ANALYSIS OF REMOTE SENSING-BASED ASSESSMENT OF POTATO STATISTICS AND ITS COMPARISON WITH GOVERNMENT ESTIMATES

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ABSTRACT

Potato (*Solanum tuberosum* L.) is a major horticultural crop of India. In the present study an effort has been made to evaluate the forecast (area, production and productivity) of potato being carried out under FASAL/CHAMAN project of DAC&FW. For this purpose, remote sensing-based forecasts were analysed for the period of 6 years (2012-13 to 2017-18). The district level area and production estimates were carried out in 5 major potato growing states of India i.e. Bihar, Gujarat, Punjab, Uttar Pradesh and West Bengal. The area estimation has been carried out using multi-spectral satellite data through supervised/ unsupervised image classification techniques. IRS P6-LISS III (, Sentinel-2A, and LANDSAT-8 OLI data were used for acreage estimation during October to March every year. District level potato crop yield has been estimated using two different procedures - i) Agro-meteorological stepwise regression models, and ii) Remote sensing index (VCI) based empirical models. The estimates of area, production and productivity were compared with the Government (DES) estimates. Good correlation (r) between the forecasted and DES estimates was observed in case of area (0.37, 0.81, 0.93, 0.68 and 0.73) and production (0.59, 0.72, 0.94, 0.30 and 0.09) for Bihar, Gujarat, Punjab, Uttar Pradesh and West Bengal states, respectively. Similarly, low RMSE (%) between the forecasted and DES estimates was observed in case of area (6.90, 14.6, 16.8, 5.4 and 3.8) and but higher RMSE (%), in case of production (18.6, 21.3, 21.8, 9.8 and 20.9) for Bihar, Gujarat, Punjab, Uttar Pradesh and West Bengal states, respectively. Year wise correlation and RMSE% reveals that the accuracy of remote sensing-based area and production has increased significantly over the last few years may be due to improvement in methodology and availability of higher resolution data along with experience gained over the crop.

1. INTRODUCTION

Potato (Solanum *tuberosum* L.) plays a vital role in food and nutritional security of India. Its contribution to the national economy is manifold. Potato production in the country has increased significantly over the last few years. Its national production and subsequent demand have raised endlessly over the years. Considering the importance of potato crop for pre-harvest estimation of potato crop using satellite data was carried out under FASAL (Forecasting Agricultural output using Space, Agro-meteorology and Land based observations) project of Ministry of Agriculture & Farmers' Welfare (Ray et al., 2016a, Ray & Neetu, 2017), using the procedures developed by Space Applications Centre, ISRO (Parihar and Oza, 2017). After the launching of the CHAMAN (Coordinated Horticulture Assessment and Management using geinformatics), project by the Ministry, the potato estimation is being carried under this project (Ray et al., 2016b, 2018)

Potato growing season begins in October, November and ends in March- April, Potato grows highly in relatively cold and humid conditions. It is absolutely sensitive to moisture stress over much of the growing season. The main source of water for potato production is the moisture stored from irrigation in previous crop and by the irrigation.

Crop area estimation as well as forecasting crop yield well before harvest is very important. This enables policy and decision makers to take decision on import in case of shortfall or on export in case of surplus or to take decision for increasing cold storage and post-harvest industries etc. (Ray & Neetu, 2017). It also may help government to plan for redistribution of food during time of any natural calamity.

The use of remote sensing has proved to be very important in monitoring the growth of agricultural crops (Prasad, et al., 2006). The estimation of crop area and prediction of crop yield have direct impact on year-to-year national and international economies and play an important role in the food management (Hayes and Decker, 1996). Remote sensing data has been found to be highly useful for crop area assessment (Panigrahy and Ray, 2006). Especially, multi-date data have been highly useful for mapping cropping pattern of Kharif and Rabi Season (Panigrahy et al., 2010).

The district wise area and production estimates under CHAMAN programme is carried out for 5 major potato growing states of India. The states are Bihar, Gujarat, Punjab, Uttar Pradesh and West Bengal. All these 5 states contribute 72% of total potato area and 78% of total potato production in the country. About 85 - 90% of potato crop is raised in winter Rabi season. Hence, under CHAMAN project potato crop production estimation has been carried out for Rabi season.

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Potato crop production estimation, using remote sensing data and agrometeorological models, have been carried out by MNCFC, since 2012-13. The objective of this study is to review the procedures adopted for potato estimation and evaluate the estimates obtained vis-à-vis government estimates.

2. STUDY AREA

The district wise area and production estimates under CHAMAN programme was carried out in 5 major potato growing states of India. The states are Bihar, Gujarat, Punjab, Uttar Pradesh and West Bengal (Figure 1)

Figure 1. Potato growing states of India for which area and production estimates are carried out under CHAMAN Project.

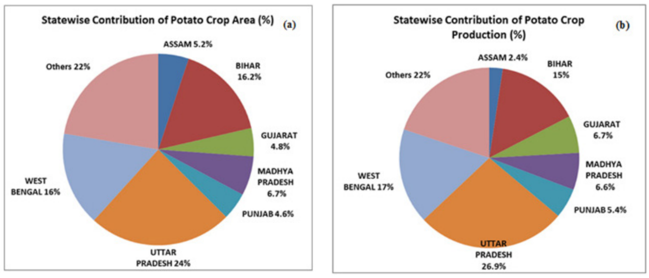


Figure 2. State-wise (2012-16) contribution to Potato (a) area and (b) Production in the country (Source: DAC&FW).

Till 2013-14, potato crop was estimated at state level. Since 2104-15, potato estimation was carried out at district level. Within each state, assessment was carried out only for the major potato growing districts. Number of districts, assessed for potato crop, under each state is given in Table 1. All total potato area and production estimations are carried out in 57 districts of 5 states. The contribution of the selected districts to the corresponding state's potato acreage range between 59.2% to 92.8 %.

3. MATERIALS AND METHODS

3.1 Potato Production Forecasts

Potato production forecasts are generated two times in the season. The first forecast (F1) is generally at state level while the second forecast (F2) is at district level. While multidate moderate resolution data (Resourcesat – 2 AWiFS with 56 m resolution and 5 day repetivity) is used for state level estimates, comparative high resolution single-date data of Resourcesat 2/2A LISS III (23.5 m resolution and 24 day repetivity), Landsat 8 OLI (30 m resolution and 16 day repetivity) or Sentinel 2 (10 m resolution and 10 day repetivity) is used for district level area estimates. Both the forecasts are done prior to potato harvest. The F1 forecast is generally given in end January to early February, while F2 forecast is produced during end February to early March (Table 2).

SN	State	No. of Districts	Names Districts	Contribution (%) to State's Potato Area
1	Bihar	17	Aurangabad, Begusarai, Bhagalpur, Bhojpur, Darbhanga, Gaya, Katihar, Madhubani, Munger, Muzaffarpur, Nalanda, Patna, Rohtas, Samastipur, Saran (Chhapra), Siwan, Vaishali	59.2
2	Gujarat	5	Banaskantha, Sabarkantha, Mehsana, Kheda, Gandhinagar	82.7
3	Punjab	8	Amritsar, Bhatinda, Moga, Patiala, Ludhiana, Jalandhar, Kapurthala, Hoshiarpur	83.0
4	Uttar Pradesh	17	Agra, Aligarh, Allahabad, Budaun, Etah, Etawah, Farukkhabad, Firozabad, Hardoi, Kannauj, Kanpur Nagar, Kasganj, Mahamaya nagar/ Hathras, Mainpuri, Mathura, Moradabad, Shahjahanpur	66.7
5	West Bengal	10	Bankura, Bardhaman, Birbhum, Coochbihar, Haora, Hugli, Jalpaiguri, Murshidabad, Paschim Medinipur, Uttar Dinajpur	92.8

Table 1. List of Study Districts for potato crop assessment

Year	Estimate/ Forecasts	Level	Date of Release
2012-13	F1	State	08-Feb, 2013
	F2	State	05-Mar, 2013
2013-14	F1	State	31-Jan, 2014
	F2	State	04-Mar, 2014
2014-15	F1	State	08-Feb, 2015
	F2	District	05-Mar, 2015
2015-16	F1	State	22-Jan, 2016
	F2	District	10-Mar, 2016
2016-17	F1	State	14-Jan, 2017
	F2	District	20-Feb, 2017
2017-18	F1	State	24-Jan, 2018
	F2	District	21-Mar, 2018

Table 2. Dates of Release of Potato Production forecasts in last 6 years

3.2 Data Used

As mentioned earlier, different satellite and senor data were used for crop area estimation. Initially, Indian Resourcesat 2 LISS III and AWiFS data were used. Later on (2014-15) Landsat 8 OLI data was also used, and then Sentinel 2 MSI data was also utilized (Table 3).

Moderate resolution remote sensing data of MODIS (Moderate Resolution Imaging Spectro-radiometer) 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 2006-2017, were used for computing VCI. The VCI based empirical models were used for crop yield estimation (Dubey et al., 2016).

Yield was also estimated using weather-based models, for which weekly weather (Rainfall, Maximum temperature, Minimum Temperature, Maximum and Minimum Relative Humidity) data of last 10-15 years, for the period October to February was collected from the India Meteorological Department.

Ground truth (GT) is an essential parameter for crop classification and accuracy assessment. The GT data was collected by the state agriculture/horticulture department officials using a smartphone-based Android App, called Bhuvan FASAL, developed by NRSC (ISRO). The GT for Potato crop was collected during October to January. The ground truth data include location, field photographs and field parameters, which are uploaded to ISRO’s Bhuvan Geoportal (https://bhuvan.nrsc.gov.in/). An example of ground truth points for Punjab state, (2017-18) available on Bhuvan Geoportal, is shown in Figure 3.

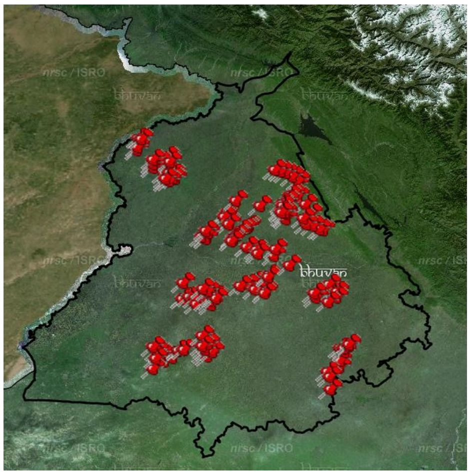


Figure 3. Example of Ground truth points for Punjab state, collected during 1-31st December 2017, available on Bhuvan portal

3.3 Acreage and Production Estimation

A summary of potato crop production estimation is given in Table 3. Crop area was estimated using satellite data and a combination of unsupervised - ISODATA (for general land cover classification) and supervised – Maximum Likelihood approach (for crop specific classification). Ground truth data was used to support the crop classification. In the first two years, crop classification was carried out in selected sample segments, while in the next four years complete enumeration approach was followed (Table 3).

After classification, district boundaries were overlaid to find out potato crop area in each district. The state level potato crop area was estimated by extrapolation (using a factor based on historical data) of study districts’ potato area.

The crop yield was estimated using weather-based correlation weighted regression models (Agrawal & Mehta, 2007), developed by India Meteorological Department (Ghosh et al., 2014; Singh et al., 2017). During 2012-13, agro-meteorological models were used at state level. Later on, they were developed at district level. From 2015-16, apart from agromet models, yield models were developed using fortnightly Vegetation Condition Index (VCI). Step wise regression was carried out between potato yield and VCI (Dubey et al., 2016).

District level yield estimates, derived from the above two approaches, were combined statistically to get the final yield estimate (Pandey et al., 1992).

3.4 Comparison of Estimates

The crop area and production estimates generated using satellite data and agromet and remote sensing-based models were compared with the government’s estimates, derived using conventional approach. The Government’s estimates were obtained from HAPIS (Horticulture Area Production Information System) database (https://aps.dac.gov.in/). Two statistical parameters were computed for comparisons. Those are RMSE and Correlation Coefficient.

Year	Level of Assessment	Satellite Data	Data Period	Image Analysis Approach	Yield Estimation Approach
2012-13	State & National	R2 AWiFS	Nov-Feb	Sample Segment Approach & Supervised MXL Classification	Agromet Model- State level
2013-14	State & National	R2 LIII & R2 AWiFS	Dec-Feb		Agromet Model-District level
2014-15	District, State & National	R2 LIII, L8 OLI & R2 AWiFS	Dec- Feb	Complete Enumeration Approach & Combination of Supervised & Unsupervised Classification	
2015-16	District, State & National	R2 LIII, L8 OLI & S2 MSI	Dec-Feb		Agromet Model & VCI based Model-District level
2016-17	District, State & National	R2 LIII, L8 OLI & S2 MSI	Dec-Jan		Agromet Model, Vegetation Index based Model
2017-18	District, State & National	R2 LIII, L8 OLI & S2 MSI	19th Nov-12th Feb		

R2 LIII – Resourcesat 2 LISS III, L8 OLI- Landsat 8 OLI, S2 MSI- Sentinel 2 MSI, VCI-Vegetation Condition Index.

Table 3. Summary of Potato Crop Estimation Process (2012-17)

3.4.1 RMSE

The RMSE (Root Mean Square Error) 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).

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

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

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

3.4.2 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).

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

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 variables (Gomez & Gomez, 1984).

4. RESULTS AND DISCUSSION

4.1 Area and Production Estimates

The national, state and district level estimates were generated for 6 years (2012-13 to 2017-18), as per the procedures given above. The trend of estimates generated, at national level, for potato area and production is given in Figure 4. There is an increasing trend in both area (r=0.94) and production (r=0.99) estimates of potato at national level.

Similar trends for state level estimates of potato area, production and yield are presented in Figure 5. In all states, potato area and production have been found to increase significantly, as seen from the higher values of correlation coefficient (Table 4). However, though the yield is increasing in most of the states, but the trend is not significant. Major increase in yield was found in West Bengal state, while in Gujarat, there was a decreasing trend.

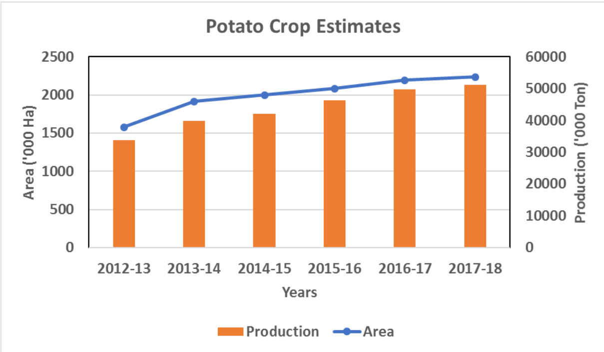


Figure 4: Trend of national level estimated Potato area, and production during last six years

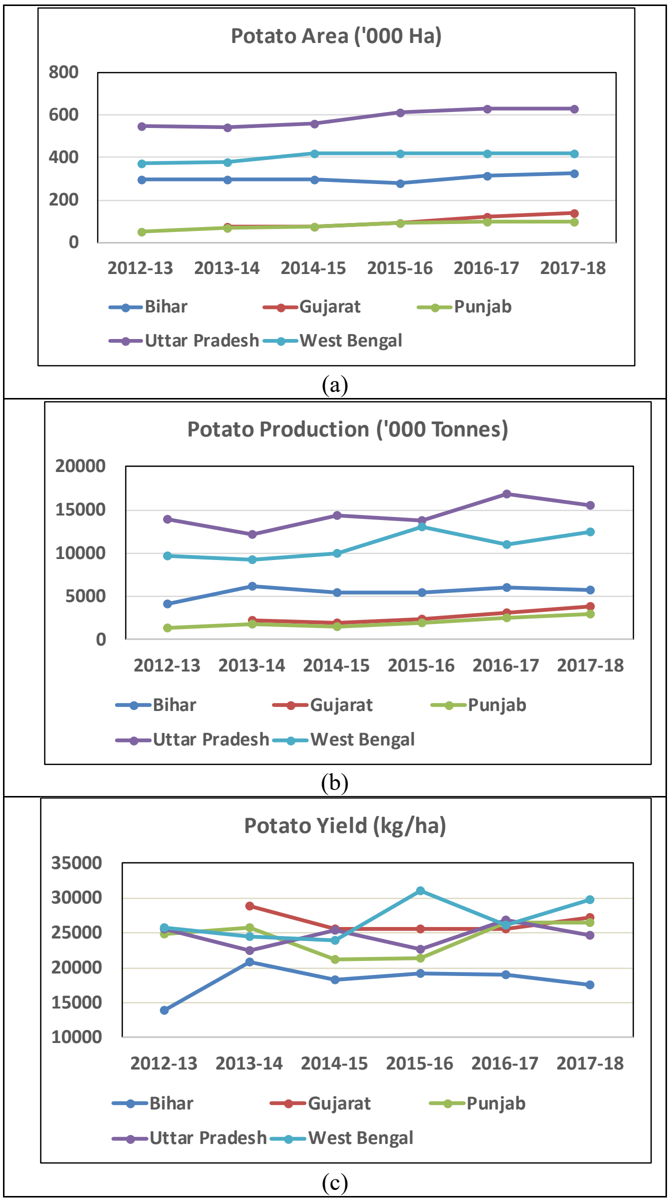


Figure 5: Trend of state level estimated Potato area, production and yield trend during last six years at state level

State	Area	Production	Yield
Bihar	0.63	0.56	0.32
Gujarat	0.96	0.91	-0.34
Punjab	0.96	0.93	0.25
Uttar Pradesh	0.95	0.71	0.17
West Bengal	0.86	0.78	0.59

Table 4. Correlation coefficient of Trend Analysis of 6 years' state level potato area, production and yield estimates.

4.1 Comparison with the Government Estimates

Ministry of Agriculture, through the Horticultural Statistics Division, generates estimates for horticultural crops, including potato, using conventional procedures (DAC&FW, 2018). The state and national level estimates generated for potato crop, under the CHAMAN/FASAL project was compared with the government estimates.

At national level the area estimates were within 5% of the government estimates, except for 2012-13. In that year, as only AWiFS (56 m) data had been used, the acreage was estimated much lower than the government estimates, which also resulted in low production estimate. Similarly, at national level potato crop production estimate was within 12% of the government estimates, for most of the years.

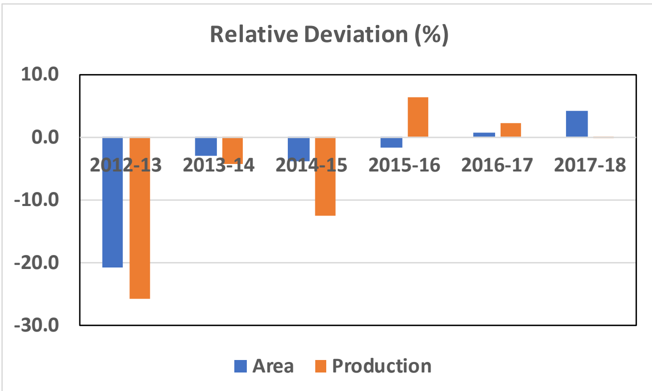
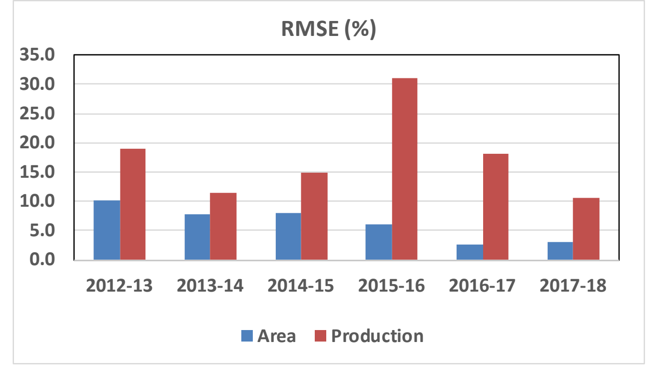


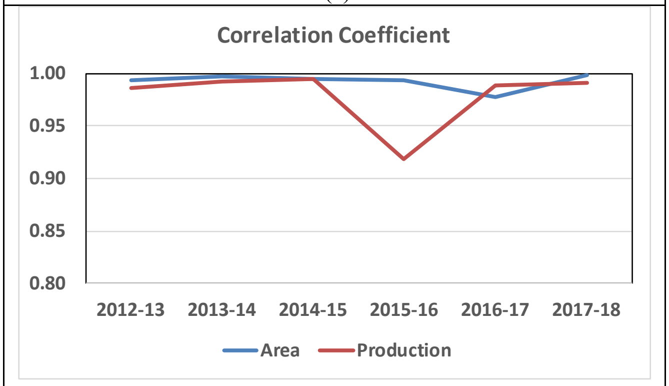
Figure 6. Relative Deviation (%) of remote sensing-based potato crop estimates, at national level, compared to government estimates.

Similar comparison for state level estimates were carried out by computing two statistical parameters, i.e. RMSE (%) and correlation coefficient. The RMSE for area and production estimates have gradually reduced, except for 2015-16 (Figure 7). In last two years the RMSE for area was below 3 %. The correlation between remote sensing-based estimates and the government estimates were, in most cases, above 0.98, except for the production in 2015-16. Among all these states, Uttar Pradseh had lowest RMSE for both area and production. States like Bihar and West Bengal had also very low RMSE for potato area estimate.

In most cases, the RMSE for production estimation is high, due to non-matching of estimated yield with the government yield figures.



(a)



(b)

Figure 7. Comparison of state level estimates of potato crop with government estimates, as seen through (a) RMSE (%) and (b) correlation coefficient, in different years.

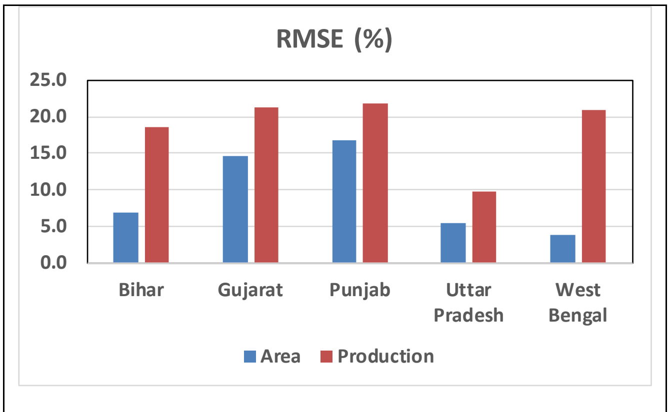


Figure 8. Comparison (RMSE) of state level estimates of potato crop with government estimates, for different states.

5. CONCLUSION

The above study analyses remote sensing and agrometeorology based potato area and production estimation, carried out under the FASAL/CHAMAN project of the Ministry of Agriculture. Six years' (2012-13 to 2017-18) estimates, at district, state and national level, have been analysed. The study shows the improvement in the procedure and satellite data use for both area and production estimates. The results have improved significantly. When compared with Government statistics, the RMSE has been reducing year to year. Correlation has remained very high all throughout. The study has shown that crop area estimation has got very low deviation, compared to the government estimates. However, there is need to further improve the yield estimation, in order to reduce the deviations.

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