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Research Paper

Determinants of productivity variation and technical efficiency of tea small holders in the low country of Sri Lanka

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Abstract: Tea is produced in Sri Lanka by the estate sector and smallholdings sector. Currently, tea smallholders contribute to 75% of the total tea production in the country. The highest extent of smallholder owned tea lands are accumulated in the low country (<300 m amsl), covering Ratnapura, Galle and Matara districts. Although the productivity of tea smallholdings sector appears comparatively higher than the estate sector, there is an extensive gap between the lowest and the highest productivity values. The objectives of this study were to identify the determinants of productivity variation and to determine the technical efficiencies of tea smallholders in the low country of Sri Lanka. A field survey was conducted for primary data collection from 300 tea smallholders representing 68 tea inspector regions. Data were analyzed by FRONTIER 4.1 and the stochastic frontier production function was estimated for both Cobb-Douglas and Trans log models. The Trans Log model fitted the best, in explaining the determinants compared to the Cobb-Douglas model. The direct effects of hired labour, family labour, fertilizer and chemical were statistically significant ($P<0.05$) in the stochastic frontier, and the coefficients for these factors were 0.07, 0.12, 0.0.95 and -0.01, respectively. The average technical efficiency was 68.81% (range: 15% to 93.43%). The possibility of increasing output, without increasing the existing level of input was 31.19%.

Keywords: Productivity variation, Technical efficiency, Stochastic Frontier, Trans log model

Introduction

Tea [*Camellia sinensis* (L) Kuntze], the brew of grandeur, contributes substantially to the economy of Sri Lanka, by occupying a considerable proportion in the export basket. Currently, the total income generated from tea accounts for US $ million 1345.9, which is 11.27% of the total revenue generated from country's exports to the world (Central Bank, 2019). In Sri Lanka, tea is cultivated by the estate sector and small holders sector, based on the ownership. The private owners having tea cultivations lesser than four hectares are defined as tea smallholders, who currently occupy 122,448 ha of cultivated tea extent accounting for 60% of total tea cultivated lands (MPI, 2018). However, in terms of production, tea smallholdings sector has contributed 75% of the total tea production in Sri Lanka (MPI, 2018). In viewing the recent performance of the tea sector in Sri Lanka, it is obvious that the average productivity of tea smallholders is comparatively higher than that of the estate sector. However, regardless of the increased extent of cultivated tea by smallholders, the productivity has fluctuated over the time. The average productivity in 2013 (2,107 kg of made tea/ha/year) has reduced to 1,958 kg of made tea/ha/year in 2018 (MPI, 2018).

"Productivity" is commonly defined as a ratio of a volume measure of output to a volume measure of input use (OECD, 2001), and thus calculated as the ratio of the amount of outputs produced to some measure of the amount of inputs used. Hence, these productivity measures are applied at different levels, *i.e.*, firms, industries and entire economies (FAO, 2017). Furthermore, with dependence of the context and the selection of input and output measures, productivity calculations can have different interpretations. However, the cause for variation in productivity is a matter of how efficiently inputs are converted into outputs. The stochastic frontier production function, proposed by Aigner *et al*. (1977), is widely used in econometric modelling of production and the estimation of technical efficiency of firms. The concept of the technical efficiency of firms is important in application of an econometric model of frontier functions. With marginal differences, the technical efficiency is defined as the ratio of its mean production (conditional on its levels of factor inputs and firm effects) to the corresponding mean production if the firm utilized its levels of inputs most efficiently (Baten *et al*., 2010).

In analyzing the productivity variation in tea in Sri Lanka, Basnayake and Gunaratne (2002) revealed that although the average yield was higher in smallholders sector (5,478 kg of green leaf/ha/year) and the yield tended to vary vastly. Their study for productivity variation in smallholding sector in the mid country further revealed that the yield could vary approximately between 2,297–22,971 kg of green leaf/ha/year. Similarly, the productivity varied within a range 3,157–28,714 kg of green leaf/ha/year among the tea smallholders in the Uva region (Shyamalie *et al*., 2015). Moreover, Shyamalie *et al*. (2014) showed that the tea productivity varied between 2,870–25,268 kg of green leaf/ha/year among the up country smallholders. However, the existing variation in almost all tea-growing regions suggests that there is an ample space to improve the productive efficiency. Hence, this study was conducted with the objectives of identifying and determining the productivity variation, and estimating the technical efficiency of tea smallholders in the low country Sri Lanka.

Materials and Methods

<u>Sample selection and data collection</u>

Eighty-six per cent of tea smallholdings in the low country are scattered in the low country tea-growing districts in Sri Lanka, namely, Ratnapura, Galle and Matara consisting 97,984, 90,524 and 67,613 holdings, respectively (DCS, 2005). Though the official statistics available dates back to 2005, the sample used for this study consisted of 300 randomly selected tea small holders representing all 68 Tea Inspection regions (Ratnapura – 25, Galle - 23, and Matara - 20) proportionate to population of tea small holders in each district. Primary data were collected by a field survey using a pre-tested questionnaire during January-December 2015.

<u>Conceptual framework</u>

The conceptual framework of the study is illustrated in Figure 1.

<u>Analytical framework</u>

The FRONTIER 4.1 software was employed to analyse data and variation (minimum, maximum and average). This program is specially automated for the Maximum Likelihood Estimates (Coelli, 1994). To identify the determinants of productivity variation and estimating the technical efficiency of smallholders in the low country, a stochastic production frontier approach was applied.

Aigner *et al*. (1977) and Meeusen and van den Broeck (1977) independently proposed estimation of a stochastic production frontier, which captures both measurement error and statistical noise affecting on production frontiers. As the frontier analysis distinguishes errors due to noise, it enables to measure the inefficiency. The technique assumes that the production function of a fully efficient firm is known and the deviation from the frontier is due to measurement errors, statistical noise, or due to technical inefficiency.

The stochastic production frontier, is explained by the Equations 1 and 2.

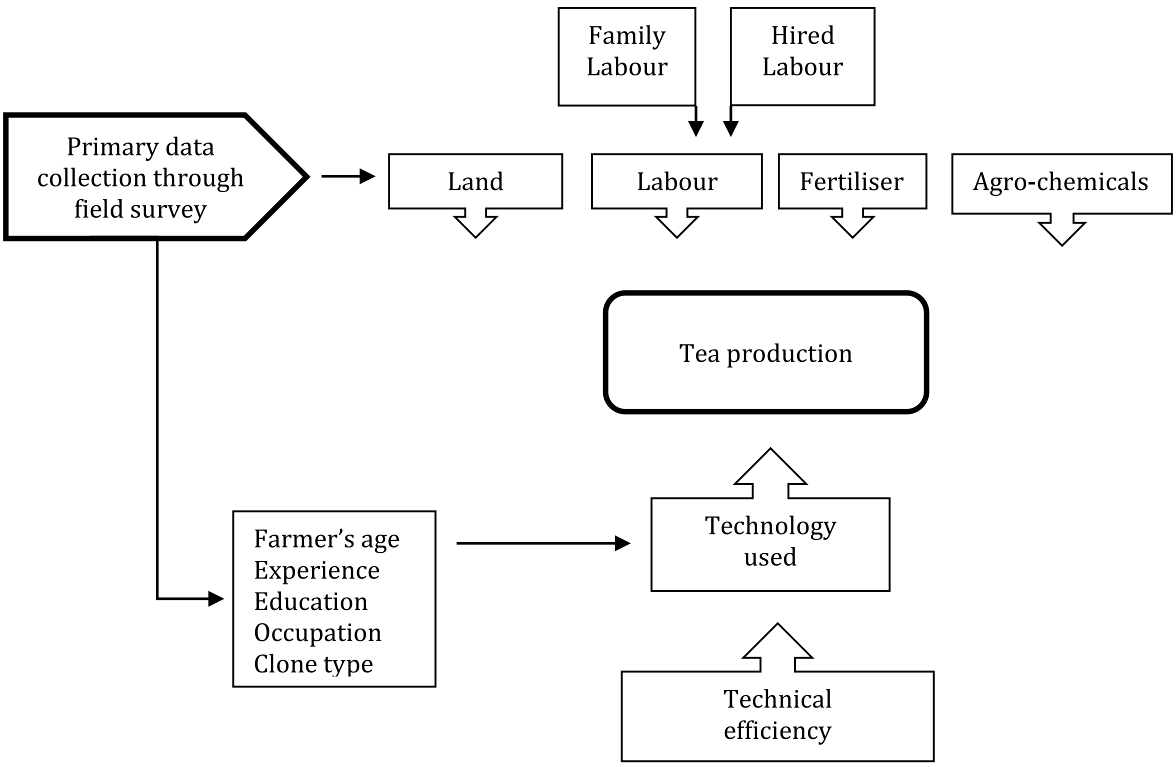

Figure 1. Conceptual framework

$$LnY_i = f(X_i;\beta) + \varepsilon_i \quad \text{……….. (Equation 1)}$$
$$\varepsilon_i = v_i + u_i \quad \text{……….. (Equation 2)}$$

Where, Y_i = Output of the i^th firm, X_i = Input of the i^th firm, β_i = Vector of unknown parameters, ε_i = Composed error term, v_i = Independently and randomly distributed errors occur due to factors out of control of the firm N (0, σ_v^2), u_i = Non-negative random variables, which are, distribute independently, identically and half normally, N (0, σ_u^2), and i = 1…, N.

The value of u_i indicates the level of efficiency of the firm relative to the frontier. If $[u_i]$=0, then it indicates that the firm is on the frontier and if, $[u_i] > 0$, then it indicates that the technical efficiency of the firm is below the frontier. Battese and Coelli (1995) has suggested the technical inefficiency as expressed by Equation 3.

$$v_i = z_i\delta + \omega_i \quad \text{……… (Equation 3)}$$

Where, z_i = Vector of explanatory variables that causes inefficiency, δ = Vector of unknown parameters, ω_i = Unobservable random variables, and i = 1…, N,. The stochastic frontier production function has been estimated for tea in both Cobb-Douglas and Translog models in different studies. According to Basnayake and Gunaratne (2002), the technical efficiency estimates are highly sensitive to the functional form. Hence, both Cobb-Douglas and Translog models were tested to select the model, which explain the relationship best. The Cobb-Douglas functional form applied is presented as the Equation 4.

$$\text{Ln } Y_i = \beta_0 + \beta_1 LnX_{1i} + \beta_2 LnX_{2i} + \beta_3 LnX_{3i} + \beta_4 LnX_{4i} + \beta_5 LnX_{5i} + \beta_6 LnX_{6i} + \beta_7 LnX_{7i} + V_i - U_i \quad \text{……. (Equation 4)}$$

Where, Ln = Logarithm value based e, Y = Output (green leaves produced in kg), X_1 = Land extent (ha), X_2 = Family labour (man days), X_3 = Hired labour (man days), X_4: Fertilizer (kg); X_5 = Chemical cost (Rupees), X_6 = Dolomite (kg), and i = 1,….., N. The technical inefficiency was estimated using the Equation 5.

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + W_i \quad \text{.........} \quad \text{(Equation 5)}$$

Where, Z_1 = Farmer's age (years), Z_2 = Experience (years), Z_3 = Education (years), Z_4 = Occupation (dummy variable, 1 - If tea cultivation is the only source of income, 0 - If otherwise), Z_5 = Clone type (dummy variable, 1 - If the clone cultivated is recommended by Tea Research Institute of Sri Lanka; 0 – if otherwise), W_i = Unobservable random variables, and i = 1, ….., N. The null hypothesis was $H_o = 0$, indicating that technical inefficiency is not present in this model. The functional form for Trans log model is presented as Equation 6.

$$\text{Ln } Y_i = \beta_0 + \sum^6_{j=1}\beta_j X_{ji} + \sum^6 \leq \sum^6_{k=1} \beta_j X_{jk} X_{ji} X_{ki} + V_i - U_i \quad \text{.........} \quad \text{(Equation 6)}$$

The inefficiency model is the same for both Cobb-Douglas and Trans log functional forms. The gamma (ϒ) is the variance ratio that explains the variation due to inefficiency (σ_u^2), from the total variation from the frontier level σ^2 (Battese and Corra, 1977) as explained by Equations 7 and 8.

$$\sigma^2 = \sigma_u^2 + \sigma_v^2 \quad \text{.........} \quad \text{(Equation 7)}$$

$$\Upsilon = \sigma_u^2 / \sigma^2 \quad \text{.........} \quad \text{(Equation 8)}$$

Results and Discussion

The summary statistics related to the study variables are presented in Table 1. Tea production of smallholders vary from 780 kg to 72,000 kg of green leaf/year and the range of the productivity was 7,706-29,640 kg of green leaf/ha/year.

Table 1. Summary statistics for variables of Stochastic Frontier production functions

Variable	Sample mean	Standard deviation	Minimum value	Maximum value
Output (kg of green leaf per year)	7,846.71	9,774.18	780	72,000
Extent (ha)	0.68	0.78	0.1	2.43
Fertilizer (kg/year)	1,518.71	2,392.4	100	25,000
Family labour (man days/year)	69.62	123.23	0	900
Hired Labour (man days/year)	412.78	731.05	0	6,000
Chemical cost (Rupees/year)	1,176.25	3,155.53	0	25,000
Zn cost (Rupees/year)	189.36	1,306.54	0	21,000
Age of farmer (years)	54	0.6	20	82
Experience (years)	23	10.8	2	55
Age of plantation (years)	16	11.66	4	76

Results of stochastic production function: Cobb-Douglas model

Empirical results of the stochastic production frontier are shown in Table 2, using both the Ordinary Least Square (OLS) and the Maximum Likelihood (ML) estimates for Cobb-Douglas production function defined in Equation 4. According to results of FRONTIER 4.1, value for ϒ was 86.45, indicating that the inefficiency error ($U_{i.}$) has made a considerable contribution to the error variation. Further, the one-sided Likelihood Ratio test value for ϒ=0 was 46.25, which exceeds the chi square critical value of 15.51 estimated by the FRONTIER 4.1 software ($P<0.05$; Table 2). Therefore, the stochastic frontier that considers the ML estimates is appropriate over OLS model in the Cobb-Douglas production function. The land, fertilizer and labour factors showed statistical significance with positive signs.

Table 2. The ordinary least square (OLS) estimate and the maximum likelihood estimates (MLE) for parameters of the stochastic frontier (Cobb-Douglas Model)

Variable	Parameter	Coefficient		Standard error		t ratio	
		OLS	MLE	OLS	MLE	OLS	MLE
Constant	β_0	6.9	7.81	0.36	0.42	18.7*	18.54*
Land	β_1	0.57	0.67	0.06	0.06	9.05*	10.88*
Family labour	β_2	0.003	0.003	0.006	0.006	0.49	0.48
Hired labour	B_3	0.017	0.013	0.008	0.008	2.11*	1.67**
Chemical	β_4	-0.001	-0.002	0.004	0.004	-0.38	-0.51
Zn	β_5	0.008	0.006	0.008	0.007	1.05	0.84
Fertilizer	β_6	0.22	0.18	0.05	0.05	4.1*	3.24*
ϒ	0.42						
σ^2	0.86						
Log likelihood value	-197.85						
Likelihood Ratio test	46.25						

*Significant at P=0.05, **Significant at P=0.1; t ratio = the estimate divided by the standard error; OLS = Ordinary Least Square estimate, MLE = Maximum Likelihood estimate

The farmer's experience, education and cultivar had a significant negative impact on the technical inefficiency while age and intercropping had a positively impact (P<0.05; Table 3).

Table 3. Inefficiency determinants based on Cobb-Douglas model

Variable	Parameter	Coefficient	Standard error	t ratio
Constant	δ_0	0.5	0.59	0.84
Farmer's age	δ_1	0.01	0.008	1.83*
experience	δ_2	-0.02	0.01	-1.94*
Education	δ_3	-0.02	0.02	-2.14*
Occupation	δ_4	0.16	0.16	0.99
Cultivar	δ_5	-0.5	0.23	-2.14*
Intercropping	δ_6	0.22	0.15	1.85*

*Significant at P=0.05, t ratio = the estimate divided by the standard error

Stochastic production function - Trans Log model

The Cobb-Douglas model have been widely accepted in literature, however, the Trans log model has also been used in estimating production frontiers for tea. The functional form that explains the relationship more precisely should identify, since the technical efficiencies estimate are particularly sensitive to the functional form specified. Accordingly, in the Trans log model, the value for σ^2 is 0.91, which indicates that a considerable contribution to error variation is due to inefficiency error U_i. The one-sided Likelihood Ratio test value for Trans log production function was 41.51 (Table 4), exceeding (P<0.05) the critical value of 15.51. Hence, the maximum likelihood estimates are efficient over ordinary least square estimates.

The hired labour, family labour, chemical and fertilizer showed a significant direct impact on tea productivity of tea smallholdings in low country of Sri Lanka (P<0.05). The output elasticity values for family labour (0.12) and hired labour (0.07) are considerably higher than that of other variables. Hence, the labour factor has a substantial significance towards productivity in the tea smallholder sector. Tea is a labour-intensive plantation crop, from the field operations to processing. The average labour requirement for plucking was 292 man days/ha/year in the low country (Sivaram and Herath 1996). Therefore, a higher output elasticity value for labour could be justified. The impact of land, in square terms, showed a negative relationship with productivity in tea smallholdings (Table 4). The respondents being smallholders, it is justifiable to stated that when the land becomes too large, the level of management declines, resulting in low productivity. However, the land factor has contributed in a significantly positive manner for the productivity in tea smallholdings in the up country (0.086), mid country (1.1) and Uva (0.83) (Shyamalie and Wellala, 2015). The effect of Zn for productivity was significantly positive (P<0.05), in square terms, with an output elasticity of 0.24. Fertilizer seems to be the most important single variable that has positively affected the productivity with an output elasticity of 0.95.

Table 4. The Ordinary leas Square (OLS) estimate and the maximum likelihood estimate (MLE) for parameters of the stochastic frontier (Trans Log Model)

Variable	Parameter	Coefficient		Standard error		t ratio	
		OLS	MLE	OLS	MLE	OLS	MLE
Constant	β_0	0.81	3.53	2.39	1.28	0.33	2.74*
Land	β_1	-1.15	-0.57	0.72	0.48	-1.59**	-1.19
Family labour	β_2	0.07	0.12	0.07	0.06	0.99	1.94*
Hired labour	β_3	0.06	0.07	0.01	0.01	4.42*	5.58*
Chemical	β_4	0.01	-0.01	0.009	0.008	-1.51*	2.13*
Zn	β_5	0.007	-0.005	0.009	0.008	0.79	-0.54
Fertilizer	β_6	1.59	0.95	0.68	0.39	2.34*	2.43*
Land* Land	β_7	-0.006	-0.004	0.003	0.003	-1.87*	-1.47**
Family labour*Family labour	β_8	0.009	0.008	0.003	0.003	2.74*	2.46*
Hired labour* Hired labor	β_9	0.009	0.009	0.01	0.009	0.86	0.92
Chemical*Chemical	β_{10}	-0.05	-0.76	0.06	0.05	-0.91	-1.38**
Zn*Zn	β_{11}	0.29	0.24	0.09	0.07	3.14*	3.09*
Fertilizer*Fertilizer	β_{12}	-0.12	-0.13	0.05	0.04	-2.15*	-2.83*
Land *Family labour	β_{13}	-0.12	-0.17	0.08	0.06	-1.47**	-1.76*
Land *Hired labour	β_{14}	0.004	0.002	0.007	0.006	0.66	0.3
Land *Chemical	β_{15}	0.01	0.018	0.004	0.004	2.52*	4.15*
Land *Zn	β_{16}	0.01	0.01	0.008	0.006	1.41*	1.7**
Land *Fertilizer	β_{17}	0.0003	-0.008	0.007	0.004	0.04	-0.15
Family labour*Hired labour	β_{18}	-0.1	-0.06	0.04	0.02	-2.12*	-2.11*
Family labour*Chemical	β_{19}	0.002	0.018	0.01	0.01	0.18	1.54**
Family labour*Zn	β_{20}	-0.002	0.003	0.01	0.01	-0.16	0.26
Family labour*Fertilizer	β_{21}	-0.004	-0.007	0.009	0.007	-0.45	-1.02
Hired labour*Chemical	β_{22}	0.002	-0.0003	0.01	0.007	0.18	-0.04
Hired labour*Zn	β_{23}	0.22	0.15	0.1	0.07	2.18*	2.17*
Hired labour*Fertilizer	β_{24}	-0.004	0.003	0.003	0.002	-1.49*	-1.55**
Chemical*Zn	β_{25}	-0.0004	0.0006	0.0008	0.0008	-0.54	-0.7
Chemical*Fertilizer	β_{26}	0.0001	0.0008	0.001	0.001	0.11	0.71
Zn*Fertilizer	β_{27}	-0.004	-0.01	0.01	0.008	-0.42	-1.34*
Υ	0.72						
σ^2	0.91						
Log likehood value	-167.59						
LR test	41.51						

*Significant at P=0.05, **Significant at P=0.1; t ratio = the estimate divided by the standard error OLS = Ordinary Least Square estimate, MLE = Maximum Likelihood estimate

The majority of tea smallholders in the study sample have used Vegetative Propagated (VP) tea cultivars for their cultivations. Usually, VP cultivars are more responsive to fertilizer than seedling tea resulting in an increased output elasticity due to fertilizer (TRI, 2000). The impact of fertilizer for tea productivity has been significantly positive for up country, mid country and Uva tea small holdings as well. Nevertheless, the impact of chemicals was negative for productivity (Table 4). The similar negative relationship of chemicals has been revealed for Uva tea-small holders (Shyamalie *et al*., 2014).

The study considered annual cost for pesticides (including weedicide/herbicide) as “chemicals”. Although manual, mechanical and chemical weeding were observed for weed control in smallholder tea fields, the majority practiced manual weeding for their young tea fields, which has resulted in high tea yields (Table 4). Hence, the inverse relationship of chemical cost towards productivity is acceptable. Although low in magnitude, several interaction effects of fertilizer and labour with other variables have become statistically significant (Table 4). Therefore, due to many direct and indirect effects being significantly different from zero, acceptance of the Trans Log model over Cobb-Douglas model could be justified. However, in previous studies conducted in the mid country, up country and Uva region, the estimates were made based on Cobb-Douglas specification. Labour, fertilizer and chemicals appear to be the most determinant factors in estimation of productivity variation in tea in spite of the geographical variation.

Accordingly, in the inefficiency model of Trans log function, experience education, occupation, cultivar and intercropping seems negative and significantly affecting on inefficiency (P<0.1). Experience seems to the most influential factor of inefficiency, which has significantly positive impact (P<0.05; Table 5). Hence, experienced farmers are efficient than those less experienced. Similarly, educated farmers are efficient than less those educated (P<0.05). Furthermore, farmers who are engaged in full-time tea cultivation seem efficient over the others. Cultivating recommended cultivars also seems to be effective that growing tea cultivars not recommended for the region. Intercropping also showed a positive influence (P<0.05) towards efficiency.

Table 5. Inefficiency determinants based on Trans Log model

Variable	Parameter	Coefficient	Standard error	t ratio
Constant	δ_0	-1.52	1.04	-1.45**
Farmer's age	δ_1	0.002	0.003	0.64
experience	δ_2	-0.017	0.007	-2.33*
Education	δ_3	-0.009	0.006	-1.6**
Occupation	δ_4	-0.013	0.009	-1.43**
Cultivar	δ_5	-0.016	0.01	-1.54**
Intercropping	δ_6	-0.013	0.009	-1.44**

*Significant at P=0.05, **Significant at P=0.1; t ratio = the estimate divided by the standard error

Based on the Trans log production model, the FRONTIER software has produced the efficiencies of each individual firm. However, for convenience, the frequency distribution of technical efficiencies was formulated (Table 6). Accordingly, a majority of tea smallholders belonged 70-80% efficiency level with a mean technical efficiency of 68.81%. The technical efficiency among the smallholders in low country varied from 15% to 93.43%. Therefore, the possibility of increasing output, without increasing the existing level of input is 31.19%. According to Basnayake and Gunaratne (2002), the mean technical efficiency among the mid country tea smallholders was 61.06%. Similarly, the technical efficiency among the up country tea smallholders ranged in between, 17.5% and 95.3 % (Shyamalie and Wellala, 2015), while among the Uva tea small holders 17.09% and the highest recorded was 99.71% (Shyamalie *et al.*, 2014).

Table 6. Distribution of technical efficiencies

Technical efficiency (%)	Number of farmers
10 - 20	2
20 - 30	8
30 - 40	18
40 - 50	20
50 - 60	33
60 - 70	53
70 - 80	83
80 - 90	75
90 - 100	8

Conclusion and Recommendations

The results clearly indicated the need to provide platforms for young farmers to collaborate with experienced farmers for knowledge exchange. As education significantly influences the productivity of tea smallholdings, improving education facilities and knowledge dissemination using new technology could be effective and efficient. This will also help new researching the farmers. Further, motivation and creating awareness to cultivate recommended cultivars, with access to planting material from certified plant nurseries, for the respective tea-growing region would reduce production inefficiencies. Although, tea is predominantly cultivated as a mono crop in Sri Lanka, Coconut (*Cocos nucifera* L.) and Pepper (*Piper nigrum* L.) could be intercropped with tea. Further research on possible intercrops for tea is of timely importance.

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