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Agricultural Economics Working Paper Series

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Agricultural

Economics

Working

Paper

Series

ISSN: 1858-6287 | AgEPS | No. 2 | 2013

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The Impact of Plot-Size on the Estimation of Wheat Yield in Sudan: The Case of New-Halfa Agricultural Scheme

Mohamed Ahmed Al-Feel[1] and Seram Kamal Mohamed Abdullah[1]

Abstract

This study was carried out to evaluate the effects of different plots sizes on the estimation of wheat yield in New-Halfa scheme. We applied crop cutting method to estimate wheat yield and multi-stage stratified sampling method for the sampling. We use a farm survey data with different plot sizes, in the four villages within the Scheme, and for season 2009/2010. The analysis of variance (ANOVA), multiple comparison, standard deviations, standard errors, and coefficients of variation were used in analyze the results. Results showed no significant differences between large and medium size plots in yield estimation. However, there were significant differences between large and small plot sizes and between medium and small plot sizes with respect yield estimation. Higher crop yields were obtained in small compared to large and medium size plots in both strata. As plot size increases, the estimated yield and standard deviation of yield decreases in the two strata. The yield estimation attains a stable value when the plot size is significantly large and it is not recommended to estimate wheat yield with plot sizes less than 42 square meters.

Keywords: Strata, plot, random sample, analysis of variance, standard error.

JEL classification: C1, D2, N5, L1.

1 Introduction

The productivity of the most strategic crops in the agricultural-based economies is one of the most important drivers of economic growth and it measures the

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extent to which the adopted agricultural policies are useful for the economy (FAO, 2012). One way of productivity estimation is full harvest of crop through selecting a representative random sample of the crop. However, this method is not always applicable due to its relatively high costs and the much time it requires. Therefore, 'eye' estimation of crop yield is widely used in productivity estimation because it is relatively affordable. Nevertheless, the results of latter could also be biased if not carefully performed due its high sensitivity. Another method of estimating productivity is the use of satellite images. The use of this method is also limited as it is difficult to differentiate between different crops, especially if the areas of cultivation are fragmented such as the case of the majority of the Sudanese agricultural production. Accordingly, crop cutting is the widely-used method in productivity estimation in most of the developing countries. To apply this method, all the information about area, number and size of plots under the selected crop is required. The accuracy of the estimation process of the yield of the selected crop will then depend on these three measures.

In this study we apply this method to the New-Halfa agricultural scheme in Sudan. The scheme was established in 1964 with the major purpose of resettling about 50 thousands of the Nubians families that was displaced from Old-Halfa by the construction of the high-dam of Egypt. The scheme is located in Eastern Sudan, on Atbara-River where Khashm-elgirba dam provides it with the irrigation water. Within the scheme, wheat is one of the most important food crops grown. Cash crops include cotton, sugar cane and peanuts.

The objective of this study is to determine the effect of plot-size on the estimation accuracy crops' yield in the New-Halfa scheme of Sudan. This specially focuses on wheat crop grown in the scheme and tries to study the relationship between the different plot sizes applied in the scheme and the accuracy of the estimation of wheat's yield.

2 Methodology

For the estimation of wheat yield in New-Halfa Agricultural Scheme, crop cutting method was applied through a multi-stage sampling procedure. Villages were considered as primary sampling units, followed by fields, while plots were considered third sampling units. There are six divisions in the Scheme, which constitute three strata's. Two strata were randomly chose and from each stratum and two villages were randomly chose in proportion to the area under wheat in each village. Namely, the selected villages were Talata-Arab, Canal-No-11, Umbakole and Hayak-Alla. The selected sample represents 7.6 % and 10.6% of the total area in the two strata, respectively.

For the purpose of crop-cutting, the term 'field' within the context of the study means the distinct patch of land that is demarcated by any means of border that could be a strip of grass or uncultivated piece of land or by means of a crop that is different from the one grown in the patch. Within each selected field, three plot sizes: small (1x1 square meters), medium (2x3 square meters) and large (6x7 square meters), were selected. Afterward, the methods of agricultural operations, soil fertility, available resources, investigator's skills, measurement tools and nature of crop grown are studied within each plot. These measures interact to determine the suitable area of the experimental plot. The total number of applied experiments was 52. The assessment Table (1) is derived by choosing the number of n-farmers and m-plots for each selected farmer. According to the number of offices of inspections (n), number of farmers (m), randomly selected from each office and plots (q), randomly selected from each selected farm, the following schedule variance table is constructed.

Table 1: Assessment of farm production plots

Total Squares	Total Plots	Production of Plots		Figure Farms
		First	Second	
Y_{21}	$Y_{1.}$	Y_{11}	Y_{12}	1
Y_{22}	$Y_{2.}$	Y_{21}	Y_{22}	2
Y_{32}	$Y_{3.}$	Y_{31}	Y_{32}	3
…	…	…	…	…
Y_{n2}	$Y_{n.}$	Y_{n1}	Y_{n2}	n
$\sum^{n}_{i=1}$	$\sum^{n}_{i=1} Y_i$			

Source: Sudan Agricultural Census (1997).

Table 2: Schedule Variance

Source of variation	D.F.	Sum of Squares	Mean Squares	F-value
Between Plots	n-1	$mq\ \Sigma^{n}_{i=1}(Y_i - Y)^2$	$S^2{}_2$	$S^2{}_2/\ S^2{}_0$
Between farmers	n (m – 1)	$q\Sigma^{n}_{i=1}\Sigma^{m}_{j=1}\ (Y_{ij} - Y)^2$	$S^2{}_1$	$S^2{}_1/\ S^2{}_0$
Between farmers within Plots	nm (q – 1)	$\Sigma^{n}_{i=1}\Sigma^{m}_{j=1}\Sigma^{k}_{k=1}(Y_{ijk} - Y)^2$	$S^2{}_0$	
Total	nmq - 1	$\Sigma^{n}_{i=1}\Sigma^{m}_{j=1}\Sigma^{q}_{q=1}\ (Y_{ijk} - Y^2)^2$		

Source: Sudan Agricultural Census (1997).

From Tables (1 and 2):

- Average production for the plot = $\Sigma ni_{=1}\ Y_i\ /2n = \Sigma ni_{=1}\ Y_i\ /nm$,
- The correction factor (C.F.) = $(\Sigma^{n}_{i=1}Y_i)/2n$,
- The sum of squares between farmers (B^2) = C.F. – K/2, and
- The total number of boxes = C.F. - $\Sigma^{n}_{i=1}\ \Sigma^{2}_{j=1}Y\ ^{2}{}_{ij}$.

The different statistical indicators are estimated using SPSS software. The methods used in the analysis included (1) Analysis of Variance (ANOVA) to test for the significance of the differences between and within groups, (2) Multiple Comparison to test for the significant differences between the applied three plot sizes, (3) Standard Deviations and Standard Errors were used to test for the precision of estimates and (4) Coefficients of Variation were used to identify the best plot size that should be recommended as suitable for yield estimation.

3 Results and Discussion

Table (3) shows the range of yield weight for the three plot sizes in the two strata. It is clear from the table that the yield weight range is not so different between the two strata. However, it is quite different between the three plot sizes within each stratum.

Table 3: Ranges of yield in kilograms per Plot-size and Strata

Plot-Size	First Strata	Second Strata
Small	0.15 – 0.55	0.10 – 0.60
Medium	0.30 – 1.15	0.20 – 1.55
Large	1.30 – 6.15	1.30 – 6.04

Source: Field Survey (2010).

Table (4) presents the overall yield per feddan[2] for the three different plots. As the figures of Table (4) read, the small size plot gave much higher yield estimates compared to the medium and large plot sizes. However, this much higher yield of the small plots was attached to a much higher variance compared to the two other plot sizes. The large plot size shows the lowest yield estimates but with least variance.

Table 4: The overall yield (kg/feddan) for the different plots

Plot Size	Mean	Standard Deviation	Standard Error
Small	1051.21	579.21	80.32
Medium	550.91	279.53	38.76
Large	414.79	168.32	23.34

Source: Authors.

Table (5) shows the Analysis of Variance (ANOVA) for the overall yield in the two strata.

Table 5: The ANOVA of the overall yield in the two strata

Source of variation	Sum of squares	Degrees of freedom	Mean squares	F-value
Between groups	11680283.58	2	5840141.79	39.64

[2] 1 Feddan = 0.42 hectares.

Source of variation	Sum of squares	Degrees of freedom	Mean squares	F-value
Within groups	22539423.21	153	147316.49	
Total	34219707.79	155		

Source: Authors.

The results of Table (6) indicate significant differences in the estimated yield between the the first and send stratum and between plots within the same strata. It is also clear that, the variation between groups is lower that the within each group. Multiple comparisons of means within the two strata as shown in columns 3 and 5 of Table (6) were used to compare the differences of estimated yield means between the three plot sizes. The results showed significant differences in estimated yield between large and small size plots. Also significant differences in estimated yield were detected between medium and small plot sizes. However, no significant differences in estimated yield were detected between large and medium plot sizes. For first stratum, the coefficients of variation in estimated yield were 5.6%, 7% and 7.6 % for the large, medium and small plot sizes, respectively.

Table 6: Multiple comparisons between mean yields (kg/feddan) in the two strata

Plots		First stratum		Second stratum	
		Mean difference	Sig.	Mean difference	Sig.
Large size	Medium size	155.58	N.S	125.82	N.S
	Small size	645.97	**	631.37	**
Medium size	Large size	155.58	N.S	125.82	N.S
	Small size	490.39	*	505.54	*
Small size	Large size	645.97	**	631.37	**
	Medium size	490.39	*	505.54	*

Source: Authors.

* mean that, the mean difference is significant at the 0.10 level of significance, ** = the mean difference is significant at the 0.05 levels and N.S. = the mean difference is not significant.

These results mean that the variation increases as the plot size decreases. The large and medium size plots gave nearly equal yield estimates with small variances. For this reason they are considered more suitable than the small plot size for yield estimation. The small plot size seems to overestimate yield (Fermont and Benson, 2011, El-Milligi, 1975 and Swallow and Wehner, 1986). This is because there is a tendency to include, rather than exclude, plants or land which stands near the boundary line or the surroundings of the experimental plot. This boundary effect becomes less and less important as the plot size increases.

In crop cutting of wheat, it was found that the estimates of total yield were much higher for sample units of small sizes as compared to actual yield obtained from harvesters and combiners. Therefore, it is not safe to work with plot sizes less than 42 square meters (Foeken and Owuor, 2000). It is noticed that estimated yield variance increases with the decrease of plot size cuts that coincides with the the previous findings. The findings of this study also coincide with the findings of Idikkadar (1969) and El-Sergani and El-Geddawy (1992).The conclusion of this study agrees with the conclusions of all these studies which confirm that the yield estimation attains a stable value when the plot size is significantly large.

4 Conclusions

This study was carried out to evaluate the effects of different plots sizes in estimation of wheat yield in New-Halfa scheme of eastern Sudan. The method selected to estimate wheat yield was crop cutting and the sampling method selected was multi-stage stratified sampling. Data was obtained from a stratified random sample of farm plots of different plot sizes in the four villages of the Scheme, for season 2009/2010. The methods used in the analysis included analysis of variance (ANOVA), to test for the significance of the between and within groups differences, multiple comparison to test for the significance of the differences between the three plot sizes used, standard deviations and standard errors were used to test for estimates' precision and coefficients of variation were used to identify the best plot size suitable for yield estimation. The results of this study revealed that a higher crop yields was obtained in small plots compared to large and medium size plots in both strata. As plot sizes increase standard deviations of crop yields increase in the two strata. Large and medium plot sizes produce smaller coefficients of variation compared to the small plot sizes in both strata. The yield estimation attains a stable value when the plot size is significantly large and therefore, it is not recommended to estimate wheat yield with plot sizes less than 42 square meters.

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University of Khartoum
Agricultural Economics Working Paper Series

Publisher	Department of Agricultural Economics, Faculty of Agriculture, University of Khartoum, Sudan.
Address	P.O. Box 32 13314 Shambat, Khartoum North, Sudan
ISSN	1858-6287
Emails	ageps@uofk.edu
Type	Online publication
Language	English
JEL	Q1, Q2, Q3, Q4, A1, C1,D1, D5, D4, D6, D8, E2, F1, H2, H3,H5, O1, O3,O4
Date	17 July 2013
No.	2 (2013)

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