8: Flow diagram for calculation of sugarcane yield using RS indices

District level yield estimates, derived from the above two approaches, were combined statistically, giving weightage to respective models' F values, to get the final yield estimate.

4.2.3 Statistical comparison of FASAL and DES Estimates

State-wise area, yield and production estimates of sugarcane crop (2013-17), under FASAL project, were compared statistically with Directorate of Economics and Statistics (DES) estimates. The Map shown in figure 9 describes the average area and production estimates of the districts under FASAL at the National level.

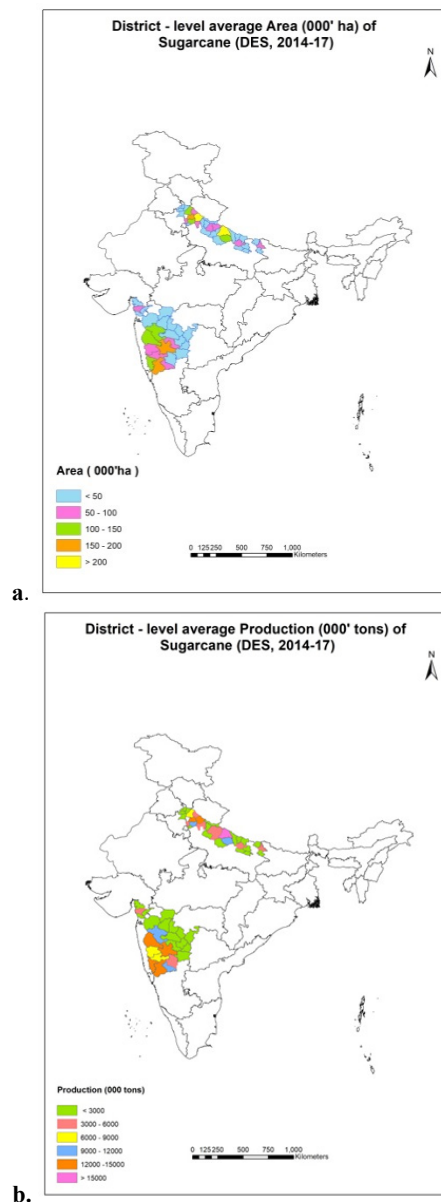


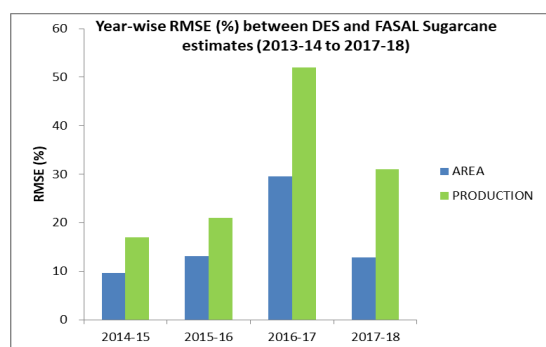
Figure 9: District- wise DES estimates of Sugarcane (a) Area (000 ha) and (b) Production (000 tons) based on 3 years average (2014-17)

The district-wise area, yield and production estimates of sugarcane were compared with the DES Data of the corresponding year. Two statistical parameters were computed namely, Root Mean Square Error RMSE (%) and correlation coefficient (R). RMSE showed the differences between two estimates, The smaller the error, the better the forecasting ability of that model according to the RMSE criterion (Hyndman & Koehler, 2006). The correlation coefficient showed the agreement between the patterns of two estimates and varies between -1 and +1. Correlation coefficient of 0

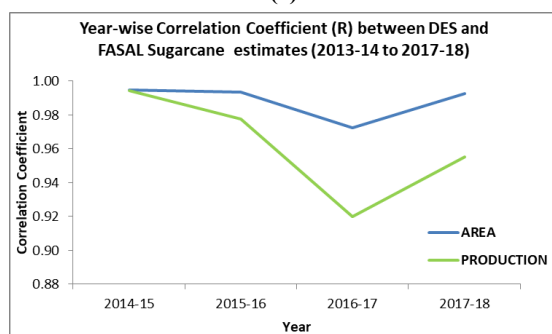
implies there is no linear relationship between the variables (Gomez and Gomez, 1984).

5. RESULTS AND DISCUSSION

State-wise area, yield and production FASAL estimates (2014-18) were analysed statistically with DES estimates of the corresponding year. The statistical parameters were computed and it was evident from Figure 11 that the RMSE (%) was highest for the state-level production estimates in 2016-17. Reason maybe the drop-in sugarcane production up to 25% in Maharashtra and 15% in Karnataka as listed by Indian Sugar Mills Association in its First Advance Estimation of 2016-17. Also, the shift of farmers from sugarcane cultivation to pulses and oilseeds cultivation was enlisted as an aspect for decreased production of the crop in Maharashtra. The correlation coefficient (R) was also computed and it was revealed that the FASAL estimates were in good agreement with the DES estimates. These results reveal that RS based technique can be effectively used for state level acreage, yield and production estimation.



(a)



(b)

Figure 10: Year-wise (a) RMSE (%) and (b) Correlation coefficient computed for the comparison of sugarcane FASAL and DES estimates at State-level (2014-15 to 2017-18)

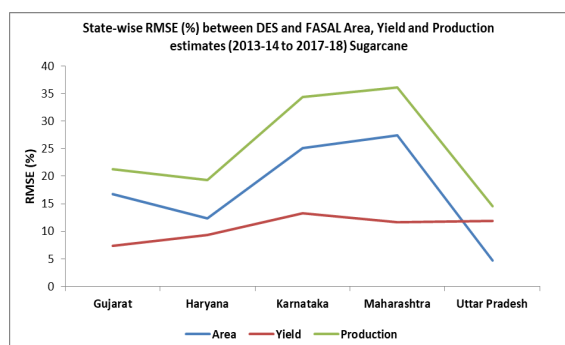


Figure 11: State-wise statistical parameters computed for the comparison of sugarcane FASAL and DES estimates (2014-15 to 2017-18)

District-wise area, yield and production FASAL estimates (2013-17) were analysed statistically with DES estimates of the corresponding year. The district wise estimates of multiple years were pooled together for the desired districts of the study states and was analyzed statistically. RMSE values as per the analysis were found to be 23.4%, 18.35% and 30% for area, yield and production, respectively. The correlation coefficient (R) between the DES and FASAL estimates was computed as 0.95, 0.60 and 0.94 for area, yield and production respectively. The yield encounters a lower value for the correlation coefficient, which may be due to lack of the capturing ability of variation found in the sowing dates of the crop over the entire country.

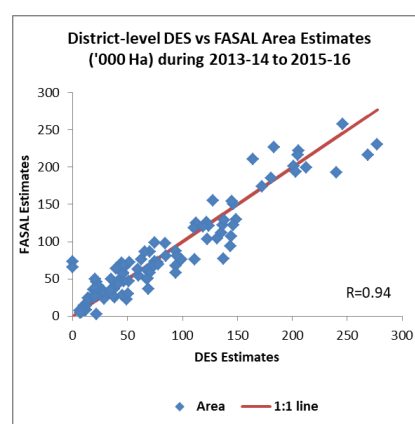


Figure 12: District-wise Area (000' ha) comparison of Sugarcane DES and FASAL estimates

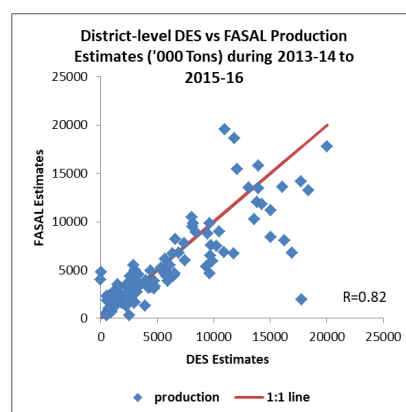


Figure 13: District-wise Area (000' ha) comparison of Sugarcane DES and FASAL estimates

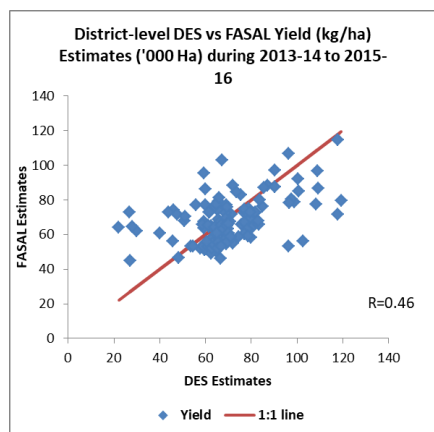


Figure 14: District-wise Yield (Kg/ha) comparison of Sugarcane DES and FASAL estimates

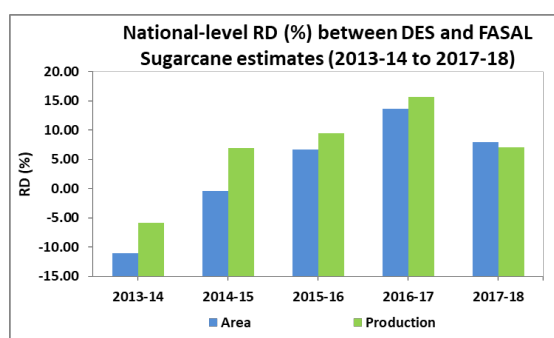


Figure 15: Relative Deviation between DES and FASAL estimates at National Level

It was concluded from the analysis that yield values had the least correlation between the DES and FASAL estimates. The relative deviation between both the estimates have been presented in the figure 11. The Relative deviation was found to be highest in the year 2016-17, which may be due to drop in the area and production of Karnataka and Maharashtra state in the particular year.

5. CONCLUSION

The Sugarcane crop area and yield is mainly dependent on sowing pattern and duration of crop (sowing to harvesting). The RS based sugarcane area and yield estimates were observed to be higher than the DES estimates mainly in Maharashtra state. The national level statistics shows that the correlation of FASAL sugarcane area and production is in good agreement with the DES estimates as compared to Yield estimates. The yield methodology although needs improvement as is elaborated in the results discussed above.

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