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Impact of Rototiller Fertilizer Applicators on Technical Efficiency of Coconut Plantations in North Western Province, Sri Lanka

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Abstract

As a major plantation crop, coconut contributes directly and immensely to the economy of Sri Lanka. With the aim of enhancing the efficiency of the industry, rototillers have been introduced recently as fertilizer applicators. Hence, the purpose of this study was to assess the impact of such application on technical efficiency and productivity of the coconut plantations. Data were collected randomly from 60 growers: 30 rototiller users and 30 non-users. Stochastic frontier production function was used to measure the technical efficiency of production using the maximum likelihood method. The productivity of the estates was used as the output, and inputs were education level, off farm income, farming experience, water availability, availability of irrigation system, cropping system, land extent, labour days, fertilizer cost and other costs. The highest technical efficiency was recorded by increasing land extent. The variables such as land area, labour days, fertilizer cost and other costs were also significant on technical efficiency. The mean efficiency of rototiller users was 71 % and non-users was 62 % owing to a less labour requirement for fertilizer incorporation. Three percent of the rototiller users was smallholders with less than three hectares of land, and their efficiency ranged between 30 -50 %. The results of the study will help coconut growers and policy makers to promote rototillers in coconut cultivations.

Keywords: Coconut, Frontier production function, Rototillers, Technical efficiency

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1. Introduction

Total coconut extent in Sri Lanka is 497,000 ha (Central Bank of Sri Lanka 2018) and the majority (56%) is located in the North Western Province. Sri Lanka is the fifth largest coconut producing country in the world. Coconut industry holds a multi-utility significance and contributes to the national economy through domestic consumption, exports, income generation and poverty alleviation. Hence, at present there is an emerging demand for coconut-based products in both domestic and overseas markets.

Continuous supply is the key to maintain such demand. Therefore, expansion of the coconut industry is pivotal in this stage. Given the condition of limited factors of production, the next ideal approach is to absorb novel technology into the industry that enhances the overall efficiency in the industry. Targeting at improving efficiency of inefficient growers are therefore important rather than pumping more and more inputs into the industry. A recent introduction of the power tiller to the industry is one intended measure to achieve such objectives. In Sri Lanka, power rototillers are recognized in different names such as Agrimec-cultivator, Roto master, mini cultivator, *Binkunda* tractor, garden cultivator and rototiller etc. . The adoption

of rototillers by farmers for carrying out farming operations are lower compared to tractors. The annual use of rototillers is only 300 hours compared to tractor which is of 1000 hours (Narang and Varshney 1995). In addition, the average annual usage of rototillers in hours are less due to its unsuitability for primary tillage operation in dry lands (Panwar et al. 2001).

The concept of power tiller came in to the world in 1920. The first successful power tiller was invented in 1947. Power tiller is a walking type machine. The operator walks behind the power tiller, holding the two handles of the tiller in his hands (Cherian and Punnan 2016). A power tiller is a motorized agricultural equipment that crushes the soil by rotating tines or blades. Rotary tillers are in two types. They can be either self-propelled or drawn as an attachment behind two-wheel tractor. Rotary tillers prepare the seedbed differently from the conventional method of ploughing. The soil is crushed by the cutting and chopping action of blades that obtain energy from the engine of the prime mover (Kepner et al. 1978). Those rototillers have been adopted in coconut plantations since decades (Fernando et al. 2013). Though the cost of fertilizer application with the power tiller is relatively low, due to high capital investment along with regular maintenance

and operation costs act as barriers that hinders its popularity among small scale coconut growers. Rototillers could be used for weeding, harrowing and fertilizer incorporation in coconut plantations. Such cost effective and efficient method of fertilizer application could enhance the efficiency of the industry in the future provided that it is being properly introduced (Evans and Gove 1986; Esch et al. 1990; Zoz, 1997; Bashford and Kocher 1999).

On an average, a coconut tree bears 50-70 nuts per year and production continues over a period of 60 years. Usually, a coconut palm produces an inflorescence once a month. The application of fertilizer would enhance the production potential of a coconut palm and the production could increase up to 100-125 nuts per year. At present, planters apply and incorporate fertilizer manually with a high labour consumption, resulting increased cost of production (Fernando et al. 2013). Therefore, growers are not motivated to apply fertilizer due to lack of labour and efficient method of application. In conventional fertilizer application in coconut, a 30 cm wide and 10 cm depth furrow is prepared manually around the coconut palm and then, the fertilizer mixture is applied and incorporated manually into

the soil. Hence, this is a labour intensive and time-consuming practice (Fernando et al. 2013). However, the question is whether planters could enhance the efficiency of the plantations thereby optimizing the productivity to cater the growing demand. This could be possibly achieved through the adoption of rototillers into the industry. However, empirical evidences on the plantation level on impact of rototillers on technical efficiency in coconut production is limited and knowledge of planters' production environment is scanty.

Therefore, the overall objective of this research was to find out the impact of the use of rototillers in fertilizer application on technical efficiency and productivity. The specific objectives of the study were to compare the technical efficiencies of two methods of fertilizer application, to identify factors that motivate farmers to use the rototiller, and to elucidate factors that have constrained the rate of adoption of the rototiller.

these recipes forming into briquettes and assess the keeping quality. This enables the selection of the two best TMR recipe briquettes considering shelf life (keeping quality), physical properties, nutritive composition, and cost analysis.

2. Materials and Methods

Study Area and the Sample

This study was carried out in Kurunegala district in North-Western province in Sri Lanka. The study covered randomly selected 30 Coconut Development Officer Divisions (CDOs) representing the entire district. Considering the time and resource availability, sample size was limited to 60 representing 2 from each CDO Divisions. The sample was selected using stratified random sampling technique.

Data Collection

Both primary and secondary data were used for the study. Primary data were collected from 60 coconut growers of which 30 of them were using the power tiller in their coconut cultivations for fertilizer incorporation whilst the rest of 30 growers as the control who were not using power tiller in coconut cultivations from July to September 2018.

A pretested questionnaire was prepared covering the information on farm experience, cropping system, water availability, irrigation system, education level, land extent and off farm income followed by data collection through face to face interviews. Secondary data were gathered from various secondary sources.

Analytical Framework and Variables

Technical Efficiency (TE) refers to farm produces possible output from a given series of inputs or if it uses the least number of inputs for the possible level of output (Atkinson and Cornwell 1994). A production plan is technically inefficient if a higher level of output is technically attainable for the given inputs (output-oriented measure), or that the observed output level can be produced using fewer inputs (input-oriented measure). It enables to identify the factors which enhance the level of efficiency in a given performance and thus, sheds light on useful insights even for policy formulation. Therefore, it's directly related to the productivity improvement. The stochastic frontier approach is much better when evaluating agriculture related efficiency (Atkinson and Cornwell 1994). Stochastic frontier approach determines the level of efficiency of data and usefulness of each source in the data. The great advantage of the stochastic frontier approach is the possibility that it offers of decomposing productivity change into parts that have straight forward economic interpretation. In addition, stochastic frontier model employs the functional form of Cobb Douglas and translog production function (Battese and Coelli 1995). The stochastic production frontier model and inefficiency model were

run simultaneously. Accordingly, stochastic production frontier model was used to measure technical efficiency. The model can be specified as follows,

$$Y_i = f(X_{ij}, \beta) + e_i \dots \dots \dots (Eq. 1)$$

$$e_i = V_i - U_i, i = 1, \dots, N, \text{ and } j = 1, \dots, N$$

Where Y_i denotes production level of the i^{th} plantation, X_i is vector of inputs and β is a vector of unknown parameter to be estimated, f is the Cobb-Douglas functional form, V_i is the random error, which is associated with random factors outside the control of the plantation and assumed to be independently and identically distributed as $N(0, \sigma_v^2)$. Term U_i is a non-negative random variable associated with farm-specific factors, which leads to the farm inefficiency of production $N(0, \sigma_u^2)$. Technical efficiency of an individual plantation is defined as the ratio of the observed output (y_i) to the corresponding frontier output (y_i^*), conditional on the levels of inputs used by the farm. Technical efficiency is given by;

$$TE = \frac{y_i}{y_i^*} \dots \dots \dots (Eq. 2)$$

$$= f(x_i) \exp(v_i - u_i) / f(x_i) \exp(v_i) \exp(u_i)$$

Technically efficient farms are those that operate on the production frontier and the level by which a plantation lies below its production frontier, is regarded as the

measure of technical inefficiency. Technical efficiency may be greater than zero and less than one. When $u_i = 0$, $TE = 1$ and production is said to be technically efficient (Battese and Coelli, 1995).

Technical inefficiency model can be specified by;

$$U_i = Z_{ij} \delta_i + W_i \dots \dots \dots (Eq. 3)$$

$$i = 1, \dots, N$$

Where Z_i is a vector of explanatory variables associated with technical inefficiency, δ_i is a vector of the unknown parameter to be estimated and W_i is unobservable random variables which are assumed to be identically distributed, obtained by truncation of the normal distribution with mean zero and unknown variance σ^2 , such that U_i is non-negative.

For model estimation, specified the stochastic Cobb-Douglas function with efficiency effects such that part of the inefficiency could be attributed to differences in farm types. The estimated model and explanatory variables are shown below,

$$\begin{aligned} \ln(y_i) = & \beta_0 + \beta_1 \ln LAND + \beta_2 \ln FERT \\ & + \beta_3 \ln OTHER + \beta_4 \ln LAB \\ & + (v_1 - u_i) \dots \dots \dots (Eq. 4) \end{aligned}$$

Where $\ln$ is the natural logarithm, Y_i is the output i (no. nuts per ha), and x_i input variables Land area in ha (LAND), Labour requirement in man-days (LAB), fertilizer cost in LKR (FERT) and other cost in LKR (OTHER), β_i is a vector of parameters to be estimated. Crop output was expressed as the quantity of yield per hectare per year. The inefficiency model estimated with the following explanatory variables; Farmer education level (EDU = 1-Pass Grade 8; 2-Up to O/L; 3-Up to A/L; 4-Diploma and 5-Basic Degree), Off-farm income (OFF) (yes=1 or no= 0), Farming experience (EXP) (years), Farm size, water availability (WATER) (land is having an effective rainfall 2500mm/year = 1 or land is not having an effective rainfall 2500mm/year = 0) Cropping system (CROPPINGSYS) (monocropping = 1, intercropping = 2) and presence of irrigation system (IRRIGATION) (yes = 1 or no = 0).

$$U_i = \alpha_0 + \alpha_1 EDU + \alpha_2 OFF$$

$$+ \alpha_3 WATER + \alpha_4 EXP + \alpha_5 IRRIGATION + \alpha_6 CROPPINGSYS + w_i \dots \dots \dots (Eq. 5)$$

3. Results and discussion

Descriptive Statistics

According to the descriptive statistics (Table 1), majority (93 %) of the planters were below 30 years of farming experience. With regard to the cropping systems of the

estates, majority (67 %) were maintained their coconut cultivations as mono-cropping system, while the rest with intercropping (33 %). Among the respondents, about 95% were having their own reliable and sustainable water resource throughout the year to meet the crop water requirement, while others (5 %) were depending on outsource irrigation systems. With regard to the level of education, about 47 % had educated up to higher education (degree or diploma) and while others (52 %) were up to secondary education. The majority of the coconut growers (87%) were small holders (less than 20 hectares) while the rest was above 20 hectares. The majority of respondents (93%) were depending on rain-fed while a trivial amount (7%) facilitated with irrigation systems.

Technical Efficiency

Results obtained from the Maximum Likelihood Estimates of the stochastic production frontier executed taking three regression variables are listed in Table 2. If the coefficients of the variables are positive and significant, it leads to an increase in production. When the sign of the coefficient becomes negative and significant, those variables lead to a decrease in production.

The coefficient 0.690 of land extent showed a positive coefficient and significantly related to the efficiency. Therefore, an increase of land area by 1 unit will increase output by 0.690. Implying that with the increase of land extent it tends to gain more efficiency. The coefficient 0.112 of labour requirement showed a positive and significant value reflecting an increase of labour requirement by 1 unit will increase output by 0.112. The coefficient -0.066 of fertilizer showed a negative significant value implying an increase of fertilizer costs by 1 unit will decrease the output by 0.066. The positive and significant coefficient 0.131 for other cost (all components except fertilizer). The null hypothesis that there is no inefficiency effect was rejected at 1 % level of significance and the estimated $\lambda = 1.35$.

Factors affecting on Technical inefficiency

The estimated coefficients in the inefficiency model were used to find the factors affecting technical inefficiency. The factors considered in the estimation of technical inefficiency of farmers and their coefficients are shown in Table 3.

Table 1: Descriptive statistics of the sample

Variable	Category	%
Observations	Tiller users	50
	Non-tiller users (Manual fertilizer application)	50
Farm experience	Above 41-50 years	03
	Between 31-40 years	03
	Below 30 years	94
Cropping system	Monocropping	67
	Intercropping	33
Water availability	Good (sustainable)	95
	Not good	05
Irrigation system	Yes	07
	No	93
Education	Basic degree	36
	Diploma	11
	Up to A/L	25
	Up to O/L	27
	Pass Grade 8	01
Land	Above 30 hectares	13
	20 and 30 hectares	00
	Below 20 hectares	87
Off farm	Yes	93
	No	07

Table 2: Maximum likelihood estimates for parameters of the stochastic production function

Variable	Coefficient	p value
Constant	9.129	<0.001*
Land area	0.690	0.014*
Labour days	0.112	<0.001*
Fertilizer	-0.066	
cost		<0.001*
Other cost	0.131	
		<0.001*
λ	1.35	
LR test	9.880	
Log likelihood	-11.072	

Note: *=Significance at 5 %

If the coefficients of the variables are negative and significant, it leads to increase the efficiency. When the sign of coefficient becomes positive and significant, those variables lead to decrease the efficiency. Among the six coefficients estimated in Table 3, the coefficient of education showed a negative value and not significantly related to efficiency reflecting its positive impact on the technical efficiency. The reasons for the negative impact of off-farm income on the technical efficiency is not clear which should be further studied. The water availability shows a negative coefficient and with non -

Table 3: Maximum likelihood estimates for parameters of the inefficiency model

Variable	Coefficient	p value
Constant	1.884	0.980
Edu	-0.073	0.607
Off	0.469	0.586
Water	-1.066	0.386
Exp	-0.005	0.791
Irrigation system	-1.220	0.328
Cropping system	-0.653	0.185

Note: Edu = Education level, off = off farm income, exp = farming, experience, water = water availability, irrigation = availability of, irrigation system, cropping = cropping system type, *= Significance at 5

significant implying that water availability would have a combine effect on overall productivity by increasing the efficiency of the fertilizer absorption. The negative coefficient of intercropping highlights its contribution in increasing the efficiency of the productivity. Also, the experience of farming showed a negative coefficient with non - significance indicating that farming experience has positively effect on farm efficiency. The positive impact by having an irrigation system on the efficiency is confirmed by its negative coefficient.

Table 4: Technical efficiency levels of tiller users and non-users

TE	Users	Non users
30-50 %	3 %	19 %
50-77 %	49 %	48 %
77-99 %	48 %	32 %
Mean efficiency	71 %	62 %
Mean inefficiency	29 %	38 %

Note: Users = Estates dealing with tillers, Non users = Estates not dealing with tillers, TE = technical efficiency score

Overall Efficiency Level of Estates

The technical efficiency levels of the estates of two categories (estates used with rototillers or not) are shown in the Table 4.

Accordingly, 48% of tiller users were shown an efficiency level of 77-99% while, it was 32% for non-users. Interestingly, nearly similar percentages (49% and 48%) from each category achieved the level of 50 -77% TE. Only a very few (3%) of tiller users were at the lowest TE (30- 50%) while, it was 19% for non-users. Eventually, the tiller users were able to achieve an overall mean TE of 71% where non- tiller users were with a

mean TE of 62% confirming the positive impact of the rototillers on coconut cultivations.

The distribution of technical efficiency level of estates operated with rotary tillers in fertilizer incorporation of coconut lands and traditional manual fertilizer application in coconut cultivation are shown in figure 1 and figure 2 respectively.

As shown in figure 1 more number of coconut estates were over 80% TE, while the TE of majority of non- tiller users were below 80%.

Figure 1: Efficiency distribution of estates with tillers

Figure 2: Efficiency distribution of conventional estates

4. Conclusions

Study used stochastic frontier production function to estimate the impact of rototillers on TE of coconut plantations. Accordingly, overall mean TE of rototiller users was much higher than the non-users. Mean efficiency of users was noted as 71%, whereas non users was 62%. Hence, there is a clear difference in the efficiency level between

users and non-users. Simultaneously, mean technical inefficiency of users was lower compared to the non-users. Interestingly, nearly half of the users achieved technical efficiency of 77-99% whereas, only 32% non-users achieved the same. Therefore, it is clearly evident that users derived higher benefits from adopting rototillers in their plantations. In addition, variables such as

land area, labour days, fertilizer cost and other costs were significant on the overall efficiency. The highest impact was from the land area. However, the variables such as education level of the growers, off farm income, farming experience, water availability, irrigation system and cropping system did not have any sort of an impact on technical efficiency. Estate sector level coconut plantations could yield more benefits from such rototiller application. Simultaneously, less awareness on the positive impact of rototillers in plantations is another aspect which limits the use of such applications by the planters.

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