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District level crop yield estimation with reduced number of crop cutting experiments

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ABSTRACT

It was observed that around 1300000 Crop Cutting Experiments (CCE) were conducted in India every year to find out the crop yield estimates of several major and minor crops under General Crop Estimation Surveys (GCES). Due to shortage of manpower and huge bulk of work day by day the data quality is becoming questionable. To tackle this problem, a pilot study was conducted by ICAR-IASRI, New Delhi sponsored by Directorate of Economics and Statistics (DES), Ministry of Agriculture and Farmers Welfare (MoA & FW), Govt. of India to generate district level estimates of major crop yield from a reduced sample size of villages selected from the states. With the reduction in number of villages, the problem of no sample size in some districts were faced during the study where common design based estimates of crop yield cannot be generated. To tackle this problem Aggregate level Small Area Estimation (SAE) was used to tackle this problem. The results obtained from this study in the state of Uttar Pradesh for two major crops, i.e. rice and wheat for two seasons, i.e. *kharif* and *rabi* of Agriculture Year 2015-16 and for paddy in Assam for *kharif* of the Agriculture Year (AY) 2015-16 in India were discussed. The yield estimates were compared with the estimates released under GCES for AY 2015-16. It was found that the estimates obtained from reduced sample size of number of CCEs w.r.t. GCES, produced similar estimates with acceptable level of precision.

Keywords: Agricultural statistics, Crop cutting experiments, Pilot survey, sample Size, Small area estimation

In view of the predominant position of the Agricultural Sector, collection and maintenance of Agricultural Statistics assume great importance. The yield rates of principal crops are estimated through GCES. Under the GCES, CCEs are done in a sample of Timely Reporting Scheme (TRS) villages by one or more state agencies (Report of Expert Committee on Agricultural Statistics 2011). The intention was to generate estimates of per ha yields of various crops within a reasonable, specified margin of standard error. During past few agricultural years, it was found that around 1300000 CCEs covering 52 food and 16 non-food crops were conducted every year in different States/UTs in India. Therefore a study was carried out to evaluate the possibility of generating reliable estimate of major crop yield from a reduced number of CCEs. The results of this study were based on the data collected independently in state of Uttar Pradesh for two major crops, i.e. rice and wheat for two seasons, i.e. *kharif* and *rabi* of Agriculture Year 2015-16 by the Department of Agriculture and Crop Insurance, Lucknow, Govt. of Uttar Pradesh and for paddy in Assam for *kharif* of the Agriculture Year 2015-16 by Directorate of Economics and Statistics, Guwahati, Govt. of Assam. The results were compared with the estimates released under GCES for the year 2015-16.

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MATERIALS AND METHODS

Under this study, a survey was undertaken in 5 states of India namely Assam, Uttar Pradesh, Odisha, Karnataka and Gujarat. The survey was conducted for the Agricultural year 2015-16 in India for both *kharif* and *rabi*. In this paper we will concentrate on two states namely Assam and Uttar Pradesh. The total number of villages and number of crop cutting experiments are around 6% of villages in the state of Assam and 10% of villages in Uttar Pradesh with respect to the sample size selected under TRS scheme. Accordingly, the total number of CCEs will also get reduced in the same proportion.

To efficiently implement the proposed sample size to generate direct estimates of crop yield, the sampling design adopted is that of stratified multi-stage random sampling as detailed below:

i. District in each participating State has been considered as a stratum.
ii. 50% of the Tehsils/Taluks in a district have been selected as First stage Sampling Units (FSUs) by simple random sampling without replacement (SRSWOR).

Villages within a FSU are taken as Second stage Sampling Units (SSUs), and within each SSU, survey/ sub-survey numbers have been taken as Third stage Sampling Units (TSUs). Experimental plot of specified size in the selected survey/sub-number is considered the ultimate stage unit for yield estimation. The SSUs and TSUs have been selected using SRSWOR. For construction of frame for selection of the CCE plots, 100 survey numbers have been selected in the form of 20 clusters of 5 survey numbers each within a selected village.

iii. Each selected survey number has been visited by the primary worker for plot to plot enumeration of crop during *kharif* and *rabi* seasons of AY 2015-16.

iv. Crop-wise frame for selections of survey number for CCE has been generated on the basis of 100 survey numbers selected randomly. For each major crop, two survey/sub-survey numbers have been selected for conducting CCEs using SRSWOR.

Selection of sample units up to the level of second stage units (SSUs) namely villages has been done by IASRI, New Delhi, whereas the selection of third stage units (TSUs), namely survey/sub-survey numbers for both area enumeration and CCEs, have been done by concerned State field officials. For field data collection, one schedule for preparation of frame and two schedules for crop cutting experiments have been designed. The methodology for estimation of average yield at district level using design based estimator was derived from Sukhatme *et al.* (1984) and Singh *et al.* (1996) while for Small Area Estimation (SAE) the Aggregate Level SAE method (EBLUP model) proposed by Fay *et al*. (1979) was used.

RESULTS AND DISCUSSION

In the state of Uttar Pradesh data on two major crops, viz. Rice and Wheat were collected by the state agency in two crop seasons *Kharif* and *Rabi* respectively during Agriculture year 2015-16. After receiving the data, while cleaning and compiling the data it was found that very less or no data on CCE was recorded in 10 districts in case of Rice in *Kharif* 2015-16 and in 7 districts in case of Wheat in *Rabi* 2015-16 out of total 75 districts. In the state of Assam in 3 districts very scanty data was recorded for Rice in *Kharif* 2015-16 out of total 26 districts. Due to conduct of less number of CCEs than the proposed, the sample size got reduced and the percentage Coefficient of Variation (% CV) of the proposed estimates got increased in few districts. Further, due to reduction of number of CCEs, in some districts sufficient sample size was not found to produce the district level direct estimates of the crop yield. Those districts are treated as the non-sample districts and the estimates are predicted using EBLUP estimator along with the estimates of all other districts with improved precision. For fitting SAE model, the district level fertilizer consumption data of the year 2015-16 for the state of Uttar Pradesh and Assam, released by Fertilizer Statistics (2015-16) was used as auxiliary information. The data on total fertilizer dose of Nitrogen (N), Phosphorus (P) and Potassium (K) fertilizers was used as the auxiliary information for construction of the SAE estimator. It was found that the correlation between the yield of rice and fertilizer dose ranged between 0.1-0.2 in the state of Uttar Pradesh, while in case of wheat the same resulted around 0.1 and in Assam the correlation was found in the tune of around 0.05. The district level yield estimates are generated using proposed design based methodology and is found to be almost same with the estimates released under the GCES scheme with acceptable % CV in the respective states in the AY 2015-16 for the sample districts. In the state of Uttar Pradesh estimates of rice and wheat was generated, whereas in Assam estimates of Paddy yield was generated. The average number of CCEs conducted for Rice crop in the state of Uttar Pradesh under this study was 42, whereas the same for wheat is 48 and in the state of Assam the average number of CCEs conducted under this study for winter paddy is only 10. Now the average number of CCEs at district level conducted under GCES for major crops like Paddy/Rice and wheat are in the tune of 100-120. So it can be seen that in the state of Uttar Pradesh the number of CCEs proposed in this study is less than half the sample size in GCES while in the state of Assam it's only around 10%.

A close perusal of data (Table 1) depicts that the % CV of the design based estimator of Rice varies from 1.3-

Table 1 District-wise Estimates of Yield (kg/ha) with % CV for Rice and Wheat crop in Uttar Pradesh for AY 2015-16.

District	Yield	% CV	EBLUP	% CV	GCES	Yield	% CV	EBLUP	% CV	GCES
			Rice					Wheat		
Agra			2181	22.93	2399	2491	6.78	2491	0.52	3226
Aligarh	2163	1.89	2164	1.89	2091	3400	2.70	3400	0.29	3177
Allahabad	2384	4.08	2377	4.04	1899	2379	6.83	2379	0.55	1912
Ambedkar Ngr	2052	6.58	2059	6.36	2111	2934	1.66	2934	0.24	3183
Amethi	1973	3.89	1978	3.84	1967	2176	9.17	2176	0.64	2375
Amroha	2103	2.97	2104	2.95	2257	3316	6.17	3316	0.42	2962

Contd.

Table 1 (*Continued*)

District	Yield	% CV	EBLUP	% CV	GCES	Yield	% CV	EBLUP	% CV	GCES
			Rice					Wheat		
Auraiya	3022	3.93	2974	3.9	2820	3434	2.98	3434	0.29	3085
Azamgarh	2241	7.02	2240	6.74	1970	2753	3.74	2753	0.36	2676
Badaun	1922	3.35	1928	3.32	1847	4091	3.33	4091	0.29	4140
Baghpat	2747	2.43	2736	2.41	2746	2734	5.81	2734	0.48	2661
Bahraich	1658	5.29	1676	5.13	1888	2695	8.62	2695	0.56	2707
Ballia	2263	4.32	2260	4.25	1694	3242	9.02	3242	0.52	2389
Balrampur	1508	9.03	1555	8.49	1803	1564	9.39	1564	0.77	1200
Banda	1449	5.68	1468	5.52	1295	3023	4.09	3023	0.36	2973
Barabanki	2675	6.43	2625	6.21	2751			2883	29.26	2930
Bareilly	2029	4.94	2037	4.81	2608	2738	3.24	2738	0.33	2615
Basti	1807	1.76	1809	1.77	1880	3244	9.43	3244	0.52	
Bhadrohi	1938	6.05	1952	6.01		2936	2.14	2936	0.27	3100
Bijnor	2546	2.65	2540	2.64	2590	3668	3.49	3668	0.31	2831
Bulandshahr	2432	4.34	2422	4.25	2688	1804	6.06	1804	0.55	3867
Chandauli	3586	6.82	3303	6.69	3085	1487	6.22	1487	0.67	1918
Chitrakoot	867	12.34	922	11.39	1156	2493	2.78	2493	0.32	1414
Deoria	1172	9.73	1222	9.08	776	2874	3.43	2874	0.35	2545
Etah	2171	4.77	2170	4.71	1545	3370	1.28	3370	0.21	2901
Etawah	2306	3.80	2301	3.74	2466	2569	6.89	2569	0.51	3326
Faizabad	2040	5.35	2046	5.23	2283	3408	3.93	3408	0.35	2854
Farrukhabad	2563	4.61	2539	4.53	2246	1617	3.78	1617	0.49	3171
Fatehpur	1703	5.79	1722	5.63	2047	3331	2.87	3331	0.32	2485
Firozabad			2311	22.55	2397	3269	6.05	3269	0.43	3287
GTBnag	2789	3.11	2768	3.07	2616	3397	6.95	3397	0.44	3423
Gaziabad	2670	3.96	2645	3.93	2568	2105	7.17	2105	0.57	3610
Gazipur	2016	7.06	2029	6.75	2165	2459	4.89	2459	0.45	2386
Gonda	2174	4.19	2176	4.14	2061	2246	6.23	2246	0.53	2766
Gorakhpur	1541	8.84	1586	8.32	1621	1351	6.01	1351	0.67	2519
Hamirpur			2124	23.68	1156	3746	2.24	3746	0.24	1752
Hapur	2784	4.79	2738	4.71	2836	3183	2.73	3183	0.28	3840
Hardoi	2318	2.51	2317	2.51	2256	3684	2.72	3684	0.27	3001
Hathras	2020	4.02	2023	3.95	1966	2965	5.34	2965	0.44	3495
Jalaun			2181	22.93	1795	2336	7.53	2336	0.56	1880
Jaunpur	1787	5.17	1802	5.05	1760			2879	29.24	2661
Jhansi			2205	22.72	1683	3590	2.69	3590	0.28	1918
Kannauj	2020	3.69	2022	3.66	2351			2821	29.49	3250
Kanpur(D)	2338	2.23	2336	2.18	2635	3299	7.97	3299	0.49	2124
Kanpur (N)	2296	5.41	2286	5.29	2274	3078	5.82	3078	0.42	3012
Kasganj			2120	23.77	1917	2266	4.53	2266	0.44	3084

Contd.

Table 1 (*Concluded*)

District	Yield	% CV	EBLUP	% CV	GCES	Yield	% CV	EBLUP	% CV	GCES
			Rice					Wheat		
Kaushambi	1506	6.43	1529	6.21	2119	2555	2.01	2555	0.27	2176
Kushinagar	1691	7.34	1722	7.03	1583	3968	9.08	3967	0.48	2336
Lakhimpur	2762	2.21	2757	2.18	2629	3177	2.25	3177	0.25	3393
Lalitpur			2192	22.81	635	2236	7.29	2236	0.58	1738
Lucknow	2152	4.83	2150	4.83	2195	676	10.86	676	1.33	2619
Maharajganj	2392	5.79	2377	5.64	2464			2820	29.51	2996
Mahoba			2148	23.32	1156	3494	6.69	3494	0.43	787
Mainpuri	2460	4.61	2445	4.54	2636	3129	7.26	3129	0.48	3332
Mathura	2643	6.62	2591	6.41	2224	5595	0.35	5595	0.07	3453
Mau	1919	2.32	1921	2.29	1456			2844	29.27	2503
Meerut	2881	3.84	2848	3.79	2711	1708	7.13	1708	0.64	3874
Mirzapur	1545	7.24	1574	6.92	1730	3102	1.97	3102	0.26	1829
Moradabad	2431	3.15	2425	3.13	2338	3698	1.96	3698	0.22	3142
Muzaffarnagar	2609	2.35	2603	2.34	2596	3990	1.84	3990	0.23	3565
Pilibhit	3480	2.89	3429	2.89	3010	1679	5.24	1679	0.54	3877
Pratapgarh	1649	7.18	1677	6.86	1799	1884	5.79	1884	0.53	2188
Raebareli	1951	6.31	1963	6.31	2126	3670	4.80	3670	0.35	1969
Rampur	2339	2.25	2337	2.22	2260			2767	30.67	3423
Saharanpur	2403	2.44	2400	2.37	2264	3517	1.80	3517	0.23	3579
Sambhal	2204	2.72	2204	2.72	2301			2828	29.41	3070
SantKabirngr	1847	10.85	1887	9.91	1755	2471	4.86	2471	0.45	2542
Shahjahanpur	3257	1.31	3250	1.29	3149	2442	9.79	2442	0.61	3509
Shamli	1903	7.72	1920	7.34	2498	4045	2.71	4045	0.25	4071
Shravasti	1668	7.91	1698	7.54	1950	2312	6.02	2312	0.52	2656
Sidharthnagar	2025	6.59	2035	6.34	2262	3241	3.76	3241	0.34	3342
Sitapur	2025	6.59	2320	8.36	2158	2400	2.12	2400	0.29	2485
Sonbhadra	1905	19.78	1985	15.31	1487	1334	13.15	1334	0.97	1590
Sultanpur	2042	4.92	2047	4.84	2077	2765	5.55	2765	0.43	2838
Unnao	1650	4.99	1665	4.86	1584	2567	1.78	2567	0.27	2222
Varanasi	2045	9.08	2054	8.52	2256	2007	6.71	2007	0.60	2414

19.78 with an average of 5.35, whereas the % CV of the SAE estimates (EBLUP) varies from 1.29-15.31 for all the sampled districts and 22.55-23.77 for non-sampled districts. For wheat crop, it can be seen that, the % CV of the design based estimator varies from 0.35-10.86 with an average of 5.10, whereas the % CV of the SAE estimates varies from 0.07- 1.33 for all the sampled districts and 29.24-30.67 for non-sampled districts. For the state of Assam it is visible that the % CV of the design based estimator varied from 1.83-16.51 with an average of 8.07, whereas the % CV of the SAE estimates varies from 1.83-10.97 for all the sampled districts with an average of 6.74 (Table 2). For the non-sampled districts, the % CV of the SAE estimator lies in the range of 15.84-16.63. As the % CV of the GCES estimates are not available hence no conclusion can be drawn about the acceptability of these estimates where from our study for around 90% of districts of Uttar Pradesh we are able to generate precise estimates of yield of Rice and Wheat crop from around 40% of CCEs on an average conducted under GCES in each district. In case of Assam, for around 96% of districts, we are able to generate precise estimates of yield of Wheat crop from around 10% of CCEs on an average conducted under GCES in each district.

The CCE is termed as a gold standard method for estimation of crop yield by FAO (Sud *et al.* 2017) and it cannot be replaced with any other existing methods. Hence,

Table 2 District wise estimate of Yield (kg/ha) along with % CV in the state of Assam for AY 2015-16.

District	Yield	% CV	EBLUP	% CV	GCES
Baksa	2975.30	4.00	3009.97	3.88	3267
Barpeta	2193.20	13.57	2392.52	10.05	2272
Bongaoigaon	2595.12	10.56	2803.90	8.97	2510
Cachar	3169.66	5.76	3256.39	5.39	3345
Chirang	3087.56	4.29	3046.86	4.20	2679
Darrang	3236.45	11.81	3278.41	9.94	3469
Dhemaji	2465.29	3.10	2241.58	3.07	2293
Dhubri	3989.76	5.61	3943.58	5.41	2658
Dibrugarh	4350.06	3.32	4282.31	3.31	3042
Dima Hassao			3620.83	15.84	3766
Goalpara	4061.14	16.29	3749.91	10.97	3295
Golaghat	3271.85	7.52	3353.06	6.84	3438
Hailakandi	3514.34	8.17	3474.35	7.55	3725
Jorhat	3547.44	10.03	3112.68	8.62	3404
K. Anglong			2807.98	14.46	2575
Kamrup (M)			3366.51	16.63	3395
Karimganj	3594.01	16.51	3681.08	10.77	2635
Kokrajhar	2458.64	8.40	2610.83	7.53	2595
Lakhimpur	3789.12	5.06	3754.29	4.86	3138
Morigaon	2718.85	16.02	2877.89	10.88	2960
Nagaon	3015.46	4.70	3050.81	4.62	3377
Nalbari	2957.99	5.04	2955.38	4.89	3192
Sivasagar	3200.00	1.83	3185.68	1.83	3155
Sonitpur	3539.60	9.05	3304.97	7.99	3294
Tinsukia	2989.91	8.55	3152.84	7.43	2890
Udalguri	3343.35	6.47	3360.67	6.09	3298

to reduce the workload and to improve the data quality with existing man power, the only way left was to reduce the total number of crop cutting experiments conducted under the GCES and we can conclude that our study resulted into success. Further, the use of SAE technique has improved the precision of the estimates. Hence we can conclude that estimates of crop yield with acceptable precision can be generated from less than 50% CCEs conducted under GCES for major food grain crops.

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