QUALITY CHECKING OF CROP CUTTING EXPERIMENTS USING REMOTE SENSING DATA: A CASE STUDY FOR RICE CROP IN ODISHA

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Commission III, WG III/10

KEYWORD: PMFBY, CCE, RISAT-1, Sentinel-1A, NDVI, NDWI.

ABSTRACT:

Under Pradhan Mantri Fasal Bima Yojana (PMFBY), a large number of Crop Cutting Experiments (CCEs) were conducted by Odisha State for Kharif Rice in the year 2016 and 2017. The present study was carried out to examine the quality of the performed CCEs using statistical methods and Remote Sensing (RS) technique. Total 24389 and 34725 CCEs were conducted. After removing outliers, 22083 and 26848 CCE points were analyzed for the year 2016 and 2017, respectively. Multi-date RISAT-1 (2016) and Sentinel-1A (2017) satellite data were used for generating the Kharif Rice crop mask, which was used to get NDVI and NDWI values for Rice pixels, from MODIS VI products. The values of these indices were divided into four strata from highest A, followed by B, C, and D (Lowest Value) based on the range (minimum and maximum) of values. The CCE based yield data were then divided into four yield strata of equal proportion. Yield and RS (NDVI+NDWI) based strata were combined to examine whether the CCE Points having high yield fall under good NDVI zone or vice versa. The results showed that there was strong match between CCE strata and the vegetation index strata in both the years. Therefore, it could be be concluded that RS based indices have the capability to assess the quality/accuracy of CCEs. Furthermore, the large variety of information available with CCEs such that crop variety, crop condition, water sources, stress conditions etc., can be used as input parameters to train any model to predict better results.

1. INTRODUCTION

Agriculture plays avital role in India’s economy, as a principal mean of livelihood and farmers are the backbone of agriculture sector. Estimation of yield of different crops is one of the important activities under taken by the government and many other organizations since it plays a major role in policy making, agricultural planning, to monitor the progress of the sector and provide insurance to the sector. The crop yield estimation, in India, is carried out on the on the basis sample survey approach, through large number of scientifically designed crop cutting experiments (CCE) (CSO, 2007). CCEs are basis of yield estimation in country and the current methodology of CCEs is proven method of yield estimation not only in India but also in many countries (Murthy, 2018).

Rice production in India is an important part of the national economy. India is one of the world's largest producers of rice and brown rice, accounting for 20% of all world rice production. Since 2010, production as well as yield of rice has increased significantly. Therefore, Rice yield estimation plays a vital role Indian Agriculture sector.

Farmers in India are exposed to huge agriculture risks due to various vagaries of nature. One of the most effective mechanisms to mitigate agricultural risks is to have an efficient crop insurance system (Gulati et al., 2018). Pradhan Mantri Fasal BimaYojana (PMFBY) (Prime Minister’s Crop Insurance Pogramme), launched in 2016, is one of largest crop insurance programmes of the world, in terms of sum insured (Ghosh, 2018). PMFBY aims at supporting sustainable production in agriculture sector by way of providing financial support to farmers suffering from crop loss/damage, stabilizing the income of farmers, encouraging farmers to adopt innovative agricultural practices and ensuring flow of credit to the agriculture sector (https://agri-insurance.gov.in/FaqLogin.aspx).

PMFBY followed the area-based approach and the lowest unit of insurance is Gram Panchayat (GP) (A cluster of villages). As indicated in the PMFBY guidelines, minimum 4 CCEs are required to estimate the yield of GPs, in case of major crops whereas in case of minor crops the estimation being carried out at Taluk or sub district level for which minimum 16 CCEs required (Revised Operation Guidelines of PMFBY, 2018). Thus, the number of CCEs has increased many folds in comparison to previous insurance scheme. Conducting of CCEs a time-consuming and cumbersome affair, Hence, carrying out requisite number of CCEs under the PMFBY is a challenging task. There is a possibility of degradation quality and accuracy of CCE, because of huge number. In most of the sates CCEs are being supervised by village level primary worker or Patwari. On an average a Patwari, who is responsible for crop enumeration, covers seven villages in each crop season. The overburdening of 'Patwaris' have resulted in errors in data collection, and delays in submission of data, both negatively impacting the quality of the outcomes (Business Today, Nov 2018). In this situation the quality of CCEs

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are being improved through two ways either by deploying large number of trained manpower or by adopting technology to improve the quality of CCEs.

The major objective of this study is to show the role of remote sensing techniques to examine the quality of CCEs carried out for crop insurance purpose, by using the state of Odisha, a case study, for two =*i.e.*, 2016-17 and 2017-18.

Satellite remote sensing-based vegetation indices are quite simple and effective algorithms for quantitative and qualitative evaluations of vegetation cover, vigor, and growth dynamics, among other applications (Xue and Su, 2017). Normalized Difference Vegetation Index (NDVI) is the most widely used as VI, as it was shown to be related not only to canopy structure and LAI but also to canopy photosynthesis (Gamon et al., 1995). NDVI is a true representative of crop biomass and growth. Higher NDVI values reflect greater crop vigour due to high photosynthetic capacity of healthy crop, whereas lower NDVI values for the same crop growing period shows some kind of stress (Dadhwal and Ray, 2000). Although vegetation development of crop fields may differ from those of natural vegetation because of human influences involved such as irrigation, use of fertilizer and pesticides, NDVI is considered as a valuable source of information for the crop conditions (Prasad *et al.*, 2006).Another popular index, Normalized Difference Wetness Index (NDWI) responds to the changes in water as well as in reflectance of NIR radiation (Gu *et al*., 2008). It is therefore a very good proxy for plant water stress and sows the leaf water content at canopy level (Yin *et al* 2012).

Both these indices have been used for crop yield estimation of major crops in the country (Dadhwal and Ray, 2000; Dubey et al, 2018) and drought assessment (Saxena et al., 2019). Therefore, both indices are considered as ideal indicators as they are highly correlated with crop condition and thereby able to accurately track yield losses.

2. STUDY AREA

Odisha, located in the sub-tropical belt in the eastern region of India, is a major rice growing state of the country. Geographically, it lies between $17^0$31’N to $20^0$31’N latitude and $81^0$31’E to $87^0$30’E longitude (Figure 1).. The state has total geographical area of 155.71 million hectares (Mha) out of which total net sown area is about 54.90 Mha which constitutes about 35.25% of the total geographical area of the state, thus Odisha is said to be an agrarian state. Despite several hurdles like frequent occurrence of natural calamities with erratic monsoon and uneven distribution of rainfall, agricultural production has been increasing in this state (Samikshya-2016).

The state has different soil types ranging from fertile alluvial deltaic soils in the coastal plains, mixed red and black soils in the Central Table Land, red and yellow soils with low fertility in the Northern Plateau and red, black & brown forest soil in Eastern Ghat region.

The climate of Odisha is characterised by high temperature, high humidity, medium to high rainfall and short and mild winters. The annual normal rainfall is 1451.20 mm out of which more than 80% of precipitation is received during south-west monsoon period.

Paddy or Rice is the most cultivable crop during Kharif and Rabi crop seasons of Odisha State. Other important crops grown in the state are Sugarcane, Pulses (Arhar, Mung, Biri, Kulthi), Oil seeds (Groundnut, Til, Mustard and Niger), Fibres (Jute, Mesta, Cotton), Horticultural crops (Mango, Banana, Coconut & Cashew Nut), Vegetables and Spices.

There are two reasons for taking Odisha as a case study. The agriculture department of Odisha has implemented smartphone based CCE data collection, using an Android App, called CCE-Agri, developed by Ministry of Agriculture, Government of India (https://agri-insurance.gov.in/CCEAppVersions.aspx) (Das, 2018). Hence, all the CCE data are geocoded, and available on the server, with lot of background information on the crop type. Secondly, rice being a cereal crop, where crop yield has high correlation with vegetation indices (Dubey et al, 2017)

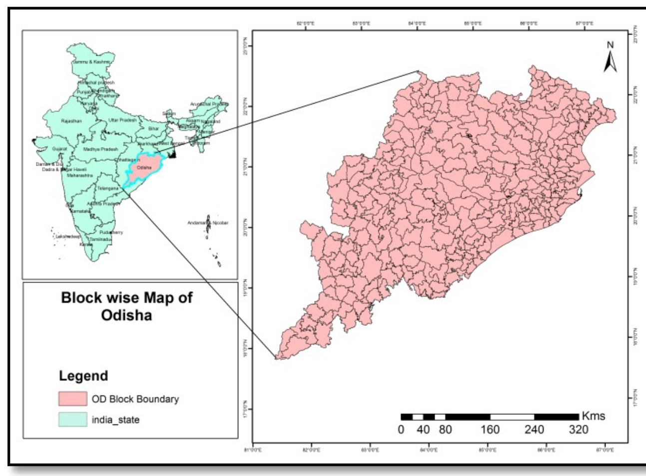

Figure 1: Study area Odisha state

3. CCE DATA COLLECTION

As mentioned earlier CCEs were conducted in Odisha, by the government departments, using a Multi-Stage Stratified Random Sampling as per the guidelines of National Sample Survey Organisation and Indian Agriculture Statistics Research Institute (CSO, 2007). In each GP 4 CCEs were conducted. All total 24389 and 34725 Crop Cutting Experiments (CCEs) were performed in Odisha state for Kharif rice crop in the year 2016 and 2017 respectively. The application CCE_Agri was used for collecting the information of these CCE points. The information collected through CCE_Agri is geo-located. It consists of various observations namely Location (Latitude, Longitude), Photographs, District, Block, Village, Name of Season, Date of Cutting, Name of Farmer, Field Size, Name of Crop, System of Cultivation, Variety, Source of Seed, Agronomic Practices, Date of Sowing and harvesting, Shape of CCE, Green weight, Moisture percentage, Dry weight, Average yield, Water Source, Land Type, Extent of damage by pest and any disease, Any Stress. All these observations are real-time uploaded the National Crop Insurance Portal. These data were downloaded for the study.

4 DATA USED

4.1 CCE data

To evaluate the quality of the CCE data first outliers were removed based on different criteria. The CCE data which were discarded include the data points i) having inaccuracy in location, ii) other than rice points, iii) replicated data and iv) points having certain important missing parameters. Thus, the final CCE data used for analysis, included 22083 CCE points in 2016-17 and 26848 CCE points in 2017-18.

4.2 Satellite Data used

In 2016-17, multi-date RISAT-1 satellite data were used for generating the kharif rice crop map Odisha state. RISAT is the first indigenous satellite imaging mission of ISRO, which used C-band SAR (Synthetic Aperture Radar) imager and provided data in HH and HV polarization (Misra et al., 2013). For the year 2017-18, Sentinel-1 data was used for generating rice crop map. Sentinel-1 has a Synthetic Aperture Radar in C band that provides data in VV and VH polarization.

5 METHODOLOGY FOR QUALITY CHECKING

5.1 Crop Map Preparation

Initially rice map was generated using multi-date SAR data by adopting a hierarchical classification algorithm, where logics of classification was prepared based on ground truth data, collected by State Agriculture Departments and Remote Sensing Centers. In order to have a better crop classification, Level -II Land Use Land Cover (LULC) maps, prepared by National Remote Sensing Centre (NRSC) for the year 2012, available on 1:50,000 scale, was also used. The classification was done using a sample segment approach. However, later on similar algorithm was used to generate the rice crop map of Odisha state.

5.2 Vegetation Index based Stratification

Moderate resolution remote sensing data of MODIS (Moderate Resolution Imaging Spectroradiometer) on-board Terra/Aqua Satellite was used for developing remote sensing-based indices. MODIS NDVI (Normalized Difference Vegetation Index) product (1 km resolution) for the maximum vegetative stage of the crop.. MODIS Reflectance data was processed to develop NDWI (Normalized Difference Wetness Index).

Rice crop mask was overlaid on NDVI and NDWI images to get values for rice pixels. After masking of rice pixels, the values of NDVI and NDWI were divided into four equal proportion or strata based on the range (minimum and maximum) of NDVI and NDWI. The highest NDVI/NDWI values were grouped in category A, followed by B, C and D (lowest values) i.e. Good, Medium, Bad and Poor category. After the individual categorization of these indices, NDVI and NDWI stratum were joined to generate combined classes of NDVI and NDWI using a matrix approach (Table: 1).

NDWI / NDVI	A or 1	B or 2	C or 3	D or 4
A or 1	1	1	2	2
B or 2	1	2	2	3
C or 3	2	3	3	4
D or 4	3	3	4	4

Table 1: Stratification of pixels on the basis of NDVI and NDWI

5.2 Yield based Stratification

Similarly, the yield data obtained from the CCEs were arranged in ascending order. The CCE yield values were then divided into four yield strata (Y1, Y2, Y3 and Y4 or High, Medium, Low and Very Low) of equal proportion i.e. 0-25%, 26-50%, 51-75% and 76-100%. The selected CCE points were overlaid on the classes of remote sensing based indices to examine whether the CCE Points having high yield fall under good NDVI zone or vice versa. For each CCE point, the remote sensing based stratum was matched with the yield category and the comparison is presented in Table 2 and 3.

The summary of the overall methodology is presented in figure 1.

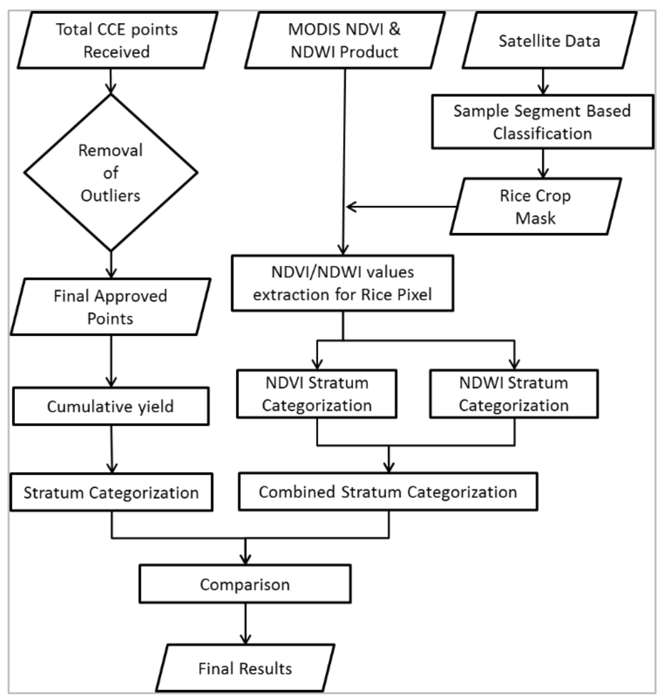

Figure 1: Flowchart of methodology.

6 RESULTS AND DISCUSSION

6.1Year 2016-17

Figure 2 shows the CCEs (with different categories of yield), overlaid on the Vegetation Index (VI) stratification map, for the year 2016-17. The stratification of vegetation index was compared with that of CCE yield. Table 2 shows that how many numbers of CCE points are exactly matching with the indices based stratum and how many are in one category difference and so on.

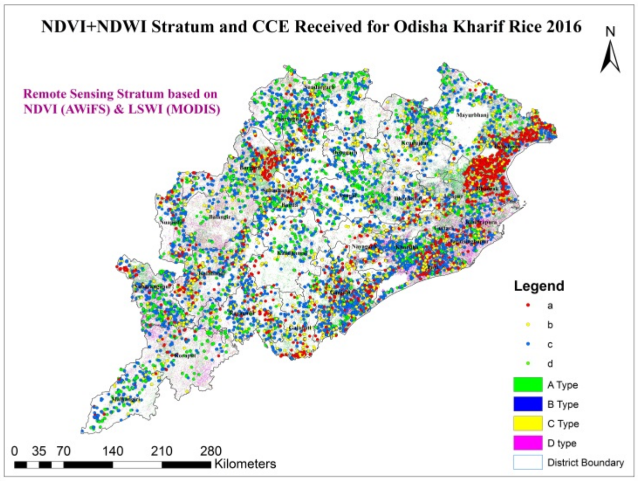

Figure 2: Stratum wise CCE distribution in Odisha in 2016-17

It was found that, in 2016-17, in 30% cases the CCE yield stratum was exactly matching with the VUI stratum. In 44% cases, it was only one category difference. 2 and 3 category difference were found in 20 and 60 per cent, cases, respectively. Thus 74 % (30+44) yield values were matching with VI strata within one category difference. The points which have more than 2 category difference were considered as outliers, which needed further checking.

Yield Stratum	Number of CCE Points				
	Remote sensing (NDVI+NDWI) Stratum				Total
	A	B	C	D	
Y1	914	712	1156	389	3171
Y2	950	878	1635	573	4036
Y3	933	1059	2204	947	5143
Y4	976	1668	4406	2683	9733
Total	3773	4317	9401	4592	**22083**

Table 2: Comparison of CCE points between yield and remote sensing stratum

6.2 Year 2017-18

Figure 3 shows the CCEs (with different categories of yield), overlaid on the Vegetation Index (VI) stratification map, for the year 2017-18. The stratification of vegetation index was compared with that of CCE yield. It is clear from the comparison (Table 5) that 27% CCE points of remote sensing stratum has been matched accurately with corresponding yield stratum. 41% falls in 1 category difference, 21% CCEs in 2 category difference and 11% under 3 category differences matching level. Thus 68 % (27+41) yield values were matching with VI strata within one category difference. The points which have more than 2 category difference were considered as outliers and needed further examination.

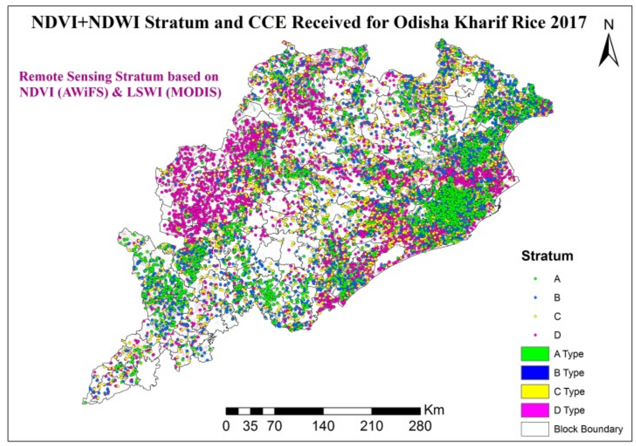

Figure 3: Stratum wise CCE distribution in Odisha in 2017-18

Yield Stratum	Number of CCE Points				
	Remote sensing (NDVI+NDWI) Stratum				Total
	A	B	C	D	
Y1	664	719	1077	503	2963
Y2	860	951	1408	714	3933
Y3	981	1154	1963	982	5080
Y4	1928	2052	4230	2483	10693
Total	4433	4876	8678	4682	**22669**

Table 3: Comparison of CCE points between yield and remote sensing stratum for the year 2017-18

The comparison of average yield values for different remote sensing strata is shown in figure 3, for both 2016-17 and 2017-18. From the figure it is seen that yield stratum and remote sensing stratum both show higher yield is associated with higher stratum category or vice versa, which means similar pattern between yield and remote sensing strata has been observed.

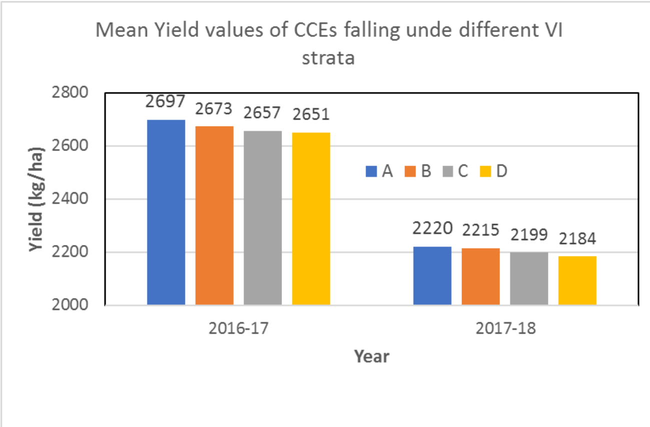

Figure 3: Comparison of average CCE yield values for different remote sensing strata

The CCE points, which were considered outliers in this analysis were subjected to further checking of the crop parameters collected during the CCE data observation.

7 CONCLUSION

From this study it can be concluded that Remote sensing technology may considered as suitable tool to identify the outliers in large series of CCEs. Quality of CCEs can be judged based on this approach since remote sensing is a proven tool to find crop health and vigour, which helps in yield estimation.

After examining all the CCEs and related information with RS indices-based outputs, this can be concluded that both the methods show about 70-75% similarities in the results hence the quality of CCE data received is good and can be used in further calculations.

Under PMFBY, number of CCEs has increased because insurance unit has been changed from district/block to Village Panchayat. Therefore, large number of CCEs is to be done and in case of lack of manpower and resources remote sensing can play a significant role in reducing the load and errors.

The analysis also shows that there are some limitations and errors/outliers in the collected data of CCEs, however there is large amount of ancillary information available with these CCE data, which can be further used in other areas such as crop status, pest and disease studies, water and nutrient stress management. These data can also be used as input parameters for different yield estimation methodologies.

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