Sugar Demand and Supply Analysis along Sugarcane Value Chain in Myanmar Sugar Industry
Part I. Sugarcane Supply Side Study[1]

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Background Context

In the implementation of AFSIS Project on Improving Statistics Data on Food Processing and Distribution Related to Sugarcane Crops in Myanmar, the study team has set up the research projects under two broad program as following;

Sugar demand side program	Sugar supply side program
Direct sugar consumption survey by household members in the whole country	Establishment of optimum sample size and determination of sugarcane yield
Survey on sugar consumption by domestic food industry	Estimation of cane acreage and production of out-growers for cottage -scale jaggery production
Survey on Sugar processing, marketing & trade, distribution and commodity inflow and outflow	Census of actors in sugarcane and sugar production at each sugar factory

In attempt to carry out these programs, Department of Agricultural Land Management and Statistics (DALMS) and Department of Agriculture (DOA)under Ministry of Agriculture, Livestock and Irrigation (MOALI) has collaborated to conduct research supply side studies and demand side studies respectively with approval of each Director General and the departmental activities are coordinated by the AFSIS Consultant U San Thein to avoid gaps and discrepancies and to ensure smooth and full stream of the program activities. Each side is performing the activities in detail as shown below;

Supply side activities by Statistics Division, DALMS, MOALI	Demand Side study by partner agency: Sugar Crop Division, DoA, and DALMS, MOALI.
Establishment of optimum sample size for cane yield estimation, November, 2018	Departmental mutual agreement process for joint study program on sugar demand side study, December, 2018
Training for field surveyors for cane yield	Designing the sugar direct consumption

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estimation, 22 December, 2018	survey, 7 January, 2019.
Collecting data, census, and field survey by DALMS workers in over 30 selected townships , December to February, 2019; Compile results; report writing 10 February, 2019.	Training the 45 enumerators for direct sugar consumption survey in selected townships of all regions and states, 28 January, 2019 and conducting survey

Objectives of the Overall Study Program

1. To conduct sugar cane production survey in new sugar factories investment areas and assess levels of sugarcane yield estimation with reliable degree of confidence interval
2. To establish a reliable statistical system of cane production estimate in place of crop census from parcels to parcels of all farmers' farm holdings for future program
3. To conduct direct sugar consumption survey by household members and types and amounts of sugar used in the food industry and sugar downstream industries.
4. To make a balance sheet of sugar demand and supply situation to help formulate the sugar import policy

Why cane yield estimate is important?

Sugarcane yield estimates provide the basis for scheduling cane supply to the factory to meet its daily crushing capacity. There must be a precise schedule of cane procurement program which in fact is dependent upon the estimate of sugarcane production. Controversy always exists between factory staffs and field staffs as to the projected amount of cane supply. Both side argues as to the accuracy of the sample estimate. In Myanmar, rice yield estimation method has been well developed. But in sugar cane sub sector, standard statistical method of cane yield estimation has not been developed yet.

Determination of Optimum Cane Cutting Sample Size and Sugarcane Yield Estimation in Sugarcane Growing Areas

Sugarcane yield estimation is a well-planned activity of every sugar factory. Sugarcane yield estimates provide the basis for scheduling cane supply to the factory to meet its daily crushing capacity. The nature of the factory is a continuous process, operated round the clock. If cane supply is irregular, the factory could run out of balance in the throughput of not only materials but also energy and steam. This upset could lead to a huge financial loss. There must be a precise schedule of cane procurement program which in fact is dependent upon the estimate of sugarcane production.

Area forecasting and yield estimation are one of the major function of Department of Agricultural Land Management and Statistics (DALMS) and extension staffs of Sugar Crops Division of Department of Agriculture (DOA). There is a prescribed procedure of yield estimation in each department. The size of sample is prescribed to be 1/100 acre. Despite a well prepared sampling procedure, actual practice varies widely. Controversy always exists between factory staffs and field staffs as to the projected amount of cane supply. Both side argues as to the accuracy of the sample estimate. Sugarcane production by farmers is always associated with sugar production of the factory. Crop area census and crop yield estimate should be aligned with the amount of sugar production at the close of cane season. But these two parameters almost always diverged and at the close of the cane season, crop census data almost differed with the actual output of the sugar factory. Sugarcane yield estimates provide the basis for scheduling cane supply to the factory to meet its daily crushing capacity. There must be a precise schedule of cane procurement program which in fact is dependent upon the estimate of sugarcane production. Controversy always exists between factory staffs and field staffs as to the projected amount of cane supply. Both sides argue as to the accuracy of the sample estimate. In Myanmar, rice yield estimation method has been well developed. But in sugar cane sub sector, standard statistical method of cane yield estimation has not been developed yet.

Objectives

The objective of this study is to determine the optimum cane sample size and to estimate sugarcane yield with reliable degree of confidence interval.

(1)Determination of optimum sample number for cane yield estimate

Materials and Methods

Comparative sample sizes

With non-spaced crop such as sugarcane, individual plants are difficult to identify. Thus sampling in square or rectangular shape is not appropriate but instead sample unit based on the length of cane row (running ft) is selected. In Myanmar, majority of sugarcane row spacing are 4 ft(m) and 3½ (m). Sample sizes are then selected as follow;

For 4 ft-row spacing		**For 3.5 ft row spacing**	
Length of running ft (cane row)	**Size of sample (acre)**	**Length of running ft (cane row)**	**Size of sample (acre)**
11	0.001	12.45	0.001
22	0.002	24.90	0.002
44	0.004	49.80	0.004
55	0.005	62.30	0.005
88	0.008	99.60	0.008
110	0.01	124.50	0.01

Sampling Procedure

At least one-acre fields of commercial sugarcane production were selected in a given locality. The field should be planted to the same variety. The selected one-acre field was then divided into two blocks. In each block three sites were again demarcated by imaginary lines.

Two subsamples were again marked out in each site. The subsamples are the basic unit of sampling. Sampling was conducted in localities.

Prior to cane sampling, 11, 22, 44, 55, 88, and 110 ft. segments of cane rows were measured and demarcated by bamboo pegs. For sampling 88 and 110 ft cane row, the 44 and 55 ft. segments on pair rows were selected rather than continuous 88 and 110 ft. of simple cane row. Two subsamples in each of three sites of each field block were generated for each sample size.

Weighing and Measurement

The millable stalk number was counted in each selected sample size and then cut and weighted by dial balance (maximum weight 50 kg ± 0.2 kg) hanged in a bamboo tri-pod. The millable stalk number and cane yield were then computed on an acre basis.

Assumptions for Sampling

Two sources of variability are considered in sampling. The first one is variability among blocks in each field which is known as experimental error. The second is variability between sampling units within plots which represent the magnitude of sampling error.

When only one sample unit is drawn from each plot with the treatment (in this study, sample size), replicated for n_p plots, the variance of a treatment mean is S_p^2 / n_p, where S_p^2, the average mean square between plots approaches θ^2, the true variance of an individual plot as n_p becomes large.

However, Le Clerg *et al.*(1966) stated that when n_s sampling units are drawn from each plot, the variance of a treatment mean is S_p^2 / $n_p n_s$, where S_p^2 / n_p estimates θ_{p2}
, the true variance of an individual plot plus the true variance of an individual plot mean or θ^2/ n_p n_s. This follows because a plot mean is now subject to variation due to more than one sampling unit. It is evident that θ_s^2 is the true variance of an individual sampling unit taken from a plot. The above relationship may be indicated as follows.

$$\frac{S_p{}^2}{n_p n_s} \rightarrow \frac{\theta_p{}^2}{n_p} + \frac{\theta_s{}^2}{n_p n_s} = \frac{1}{n_p}\left\{\theta_p{}^2 + \frac{\theta_s{}^2}{n_s}\right\}$$

The left hand side approaches the right hand side as the number of degrees of freedom become large. Then

$$S_p{}^2 \rightarrow n_s \theta_p{}^2 + \theta_s{}^2$$

S_p^2= estimated error variance between plots

S_s^2= estimated error variance between sampling units within plots

n_s= number of sample units

n_p= number of replications

The variance components will be partitioned and the estimates of variance components will be used to determine the relationship between an increase in number of sampling units or

replications to reduction of experimental error. The next question to be address is how large a sample we need. As Snedcor and Cochran (1980) pointed out, the estimate is too accurate to be useful by making sample so small. Equally, the estimate is too accurate to be useful by making so small. Equally, the estimate is more accurate than we require by taking too large sample.
Thus the magnitude of allowable error (L) in terms of the confidence limit of the estimate could be set first.

Hence $\bar{y} \pm \frac{2s}{\sqrt{n}}$

we put $L = \frac{2s}{\sqrt{n}}$

This gives for the required sample size

$$n = \frac{4s^2}{L^2}$$

Results and Discussions

Table 1. Sample sizes and sampling variances related to cane yield and millable stalk population.

- **Cane yield (ton/acre)**

Sample size	**Experimental error**	**Sampling error**	**Mean yield mt/acre**
11 ft (0.001 acre)	112.62	85.76	30.53
22 ft (0.002 acre)	179.75	35.99	29.73
44 ft (0.004 acre)	73.83	35.85	29.71
55 ft (0.005 acre)	52.31	43.92	29.02
88 ft (0.008 acre)	38.90	30.74	28.73
110 ft (0.01 acre)	45.38	30.03	28.56

Table 1 gives the mean cane yield, sampling error, and true plot variance (experimental error). From (Table 1), it was found that sampling error decreases with increased size of sample. The sample size of 11 running ft (0.001 acre) gave the largest variance which then decreased by 50 percent in the sample size of 22 and 44 running ft. But the rate of error reduction did not appear stable even though the sample size increased to 55 running ft. (0.005 acre). The running feet of 88 and 110 showed the least sampling error. The estimate for mean cane yield was upward trend with decreasing sample size (Table 1). The estimated mean yield was 28.56 to 28.73 mt/acre in the respective 110 ft. and 88 ft. sample size while yield estimation for 11 ft sample size was 30.53 mt/acre.

The sources of variation and mean sums of square in the analysis of variance for sampling with six different sample sizes were shown in (Table 2). It indicates that the location but sample size did not significantly affect the estimated mean cane yield. As shown in (Table 1), the small sample size tended to estimate higher cane yield but as seen in (Table 2), there were no significant differences in cane yield in respective of sample size. However, the reliability of the estimated value or the degree of precision should be considered. It needs to find out the relation between increase in number of sample units or replication and reduction of experimental error.

Table 2. Sources of variation, experimental error and sampling error in sampling for sugarcane yield estimation.

Sources of variation	**df**	**Mean sums of square**
Location	4	7071.51*
Blocks within location	5	414.02
Site within block (experimental error)	20	266.48
Sample size (S)	5	33.43^{ns}
S x Location	20	19.33^{ns}
S x block (Location)	25	17.75^{ns}
S x Site within Block (L)	100	22.94
Sampling error	180	43.72
CV	**22.5%**	

*significant at P≤0.05, ^{ns} not significant

The magnitude of allowable error (L) in terms of the confidence limit of the estimate could be set first to determine optimum sample size (n).

Hence $\bar{y} \pm \frac{2s}{\sqrt{n}}$

we put $L = \frac{2s}{\sqrt{n}}$

where s = standard deviation

This gives for the required sample size

$$n = \frac{4s^2}{L^2}$$

The next step is to estimate the number of fields required to take sample for yield estimation. We wish to estimate the true mean yield within 1 mt/acre, with a 5% risk that the error will exceed 1 mt. Then

$$n = \frac{4S^2}{L^2}$$

The variance of the cane yield per acre from field to field was determined previously by San Thein et al., 2006 as follows;

$$S^2 = MSE = 266.48$$

$$L = 5 tons / acre$$

$$n = \frac{4S^2}{L^2} = \frac{4(266.48)}{L^2}$$
$$= \frac{4(266.48)}{25}$$
$$= 42.64 \, fields$$

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Results and Discussion

The results showed that at least 43 fields should be randomly surveyed for yield estimation if we wish to estimate the true mean yield within 5 tons/acre and the bound on the error of estimate was 5 percent. if we wish to estimate true mean yield within 1 ton/acre, we need to survey and conduct yield estimation from at least 1066 fields. There will be 1% risk that the error will exceed 1 ton/acre. Evidences from previous research activities indicate that small sample sizes tended to overestimate cane yield. The sample sizes of 88 and 110 running feet of sugarcane showed the least sampling error. For practical purposes, a pair of sugarcane rows of 44 running feet could be selected to achieve the same level of precision. In sampling practice, the cane field of at least one acre should be selected.

(2) Sugarcane yield estimation in sugarcane growing areas

(a)Materials and Methods

According to the finding of research 1, sugarcane yield estimation would be done from 43 fields of one acre size each in 9 townships in upper Myanmar and Shan State during 2018 December to 2019 January. These townships are ShweKu, HlaingBwe, Katha, Hteegiant, Paukaung, Thapaikkyin, Tagaung, Hsipwe and NaungCho. In each randomly selected field, cane field must be divided into two blocks. Within each block, three sample units will be selected. At each sample unit, sample size to be taken is twin row of 44 running feet. At the cane harvest season, millable cane stalks are cut from each sample unit, tied it into cane bundle and weighted by dial balance of at least 50 Kg. scale with a sensitivity of at least 0.2 Kg. Follow the Table 2 for data collection.

Sampling Procedure Diagram

Cane Field

Block I	Block II
	Sample Unit 1
	Sample Unit 2
	Sample Unit 3

Sub division of two blocks in each cane field; sub division of three samples units in each block. The average value of 43 fields of yield estimate sampling is considered to be the productivity of that project area. Yield estimate at each sample filed will be recorded in the following table format.

In each sample units(pair of 44 ft. cane rows), millable cane stalk is cut at the ground level to the TVD leave of each cane stalk. All cane stalks from the sample unit are weighted by digital balance (max 50 kg with 0.2 kg sensitivity). Millable cane stalk population is counted from the standard ground area (44 ft. X cane row distance in ft.). Ground space for border area is also taken into account in computing ground area of millable stalk. Farmers' practice of cane row spacing may vary from 3 ft to 6 ft. from these sample units. Sugarcane yield is estimated from the sample weight of cut cane stalk and cane population. .

Table 1. Sampling frame and data entry format

Township	Village	Selected filed no.	Block within field	sample unit within block, 2 X 44ft.	No. of millable cane stalks	cane stalk weight, kg
Kathar	AAA	1	1	1	X1	y1
				2	X2	y2
				3	X3	y3
			2	1	X4	y4
				2	X5	y5
				3	X6	y6
		2	1	1	X7	y7
				2	X8	y8
				3	X9	y9
			2	1	X10	y10
				2	X11	y11
				3	X12	y12
KaThar	BBB	3	1	1	X13	y13
				2	X14	y14
				3	X15	y15
			2	1	X16	y16

				2	X17	y17
				3	X18	y18
		4	1	1	X19	y19
				2	X20	y20
				3	X21	y21
			2	1	X22	y22
				2	X23	y23
				3	X24	y24
KaThar	CCC	5	1	1	X25	Y25
				2	X26	y26
				3	X27	y27
			2	1	X28	y28
				2	X29	y29
				3	X30	y30
		6	1	1	X31	y31
				2	X32	y32
				3	X33	y33
			2	1	X34	y34
				2	X35	y35
				3	X36	y36
KaThar	DDD	7	1	1	X37	y37
				2	X38	y38
				3	X39	y39
			2	1	X40	y40
				2	X41	y41
				3	X42	y42
About 6 townships						
Total		43 Fields			X258	Y258

= 258 total sample units for the whole project area

Cane yield was estimated in MT per acre. Yield component data was also collected. These variables are cane stalk population per acre, and unit cane weight, kg. Training for sugarcane sampling: One day training and demonstration and data analysis was conducted at Pyinmana Sugarcane Research Station, Sugarcane Crops Division, and Department of Agriculture. Materials required for yield estimation is as follow;

- Dial balance (50 kg +/- 0.2 kg) = 4 numbers
- Bamboos for making tripod to hang dial balance
- Knife and twines
- Measuring tape 20 meter= 4

Figure 1. Use of tripod and dial balance (50 kg max) in weighing cane stalks in the field.

Nested cane yield estimation design;

- 9 townships (T) are selected. (Fixed effect). T_i
- 3 Village tracts (VT) in each township is randomly selected (Random effect). It is denoted as $VT_{j(i)}$
- 2 farmers' fields (F) are randomly selected in each Village Tract (VT). We denote it as $F_{k(j(i))}$
- Each filed (F) is divided into 2 Blocks (B). $B_{l(k(j(i)).}$
- In Each Block, 3 sampling units, each consisting of pair rows of 44 ft. running feet is selected.

ANOVA for Nested Sampling Design for cane yield estimate

Sources of variation	DF	F Test
T_i	9-1=8	$T_i / VT_{j(i)}$
$VT_{j(i)}$	9(3-1)= 18	$VT_{j(i)} / F_{k(j(i))}$
$F_{k(j(i))}$	9X3 (2-1)= 27	$F_{k(j(i))} / B_{l(k(j(i))}$
$B_{l(k(j(i))}$	9X3X2(2-1)=54	$B_{l(k(j(i))} / S_{n(l(k(j(i))}$
$S_{n(l(k(j(i))}$	9X3X2X2 (3-1)=216	Experimental error $S_{n(l(k(j(i)) /}{}^{e}$
Total	(9X3X2X2X3)-1=323	

From Estimated Mean Squares, 95 % Confidence Interval for cane yield is computed.

Results and Discussions

Results of pilot study conducted in Upper Myanmar and Shan State showed that sugarcane yield is estimated to be 32 MT per acre and the bound on the error of estimate is 5 MT per acre. This is a pilot study conducted in Upper Sagaing Region and Shan State. The previous gross estimate for national standard sugarcane yield was 25 MT per acre. It appears that the cane yield is slightly higher than the national average yield (Figure 2). It is because the yield estimate is conducted in plant cane area while ratoon cane fields are mostly harvested by farmers by the time of cane yield estimate. The national cane yield level is the average of plant and ratoon cane fields. Moreover, the sugarcane yield in Shan State areas is generally higher than that of lowland plain area such as Bago, Mandalay and Yangon regions. For the whole country, yield estimate could be generated from the representative field samples composite of all parts of the sugarcane growing areas including plant cane as well as ratoon cane in early (November) , mid (January) and late (February) cane seasons in the whole country.

Conclusion

Evidences indicate that small sample sizes tended to overestimate cane yield. The sample sizes of 88 and 110 running feet showed the least sampling error. For practical purposes, a pair of sugarcane rows of 44 ft and 55 running feet could be selected to achieve the same level of precision.

If we wish to estimate the true mean within 1 ton/acre, we need to conduct cane yield estimation at least on 1066 fields. There will be 1% risk that the error will exceed ±1 ton/acre. If we wish to estimate the true mean yield within 5 tons/acre, the number of 1-acre fields should be at least 43 fields to achieve 5% allowable error of estimate.

Estimated Mean Square (EMS) for Cane Yield Estimation and 95 % Confidence Interval of cane yield

Sources of variation	**DF**	**EMS**
Township	8	1711.91***
VT within Township	18	588.93 ***
Field within VT	27	152.92 **
Block within Field	54	55.87 ns
Sample units within Block (Experimental error)	216	98.55
Total	323	

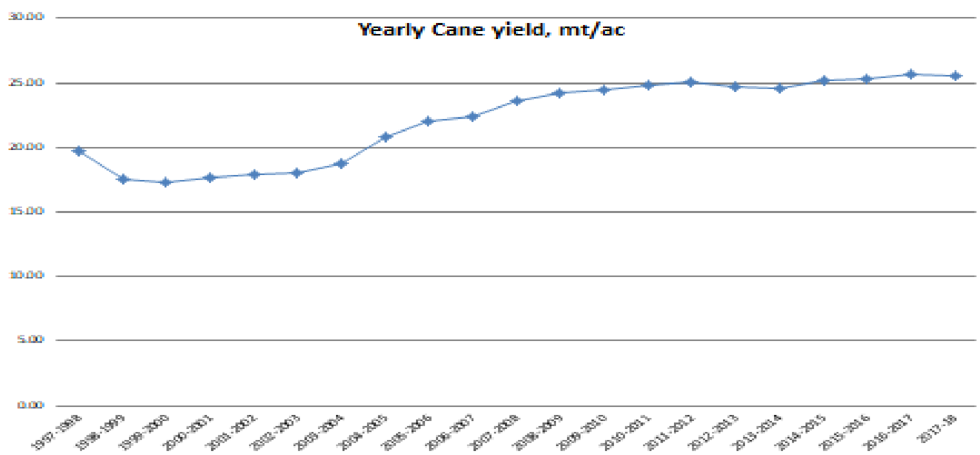

Figure 2. Yearly record of national average sugarcane yield (MT) per acre. (DALMS, 2018)

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