JUTE CROP PRODUCTION ESTIMATION IN MAJOR STATES OF INDIA: A COMPARATIVE STUDY OF LAST 6 YEARS' FASAL AND DES ESTIMATES

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Commission III, Working Group III/10

KEY WORDS: FASAL, Jute, Area, Production, Yield, RMSE, Resourcesat-2, SAR

ABSTRACT:

In the last few years, remote sensing technique has emerged as a viable technology for crop acreage estimation. Under the FASAL project, the jute acreage estimation was carried out in the last 6 years by using both microwave SAR data (2012-13 to 2016-17) and high resolution optical multi-spectral data (2017-18). In the assessment using SAR data, hierarchical decision rule classification technique and for optical data hybrid classification approach was used. Yield was estimated using, agro-meteorological parameter based statistical models. In the present study, different statistical parameters such as correlation coefficient (r) and RMSE were used for evaluating and comparing the results of the last 6 years (2012-13 to 2017-18) with DES (government) estimates. The RMSE values over the years were found to be 7-20%and 5-13% for area and production, respectively. The correlation coefficient (r) over the years between DES and FASAL estimates ranging between 0.995 to 1.00 and 0.996 to 1.00 in acreage and production estimates respectively. At district level, the correlation coefficient (r) values for the area and production were 0.967 and 0.962 respectively. On the basis of statistical criteria used in this study, FASAL estimates were close to DES estimates and improved over the years. The FASAL jute production estimates could be called better than DES ones in terms of good accuracy, timely reporting and low labour intensive. Thus, the FASAL estimates can be continued for policy purposes as far as jute production forecasts are concerned in India.

1. INTRODUCTION

Jute (*Corchorus olitorius*) the golden fiber of India and is the 2nd most important fiber after cotton. India is ranked in 1st position in jute production and accounting for about 62.2 percent of world production and 59.3 per cent of the total area in the World (Gupta et al.,2009). In India Jute is cultivated on 0.71 million hectares with an annual production of 9.98 million bales. West Bengal, Assam and Bihar are the major jute growing states in the country, which accounts for about 98 percent of the country's jute area and production (State of Indian Agriculture, 2016-2017).

The suitable climate for growing Jute (warm and humid climate) is during the monsoon season. Jute is a crop of humid tropical climates. For better growth, a mean maximum and minimum temperature of 34 ˚C and 15 ˚C and a mean relative humidity of 65% are required. The most suitable soil types are clay loam for *C. capsularis* and sandy loam for *C. olitorius.* Generally, sowing in the middle of March is optimum for *Capsularis* and for *Olitorius*, middle of April. (Mitra *et al*., 2006).

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 level pre-harvest crop production forecasting (DES, 2016; Ray and Neetu, 2017, Ray et al., 2016). Every year since 2012 one pre-harvest crop production forecast of Jute is generated using a remote sensing based approach under FASAL project at National/State/District level, which is submitted to Ministry of Agriculture & Cooperation & Farmers Welfare. The forecast is given in June end. Crop yield is generated using correlation weighted agromet modelling with weather data, i.e. rainfall, temperature maximum and minimum.

In the last few years, remote sensing technique has emerged as a viable technology for crop forecasting which provides comprehensive, reliable and timely information on agricultural resources. It is quite necessary for a country like India whose mainstay of the economy is agriculture (Balaselva kumar and Saravanan, 2009). Accurate predictions of crop acreage and production are critical for developing effective agricultural and food policies at the regional and global scales. (Jeong *et al*., 2016).

In present study comparison of the accuracy of satellite based estimation with traditional method has been described for jute area, production and yield estimates at national, state and district level using past six years (2012-2017) data.

At present, no information is available on the comparative accuracy study of FASAL and DES (government) estimates. Hence, the present study was planned to compare FASAL project estimates with the Directorate of Economics and Statistics (DES) production estimates of jute crop (2012 to 2017). Two statistical parameters were computed namely, Root Mean Square Error RMSE (%) and correlation coefficient (r). While RMSE showed the differences between the two estimates, the correlation

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https://doi.org/10.5194/isprs-archives-XLII-3-W6-129-2019

coefficient (CC) showed the agreement between the patterns of the two estimates.

2. STUDY AREA AND DATA SETS

The district level area and production estimates are carried out in 3 major Jute growing states of India. The states are Assam, Bihar and West Bengal. (Figure 1). In each state, the major districts growing Jute crop are selected for the analysis.

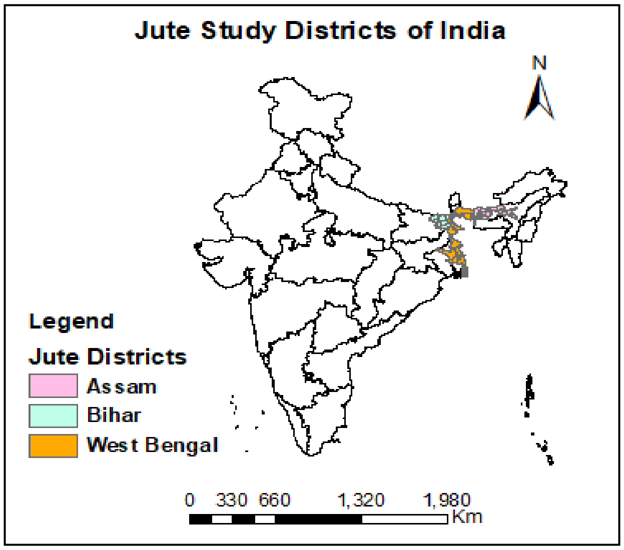


Figure1. Jute study districts of India under FASAL Project

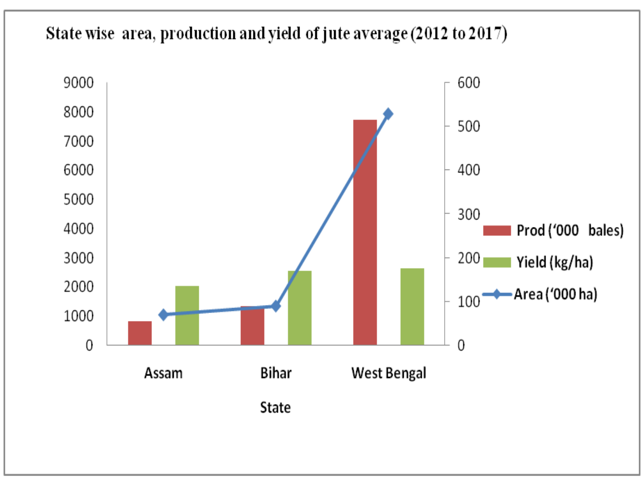


Figure 2. State-wise average (2012 to 2017) Jute Area, Production and Yield

The Jute acreage estimation is carried out in the last 6 years by using SAR data and in 2017-18 estimated using high resolution optical multi-spectral data (Sentinel-2A/LISS-III / Landsat-8 OLI). Three sets of RADAR SAT Wide Beam 2 SAR data were used in 2012-13 and Three Dates RISAT-1 SAR MRS mode was used continuous 4 year from 2013-14 to 2016-17. Optical data were used as reference images for verification of Jute area.

3. METHODOLOGY

3.1 Jute classification using SAR Data

Jute classification was carried out with hierarchical decision rule classification technique. On the basis of the temporal backscatter value of different land cover classes were identified based on temporal backscatter value. Based on crop condition, soil moisture level, decision rule was framed as D1, D2 and D3 as first, second and third date respectively. In first date, backscatter value was high due to high soil moisture and rough ploughed field. In second date, plant had grown vertically and soil exposure to sensor reduced leading to decreased backscatter value. But in third date, backscatter value is high owing to volume scatter due to crop leaves and stems. Synthetic Aperture Radar (SAR) responds to the large scale, crop structure (size, shape and orientation of leaves, stalks, and fruits) and the dielectric properties of the crop canopy (Haldar *et al.*, 2012). Figure 3, explains the steps used in acreage estimation of jute.

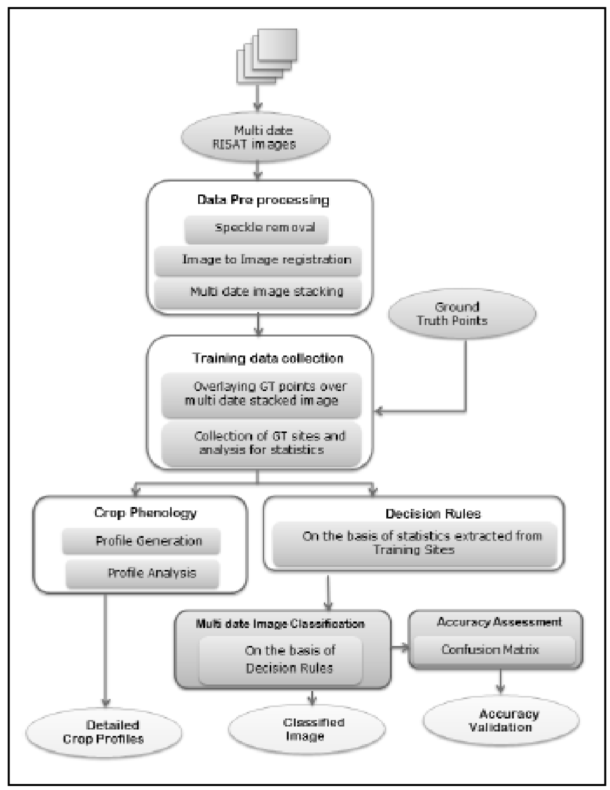


Figure 3: Flow chart of methodology followed in SAR data

The temporal backscatter value of the jute crop was different with respect to other land cover in the study area. Its temporal Profile behaves like V shape curve. High backscatter values of built-up areas range from -2.3 to -2.1. They appear bright in all dates with little variation in db. values due to no change in structure.

Backscatter values less than -17 characterize water bodies like river, ponds and lake (Figure 4).

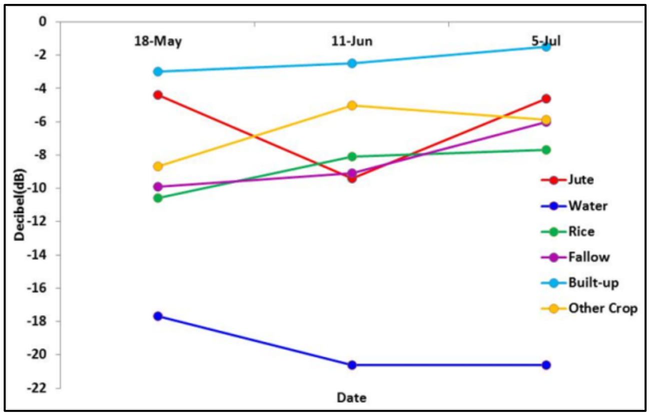


Figure 4: Temporal spectral profile of Different land cover of West Bengal

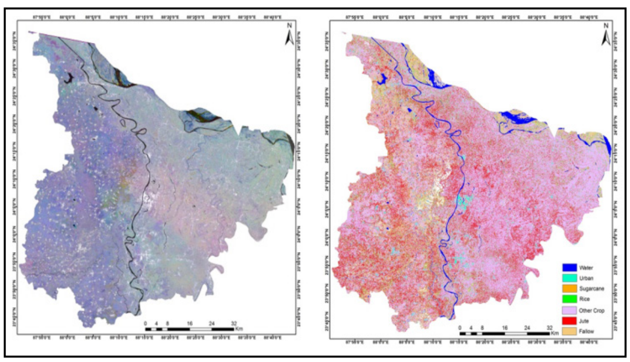


Figure 5: False colour composite image (left) and Classified image (right) of Murshidabad, West Bengal

3.2 Jute classification using Optical Data

Crop 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, hybrid classification approach was followed using ground truth sites collected by state agricultural department officials. Signatures of Jute crop and other land cover features were identified using ground truth data, tone, texture, pattern and association of the satellite image (Ray and Neetu, 2017). The maximum likelihood classifier was used which calculates the probability of a pixel belonging to a particular class. Data from the training sets (signature) were 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 et al., 2014). After the classification Jute crop mask was generated and accuracy of the classified results was verified using ground truth. Then the Jute classified image was used to generate the acreage estimates, by overlaying the district boundary. Additional data used for crop classification include agricultural crop mask, collected from the LULC mapping program of NRSC (NRSC, 2006).

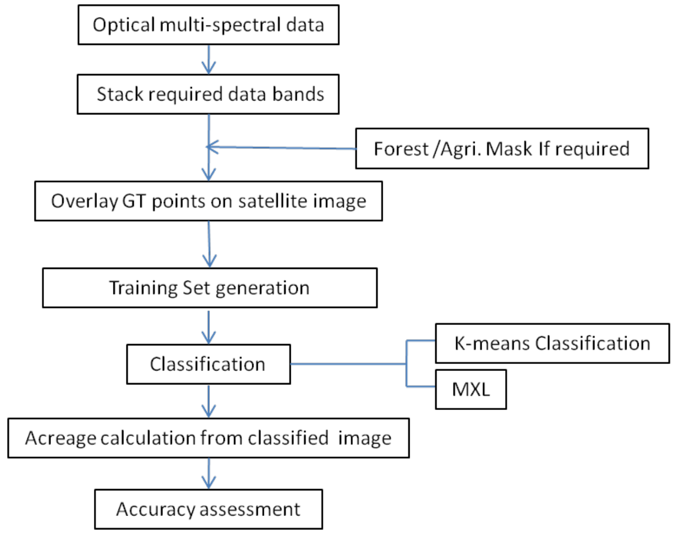


Figure 6. Classification methodology for Jute using multi spectral data

3.3 Crop Classification

Mean DN (Digital number) values of different crops as observed in multispectral data are given in Figure 7. Jute has higher values in the NIR band compared to the other competing crop. These spectral differences between different classes were used for crop classification (Figure 6). After classifying the crops, the district boundaries were overlaid on the classified maps to generate district level crop area. These spectral differences between different classes were used for crop classification using Maximum Likelihood approach. An example of classified Jute crop is given in (Figure 8).

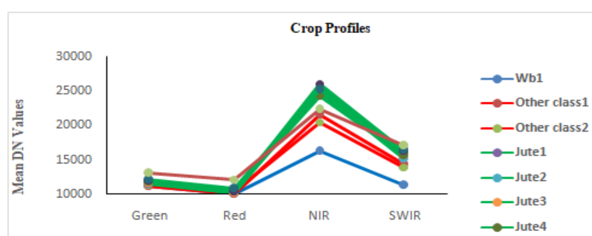


Figure 7. Mean DN values of different crops as seen in multi-spectral data (Green: Jute and red& Blue: Other Crop)

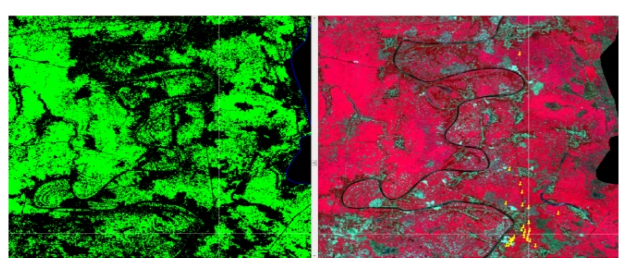


Figure 8. Jute classified image with reference FCC (Sentinel 2A) in Murshidabad District (West Bengal)

3.4 Yield Estimation

District level Jute yield was estimated using Agro-meteorological regression models developed by IMD in collaboration with state agricultural universities (Ghosh et al., 2014) Weather based yield estimation were carried out by MNCFC using weekly weather (Rainfall, Maximum temperature, Minimum Temperature, Maximum and Minimum Relative Humidity) data of last 20 years, using data from March to June 2017 (Ray et al., 2016).Daily weather data comprising of Maximum and Minimum Temperature, Rainfall and Morning & Evening Relative Humidity have been downloaded from IMD website (http://imdagrimet.gov.in/imd_datalist/form) and pre-processed to obtain weekly observations(FASAL Technical Report, 2017).

District and state-wise area, yield and production estimates of jute crop (2012-13 to2017-18), under FASAL project, were compared statistically with DES estimates. The district-wise area, yield and production estimates of jute 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). While RMSE showed the differences between the two estimates, the correlation coefficient showed the agreement between the patterns of the two estimates. Remote sensing Indices i.e. NDVI, VCI and Biomass based model method was used during 2017 and District/Met-Subdivision level Correlation weighted agromet models using weather data was used during 2012-2017 for yield estimation.

3.5 Statistical parameters for accuracy estimation

3.5.1 RMSE

The RMSE depends on the scale of the dependent variable. It should be used as relative measure to compare forecasts for the same series across different models. The smaller the error, the better the forecasting ability of that model according to the RMSE criterion (Hyndman & Koehler, 2006).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (X_{obs,i} - X_{model,i})^2}{n}} \quad (1)$$

Where X_{obs} is observed values and X_{model} is modelled values at time/place i.

RMSE (%) = (Calculated RMSE / Avg. of actual values) *100

3.5.2 Karl-Pearson correlation coefficient (r)

Correlation – often measured as a correlation coefficient – indicates the strength and direction of a linear relationship between two variables (for example model output and observed values).

$$r = \frac{\sum_{i=1}^{n} (x_i - \overline{x}) \cdot (y_i - \overline{y})}{\sqrt{\sum_{i=1}^{n} (x_i - \overline{x})^2 \cdot \sum_{i=1}^{n} (y_i - \overline{y})^2}} \quad (2)$$

The correlation is +1 in the case of a perfect increasing linear relationship, and -1 in case of a decreasing linear relationship, and the values in between indicates the degree of linear relationship between for example model and observations. A correlation coefficient of 0 means the there is no linear relationship between the variablesGomez & Gomez, 1984).

3.6 Competing crop in jute growing areas

The information about competing crops in jute growing areas play an important role to achieve high accuracy in crop classification and precise acreage estimation. The major competing crop Boro rice is found in Assam and West Bengal. The list of competing crops in jute study states are given below, which we have to consider during jute classification process.

S.No.	States	Competing crops
1.	Assam	Boro rice, Maize and vegetables
2.	Bihar	Maize and pulses
3.	West Bengal	Sesbania, Boro rice, Mix vegetables

Table 1: Competing crop in the jute study area

3.7 Estimation of classification accuracy

Accuracy assessment of classified maps is one of the foremost and important tasks of RS image classification technique. Without accuracy assessment the quality of map or output produced would be of lesser value to the end user. 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.

One basic accuracy measure is the overall accuracy, which is calculated by dividing the correctly classified pixels (sum of the values in the main diagonal) by the total number of pixels checked. (Bharatkar and Patel, 2013)

Overall accuracy (%) = (Correctly classified pixels/Total number of pixels)

The kappa coefficient (K) can be computed as follows,

$$K = \frac{p_o - p_e}{1 - p_e} \quad (3)$$

Where, P_0 = proportion of units which agree, = overall accuracy P_e = proportion of units for expected chance agreement A Kappa coefficient of 90% may be interpreted as 90% better classification than would be expected by random assignment of classes. The general range for Kappa values are if K < 0.4, a poor kappa value; while, if 0.4 < K < 0.75, is a good kappa value and if K > 0.75, it is an excellent kappa value (Congalton and Green, 1999).

The statistical measures used during the work were analyzed as, over all classification accuracy and Kappa statistics found 88.06% and 0.8526 respectively.

Classes	Other Cro	Jute	Fallow	Rice	Built-up	Water	Row total
OtherCrop	12	2	0	0	0	0	14
Jute	4	33	1	0	0	0	38
Fallow	1	1	25	1	0	2	30
Rice	0	0	3	16	0	0	19
Urban	0	1	0	0	14	0	15
Water	0	0	0	0	0	18	18
Total	17	37	29	17	14	20	134

Overall Classification Accuracy = 88.06%

Overall Kappa Statistics = 0.8526

Table 2: Confusion Matrix for Murshidabad district of West Bengal

4. RESULTS AND DISCUSSION

4.1 Jute area and production comparison in last six years at national level

National level acreage and production estimates since the beginning of the FASAL project (MNCFC) are given in figure 9 and 10, respectively. Jute acreage at national level in DES estimates were higher compare to FASAL estimates over the years 2012-13 to 2017-18(Figure 9). In DES estimates the total area under jute cultivation at national level, decreased gradually from 0.78 million hectares in 2012-13 to 0.71 million hectares in 2017-18 whereas, FASAL estimates shows more or less similar trend over the years except 2014-15, this sharp decline in acreage during 2014-15 may be due poor pre- monsoon rainfall distribution, which is most important to the sowing of Jute crop under rain fed condition (Satpathy *et al.*, 2016-17). The total annual production of jute in DES estimates shows fluctuating trend whereas in FASAL estimates shows more or less similar trend over the years.
The total annual production of jute in DES estimates was highest around 11.08 million bales during 2013-14 and lowest 9.94 million bales in 2015-16 (Figure 8). In FASAL estimates jute production was around 10.09 million bales during 2012-13, and decreased to 9.87 million bases in 2014-15 and again increased to over 10.30 million bales in 2016-17 (Figure 9). Overall results indicated that the difference in the FASAL and DES estimates have narrowed down over the years since the beginning of the project due to improvement in methodology and timely availability of satellite data.
The trend of area under jute in the country remained fluctuating (≈ 7-8 lakh ha) since last 5-6 years but, the production trend has been increasing owing to the constant improvement in the productivity of jute with respect to the DES estimates. The major factors that contributed to this growth are continued development of improved, well adapted, highly productive jute and allied fiber varieties and technologies. The jute acreage in the country always witnesses fluctuation mostly due to the extent and time of onset of summer rain, trend of raw jute price in the previous season and the returns realized from competing crops (Satpathy *et al.*, 2016-17).

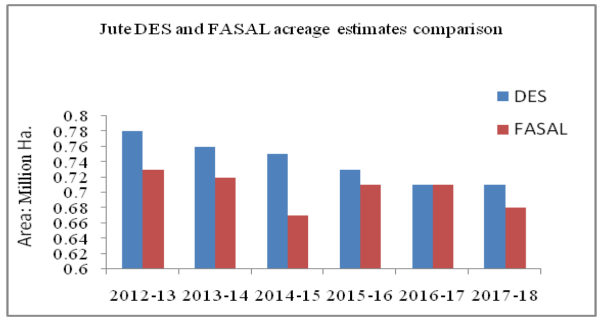
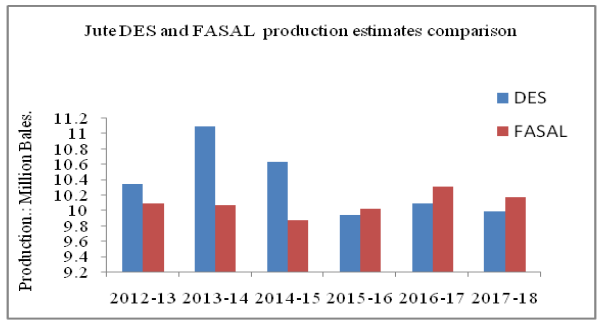


Figure 9.Comparison of Jute acreage in last six years at National level



*1 Bale= 180 Kg

Figure 10. Comparison of Jute productionin last six years at national level

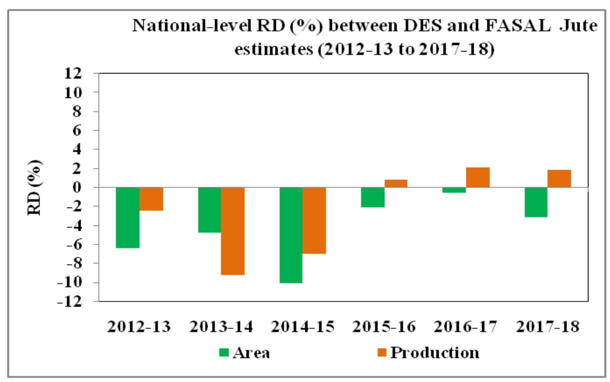


Figure 11. National level RD (%) comparison over the years

4.2 National Relative Deviation (%) comparison between DES and FASAL estimates over the years

The Relative Deviation (%) calculation carried out between DES and FASAL estimates at national over the years. In different years, the national level RD (%), values between DES and FASAL estimates of an area and production over the years (2012 to 2017) have been depicted in Figure 11. Year 2012 and 2013 in area showing higher negative RD %, whereas in production higher negative RD % was in 2013 and 2014. The higher positive RD % indicates that FASAL area estimates are higher over DES estimates. The RD % of both the area and production estimates between FASAL and DES, is (± 10%) over the years. Studies showed low estimates for area and production because of poor pre monsoon rainfall occurred in major jute growing areas of the country during February and March 2014, caused poor sowing of the jute crop. The accuracy of the satellite-based estimates depends on the methodology adopted for interpreting and analysing the satellite data. Relative Deviation (RD) of the FASAL estimates in comparison to DES estimates, as given in Figure 11, has significantly improved since the beginning of the project, currently we have a difference of 2-3 % at the national level. The acceptable deviation in acreage and production estimates between FASAL and DES, may be attributed to high resolution satellite data and improvement in methodology.

4.3 Year-wise RMSE (%) and Correlation coefficient analysis of jute DES and FASAL estimates

Year-wise area and production FASAL estimates (2012-13 to 2017-18) were analyzed statistically with DES estimates of the corresponding year. The RMSE (%) and correlation coefficient between DES and FASAL estimates of area, and production have been presented in Figure 12& 13 respectively. The RMSE values for both area and production were in fluctuating trend over the study years. The RMSE values over the years ranging between 7-20% and 5-13% for area and production, respectively. The highest and lowest RMSE value was in 2014-15 and 2012-13 i.e. 20.87 and 7.11% respectively. The correlation coefficient (r) over the years between DES and FASAL estimates ranging between 0.995 to 1.00 and 0.996 to 1.00 in acreage and production estimates respectively. These results show that RS based technique was effectively used over the years for production estimation.

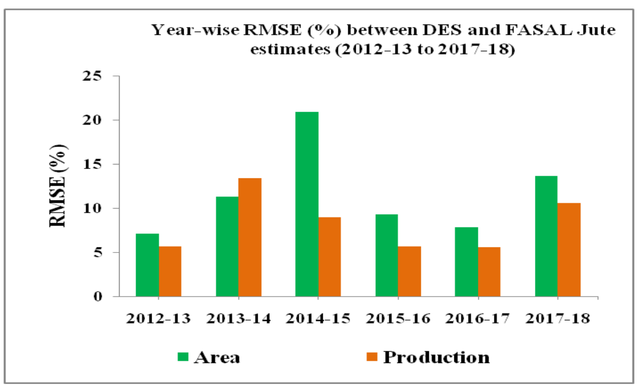


Figure12. DES and FASAL estimates comparison (RMSE %) over the years

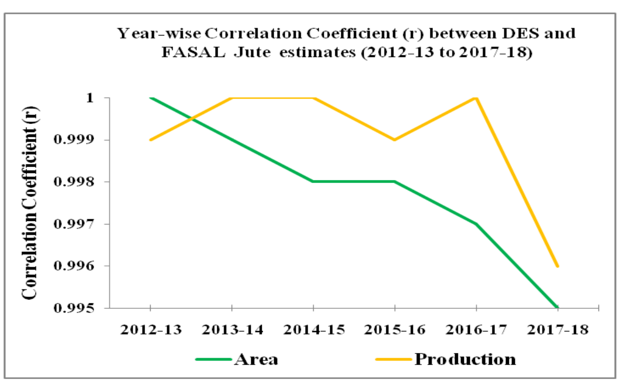


Figure13.DES and FASAL estimates comparison correlation coefficient (r) over the years

4.4 State-wise RMSE (%) and Correlation coefficient analysis of jute DES and FASAL estimates

State-wise area and production FASAL estimates (2012-13 to 2017-18) were analyzed statistically with DES estimates. The RMSE (%) and correlation coefficient between DES and FASAL estimates of area and production have been presented in Figure 14& 15 respectively. The RMSE values for different states were found to be 8-29% and 5-18% for area and production, respectively. Among the states in production the higher RMSE (%) value was observed in Bihar (18.72) and lowest (5.50) in West Bengal. The correlation coefficient (r) among the states between DES and FASAL estimates were range between 0.20 to 0.50in acreage estimate. The production estimates were poorly correlated, ranging between +0.32 to -0.75.This indicate that we still need to improve upon our acreage and yield methodology to improve the estimates accuracy at state level. It is clear from the results that jute acreage at state level can be estimated using satellite data with fairly good accuracy.

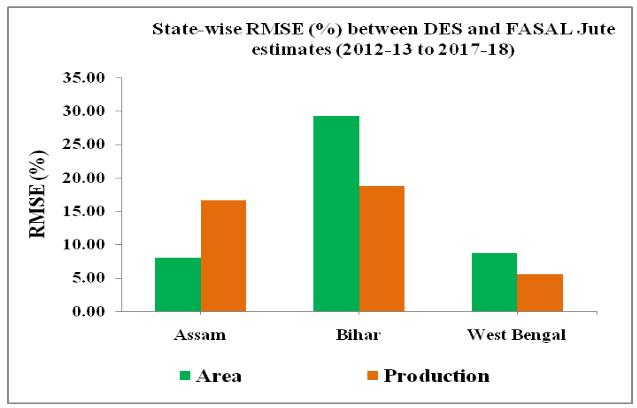


Figure14.State wise DES and FASAL estimates, comparison (RMSE %)

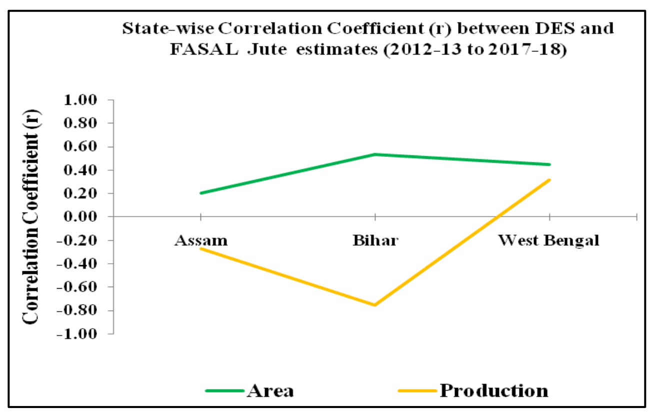


Figure 15. State wise DES and FASAL estimates, comparisons correlation coefficient (r)

4.5 District level Correlation coefficient (r) analysis of jute DES and FASAL estimates

District-level area and production FASAL estimates (Pooled 3 years, 2013-2015) were analyzed statistically with DES estimates (last 3 years). The correlation coefficient (r) between DES and

FASAL estimates were computed between DES and FASAL estimates of an area and production and depicted in Figure 16, and 17 respectively. The correlation coefficient (r) between DES and FASAL estimates were computed as 0.967and 0.962for the area, and production, respectively. Considerable association between DES and FASAL estimates was observed and showed highly positive correlation.

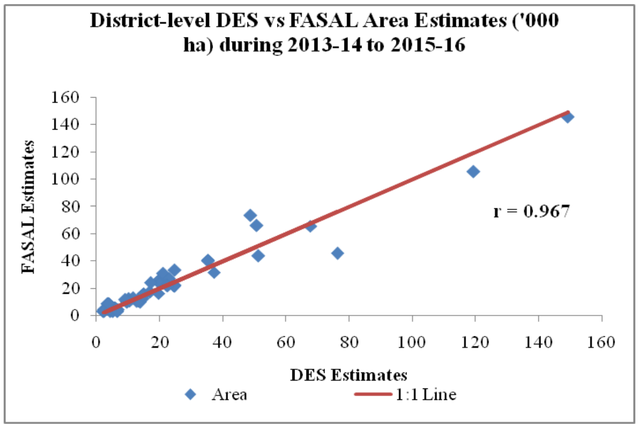


Figure 16. District-wise Area ('000 ha) Comparison of Jute DES and FASAL Estimates (Pooled 3 years, 2013-2015)

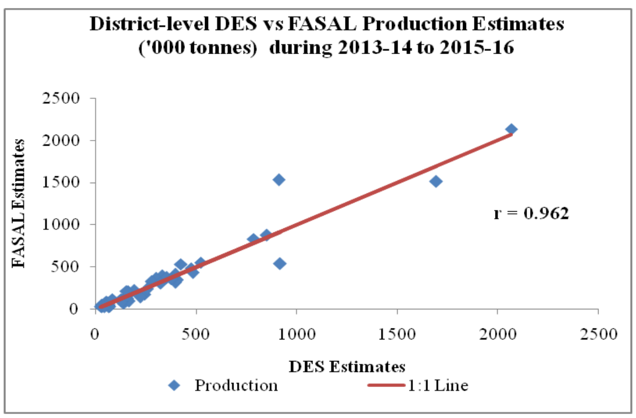


Figure17. District-wise Production ('000 bales) Comparison of Jute DES and FASAL Estimates (Pooled 3 years, 2013-2015)

4. SUMMARY AND CONCLUSIONS

In the present article we compared the DES and FASAL estimates over the years 2012-13 to 2017-18, also estimate the values of RD correlation coefficient (r) and RMSE (%) for accuracy estimation and data taken from the statistics of the DES and FASAL estimates.The total annual area and production of jute at national level in DES estimates shows fluctuating trend, whereas in FASAL estimates shows more or less similar trend over the years, except 2014 -15.The jute crop area and yield is mainly dependent on pre-monsoon and monsoon rain, fluctuating over the years at National level. The RMSE values for both area and production were in fluctuating trend over the study years. The accuracy of FASAL estimates in comparison to DES estimates, has significantly improved over the years. The RS based technique can be effectively used for National and state level acreage, yield and production estimation whereas, at district level needed to improve production forecast. Need to have district wise yield models in place of Zonal models to improve the accuracy of the yield estimates. Timely availability of the meteorological data at the district level is the main constraint in developing such models.The analysis gave an understanding about the issues involved in district and some state level (Bihar) jute production estimation.

On the basis of statistical criteria used in this study, this paper may conclude that FASAL estimates were close to DES estimates and improve over the years and better than DES to forecast the jute productions in terms of good accuracy, timely reporting results and low labour intensive. Thus, the FASAL estimates can be continued for policy purposes as far as forecasts for the jute production in India are concerned.

ACKNOWLEDGEMENTS

The crop estimation work has been carried out under the FASAL (Forecasting Agricultural output using Space, Agro-meteorology and Land based observations) of Department of Agriculture, Cooperation & Farmers Welfare (DAC&FW). The authors are thankful to the senior officials of DAC&FW, for their strong support and keen interest in the work.. The ground truth data collected and expert knowledge provided for remote sensing data analysis by the officials of the State Agriculture Departments and State Remote Sensing Centres, are gratefully acknowledged. The satellite data provided by ISRO (Resourcesat 2 & 2A), ESA (Sentinel-1, 2), NASA (MODIS & Landsat-8) and the weather data provided by IMD are thankfully acknowledged. Thanks, are also due to the Analysts of FASAL team, who carried out the annual wheat crop analysis. Thanks are also due to scientists of SAC(ISRO), who developed the procedures for crop estimation under FASAL project.

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