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Technical Efficiency of Smallholder Out-grower Tea (*Camellia Sinensis*) Farming in Chipinge District of Zimbabwe

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ABSTRACT

An investigation into the technical efficiency of smallholder out-grower tea farmers of Chipinge district, Zimbabwe was carried out. The method employed was the Data Envelope Analysis (DEA) approach on 50 smallholder out-grower farmers collected in November, 2013. The estimates of technical efficiencies of the farmers range from 0.37 to 1.0 while the mean technical efficiency was found to be 0.79. This suggests that 21 % of smallholder out-grower tea output is lost because of inefficiency. Experience in tea farming, area under tea production, amount of fertiliser used in production, access to extension services, extent of farm commercialization, amount of labour used in production and yield of tea significantly affect technical efficiency among smallholder out-grower tea farms. The study results imply that improvement in technical efficiency should be the first logical step for increasing productivity in smallholder out-grower tea farming in Chipinge district.

INTRODUCTION

Zimbabwe is amongst more than thirty five countries worldwide that produce tea. China, India, Kenya and Sri Lanka are responsible for almost three-quarters of the total world production (van der Wal, 2008). The Zimbabwean tea growing sector comprises of large scale farms supported by surrounding smallholder out-growers schemes. The first commercial tea plantation was established at New Year's Gift Estate in Chipinge district of Zimbabwe in 1924. Woodend (2003) notes that smallholder out-grower tea production can be traced as far back as the 1960s in the Eastern Highlands of Zimbabwe comprising of farmers whose lands bordered the large scale commercial tea estates. An out-grower scheme is a form of contract farming where growers/landholders have a contractual partnership with a processing company for the production of a commercial plant produce (Mayers, 2000, FAO, 2001).

In most countries, tea growing, compared to other crops, seem to give competitive returns. Small-scale farmers prefer tea to other land uses for reasons such as higher returns, lower risk, use of barren/sloppy lands, and long-term returns (Thapa, 2003). The growing of tea thus seems an attractive venture for smallholder farmers as it provides work and income throughout the year, for many years.

However, in Zimbabwe, despite the presence of the out-grower schemes, tea production by smallholder out-grower farmers has been steadily declining in recent years with a majority of the farmers abandoning tea production as a commercial enterprise in favour of annual crops like sweet potatoes, sugar beans, maize and horticultural crops. Yield levels are also well below their potential indicating serious productivity challenges in the sector (Dube and Guveya, 2014).

This study aims at assessing the technical efficiency of smallholder out-grower tea farming and its determinant factors. Low yield levels amongst smallholder out-grower tea farmers and the lack of empirical studies in Zimbabwe, focusing on the factors affecting efficiency of tea production, motivated this study. Determining the existing level of efficiency for out-grower tea farming will be useful to improve those relationships that can help farmers to allocate their resources more wisely and also to inform policy makers in designing and searching for new policy tools aimed at improving the productivity of the smallholder out-grower tea sector.

RESEARCH METHODOLOGY

Study area

This study was conducted in Chipinge district of Manicaland province. Chipinge district is one of the major tea producing districts in Zimbabwe. The eastern highlands of Chipinge district experiences a cool and warm climate with annual rainfall ranging from 1500-2500mm, mean annual minimum temperature range of 7 to 11 °C and a mean annual maximum of 21 to 28 °C (Moyo *et al*., 1993). It is within a wet agro-ecological zone of high agricultural potential which is ideal for production of plantation crops especially tea (Muir, 1994).

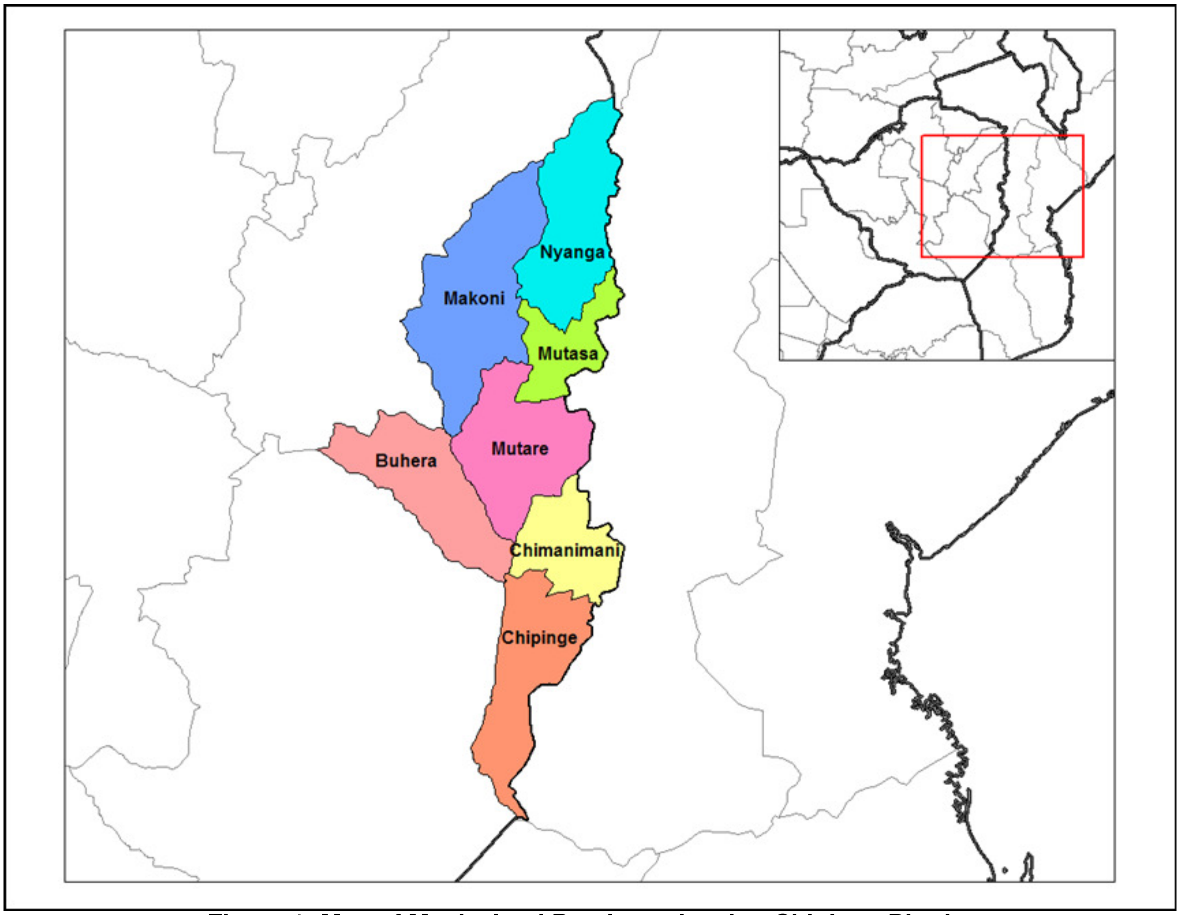

Figure 1: Map of Manicaland Province showing Chipinge District

Data Collection

Data was collected in November 2013 by a structured questionnaire from a random sample of 50 out-grower farmers selected from the out-grower register of smallholder farmers at Tanganda Tea Company Ltd's Rattelshoek estate.

ANALYTICAL FRAMEWORK

Measuring Efficiency

The efficiency of a firm (or farm in this case) consists of two components: technical efficiency and allocative efficiency (Coelli, 1996a and Coelli et al., 2005), Technical efficiency reflects the ability of a firm to obtain maximal output from a given set of inputs, while allocative efficiency reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices (Coelli et al., 2005). These two measures are then combined to provide a measure of total economic efficiency.

Input-oriented measure of efficiency

The idea of efficiency can be illustrated in an output/input space. Using a simple example, suppose a farm which uses two inputs (x_1 and x_2) to produce a single output (y), under the assumption of constant returns to scale. Knowledge of the unit isoquant of the fully efficient firm, represented by SS' in Figure 2, permits the measurement of technical efficiency (Coelli, 1996a). An isoquant can be described as a curve showing the set of technologically efficient possibilities for producing a given level of output (Lipsey, 1989).

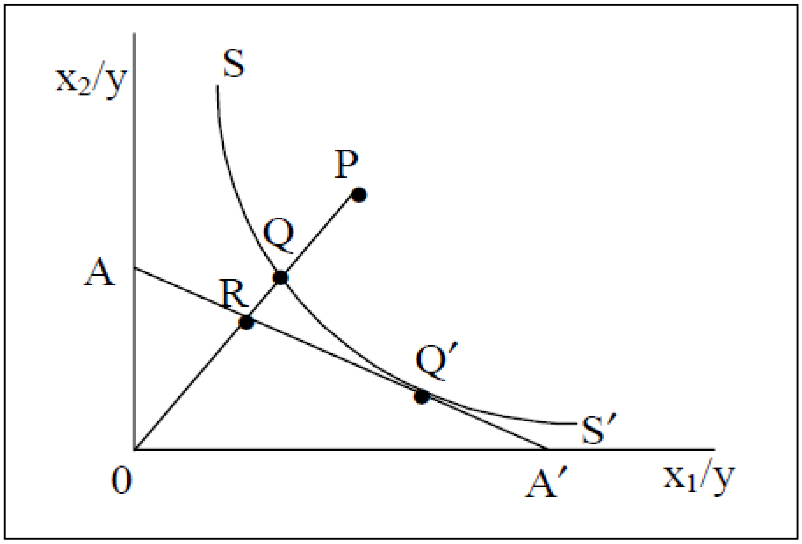

Figure 2: Input-Oriented Technical and Allocative Efficiencies
Source: Adapted from Green, (2007) and Coelli, (1996a)

If a farm uses quantities of inputs, defined by the point P, to produce a unit of output, the technical inefficiency of that farm could be represented by the distance QP, which is the amount by which all inputs could be proportionally reduced without a reduction in output. The technical efficiency is expressed in percentage terms by the ratio QP/OP, which represents the percentage by which all inputs could be reduced (Coelli, 1996a). The technical efficiency (TE) of a farm is given by the ratio:

$$TE_I = OQ/OP = 1 - QP/OP$$

[1]

The technical efficiency of a firm takes a value between zero and one, and it indicates the degree of technical inefficiency of the firm. A value of one indicates that the farm is producing on the production frontier and is fully technically efficient firm and a value of zero indicates that a farm is fully technically inefficient (Coelli, 1996a). The point Q in Figure 2 is technically efficient as it lies on the efficient isoquant.

Allocative efficiency may also be calculated if the input price ratio, represented by the line AA’ in Figure 2, is known (Coelli, 1996a). The allocative efficiency (AE) of the firm operating at P is given by the ratio:

$$AE_I = OR / OQ$$

[2]

Since the distance RQ represents the reduction in production costs that would occur if production were to occur at the allocatively (and technically) efficient point Q’, instead of at the technically efficient, but allocatively inefficient, point Q. The total economic efficiency (EE) is defined by the ratio:

$$EE_I = OR / OP$$

[3]

Where the distance RP can also be interpreted in terms of a cost reduction. The product of the technical and allocative efficiency provides the overall economic efficiency:

$$TE_I * AE_I = (OQ / OP) * (OR / OQ) = OR / OP = EE_I$$

[4]

All the three measures, TE_I, AE_I and EE_I are bounded by zero and one (Coelli, 1996a).

Data Envelopment Analysis

For this study, technical and scale efficiency of smallholder out-grower tea farmers in Chipinge district are estimated using the Data Envelopment Analysis (DEA) methodology following Agrell (2013), Todsadee *et. al*. (2012), Greene (2007), and Coelli (1996a). DEA is the non-parametric mathematical programming approach to frontier estimation.

The analysis begins from the premise that there exists a production frontier which acts to constrain the producers in an industry, in this case the smallholder out-grower tea industry. With heterogeneity across producers, they will be observed to array themselves at varying distances from the efficient frontier. By wrapping a hull around the observed data, we can reveal which among the set of observed producers are closest to that frontier (or farthest from it). Presumably, the larger is the sample, the more precisely will this information be revealed. In principle, the DEA procedure constructs a piecewise linear, quasi-convex hull around the data points in the input space. Technical efficiency requires production on the frontier, which in this case is the observed best practice. Thus, DEA is based fundamentally on a comparison of observed producers to each other. The estimated model of production, cost or profit is the means to the objective of measuring inefficiency. Inefficiency can arise from two sources, technical inefficiency when inputs results to suboptimal outputs, and allocative inefficiency, which results from suboptimal input choices given prices and output. The assumptions made here are that there exists an ideal production point and, second, that producers strive to achieve that goal.

The DEA models can be input or output-oriented and one of the a priori assumptions concerns the returns to scale. The models can be specified as constant returns to scale (CRS) or variable returns to scale (VRS). For this study, CRS are adopted. Using the duality in linear programming, a DEA model is defined by:

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ \text{s.t.} \quad & -y_i + Y\lambda \geq 0; \\ & \theta x_i - X\lambda \geq 0; \\ & \lambda \geq 0 \end{aligned} \qquad [5]$$

where *xi* are *k x 1* vectors representing input quantities for farm i; y_i is an *m x* 1 vector representing the given output bundle; *X* and *Y* are input and output matrices namely, a *k x N* and an *m x N* matrix consisting of the input and output bundles for all farms in the sample; *N* is an *N x* 1 vector of ones; and λ is an *N x* 1 vector of non-negative constants to be estimated. Yλ and Xλ are the efficiency projections on the frontier. The value of θ obtained is the efficiency score for the i-th farmer. The measure of technical efficiency can take values ranging from 0 to 1, where θi = 1 for a fully technically efficient farmer. Therefore, 1 – θi shows how much of i-th farmer input can be proportionally reduced without any loss in outputs according to Farrell's definition.

The Equation 5 has used the assumption that all farms operate at an optimal scale. However, constraints such as finance and imperfect competition that occur at the field cause only part of the farm to operate at that level. Therefore, the above model can be estimated based on the Variable Returns to Scale (VRS), which evaluates the efficiency of farms based on their capabilities. VRS model is formed by inserting the constraints N1'λ in Equation 6, where N1 is N x 1 vector (Coelli, 1996):

$$\begin{aligned} &\min_{\theta,\lambda} \theta, \\ \text{s.t.} \quad & -y_i + Y\lambda \geq 0; \\ & \theta x_i - X\lambda \geq 0; \\ & N1'\lambda = 1 \\ & \lambda \geq 0 \end{aligned} \qquad [6]$$

Constraints of N1'λ = 1 indicate the inefficiency of a farm evaluated against other farms of similar size. In this way, the efficiency of the farm can be evaluated based on technical and scale efficiency. Technical efficiency describes the ability of farms to achieve maximum production with the use of inputs given while the scale efficiency is the ratio between CRS and VRS.

To compute the technical and scale efficiencies of smallholder out-grower tea farmers in Chipinge district, the Data Envelopment Analysis Program (DEAP) is used. The output is measured by the annual tea production (tonnes). The inputs for tea production are:

i. the area under tea production (ha);
ii. number of labour days per year; and
iii. fertilizer use(kg).

Determinants of Farm Technical Efficiency

To assess the determinants of farm level technical efficiency, a Tobit regression model is invoked. The Tobit model was introduced by Tobin (1958) for censored regression models. Briefly the structural model of the Tobit model is given as:

$$y^*_t = x'_t \beta_0 + \mu_t \text{ , } t = 1,2,3,\ldots,n \qquad [7]$$

$$y_t = y^*_t \text{ if } y^*_t > c; \text{ and } y_t = c, \text{ otherwise} \qquad [8]$$

where, y_t is a DEA efficiency index used as a dependent variable, $\mu_t \,|x_t$ is $N(0,\sigma_0^2)$ and $\{y_t,x_t\}(t = 1,2,\ldots,n)$ is a vector of independent variables related to farm-specific attributes, value of c is known. y^*_t is a latent variable. ß is an unknown parameter vector associated with the farm-specific attributes and µ is an independently distributed error term that is assumed to be normally distributed with zero mean and constant variance, σ^2. A Tobit regression model applying the maximum likelihood approach is used to estimate the model in Equation 7 such that Equation 9:

$$L = \prod_{yt=0}(1 - Ft)\prod_{yt>0}\frac{1}{(2\prod\sigma^2)^{\frac{1}{2}}}e\left[\frac{1}{2\sigma^2}\right](yt - \beta x)^2$$

Where,

$$Ft = \int_{-\infty}^{\beta^t xt/\sigma}\frac{1}{(2\Pi^{1/2})}e^{-\,{}^{-i^2}/_2}\,\delta i \qquad [9]$$

The Equation 8 refers to the efficiency score of farmers 100% (y = c) and the second term represents inefficient farmers (y > c). F_t is normally scattered in the $\beta^t x_t / \sigma$.

Farm level crts technical efficiency scores are used in the regression model to show the relationship between the measurement of the efficiency and characteristics of farmers. The determinants of farm level technical efficiency are assessed using the following multiple regression function:

$$TE_{crs} = \beta_0 + \beta_1 AGE + \beta_2 AREATEA + \beta_3 FERT + \beta_4 EXTENSION + \beta_5 COMXTENT + \beta_6 TEAAGE + \beta_7 LABOR + \beta_8 TEAYIELD + \mu_t \quad [10]$$

A description of the variables for the multiple regression model are presented in Table 1 together with their a priori expectations.

Table 1: Variables for multiple regression model to assess the determinants of smallholder out-grower tea technical efficiency

Variable	Variable Description	Hypothesis
Dependent Variable		
TE_{CRS}	Technical Efficiency	
Independent / Explanatory Variables		
AGE	Age of farmer (years)	-
AREATEA	Area under tea production (ha)	+
FERT	Total annual fertilizer use in tea production (Kg)	+
EXTENSION	Dummy variable for access to extension services: 1 = Yes, 0 = No	+
COMXTENT	Dummy variable for extent of commercialization: 1 = Communal; 0 = Small-scale commercial	-
TEAAGE	Dummy variable for age of tea: 0 = > 35 years; 1 = 35 years and below	-
LABOR	Annual labour use in tea production (labour days)	+
TEAYIELD	Annual tea production per hectare (Kg / ha)	+
β_i	Model coefficients	
μ_i	Error term	

RESULTS AND DISCUSSION

Farmer Efficiency Results

The frequency distribution of the efficiency results are presented in Table 2. The estimated efficiency measures reveal the existence of substantial technical inefficiencies in smallholder out-grower tea production. The average CRS technical efficiency for smallholder out-grower tea farmers is 79 percent ranging from a minimum of 37 percent to a maximum of 100 percent. Given the present state of technology and input levels, this suggests that smallholder out-grower tea farms in Chipinge district can increase their tea production by a further 21 percent without increasing their input levels. About 10 percent of the farmers have a technical efficiency up to 50 percent while about 62 percent of the farmers have technical efficiencies of at least 71 percent.

Table 2: Percent distribution of efficiency measures for out-grower tea farmers

Efficiency Score (%)	Technical Efficiency		Scale Efficiency
	CRS	VRS	
<= 20			
21 – 30			
31 – 40	2.0%		2.0%
41 – 50	8.0%	2.0%	4.0%
51 – 60	12.0%	6.0%	2.0%
61 – 70	16.0%	10.0%	8.0%
71 – 80	10.0%	4.0%	6.0%
81 – 90	14.0%	14.0%	10.0%
>= 90	38.0%	64.0%	68.0%
Mean Efficiency	0.786	0.894	0.886
Minimum Efficiency	0.37	0.47	0.37
Maximum Efficiency	1.00	1.00	1.00
Scale Efficiency Category			
Decreasing Returns to Scale			22.0%
Constant Returns to Scale			30.0%
Increasing Returns to Scale			48.0%

Source: Survey Data, 2013

An analysis of the VRS technical efficiency of smallholder out-grower tea farmers shows that the average technical efficiency is about 89 percent which is higher than the CRS technical efficiency.

The average scale efficiency is about 89 percent. This implies that the observed farms can further increase their output by about 11 percent if they adopt an optimal scale of production. Results also indicate that about 48 percent of the farms exhibit increasing returns to scale, 22 percent of the farms exhibit decreasing returns to scale, and 30 percent of the farms are producing at the optimal size. Thus about 48 percent of the farmers have output levels that are lower than optimal levels and they should be improved to reach the optimal scale.

The empirical findings reported above show that the estimated degree of technical efficiency is significantly lower than the degree of scale efficiency (on average, a range of more than 10 percentage points). This implies that the greater portion of overall inefficiency in smallholder out-grower tea production in Chipinge district results from producing below the production frontier than on operating under an inefficient scale. The room for improving technical efficiency is, on average, larger (21 percent) than the margin due to scale inefficiency (11 percent).

These efficiency results imply that improvement in both technical and economic efficiency should be the first logical step to increase productivity in smallholder out-grower tea production in Chipinge district. The average smallholder out-grower tea farmer in Chipinge district operate more or less at the optimal scale of production.

Determinants of Smallholder Out-Grower Tea Farm Technical Efficiency

The multiple regression model parameters to assess the determinants of the technical efficiency of smallholder out-grower tea farmers in Chipinge district are obtained using the STATA. Table 3 presents the mean values for the variables included in the multiple regression model. The model parameter estimates along with the related standard errors and t-ratios are presented in Table 4.

Table 3: Mean values of technical efficiency multiple regression analysis model variables

Variable	Mean	Std. Dev.
TE_{CRS}	0.786	0.199
AGE	0.66	0.479
AREATEA	1.184	1.030
FERT	76.000	94.890
EXTENSION	0.66	0.479
COMXTENT	0.74	0.443
TEAAGE	0.74	0.443
LABOR	25.521	22.949
TEAYIELD	1044.016	710.834

Source: Survey Data, 2013

All the model variables have expected signs except for total annual fertilizer use (FERT), and total annual labour use (LABOR). As indicated before, *a priori*, area under tea production (AREATEA), access to extension (EXTENSION) and annual tea yield are expected to positively influence technical efficiency. The age of the farmer and the extent of commercialization are expected to have a negative influence on technical efficiency. The age of the tea bushes is also expected to negatively farmer technical efficiency (Dutta *et.al.*, 2011) .

Table 4: Probit regression estimates of factors influencing technical efficiency

Variable	Coefficient	Std. Error	T	Sig.
Constant	0.577	0.093	6.180	0.000
AGE	-0.077	0.043	-1.760	0.085
TEAAREA	0.206	0.069	2.970	0.005
FERT	-0.002	0.001	-3.610	0.001
EXTENSION	0.106	0.044	2.440	0.019
COMXTENT	-0.117	0.053	-2.190	0.034
TEAAGE	-0.047	0.048	-0.990	0.330
LABOR	-0.007	0.002	-2.970	0.005
TEAYIELD	0.000	0.000	5.170	0.000
Log likelihood = 28.12				
LRchi2(8) = 40.82				
Prob>chi2 = 0.000				
Pseudo R^2 = -2.648				

Source: Survey Data, 2013

The log likelihood for the fitted model was 28.12 and the *chi*-square was 40.82 and strongly significant at 1% level. Thus the overall model was significant and the explanatory variables used in the model were collectively able to explain the variations in smallholder out- grower tea productivity.

The variable which does not significantly affect farmer technical efficiency production is age of tea (TEAAGE). The variables which are important in determining technical efficiency of smallholder out-grower tea production are the age of farmers (AGE), area under tea production (TEAAREA), total quantity of fertiliser used (FERT), access to extension services (EXTENSION), extent of commercialization (COMXTENT), total quantity of labour used (LABOUR), and tea yield (TEAYIELD).

The results indicate that farm technical efficiency decreases with age of tea farmers and is significant at 10% level. This result is consistent with Kibaara (2005), Sibiko *et al*., (2013) and Gul *et al*., (2009). This means that older farmers were less technical efficient in tea production than younger farmers. This result may be attributed to the fact that younger farmers are more to take up better technologies of managing tea production. Older farmers are relatively more reluctant and prefer to hold on to the traditional farming methods and are thus more technical inefficient when compared to younger farmers.

The area under tea production was found to have a positive and significant effect on technical efficiency as hypothesized and it was significant at the 5% level. It may be argued that farmers with larger areas under tea production make use of economies of scale and have an opportunity to be efficient in tea production. This result is consistent with the results of Sarwar et al., (2012), Idris *et al*., (2013), Gul *et al*., (2009), Alvarez and Arias (2004), Cheng and Lo (2004), Sibiko et al., (2013), Ghorbani *et al*., (2009), Alemdar and Oren (2006) and Gul (2006).

The results also show that increases in fertiliser use and labour use results in significant decreases in technical efficiency. These results are unexpected given that the majority of the farmers are using less fertilizer than the recommended rates. One possible reason for the decrease in technical efficiency as fertiliser use increases is due to poor soil fertility management or wrong type of fertilisers used. Thus, farmers need to carryout soil fertility tests to determine the correct type and quantity of fertilisers to use. The result for the decrease in technical efficiency as the farmers increase the amount of labour days used suggest that the farmers are already using excess labour than what is necessary. Thus, farmers need to better manage their labour in order to improve on its productivity.

Tea yield contributes positively and significantly to technical efficiency and is significant at the 1% level. The result is consistent with Murthy *et al*., (2009) and Lubis *et al*., (2014). The implication is that farmers achieving higher tea yields per hectare can afford better technologies to improve technical efficiency.

The results also show that farmers who have access to extension services are more technical efficient compared to those who have no access. This result is consistent with Angi (2012), Illukpitiya (2005), Al-Hassan (2008), Jaforullah and Whiteman (1999) and Sibiko *et al*., (2013). Access to extension services improves farmers' skills and also provides them with information on good crop husbandry practices thereby influencing technical efficiency positively.

The results also show that communal farms are 12 percent less technical efficient compared to small scale commercial farms. Thus farms tend to become more technical efficient as the extent of commercialization in tea production increases.

CONCLUSION AND RECOMMENDATIONS

The results of the study reveal the existence of substantial technical inefficiencies in smallholder out-grower tea production. The study also reveals that increasing area under tea production, access to extension services and increasing tea yields can significantly improve technical efficiency among tea farmers.

There are important policy implications that can be derived from the results of this study. It is important that those involved with the smallholder out-grower tea production sub-sector are aware of the existence of the inefficiencies in production. Reducing the technical inefficiencies could improve the allocation of resources across the farming industry. This means the inputs used in excess of optimal requirements on some of the farms can be reallocated to other uses, thereby increasing the total volume of production by the smallholder farming sector in Chipinge district.

The study results imply that improvement in technical efficiency should be the first logical step for considerably increasing productivity in smallholder out-grower tea production in Chipinge district. Efficiency in tea production could be improved through optimal use of production inputs like labour and fertilizers. In addition, it is necessary to increase extension services coverage and training courses for smallholder out-grower tea producers.

COMPETING INTEREST

I declare that amongst the two authors, there are no competing interests.

AUTHORS' CONTRIBUTION

Dr Lighton Dube. He is the primary researcher and author. He did the data collection, analysis and drafting of the manuscript. He is also the corresponding author.

Dr Emmanuel Guveya. He assisted with the review of the analytical framework, data analysis and review of the draft manuscript.

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