

Sampling with Probability Proportional to Aggregate Size using Nonparametric Bootstrap in Estimating Total Production Area of Top Cereals and Root Crops across Philippine Regions

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Cereal and root crop production are of primary interest to the country's agricultural industry. The need to obtain reliable estimates of total area of production is therefore crucial. This paper examines the Sampling with Probability Proportional to Aggregate Size (PPAS) in terms of unbiasedness and precision of estimates as compared to two known sampling designs, Simple Random Sampling without Replacement (SRSWOR) and Sampling with Probability Proportional to Size Without Replacement (PPSWOR).

Crop area, is used as auxiliary information. Estimates of total production area are obtained at 1%, 5% and 10% sampling rates. To be able to evaluate precision of PPAS estimates, nonparametric bootstrap variance estimation is performed.

PPAS estimates are generally better than the two other sampling designs when it comes to precision but almost at par when it comes to unbiasedness.

Keywords: Probability Proportional to Aggregate Size Sampling, Probability Proportional to Size Sampling, Simple Random Sampling, Nonparametric Bootstrap Estimation

1. Introduction

With a corresponding increase in population follows an increase in demand for man's basic needs such as food. Notching annual increase of no less than two percent over the past decade, the country's population is considered as one of the highest in the Southeast Asian region. Since the growth is skewed towards

the youth, this trend will represent a higher potential demand for food (Catelo, 2005). Thus, the agriculture sector has been a major player in the Philippine economy for many years now. In 2006, it directly contributed 18.7%, with flow-on effects about 75% of GDP as well as 40% of market transactions, and 70% of employment (Johnson et al., 2008).

However, even if the rapidly increasing and largely urban population acts as a main driver of demand for food, it can also be observed that there is a decline in the food supply in the country. Over the past six decades, the agricultural sector was confronted by both internal and external bottlenecks that constrained its performance and growth. Between 1978 and 2003, per capita total food availability declined by 1.2% annually. In the first half of 2010, agriculture contracted by 2.59% largely because of the El Niño phenomenon. The crops subsector registered the biggest production slump wherein production declined by 6.72%. In particular, the production of rice and corn dropped by 10.24% and 24.95%, respectively (Bureau of Agricultural Statistics, 2010). Moreover, vegetable per capita availability has declined by 23%, to just over a quarter of the WHO recommendation for consumption of fruit and vegetables, with most of the decline occurring in 1978-1987 (FNRI, 2003).

Together with the challenges of natural disasters, the declining total area devoted to agriculture is viewed as an essential factor affecting the decreasing food supply in the Philippines. It can be noted that in 1989, the area allotted for agriculture was 13,147,100 hectares; in 1998, this was reduced to 11,664,600 hectares, a decrease of 1.48 million hectares (Espino et al., 1999). In addition, one of the most important factors affecting food security is the physical and biological characteristics of soil as natural habitat for the production of food and raw materials. Hence, it is necessary to understand the soil's nature and characteristics in order to optimally manage and conserve the resource.

With these issues in mind, we aim to come up with an optimal sampling design that would facilitate in the estimation of the total production area of the top cereals and root crops grown across the different regions. Estimation of total production area is necessary not only because it provides us with a direct estimate of yield but also because it allows us to look into the current state of the land which is very much susceptible to damage. Also, with the current trend of land conversion for business and residential purposes, growing proportion of poor families and continued challenges in food security, estimation of total production area of the staple food grown in the country poses a significant role in providing awareness to concerned government agencies and segments of the population.

To be able to do so, parameter estimates computed using Probability Proportional to Aggregate Size Sampling (PPAS) was compared with the results of the Simple Random Sampling without Replacement and Probability Proportional

to Size without Replacement procedure. Nonparametric Bootstrap Resampling method was also employed to address the problem of zero and negative estimates for the variance in PPAS.

2. Sampling Designs

This section discusses the sampling designs used in estimating the population total. For a given population with N units, let Y be the characteristic of interest and $\{Y_1, Y_2, \dots, Y_N\}$ be the observed values among all units. Further, let $\{Y_1, Y_2, \dots, Y_N\}$ denote the sample of size n . The population total is given by $\tau = \sum_{i=1}^N Y_i$.

2.1 Simple Random Sampling without Replacement (SRSWOR)

This sampling design assigns equal probability to every subset of the population that contains exactly n distinct elements. SRSWOR can be implemented by drawing the first element from a uniform distribution on all N elements. Discard the first element and draw the second element from a uniform distribution on the remaining $N - 1$ elements. Discard the second element and continue this process to select the n th element from a uniform distribution on the last $N - n + 1$ elements. The inclusion probability of every population element i under SRSWOR is $\pi_i = \frac{n}{N}$. An unbiased estimator for the population total t and its variance are presented in Table 2.1.

Table 2.1 Estimator of population total and its estimated standard error using SRSWOR

Estimator	Standard Error of the Estimate
$\hat{t}_{SRS} = \sum_{j=1}^n \frac{N}{n} y_j$	$\sqrt{\left(\frac{N-n}{N(n-1)}\right) \left(\frac{1}{n} \sum_{j=1}^n (y_j - \bar{y})^2\right)}$, where $\bar{y} = \frac{1}{n} \sum_{j=1}^n y_j$

2.2 Sampling with Probability Proportional to Size (PPS)

In surveys of finite populations, auxiliary information is often available for every element in the population. It is a characteristic of sampling theory that it lays great emphasis on the use of auxiliary information for improving precision of estimation.

Consider a population $U = \{1, 2, \dots, N\}$ of N elements and let the value of the variable of interest for element i be denoted by Y_i . For sample generation, let n be the predetermined sample size and assume target inclusion probabilities π_i to be proportional to a size variable X_i known for all $i \in U$. Let $z_i = \frac{X_i}{\sum_{i=1}^N X_i}$ and assume

$$nz_i < 1 \text{ for all } i. \quad CF_k = \sum_{i=1}^k nz_i$$

The PPS sampling procedure is as follows:

- 1) Arrange the N population units in a random order and let $CF_0 = 0$ and $CF_k = \sum_{i=1}^k nz_i$ be the cumulative totals in that order so that $0 = CF_0 < CF_1 < \dots < CF_N = n$.
- 2) Let u be a uniform random number over $[0, 1]$. The n units to be included in the sample are those with indices k satisfying $CF_{k-1} < u + j < CF_k$ for $j = 0, 1, \dots, n-1$.

Let s be the set of n sampled units and $\pi_i = P(i \in s)$ be the first-order inclusion probability. The PPS sampling procedure satisfies the condition $\pi_i = nz_i$, for $i = 1, 2, \dots, N$. Table 2.2 shows the Hurvitz-Thompson estimator for the population total.

Table 2.2 Hurvitz-Thompson Estimator of the Population Total and its Estimate of the Standard Error

Estimator	Standard Error of the Estimate
$\hat{\tau}_{HT} = \sum_{j=1}^n \frac{y_j}{\pi_j}$	$\sqrt{\sum_{j=1}^n \sum_{k=1}^n \left(1 - \frac{\pi_j \pi_k}{\pi_{jk}}\right) \frac{y_j y_k}{\pi_j \pi_k}}$

The first-order inclusion probability is given by π_j and π_{jk} is the second-order inclusion probability. The Hurvitz-Thompson estimator for the population total is extremely efficient when Y is highly correlated with the size variable X .

2.3 Probability proportional to size sampling: Brewer's Method

This method is a fixed size procedure designed to handle the problem of PPS sampling when more than one unit is to be included in the sample. In this context,

the sample size is fixed at $n=2$. Let u_i be a uniformly distributed random number over the interval $(0,1)$ assigned to each unit in the population. Starting with a set of permanent random numbers $\{u_i; i=1,2,\dots,N\}$, the transformed random numbers are computed as

$$\xi_i = -\frac{\log(1-u_i)}{X_i \frac{1-X_i}{1-2X_i}}$$

The unit with the smallest ξ_i is selected as the first unit of the sample. Such a procedure is called Exponential Sampling, with modified transformed random numbers. After removing the unit drawn in the first round, a second unit is drawn with the original transformed random numbers of Exponential Sampling, given by

$$\xi_i = -\frac{\log(1-u_i)}{X_i}$$

Cochran shows that these two steps yield a sample of size 2 with the required inclusion probabilities equal to $\pi_i = nz_i$.

2.4 Sampling with Probability Proportional to Aggregate Size (PPAS)

A sample of size n is chosen by choosing the first unit, say i , with probability proportional to a known size measure $X_i > 0$ and the remaining $n-1$ units by the Simple Random Sampling without Replacement. It is known that the first-order inclusion probability π_i for unit i and the probability of selecting the sample $s = \{i_1, i_2, \dots, i_n\}$ are given by

$$\pi_i = \frac{n-1}{N-1} + \frac{(N-n)}{(N-1)} \cdot \frac{X_i}{\sum_{j=1}^N X_j} \quad \text{and}$$

$$P(s) = P(\{i_1, i_2, \dots, i_n\}) = \frac{1}{\binom{N-1}{n-1}} \cdot \frac{\sum_{i \in s} X_i}{\sum_{j=1}^N X_j}.$$

In PPAS sampling, the estimator of the population total and the standard error of the total is presented in Table 2.3.

Table 2.3 Estimator of Population Total and its Estimated Standard Error using PPAS

Estimator	Standard Error of the Estimate
$\hat{\tau}_{PPAS} = \sum_{i=1}^N X_i \frac{\sum_{j=1}^n y_j}{\sum_{j=1}^n X_j}$	$\sqrt{\left[\sum_{i=1}^n \sum_{i < j} \frac{(y_i + y_j)^2}{X_i + X_j} - \left(\sum_{i=1}^n y_i \right)^2 \right] \left(\frac{1}{N-1} \sum_{i=1}^N X_i \right)}$

The estimator of the variance of $\hat{\tau}_{PPAS}$ may yield negative values. A systematic bias will be induced if the variance estimates are restricted to zero.

2.5 Variance Estimation using Nonparametric Bootstrap Method

The bootstrap was first introduced by Efron (1979) for samples of independent and identically distributed observations from some distribution F . This is a basic approach to variance estimation under complex sampling designs.

The general process is as follows:

1. Observe a sample $y = \{y_1, y_2, \dots, y_n\}$.
2. Compute $\hat{\theta}(y)$ which estimates some parameter θ of the model.
3. For $i = 1$ up to s where s is the number of bootstrap samples being generated:
 - 3.1. Generate a bootstrap sample $y^k = \{y_1^k, y_2^k, \dots, y_n^k\}$ by sampling with replacement from the original observed sample.
 - 3.2. Compute $\hat{\theta}^k = \hat{\theta}(y^k)$ in the same way that the original estimate $\hat{\theta}(y)$ was calculated.
4. Compute the arithmetic mean and the variance of the $\hat{\theta}^k$'s as shown in Table 2.4.

Table 2.4 Arithmetic mean and variance of the estimator of the Bootstrap Samples

Mean	Variance
$\bar{\hat{\theta}} = \frac{\sum_k \hat{\theta}^k}{s}$	$\text{var}(\hat{\theta}^k) = \frac{\sum_k (\hat{\theta}^k - \bar{\hat{\theta}})^2}{s-1}$

Meanwhile, $\hat{\theta}$ is the estimated value of the parameter θ and $\sqrt{\text{var}(\hat{\theta}^k)}$ is the bootstrap estimate of the standard error of $\hat{\theta}$. The number of bootstrap samples s needs to be large but since the error in evaluating the variance decreases as $\frac{1}{\sqrt{s}}$, there is no point in making s too big.

3. Results and Discussion

The ratio estimator arrived at using Probability Proportional to Aggregate Size (PPAS) sampling was compared with the estimator of total using Simple Random Sampling without Replacement (SRSWOR) and Probability Proportional to Size without Replacement (PPSWOR). To perform the necessary comparisons, the three sampling designs were illustrated using the 2002 Census of Agriculture data set. The parameter that will be estimated is the total production area of top cereals grown in the country which are rice and corn as well as the top roots crops, in particular, cassava and sweet potato.

Table 3.1 presents the total number of farming households per region who engage in the production of the aforementioned crops. PPAS and SRSWOR were used to obtain 1%, 5% and 10% of the population as the samples. However, for PPSWOR only 1% sampling rate is used. This is so because PPSWOR is designed for selection of small samples only. Hence, for large samples (with 5% and 10% sampling rates), the estimates using PPAS will be compared to the estimates using SRSWOR. Comparison of PPAS, SRSWOR and PPSWOR Sampling is done only for 1% sampling rate.

With the seventeen political regions in the country as domain, the sampling units considered in this illustration are the farming households. The target variables are the production area of the aforementioned temporary crops. The auxiliary variable used is the crop area. Crop area, also called the gross area, is the area measured for cadastral purposes which includes the area cultivated, headlands, ditches and other non-cultivated areas. Meanwhile, production area is considered as the net area which includes only the portion of the gross area actually cultivated. Consequently, crop area is intuitively directly correlated to the total area harvested of crops. It was posited that the larger the crop area, the larger is the area harvested. However, there are some farmers who harvest several times in a year, which implies that the relationship between crop area and production area harvested is not necessarily direct.

Among the references used for sampling, Cochran (1977) presented straightforward formulas for the estimation of variance under several sampling designs. However, after implementing sampling with probability proportional

Table 3.1 Total Number of Farming Households per region who are engaged in the production of rice, corn, cassava and sweet potato

Region	Rice	Corn	Cassava	Sweet Potato
Region I	26384	5091	122	480
Region II	29794	26009	1433	3451
Region III	11267	481	555	699
Region IV-A	4201	1222	1472	1085
Region IV-B	4662	906	1362	1098
Region V	7754	2411	4656	3677
Region VI	16002	2816	2308	2230
Region VII	6800	10816	4296	3702
Region VIII	7461	1655	3213	2909
Region IX	2547	3129	2520	1970
Region X	6151	15824	6782	5819
Region XI	2590	4178	3618	3158
Region XII	6570	7827	2235	1792
CAR	10878	1708	401	1488
NCR	155	80	58	73
ARMM	3015	4518	1796	1069
CARAGA	1021	831	936	945

to aggregate size, determining the precision of estimators yielded problematic results. In particular, the variance estimators proposed in the literature produced negative values with appreciable probabilities. Thus, to derive a nonnegative variance estimator, an alternative approach utilized is the nonparametric bootstrap resampling method. To implement this method, 200 bootstrap resamples were taken. Estimates were computed from each of this resample, after which the average and standard deviation were calculated.

It should be noted that the tables hereafter present the bias and standard error estimates under SRSWOR, computed using equations presented in Table 2.1. Meanwhile, the precision of PPAS estimates is evaluated using nonparametric bootstrap variance estimation provided in Table 2.4. In addition, the highlighted values indicate better values after comparing the sampling designs.

3.1 Estimation of total rice production area

The regional estimates of the total rice production area (in hectares) using SRSWOR, PPAS and PPSWOR incorporating the three sampling rates are presented in Table 3.2.

Table 3.2 Regional Point Estimates of the Total Rice Production Area by sampling design and sampling rate

Region	Total	10%		5%		1%		
		SR-SWOR	PPAS	SR-SWOR	PPAS	SR-SWOR	PPAS	PPS
Region I	9193.55	8411.86	9278.08	8898.36	9279.75	8010.49	9675.72	2345.44
Region II	29378.22	28939.00	25341.58	30580.00	30696.88	29567.00	25740.45	28088.15
Region III	13368.61	13618.00	12750.21	15015.00	11604.46	13109.00	13560.55	4438.97
Region IV-A	3189.83	5331.56	3140.47	3071.87	3163.15	3171.27	6083.68	1893.33
Region IV-B	5401.84	4971.58	5408.31	6008.21	4124.53	4991.87	5890.95	8915.12
Region V	5738.66	5479.61	5319.63	5825.64	4226.09	5660.35	4694.00	1372.52
Region VI	11568.97	11232.00	11071.34	10777.00	11103.81	12150.00	5494.91	29154.65
Region VII	3490.26	2996.52	2859.54	3219.15	3190.48	2852.07	3971.96	106.07
Region VIII	6670.38	4871.51	4905.10	6420.87	5261.20	7939.71	9098.97	1937.62
Region IX	2538.88	3736.38	3022.37	2008.33	2254.71	3028.11	1445.29	688.44
Region X	6247.35	4409.06	6333.94	6969.92	5890.65	9666.85	10609.17	6576.45
Region XI	2641.16	2309.75	2315.76	2163.50	2253.97	4463.55	2517.75	519.37
Region XII	8002.85	9761.82	6515.97	8157.20	8046.62	6974.73	8954.85	1217.09
CAR	4200.03	3474.27	4041.30	4550.47	4552.04	3191.16	5641.58	19882.88
NCR	300.37	199.93	200.23	74.10	286.55	299.90	148.07	26.40
ARMM	2897.93	2944.04	2608.52	3132.03	3182.60	2329.54	2811.60	939.84
CARAGA	1045.30	1317.07	797.95	1321.77	985.28	1169.62	1209.65	395.27

Results in Table 3.3 showed that estimates of the total production area for rice using 10% and 5% sampling rates are generally biased across regions. Using PPAS, most of the regional estimates of the total rice production area yielded better values in terms of the bias than that of the SRSWOR. In particular, for both the 10% and 5% sampling rates, the Region I, Region IV-A Region IX, Region X, Region XI, Region XII, CARAGA and National Capital Region has lower values for the bias than its SRSWOR counterpart.

Table 3.3 also highlights that the precision estimates of PPAS is better than SRSWOR. Similarly, Table 3.4 presents that even for 1% sampling rate, PPAS yields better estimates of the standard error of the total production area compared to SRSWOR.

Using 1% sampling rate, the precision estimates of SRSWOR is remarkably inferior to the estimates of PPSWOR and PPAS as shown in Table 3.4. Among the latter two, PPAS has better precision estimates than PPSWOR for most of the regions. Only four regions namely, Region VII, Region VIII, CARAGA and National Capital Region have better precision estimates using the PPSWOR. Also, it could be seen that the difference in the estimates of PPAS and PPSWOR are not substantial unlike the standard error of the estimates of SRSWOR.

Table 3.3 Standard Error Estimates and Bias for Total Rice Production Area for 5% and 10% sampling rates

Region	10%				5%			
	Std Error of Total		Bias		Std Error of Total		Bias	
	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS
Region I	808.7	21.6	781.7	-84.5	382.1	33	295.2	-86.2
Region II	2011.4	164.9	439.2	4036.6	1142.2	203.1	-1201.8	-1318.7
Region III	1517.4	39.4	-249.4	618.4	1227.9	70	-1646.4	1764.2
Region IV-A	1821	20.7	-2141.7	49.4	305.2	27.7	118	26.7
Region IV-B	1063	28.2	430.3	-6.5	802.1	94	-606.4	1277.3
Region V	930.3	48.7	259	419	419.8	58.3	-87	1512.6
Region VI	1224.4	39.8	337	497.6	625	87.2	792	465.2
Region VII	439.6	35.2	493.7	630.7	301.3	45.8	271.1	299.8
Region VIII	844.6	145.7	1798.9	1765.3	444.5	108.5	249.5	1409.2
Region IX	1066.3	37.2	-1197.5	-483.5	248.6	35.8	530.6	284.2
Region X	905.2	44.8	1838.3	-86.6	931.7	46.8	-722.6	356.7
Region XI	530.1	17.7	331.4	325.4	276	27.4	477.7	387.2
Region XII	1709.1	140.5	-1759	1486.9	693.5	81.8	-154.3	-43.8
CAR	695.1	26.6	725.8	158.7	327.3	29.1	-350.4	-352
NCR	198.9	9.3	100.4	100.1	48.9	4.3	226.3	13.8
ARMM	1105.2	28.6	-46.1	289.4	311.7	21.7	-234.1	-284.7
CARAGA	576.7	8.8	-271.8	247.3	430.6	14.3	-276.5	60

It is interesting to note that NCR and CARAGA are the bottom two regions in terms of the number of farming households engaging in rice production. Also, Region VI is dubbed as the rice granary of the Visayas region indicating higher production compared to Regions VII and VIII. This is a plausible explanation for the higher variability observed in the rice production area among the farming households especially if the sampling rate considered is small.

Comparing the three sampling rates, Tables 3.3 and 3.4 illustrate that the PPAS estimates in Regions I, XI and XII are superior to their SRSWOR counterpart in terms of both bias and standard error of the total. Based on the descriptive indices of the different regions, Region I have the smallest variability of the rice production area. This resulted to the better performance of PPAS.

On the other hand, the better performance of PPAS in Region XII is attributed to the fact that Region XII leads the other Mindanao regions in terms of total rice production and area harvested, and even ranks among the top five rice-producing regions in the country. Though Davao region exhibits among the lowest volume

Table 3.4 Standard Error Estimates and Bias for Total Rice Production Area for 1% sampling rate

Region	Std Error of Total			Bias		
	SRSWOR	PPS	PPAS	SRSWOR	PPS	PPAS
Region I	697.8	1100.9	55.4	1183.1	6848.1	-482.2
Region II	2565	12483.6	203.6	-188.8	1290.1	3637.8
Region III	1665	2496.9	198.9	259.6	8929.6	-191.9
Region IV-A	702.8	1062.1	84.1	18.6	1296.5	-2893.9
Region IV-B	990.9	6686.3	81.7	410	-3513.3	-489.1
Region V	852.3	1000.3	129.8	78.3	4366.1	1044.7
Region VI	1323.1	25368.3	239.2	-581	-17585.7	6074.1
Region VII	492.3	43.7	57.5	638.2	3384.2	-481.7
Region VIII	1303.7	215.3	243.1	-1269.3	4732.8	-2428.6
Region IX	844.8	98.3	52.7	-489.2	1850.4	1093.6
Region X	2196.6	3288.2	178.5	-3419.5	-329.1	-4361.8
Region XI	1313.4	180.6	58.6	-1822.4	2121.8	123.4
Region XII	1061.2	1127.8	102.7	1028.1	6785.8	-952
CAR	740.8	4364.5	92.3	1008.9	-15682.8	-1441.5
NCR	172.2	0.8	13	0.5	274	152.3
ARMM	611.9	769	65.1	568.4	1958.1	86.3
CARAGA	507.8	26.4	39.3	-124.3	650	-164.3

of rice production and area harvested, this region has consistently obtained the highest average yield per hectare among the six Mindanao regions (BAS, 2004). The Department of Agriculture claims that this trend in the Davao provinces is due to the high rate of adoption of modern rice varieties (especially hybrid in recent years) and to the availability of good water supply.

Another striking result is that ARMM yielded a better value for the bias for 1% sampling rate only. This is so because ARMM is known as a principal growing area for cassava instead of rice. Evidently, cassava figures largely in the diet of the Muslim population in Lanao del Norte, Lanao del Sur and Cotabato. In fact, highest per capita consumption of cassava in the Philippines is in the islands situated in the Sulu Archipelago where cassava is the staple food.

3.2 Estimation of total corn production area

After employing the three sampling designs and sampling rates, the computed estimates for the total corn production area per region are shown in Table 3.5.

Table 3.5 Regional Point Estimates of the Total Corn Production Area by sampling design and sampling rate

Region	Total	10%		5%		1%		
		SR-SWOR	PPAS	SR-SWOR	PPAS	SR-SWOR	PPAS	PPS
Region I	1393.08	1346.77	1475.26	764.54	1514.98	135.71	1265.72	580.40
Region II	23147.01	23572.43	23089.96	11879.68	26211.31	2221.05	28663.70	1355.24
Region III	339.82	346.48	276.69	128.45	741.72	53.99	397.57	22.95
Region IV-A	502.19	537.41	657.45	284.57	375.49	58.58	230.95	42.80
Region IV-B	432.54	529.42	594.77	181.13	495.74	54.72	441.59	2.46
Region V	1417.94	1271.23	1211.11	707.49	767.24	148.08	985.36	5.92
Region VI	1475.01	1613.39	1342.12	738.69	1360.41	239.54	1495.05	1490.00
Region VII	4161.71	4290.67	4024.82	1816.28	2399.71	459.13	4944.27	616.51
Region VIII	624.11	765.71	522.61	376.70	979.21	69.70	1071.04	529.53
Region IX	5309.98	2357.49	2495.28	1197.35	1407.58	507.64	2601.09	3248.40
Region X	16808.33	17270.76	18582.89	8377.93	23575.33	1682.01	20897.71	10952.12
Region XI	3163.58	3167.36	3142.62	1584.19	2653.28	349.63	2660.80	349.91
Region XII	11145.52	10557.22	11205.12	5187.56	18697.32	1190.29	9446.82	4959.54
CAR	1116.87	1134.61	1868.23	562.97	912.57	134.35	493.54	1233.06
NCR	105.07	40.79	138.79	80.42	324.57	0.09	462.49	207.42
ARMM	4299.25	4058.74	4265.54	2215.50	3021.55	416.84	5637.63	787.64
CARAGA	648.52	607.56	730.75	329.54	538.32	66.28	1143.85	243.86

The bias and standard error estimates of the total production area for corn using 10% and 5% sampling rates are presented in Table 3.6. With 10% sampling rate, the precision estimates using PPAS is better across all the regions. For the 5% sampling rate, the precision estimates using PPAS is better among all provinces except Region III, Region VII and Region XII.

Similar to the estimation of total rice production area, the estimates for the total corn production area are generally biased across the regions; most of which are overestimates. For both the 10% and 5% sampling rates, the Region II, Region VI, Region IX, and ARMM has lower values for the bias using PPAS compared to SRSWOR. Conversely, Region III has a lower bias using SRSWOR for the two sampling rates.

Based on Table 3.7 most of the precision estimates arrived at using SRSWOR is superior to both PPSWOR and PPAS. However, PPAS has better precision estimates than PPSWOR for most of the regions. Also, it could be seen that the difference in the estimates of PPAS and SRSWOR are not substantial unlike the standard error of the estimates of PPSWOR.

Table 3.6 Standard Error Estimates and Bias for Total Corn Production Area for 5% and 10% sampling rates

Region	10%				5%			
	Std Error of Total		Bias		Std Error of Total		Bias	
Region	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS
Region I	70.2	7.3	46.3	-82.2	51.1	22.8	628.5	-121.9
Region II	466.6	53.3	-425.4	57	378.6	159	11267.3	-3064.3
Region III	52.1	3.9	-6.7	63.1	27.8	29.6	211.4	-401.9
Region IV-A	77.2	8.2	-35.2	-155.3	54.3	13.6	217.6	126.7
Region IV-B	110.6	6.4	-96.9	-162.2	34.9	21	251.4	-63.2
Region V	113.4	13	146.7	206.8	76.7	36.3	710.5	650.7
Region VI	143.6	18.4	-138.4	132.9	61.6	27.4	736.3	114.6
Region VII	208.4	68.7	-129	136.9	86.6	88.8	2345.4	1762
Region VIII	121.7	7.8	-141.6	101.5	82.5	25.4	247.4	-355.1
Region IX	159	25.2	2952.5	2814.7	118.9	45.8	4112.6	3902.4
Region X	500	96.1	-462.4	-1774.6	355.8	213.9	8430.4	-6767
Region XI	138.4	20.7	-3.8	21	133.5	50.5	1579.4	510.3
Region XII	307.4	54.5	588.3	-59.6	214.9	627.5	5958	-7551.8
CAR	127.2	18.2	-17.7	-751.4	87.3	23.1	553.9	204.3
NCR	12.8	7.4	64.3	-33.7	79.9	15.9	24.6	-219.5
ARMM	168.1	25.2	240.5	33.7	127.2	80.1	2083.7	1277.7
CARAGA	59.7	7.7	41	-82.2	56	10	319	110.2

In terms of bias, using PPAS yielded lower values except for Region VIII, NCR and CARAGA. About 60% of the country's annual corn production is from Mindanao, and of this island's six main corn production areas, the CARAGA region has the lowest average yield production in 2005. This is mainly attributed to low adoption of modern corn production technologies and use of low yielding traditional or open-pollinated varieties by the farmers (FFTC Annual Report, 2007). The lowest number of farming households involved in the production of corn is found in NCR. Region VIII is also among the regions with relatively low number of farming households planting corn compared to the regions known to be the major corn producers. This posits that selecting a small sampling rate is most likely an underestimation or overestimation of the actual population value.

In lieu with this, estimates using SRSWOR may have yielded better precision estimates but the bias is notably high. Combining both standard error and bias as basis for comparison, PPAS provides better estimates in general.

Tables 3.6 and 3.7 reveal that the PPAS estimates of Region VI and Region IX are superior in terms of both bias and standard error of the total. In addition,

Table 3.7 Standard Error Estimates and Bias for Total Corn Production Area for 1% sampling rate

Region	Std Error of Total			Bias		
	SRSWOR	PPS	PPAS	SRSWOR	PPS	PPAS
Region I	15.8	411.7	17.8	1257.4	981.3	127.4
Region II	115.1	43.7	186.1	20926	23103.3	-5516.7
Region III	23.5	22.7	15.1	285.8	317.2	-57.7
Region IV-A	19.4	41.7	9.2	443.6	460.5	271.2
Region IV-B	16.4	1.8	20.9	377.8	430.7	-9.1
Region V	29.8	5.5	14.4	1269.9	1412.5	432.6
Region VI	65.7	1268.3	31.8	1235.5	206.7	-20
Region VII	50.1	549.1	109.4	3702.6	3612.6	-782.6
Region VIII	18.6	513.9	48.6	554.4	110.2	-446.9
Region IX	295.8	1299.4	65.4	4802.3	4010.6	2708.9
Region X	119.3	5736.8	196.2	15126.3	11071.5	-4089.4
Region XI	45.3	348.2	48	2813.9	2815.4	502.8
Region XII	167.7	3792.6	162.2	9955.2	7352.9	1698.7
CAR	26.6	230.6	53	982.5	886.3	623.3
NCR	0	30.5	14.3	105	74.6	-357.4
ARMM	69.5	719.8	96.2	3882.4	3579.4	-1338.4
CARAGA	16.3	166.9	48.6	582.2	481.7	-495.3

PPAS estimates for Region II and ARMM yielded better estimates than the other sampling designs especially when the sampling rate is high (10% or 5%). These regions, together with Region VI and Region IX are known as major corn producers in the country.

3.3 Estimation of total cassava production area

Table 3.8 presents the regional estimates of the total cassava production area (in hectares) using SRSWOR, PPAS and PPSWOR and utilizing three sampling rates.

Table 3.9 presents the bias and the estimated standard error of total area estimates of cassava production under SRSWOR and PPAS. For both 5% and 10% sampling rates, the estimated standard error of PPAS estimates are all smaller than SRSWOR estimates. However, bias is generally higher for PPAS estimates than for SRSWOR. Only the Region III and Region XII showed lower bias under PPAS for both 10% and 5% sampling rates.

Nonparametric Bootstrap estimates of the precision of PPAS estimates of total area of cassava production show that indeed PPAS is a better sampling design than SRSWOR under 5% and 10% sampling rates. However, the general distribution

Table 3.8 Regional Point Estimates of the Total Cassava Production Area by sampling design and sampling rate

Region	Total	10%		5%		1%		
		SR-SWOR	PPAS	SRSWOR	PPAS	SR-SWOR	PPAS	PPS
Region I	12.06	23.23	6.37	8.77	3.12	30.68	67.50	2.54
Region II	121.62	136.45	178.40	83.07	198.87	293.67	64.58	28.14
Region III	171.63	77.62	128.83	349.79	176.19	69.75	152.50	127.77
Region IV-A	162.69	215.58	221.94	118.75	255.26	161.72	108.61	32.16
Region IV-B	172.28	148.95	232.58	209.97	195.69	254.50	84.56	17.95
Region V	492.75	500.83	425.61	507.88	574.24	813.21	1042.42	42.95
Region VI	103.57	102.57	70.37	82.83	74.25	105.88	36.63	0.29
Region VII	458.39	436.81	510.29	421.25	413.24	250.37	687.29	724.19
Region VIII	348.71	321.88	389.99	392.52	329.36	709.68	194.44	707.21
Region IX	375.50	396.51	414.38	410.48	538.91	399.52	242.03	1034.01
Region X	913.96	706.98	897.86	958.38	844.83	998.25	921.42	8.97
Region XI	275.08	304.44	199.67	204.79	290.99	151.76	129.92	143.02
Region XII	133.36	433.08	89.82	89.22	103.10	55.10	136.28	2.59
CAR	5.32	2.93	1.65	10.77	1.24	0.88	0.71	0.30
NCR	47.30	10.46	380.98	41.62	442.89	1392.00	6.45	0.54
ARMM	431.10	457.77	412.72	462.37	504.15	279.68	336.36	9.56
CARAGA	172.47	197.26	135.30	168.98	161.39	244.39	71.65	9.26

of the bias between the two competing sampling designs weakens the obvious conclusion at first glance. It is noteworthy to mention that total area of cassava production is measured at the province level, hence, making the measurements at the regional level an aggregate. These aggregate measurements can induce bias and affect precision of estimates.

Hard facts in the Philippine provinces can possibly provide insights about estimated total area of cassava production. In 2002, the five major producers of cassava in the country are ARMM, Region V, Region X, Region VII, and Region IV-A. Six provinces have been identified as best suited for growing cassava in the study of Ranola et al. (2009). These provinces are Sarangani, South Cotabato, Sultan Kudarat, Misamis Oriental, General Santos and Zambales, which are located at the regions of Region XII, Region X and Region III. Furthermore, cassava consumption is highest in Sulu archipelago, which is located in ARMM.

PPAS estimates under 10% have lower bias at the major cassava producers, which are ARMM and Region X, and also at regions best suited for cassava production, which are Region XII, Region X and Region III. However under 5%, PPAS estimates are shown to have lower bias only at regions best suited for cassava production, which are Region XII and Region III.

Table 3.9 Standard Error Estimates and Bias for Total Cassava Production Area for 5% and 10% sampling rates

Region	10%				5%			
	Std Error of Total		Bias		Std Error of Total		Bias	
	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS
Region I	15	0.2	-11.2	5.7	4.2	0.1	3.3	8.9
Region II	54.3	6.1	-14.8	-56.8	20	10.8	38.5	-77.3
Region III	24.5	3.3	94	42.8	199.2	5.4	-178.2	-4.6
Region IV-A	55.9	4.1	-52.9	-59.3	29.8	5.5	43.9	-92.6
Region IV-B	27.5	3.8	23.3	-60.3	64.6	3.6	-37.7	-23.4
Region V	88.3	5.7	-8.1	67.1	87.7	6.6	-15.1	-81.5
Region VI	18.5	1.9	1	33.2	16.7	1.5	20.7	29.3
Region VII	45.1	6.8	21.6	-51.9	51.9	10.5	37.1	45.2
Region VIII	33.6	4	26.8	-41.3	62.4	4.1	-43.8	19.3
Region IX	69	4.2	-21	-38.9	77.3	14.4	-35	-163.4
Region X	73.5	7.1	207	16.1	156.5	10.2	-44.4	69.1
Region XI	44.6	2.4	-29.4	75.4	41.3	3.8	70.3	-15.9
Region XII	320	2.2	-299.7	43.5	24.7	6.1	44.1	30.3
CAR	0.7	0.1	2.4	3.7	5.3	0.1	-5.5	4.1
NCR	9.5	20.3	36.8	-333.7	16.4	35.9	5.7	-395.6
ARMM	58.7	4.4	-26.7	18.4	80.6	7.2	-31.3	-73.1
CARAGA	47.4	2.1	-24.8	37.2	80.3	6.3	3.5	11.1

This tells us that in this case, PPAS provides more precise estimates than SRWOR since the latter cannot accommodate the error induced by aggregating measurements. Bias of estimates yielded by PPAS, regardless of the sampling rates, tend to be lower when the samples are taken from regions which are either major producer or best suited for cassava production.

It can be seen from Table 3.10 that in general, more regions have lower standard error estimates for the total production area using PPAS. However, the following regions yielded lower standard error estimates using PPSWOR Sampling: Region I, Region VI, Region X, Region XII, and ARMM.

When it comes to having lower bias, the results of the estimates under PPAS and SRSWOR are almost comparable. PPAS estimates have lower bias at the following regions: Region II, Region III, Region IV-A, Region VIII, Region X, Region XII, NCR, and ARMM.

Small samples are generally preferred to large samples when estimation cost is a major setback. The compromise comes in by getting accurate but less precise estimates under PPAS. As an alternative, PPS Sampling seems to produce more precise but less accurate estimates.

Table 3.10 Standard Error Estimates and Bias for Total Cassava Production Area for 1% sampling rate

Region	Std Error of the Total			Bias		
	SRSWOR	PPS	PPAS	SRSWOR	PPS	PPAS
Region I	30.3	0.9	18.8	-18.6	9.5	-55.4
Region II	191.4	27.6	2.4	-172.1	93.5	57
Region III	47.3	55.2	9.7	101.9	43.9	19.1
Region IV-A	98.2	25.3	4.6	1	130.5	54.1
Region IV-B	98.4	8.2	5.7	-82.2	154.3	87.7
Region V	310.6	42.6	31.3	-320.5	449.8	-549.7
Region VI	59.4	0.3	1.5	-2.3	103.3	66.9
Region VII	64.2	324.6	17.5	208	-265.8	-228.9
Region VIII	326.3	705	8.8	-361	-358.5	154.3
Region IX	114.6	1032.9	6.7	-24	-658.5	133.5
Region X	251	6.1	23	-84.3	905	-7.5
Region XI	58.7	61.3	4.1	123.3	132.1	145.2
Region XII	33.2	2.3	9.8	78.3	130.8	-2.9
CAR	0.3	0.2	0	4.4	5	4.6
NCR	0	0.5	0.3	-1344.7	46.8	40.8
ARMM	80.5	8.5	12.4	151.4	421.5	94.7
CARAGA	56.5	8.5	2.6	-71.9	163.2	100.8

3.4 Estimation of total sweet potato production area

Table 3.11 shows the computed estimates for the total sweet potato production area per region after employing the three sampling designs and sampling rates.

Evaluation of estimates of total area for sweet potato production is done by comparing bias and estimated standard error under SRSWOR and PPAS, which are presented in Table 3.12. The quality of the estimates is much harder to interpret for sweet potato production compared to the other crops. It can be seen that precision and unbiasedness of PPAS estimates do not go hand in hand. For most of the regions, the estimates for total area of production tend to be either only one of the two criteria. The same can be said about the behavior of the estimates under 1%, 5%, and 10% sampling rates. There is no distinct pattern that can be useful in explaining the results.

The only desirable conclusion for total area of sweet potato production is that for both 5% and 10% sampling rates, PPAS produced lower standard error estimates and thus, yielded more precise estimates than SRSWOR. When it comes to bias, SRSWOR produced lower bias for most of the regions. For 5% and 10% sampling rates, PPAS estimates consistently turned out to be better both

Table 3.11 Regional Point Estimates of the Total Sweet Potato Production Area by sampling design and sampling rate

Region	Total	10%		5%		1%		
		SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS	PPS
Region I	20.62	24.03	32.60	42.60	31.10	7.78	64.57	37.80
Region II	214.02	224.90	208.90	245.86	203.44	239.30	53.67	332.05
Region III	113.56	117.85	271.92	99.64	121.09	131.11	296.58	463.03
Region IV-A	118.82	102.39	142.05	190.19	214.74	269.08	103.87	125.61
Region IV-B	70.20	80.61	71.53	62.43	70.18	34.34	91.31	2.06
Region V	387.23	471.92	282.95	396.26	388.12	254.31	332.07	28.41
Region VI	83.75	62.33	57.75	63.95	130.81	40.82	52.20	2.83
Region VII	309.85	308.50	300.37	280.50	213.53	265.37	223.02	106.58
Region VIII	320.59	299.54	454.55	252.01	309.46	247.17	481.02	297.37
Region IX	208.35	216.15	296.87	283.94	52.85	180.45	170.60	90.41
Region X	510.26	536.67	420.30	445.22	395.80	612.28	349.99	2.61
Region XI	408.95	403.17	421.71	441.90	506.57	840.72	244.33	343.31
Region XII	100.99	181.20	111.79	106.23	90.20	146.65	453.63	0.90
CAR	139.50	132.57	129.61	149.47	132.15	71.13	58.20	0.54
NCR	20.68	3.64	17.81	4.64	3.57	109.50	29.36	4.24
ARMM	94.67	59.66	105.02	138.06	100.78	125.75	194.72	0.93
CARAGA	210.27	148.83	262.86	351.70	280.71	212.81	230.79	23.93

in terms of precision and unbiasedness only for Region II, Region IV-B, ARMM and CARAGA. In 2002, the five major sweet potato producers in the country are Region V, Region VII, Region VIII, CARAGA and Region IV-A.

With only precision as the criteria for evaluating the quality of estimates of total area for sweet potato production, the obvious conclusion is that PPAS is better than SRSWOR for both 5% and 10% sampling rates. Looking at another important criteria, which is the bias of the estimates, SRSWOR seem to be superior to PPAS.

For 1% sampling rate presented in Table 3.13, it can be concluded that PPAS performed better in terms of precision for most of the regions. The following regions have lower estimates of standard error under PPAS: Region II, Region III, Region IV-A, Region VII, Region VIII, Region IX, Region XI and CARAGA.

The same can be observed in terms of unbiasedness. PPAS yielded lower bias only for the following regions: Region IV-B, Region V, Region VI, Region X and NCR.

Table 3.12 Standard Error Estimates and Bias for Total Sweet Potato Production Area for 1% sampling rate

Region	10%				5%			
	Std Error of Total		Bias		Std Error of Total		Bias	
	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS	SRSWOR	PPAS
Region I	9.2	0.9	-3.4	-12	22.4	1.1	-22	-10.5
Region II	32.9	2.3	-10.9	5.1	71.6	3	-31.8	10.6
Region III	45	4.8	-4.3	-158.4	60.6	4.7	13.9	-7.5
Region IV-A	23.3	2.7	16.4	-23.2	83	3.9	-71.4	-95.9
Region IV-B	21	1.4	-10.4	-1.3	24.1	2.1	7.8	0
Region V	52.7	2.9	-84.7	104.3	50.3	6.5	-9	-0.9
Region VI	11.4	0.9	21.4	26	17.1	2.7	19.8	-47.1
Region VII	48.4	5.5	1.3	9.5	46.4	4	29.4	96.3
Region VIII	34.3	5.7	21.1	-134	38.6	18.4	68.6	11.1
Region IX	34.7	4.7	-7.8	-88.5	68.9	3	-75.6	155.5
Region X	63.1	4.8	-26.4	90	60.8	4.6	65	114.5
Region XI	64.4	5.7	5.8	-12.8	88.8	6.9	-33	-97.6
Region XII	100.5	2.3	-80.2	-10.8	26.3	1.8	-5.2	10.8
CAR	26.1	2.8	6.9	9.9	40.8	3.9	-10	7.4
NCR	2.2	0.8	17	2.9	4.5	0.3	16	17.1
ARMM	14.2	2.4	35	-10.3	37.1	2.5	-43.4	-6.1
CARAGA	20.6	6	61.4	-52.6	95.9	6.4	-141.4	-70.4

4. Conclusion and Direction for Future Research

Implementation of sampling with Probability Proportional to Aggregate Size (PPAS) produced biased estimates. In estimating the total rice production area, most of the PPAS regional estimates have lower bias using 10% or 5% sampling rates while SRSWOR provides better values when small sampling rate is selected. Moreover, in terms of the precision of the estimates, PPAS is better than SRSWOR across all regions when 10% or 5% of the population is selected as sample. In fact, for small samples, SRSWOR is remarkably inferior to the estimates of PPSWOR and PPAS. Between PPAS and PPSWOR, PPAS has better precision estimates than PPSWOR for most of the regions. Only Regions III, VIII, CARAGA and NCR have better precision estimates using PPSWOR but the difference in the precision estimates are not substantial.

For total corn production area, precision estimates using PPAS are better than SRSWOR among all the regions if the sampling rate used is 10%. With a decrease in the value of the sampling rate, there is also an observable decrease

Table 3.13 Standard Error Estimates and Bias for Total Sweet Potato Production Area for 1% sampling rate

Region	Std Error of the Total			Bias		
	SRSWOR	PPS	PPAS	SRSWOR	PPS	PPAS
Region I	4.1	37.4	7.6	12.8	-17.2	-44
Region II	111.5	294.5	2.3	-25.3	-118	160.3
Region III	97.6	418.9	9.7	-17.6	-349.5	-183
Region IV-A	150.4	113.6	3.6	-150.3	-6.8	15
Region IV-B	20	0.7	4.9	35.9	68.1	-21.1
Region V	105.6	4.6	10.1	132.9	358.8	55.2
Region VI	15.5	0.5	1.8	42.9	80.9	31.6
Region VII	84.4	76.1	7.1	44.5	203.3	86.8
Region VIII	65.1	297.4	13.4	73.4	23.2	-160.4
Region IX	57.9	33.3	9.3	27.9	117.9	37.7
Region X	148.9	2.1	9.3	-102	507.7	160.3
Region XI	495.3	194	7.2	-431.8	65.6	164.6
Region XII	69.7	0.8	18.9	-45.7	100.1	-352.6
CAR	48.6	0.5	3	68.4	139	81.3
NCR	0	4.2	1.3	-88.8	16.4	-8.7
ARMM	94.9	0.9	13	-31.1	93.7	-100.1
CARAGA	52.6	23.4	7.3	-2.5	186.3	-20.5

in the number of regions with better precision estimate using PPAS. In the case of small sampling rate, SRSWOR may have yielded better precision estimates but the bias is notably high. Combining both standard error and bias as basis for comparison, PPAS provides better estimates in general.

PPAS precision estimates of total area of cassava production are all smaller than SRSWOR estimates using 5% and 10% sampling rates. In general, more regions have lower standard error estimates for the total production area using PPAS. However, Regions I, VI, X, XII and ARMM yielded lower standard error estimates using PPSWOR Sampling with 1% sampling rate. In general, estimates of total area for cassava production in Regions III and XII using PPAS yielded lower bias across three different sampling rates.

For both 5% and 10% sampling rates, PPAS produced lower standard error estimates and thus, yielded more precise estimates of total sweet potato production area than SRSWOR. For 1% sampling rate, PPAS also performed better in terms of precision for most of the regions. Region IV-B is the only region which consistently produced lower bias across all sampling rates using PPAS.

Comparing both bias and standard error of the total, the PPAS estimates of total rice production area in Regions I, XI and XII are superior to their SRSWOR

counterpart. On the other hand, PPAS estimates of total corn production area are consistently superior in Region VI and IX based on the precision and validity. In addition, PPAS estimates for Regions II and ARMM yielded better estimates than the other sampling designs especially when the sampling rate is high (10% or 5%).

It is noteworthy that the regions with superior PPAS estimates of the total rice production area are those regions which are known as major producers of the said crop. The same is true for the regional estimates of the total corn production area. Moreover, the Region IX consistently has superior estimates for total rice production area and total corn production area using PPAS.

Evaluation of the optimality of estimates of total area for cassava and sweet potato production is much harder to interpret compared to the cereals. It can be seen that precision and unbiasedness of PPAS estimates do not go hand in hand. For most of the regions, the estimates for total area of production tend to be either only one of the two criteria. There is no distinct pattern that can be useful in explaining the behavior of results using the three sampling rates.

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