Technical Efficiency Analysis of the Cinnamon Cultivation Sector in Galle District of Sri Lanka

Colombo Economic Journal (CEJ)
Volume 2 Issue 1, June 2024: PP 89-109
ISSN 2950-7480 (Print)
ISSN 2961-5437 (Online)

Published by Department of Economics, University of Colombo, Sri Lanka
Website: https://arts.cmb.ac.lk/econ/colombo-economic-journal-cej/

J.A.S.H. Jayakody[1], T.A.M. Pushpakumara[2]

[1]Postgraduate Student - Department of Economics, University of Colombo, Sri Lanka - sandunikahansani1991@gmail.com
[2]Senior Lecturer - Department of Economics, University of Colombo, Sri Lanka - mahinda@econ.cmb.ac.lk
Correspondence: *sandunikahansani1991@gmail.com*

***Received**: 12 January 2024*, ***Revised**: 10 May, 2024*, ***Accepted**: 01 June 2024.*

Abstract

Ceylon Cinnamon, a globally acclaimed spice crucial to Sri Lanka's economy, has encountered the persistent challenge of low productivity in cultivation over the past decade. This study aimed to evaluate the technical efficiency and its determinants in the cinnamon cultivation sector of the Galle District in Sri Lanka. The study employed Cobb-Douglas stochastic frontier production function model along with the technical inefficiency effect model. Primary data were collected from 80 cinnamon farmers in the Galle District relevant to the 2021 production year. The results of the estimated production function model revealed a positive and significant impact of labor and fertilizer on cinnamon output, with decreasing return to scale in production. The results of the inefficiency model showed a negative and significant effect of farming experience, family size, occupation, membership, and access to credit on technical inefficiency while farmer's age, level of education, and age of cinnamon plants demonstrated a positive influence on technical inefficiency. The mean technical efficiency of farmers in the study area was 74.8%, implying the possibility of enhancing output by 25.2% through better utilization of the existing inputs and technology. Key policy implications, including establishing sufficient advisory and extension services, increased youth involvement, incentivizing cinnamon replanting, and improving credit access, will lead to elevate farmers' technical efficiency, thereby boosting the production and productivity of the cinnamon cultivation sector in Sri Lanka.

Key Words: *Stochastic Frontier Model, Technical Efficiency, Productivity, Cinnamon Farmers, Galle District, Sri Lanka.*

Introduction

Sri Lanka, known as the 'Spice Island', is endowed with a diverse range of spices including Cinnamon, Pepper, Cloves, Cardamom, Nutmeg, and Mace, which are primarily utilized for flavoring, coloring, and preserving food (National Export Strategy of Sri Lanka, n.d.). Within this array of spices, Ceylon Cinnamon (*Cinnamomum zeylanicum* Blume), colloquially known as 'True Cinnamon', stands out as the most preeminent spice crop in Sri Lanka due to its unique quality, color, flavor, and aroma (Tridge, 2020). Cinnamon cultivation primarily takes place in the wet and intermediate zones of Sri Lanka, particularly in the districts of Galle, Matara, Ratnapura, Kalutara, and Hambantota, covering a total land extent of 32,985 hectares (ha) and contributing 22,341 metric tons (mt) to nationwide production (Department of Export Agriculture, 2018). Comprising approximately 250,000 cinnamon cultivators and 400,000 employees, commonly referred to as 'peelers', this sector plays a pivotal role in providing substantial direct and indirect employment opportunities to a large number of rural people, while becoming the primary income source for 60,000 family units in Sri Lanka (Piyasiri & Wijeratne, 2016).

The cinnamon production industry annually generates about USD 213 million in foreign exchange to the economy and constitutes 60% of the total spices export revenue of the country (Central Bank of Sri Lanka, 2018). At present, Sri Lanka exports approximately 85% of True Cinnamon to the global market and has become the largest producer and exporter of True Cinnamon in the world. Despite being the global leader, Sri Lanka faces increased competition in the international market, as the global cinnamon market is comprised not only of True Cinnamon but also of Cassia, the closest substitute and spice inferior to True Cinnamon (Piyasiri & Wijeratne, 2016).

Although the cinnamon cultivation sector excels in both domestic and international economies, it confronts several challenges including, a shortage of skilled labor, high cost of labor and planting materials, price volatility in the international market, and low productivity (Institute of Policy Studies 2017; Tridge, 2020). Among these challenges, the predominant issue requiring immediate attention in the cinnamon cultivation sector is low productivity, as it prevents farmers from realizing the maximum possible production of their plantations (Piyasiri & Wijeratne, 2016). And also, it has led to creation of a larger yield gap between the potential and actual yield of dry cinnamon quills. Currently, in the cinnamon cultivation sector, the average annual productivity of dry cinnamon quills is recorded as 500 kg/ha whereas the annual potential yield of dry cinnamon quills is estimated to be 1500 kg/ha. Additionally, it has been disclosed that the majority of cinnamon farmers (92%) are obtaining yields below 1000 kg per ha, indicating a considerable deviation from the annual optimum productivity level (Jayasinghe *et al.*, 2016). Moreover, the level of productivity of the cinnamon cultivation sector in Sri Lanka is far below compared to that of cassia-producing countries like China and Indonesia, where an average annual productivity of 1350 kg/ha and 1000 kg/ha, are achieved, respectively (Piyasiri & Wijeratne, 2016). In light of the above facts, it is essential to boost the productivity of the cinnamon cultivation sector in order to enhance performance and expand its market share in the international market.

There are two main strategies available for addressing the issue of low productivity: introducing and adopting new technologies or enhancing technical efficiency of production (Bhende & Kalirajan, 2007). Although many countries tend to introduce new agricultural technologies as a key solution for increasing productivity, Sri Lanka, as a resource-limited nation, is not currently positioned to incur higher costs and make substantial investments in technological advancement in the short run. However, in developing countries, the adoption of new agricultural technologies has been partially successful in improving productivity because most farmers in these countries lack the ability or desire to adjust input levels, given their familiarity with traditional agricultural systems or other institutional constraints (Binam *et al.*, 2004). Therefore, improving farmer's technical efficiency is the most viable option for productivity growth because it enables farmers to raise the productivity of crops without increasing the input application and incurring additional farming expenses (Shumet, 2011; Adeoye *et al.*, 2014).

Technical efficiency refers to the ability of a farmer to produce a maximum level of output from a given set of inputs under the given technology (Coelli, 1995). There are several crucial reasons for assessing technical efficiency at the farm level in agricultural production. Firstly, if farmers are not using the existing technologies effectively, enhancing efficiency would be the most economically feasible strategy compared to introducing new technology as a means of increasing output. Secondly, efficiency measurement contributes to sustainable resource savings, which leads to important implications for both policy formulation and farm management. Thirdly, identification of sources of inefficiency provides significant insight for formulating relevant policies and strategies to enhance the performance of agricultural production (Karunarathna, 2014). Consequently, it is evident that measuring the technical efficiency of farmers and analyzing the factors affecting inefficiency is the most cost-effective strategy for addressing low productivity in the cinnamon cultivation sector in Sri Lanka.

When clarifying the research problem, it is crucial to examine the studies previously conducted in the Sri Lankan context pertinent to this field. Several scholars have reported on the low productivity in cinnamon lands in Sri Lanka and have discussed suitable methods to increase cinnamon yield through appropriate cultural practices such as earthing up, selective pruning, proper slash weeding, and the application of prescribed fertilizer doses with organic manure to control pest and diseases

(Darshanee *et al.*, 2007; Jayasinghe *et al*., 2016; Wijesinghe *et al.*, 2017). In addition, Aluthgamage *et al.* (2023) have revealed that yield indices, bush architecture, and the type of planting material are major determinants in the productivity and quill quality of cinnamon. However, none of the conducted studies have explored the impact of increasing the efficiency of cinnamon farmers on productivity improvement. Hence, this underscores a significant research gap that necessitates further investigation and exploration.

Furthermore, several empirical studies have been undertaken to assess the technical efficiency of diverse agricultural crop production in Sri Lanka, evidenced by works such as those by Basnayake and Gunaratne (2002) on tea cultivation, Bhavan and Maheswaranathan (2012) on paddy farming, Esham (2014) on maize production, Karunarathna (2014) on vegetable farming, and Kariyawasam *et al.* (2019) on vanilla production. However, to the best of the authors' knowledge, there is currently no study dedicated to estimating the technical efficiency of cinnamon farmers in Sri Lanka. Thus, it is timely and imperative to conduct a study on evaluating the level of technical efficiency of cinnamon farmers in the country. Hence, this study intends to bridge the existing knowledge gap. In this backdrop, the study aims to investigate the technical efficiency and its determinants of cinnamon farmers in the Galle District while providing important implications for policymakers to establish appropriate policies and strategies for steering future development of the cinnamon cultivation sector in Sri Lanka.

The objectives of this study are to identify the significant input factors that determine the level of output in the cinnamon cultivation sector of the Galle District, to examine the determinants of technical inefficiency in the cinnamon cultivation sector of the Galle District, and to estimate the level of technical efficiency in the cinnamon cultivation sector of the Galle District.

The rest of the paper is organized as follows: Section two presents the literature review, focusing on the existing literature on technical efficiency in agricultural crop production. Section three outlines the methodology adopted for the study. Section four presents the results and discussion, and section five is the conclusion.

Literature review

Numerous studies have been carried out to assess the technical efficiency of various agricultural crop production in both global and Sri Lankan contexts. Many of these studies have applied the stochastic frontier approach to measure technical efficiency. As per the existing literature, the variables most frequently used to estimate the production function and inefficiency effect model include land holding size, number of plots owned, farmer's access to fertilizer and agrochemicals, farmer's age, educational level, farming experience, access to credit, family size, gender, tenancy, use of improved seeds, market access, and membership in farming association (Ahmad *et al*., 2002; Basnayake & Gunaratne, 2002; Amos, 2007; Kibaara, 2005;

Karunarathna, 2014; Khatiwada & Yadav, 2022; Khan *et al.*, 2022; Mairabo *et al.*, 2023).

The studies by Amos (2007), Jha *et al*. (2005) and Barnes (2008) found a positive relationship between land holding size and technical efficiency, diverging from the findings of Kalaitzandonakes *et al*. (1992), which did not find a positive relationship. However, Jha *et al*. (2005) noted that the influence of the number of plots on efficiency was negative, suggesting that land fragmentation which is measured in terms of the number of plots, had a negative impact on yield.

Chaovanapoonphol (2022) assessed the technical efficiency of rice production in the Upper North of Thailand, revealing significant and positive effect of land, cost of chemicals, and labor on output. The study estimated the mean technical efficiency of 57.9%, with a maximum of 99.6% and a minimum of 11.3%. Khan *et al.* (2022) measured the technical efficiency of rice farmers in Khyber Pakhtunkhwa province of Pakistan, finding a significant and positive correlation between farmers' age and inefficiency in rice production. Conversely, farmers' education and experience negatively and significantly influenced inefficiency. The study reported an average technical efficiency of 87% among rice farmers in the area, with efficiency levels ranging from a minimum of 66% to a maximum of 99%. Similarly, Kariyawasam *et al*. (2019) found that both experience and education significantly and positively influence the technical efficiency of vanilla farmers in the Kandy district of Sri Lanka. The mean technical efficiency of the study area was 37.2%, suggesting that, on average, there is significant room for improvement in the vanilla production using the existing inputs and technology.

Udayanganie *et al.* (2006) assessed the technical efficiency of the agrochemical input usage in the paddy farming systems in the dry zone of Sri Lanka, employing the stochastic frontier approach and revealing a notably low technical efficiency level of 37%. The results of the production function exposed that the cost of pesticides had a negative impact on yield due to the overuse of pesticides Furthermore, the researchers have emphasized the significance of credit and extension services in enhancing farmers' efficiency in the study area. In contrast, Illukpitiya and Yanagida (2004) found mean technical efficiency of 74% in small holder paddy farms in Sri Lanka, using stochastic frontier approach. The results showed that farm size, inorganic fertilizer and method of planting had a significant effect on paddy yield while factors including farmer's age, education, experience, and extension assistance received were identified as the major determinants of the technical inefficiency of paddy farms in Sri Lanka. Similar findings were reported by Legesse *et al.* (2020), who examined the technical efficiency of smallholder honey farmers in Jimma zone of Ethiopia. The study exposed an average technical efficiency level of 74%, indicating that farmers' education level, landholding, income, extension contact, and training were significant determinants of technical efficiency.

Methodology

The study was conducted in the Galle District, the key cinnamon-cultivating region in the Southern Province of Sri Lanka. Galle District accounts for 49% of the total land area dedicated to the cinnamon cultivation in the Southern province and contributes 77% to the country's total cinnamon production. The total land area under cinnamon cultivation and the total cinnamon production made by the Galle District are recorded as 11,805 ha and 6036 mt, respectively (Department of Export Agriculture, 2018).

The multistage sampling technique was adopted for sample selection, with individual cinnamon farmers serving as the primary sampling units. According to the Department of Export Agriculture (DEA), 10 Divisional Secretariats Divisions (DSDs) were identified as the main cinnamon-cultivated areas in the Galle District. In the first stage, among these 10 DSDs, Karandeniya and Elpitiya DSDs were purposively selected for this study due to their highest contribution to the total cinnamon production of the region. Karandeniya DSD contains 1379 cinnamon farmers with 3923 ha of lands under cinnamon cultivation, while the Elpitya DSD consists of 1041 cinnamon farmers with 861 ha of cultivated lands (Department of Export Agriculture, 2018). Considering the ease of accessibility, the researchers decided on a sample size of 80 cinnamon farmers for the study. Hence, in the second stage, 46 farmers from Karandeniya DSD and 34 farmers from Elpitiya DSD were selected randomly by means of the proportional allocation technique. The following formula was used for the calculation (Cochran,1977).

$$ni = \frac{Ni}{N} \times n \qquad (1)$$

Where, n_i - cinnamon farmers selected from i^{th} DSD; n - total cinnamon farmers in sample, N_i - total cinnamon farmers in selected DSD; N - total cinnamon farmers in all selected DSDs.

Table 1: Cinnamon farmers sampling frame

Name of the DSD	Total number of cinnamon farmers	Sample representation (percentage)	Sample farmers
Karandeniya	1379	57%	46
Elpitiya	1041	43%	34
Total	2420	100%	80

Source: Authors' computation, 2021

Accordingly, in Karandeniya DSD, 46 farmers were randomly selected from Uragasmanhandiya North and Magala South Grama Niladhari Divisions (GNDs), and in Elpitiya DSD, 34 farmers were randomly selected from Nawadagala and Batuwanhena GNDs. The contact details of the farmers in each DSD were taken from the cinnamon farmers' register that was available at the DEA regional office in Galle. Therefore, a cross-sectional survey was conducted to collect primary data from 80 Cinnamon farmers in Karandeniya and Elpitiya DSDs in the Galle District, pertaining to the harvesting year of 2021. A well-structured questionnaire was used as an instrument for data collection, which was prepared and administered under close supervision of the researchers.

Specification of the empirical model

Technical efficiency is a component of productive efficiency that is derived from the production function (Forsund *et al.*, 1980). According to Ellis (1993), technical efficiency in production refers to the extent to which the actual output of a production unit reaches its maximum possible output level under the given level of inputs and technology. A firm is said to be technically efficient if it operates on the frontier, representing that the firm has achieved the maximum attainable output from each input level. All feasible points beneath the frontier are considered technically inefficient points (Coelli, 1995). There are two main approaches for measuring and analyzing the technical efficiency of production: the parametric frontier method and the non-parametric frontier method. In the parametric frontier method, the stochastic production frontier model is used to estimate the technical efficiency of production by accounting random error and inefficiency. In contrast, in the non-parametric frontier method, Data Envelopment Analysis is used to compute technical efficiency without making any specific assumption about the functional form of the production process. According to the previous literature, the stochastic production frontier approach has been the widely accepted technique for measuring technical efficiency as it captures stochastic errors due to statistical noise or measurement errors in addition to the technical inefficiency of production (Forsund *et al.*, 1980; Battese, 1992). Therefore, Stochastic Frontier Analysis (SFA) is particularly suitable for this study for several reasons. First, it accounts for random errors due to factors beyond the control of farmers, such as weather conditions, pests and diseases, which can significantly impact agricultural output. This characteristic allows SFA to separate inefficiency from statistical noise, providing a clearer and more accurate measure of the inefficiency that is within the control of the farmer, compared to non-stochastic methods like DEA. While DEA is useful for efficiency analysis, it does not account for random fluctuations and noise, which can lead to biased efficiency scores, especially in agriculture where such random factors are prevalent (Battese & Coelli, 1995). Therefore, in this study, the stochastic production frontier method was employed to estimate the technical efficiency of the Cinnamon cultivation sector.

The stochastic frontier model was independently proposed by Aigner et al. (1977) and Meeusen and Van den Broeck (1977). The stochastic frontier model splits the deviation (error term) into two parts. One component captures the random shocks outside the control of the firm such as statistical noise and measurement errors, and is considered a two-sided random error. The other component represents the technical inefficiency of the firm, which is considered a one-sided error. Application of the stochastic frontier method requires a specification of the appropriate functional form to estimate the technical efficiency. In this study, the Cobb-Douglas functional form was specified as it is the most commonly accepted functional form in the literature (Bravo-ureta & Evenson, 1994; Bhende & Kalirajan, 2007; Ngango & Kim, 2019).

The specification of the production function form is given by;

$$\ln Y_i = f(X_i, \beta) + \varepsilon_i \quad \text{where, } i = 1, \ldots, N \qquad (2)$$

$$\varepsilon_i = v_i - u_i \qquad (3)$$

Where Y_i denotes the level of output of the i^{th} farmer, X_i represents inputs used by the i^{th} farmer, and β is a vector of unknown parameter to be estimated. ε_i is the composed error term, and V_i is the two-sided error term, while U_i is the one-sided error term. The term V_i is a random error which is assumed to be independently and identically distributed with mean zero and constant variance as N $(0, \sigma_v^2)$. This signifies the stochastic effect outside the farmer's control, such as measurement errors, weather conditions, and other statistical noise (Aigner *et al.*, 1977). U_i is a non-negative ($U_i \geq 0$) random variable, which is assumed to be independently and identically distributed as N $(0, \sigma_u^2)$, and follow a half-normal distribution. U_i is associated with technical inefficiency of production and ranges between zero and one. N indicates the number of farmers involved in the cross-sectional survey.

According to Battese and Coelli (1995), the technical inefficiency effect is defined by;

$$U_i = \delta Z_i + W_i \quad \text{where, } i = 1, \ldots, N \qquad (4)$$

Where Z_i is a vector of explanatory variables associated with the technical inefficiency effect, δ is a vector of unknown parameter to be estimated, and W_i is a set of unobservable random variables.

The stochastic frontier model can be estimated by using either the Ordinary Least Square (OLS) method or the Maximum Likelihood (ML) method. Since the OLS method is impossible to decompose the technical inefficiency from random shocks, the ML estimation method was employed to estimate the parameters of both the stochastic frontier model and the inefficiency effect model.

According to Battese and Corra (1977), the variance ratio parameter (γ), which relates the variability of U_i to total variability (σ^2), can be calculated as follows.

$\gamma = \sigma^2_u / \sigma^2$ (5)

Where, $\sigma^2 = \sigma^2_u + \sigma^2_v$ (6)

Thus, $0 \leq \gamma \leq 1$ (7)

The γ parameter measures the technical inefficiency effect in cinnamon production, representing variation of observed output from the optimal output. It takes a value between zero and one. This means that if γ equals zero, the difference between the farmer's yield and the efficient yield is entirely due to statistical noise. Conversely, if γ equals one, it indicates a farmer's level of inefficiency in utilizing existing resources and technology, known as technical inefficiency (Coelli, 1995).

The SFA is mainly directed toward the estimation of the inefficiency effect (Battese & Coelli, 1995). The most common output-oriented measure of estimating the technical efficiency of an individual farmer is defined as the ratio of observed (actual) output to the corresponding stochastic frontier output, which represents the maximum possible output.

$TE_i = Y_i / Y_i^*$ (8)

Where, TE_i = Technical efficiency of the i^{th} farmers in cinnamon production

Y_i^* = The frontier output of the i^{th} farmers in cinnamon production

Y_i = The actual output of the i^{th} farmers in cinnamon production

Then $Y_i^* = Y_i / TE_i$ (9)

The technical inefficiency effect can be derived by using the following formula.

$TE_i = Y_i / Y_i^*$

$$TE_i = \frac{f(X_i;\beta) + \exp(V_i - U_i)}{f(X_i;\beta) + \exp(V_i)} \quad (10)$$

$TE_i = \exp(-U_i)$ (11)

Therefore, the technical efficiency of production for the i^{th} cinnamon farmers could be defined by, $TE_i = \exp(-U_i)$.

Then, the technical inefficiency can be obtained as one minus technical efficiency ($1 - TE_i$).

The following model specifications were used in the analysis.

The Cobb-Douglas production function is stated as follows.

$\ln Y_i = \beta_0 + \beta_1 \ln X_{1i} + \beta_2 \ln X_{2i} + \beta_3 \ln X_{3i} + V_i - U_i$ (12)

Where, ln denotes natural logarithm, Y_i = Output (kilograms of Cinnamon quills), X_{1i} = Land size (hectares), X_{2i} = Labor (working hours), X_{3i} = Fertilizer (Kilograms), β_0 = Constant term, β_i = Unknown parameters to be estimated, V_i = Two-sided random error that represents factors outside the control of the farmer, and U_i = One-sided non-negative random error which represents the technical inefficiency.

According to the inefficiency model specified in Battese and Coelli (1995) specification, it was stated as follows:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + W_i \quad (13)$$

Where U_i = Technical inefficiency effect, Z_1 = Farmer's age (years), Z_2 = Farming experience (number of years), Z_3 = Level of education (number of years of schooling), Z_4 = Family size (Number of members living in the household), Z_5 = Age of cinnamon plants (years), Z_6 = Occupation (a dummy variable which equals one if the farmer permanently involved in cinnamon cultivation only; zero otherwise), Z_7 = Membership (a dummy variable which equals one if the farmer is a member of any farming union or group; zero otherwise), Z_8 = Access to credit (a dummy variable which equals one if the farmer has access to credit; zero otherwise), δ_0 = Constant term, δ_i = Inefficiency parameters to be estimated, and W_i = unobservable random variables.

The maximum likelihood estimates of the parameters for the stochastic frontier production function and predicted technical efficiency were obtained using the computer software STATA version 14.

Results and discussion

Descriptive statistics for the variables

Table 2 presents the summary statistics results of the variables in the Cobb-Douglas stochastic frontier production function and inefficiency effect model. The results depicted that, on average, cinnamon farmers in the sample produced an output of 646.82 kg per ha, ranging from 50 kg to 1250 kg per ha, with a standard deviation of 404.11. This indicates a significant variability of output among the farmers in the sample. The average land area allocated to cinnamon cultivation was approximately 0.85 ha, ranging from 0.10 ha to 2.40 ha and a standard deviation of 0.69. The average labor utilization by the farmers in the sample, including both family and hired labor, was 625.48 hours per ha, varying from 150 hours per ha to 1250 hours per ha. The mean rate of fertilizer application in the sample was 531.72 kg per ha, ranging from a minimum of 0 kg per ha to a maximum of 1438 kg per ha with a standard deviation of 347.63 during the year. According to the DEA, the average standard levels of cinnamon output, labour utilization, and fertilizer application per year were recorded as 600 kg per ha, 1600 hours per hectare, and 600 kg per hectare, respectively (Department of Export Agriculture, 2018). Therefore, these results align with the standard values set by the DEA for cinnamon output and fertilizer application, but labor utilization fell below prescribed standards.

Descriptive statistics of variables in the inefficiency model, as presented in Table 2, shows the demographic profile of farmers in the sample. The average age of farmers in the sample was 44.66 years, with a minimum of 31 years and a maximum of 72 years. Notably, the majority (55%) fell within the 31- 40 age group, suggesting that a significant portion of the farmers in the sample was relatively young. The mean length of cinnamon cultivation experience was 12.6 years, spanning from 2 - 40 years, with 65% of farmers having 1 to 10 years of experience, indicating that the majority are relatively new to cinnamon cultivation. The farmers had an average of 11 years of education, ranging from 5 to 10 years, signifying that most of the farmers have attained at least secondary education. The average household size was 4, ranging 2 to 6 members. The mean age of cinnamon plants in the study area was 10.91 years with a range of 1 to 80 years and a standard deviation of 17.32. Regarding occupation, 41% of farmers were permanently engaged in cinnamon cultivation on a full-time basis, while the remaining 59% pursued it as a secondary activity, aiming to generate an additional income. The findings revealed that 28% of farmers were affiliated with a cinnamon cultivators' union, group, or association, whereas the remaining 72% did not hold such membership. Only 16% of farmers in the sample had access to credit facilities, with the remaining 84% had no access. This was primarily due to financial constraints which impeded their capacity to obtain loans or credit facilities.

Table 2: Descriptive statistics for variables in the stochastic frontier production function model

Variable	Mean	Standard Deviation	Minimum	Maximum
Production function model				
Output (kg / ha)	646.82	404.11	50	1250
Land size (ha)	0.85	0.69	0.10	2.40
Labor (hrs / ha)	625.48	281.49	150	1250
Fertilizer (kg / ha)	531.72	347.63	0	1438
Inefficiency model				
Farmer's Age	44.66	11.87	31	72
Farming Experience	12.6	10.66	2	40
Level of Education	11.35	1.91	5	13
Family Size	4.05	0.86	2	6
Age of Cinnamon Plants	10.91	17.32	1	80
Occupation	0.41	0.49	0	1
Membership	0.28	0.46	0	1
Access to Credit	0.16	0.37	0	1

Source: Sample Survey, 2021

Estimates of Cobb-Douglas stochastic frontier production model

The Cobb-Douglas stochastic frontier production function model (Equation 12) was employed to address the first objective of the study, which is to identify the significant input factors determining the level of output in the cinnamon cultivation sector in the Galle District.

Table 3: Maximum likelihood estimates for parameters of the Cobb-Douglas stochastic frontier model

Variable	Parameters	Coefficient	Standard Error	Z -Value
Constant	β_0	1.326	0.686	1.93*
Land size	β_1	0.060	0.073	0.82
Labor	β_2	0.732	0.112	6.53***
Fertilizer	β_3	0.159	0.027	5.89***
Variance Parameters				
Sigma _ v (σ_v)		0.218	0.048	
Sigma _ u (σ_u)		0.689	0.084	
Sigma-squared (σ^2)		0.522	0.108	
Gamma ($\gamma = \sigma^2_u / \sigma^2$)	0.908			
Total number of observations	80			

*, **, *** significant at 10%, 5%, 1% significance levels, respectively.
Source: Sample Survey, 2021

According to the results presented in Table 3, the maximum likelihood estimates of the variance ratio parameter (γ), which elucidates the ratio of the variance of the inefficiency component to the total error term, was 0.908. It indicates that 90.8% of the error variance for the cinnamon farmers was due to the inefficiency error (u_i) whereas the remaining 9.2% arose from random error (v_i), which was beyond the control of the farmer. The results revealed that labor and fertilizer were highly significant at 1% level of significance; however, land size was insignificant in determining cinnamon output. The estimated maximum likelihood coefficients for labor and fertilizer showed positive values of 0.732 and 0.159, respectively, implying that a 1% increase in inputs such as labor and fertilizer will result in an increase in output by 0.732 and 0.159, respectively. Moreover, the results disclosed that inputs of labor and fertilizer used in the production function were inelastic; indicating that a 1% increase in these inputs would result in a less than 1% increase in cinnamon output. According to the results, labor was the most significant factor in cinnamon production as it exhibited the highest elasticity value (0.732). This is likely due to cinnamon cultivation being an entirely labor-intensive farming practice, greatly influencing the total output. Furthermore, the estimated coefficient values of the Cobb-Douglas production function represent the production elasticities, which measure the responsiveness of cinnamon output to the variation in a particular input. Accordingly, the sum of the individual elasticity of each input variable in the production function is referred to as scale elasticity, which indicates the return to scale. Hence, the results revealed that the sum of all production elasticities was 0.89, indicating that farmers in the study area were experiencing a decreasing return to scale in cinnamon production. This means that a proportional increase in input variables (labor, fertilizer) in the production function results in a less than proportional increase in cinnamon output.

Determinants of technical inefficiency

The second stage of the analysis focuses on addressing the second objective of the study, which is to examine the determinants of technical inefficiency in the cinnamon cultivation sector in the study area. For this purpose, the inefficiency model (Equation 13) was employed, incorporating various socio-economic factors. Table 4 presents the maximum likelihood estimates for the variables in the inefficiency effect model.

Table 4: Maximum likelihood estimates of the technical inefficiency model

Variable	Parameters	Coefficient	Standard Error	Z -Value
Constant	δ_0	-9.552	4.414	-2.16**
Farmer's Age	Z_1	0.411	0.149	2.75***
Farming Experience	Z_2	-0.510	0.209	-2.44**
Level of Education	Z_3	0.241	0.146	1.65*
Family Size	Z_4	-2.326	0.516	-4.50***
Age of Cinnamon Plants	Z_5	0.123	0.051	2.40**
Occupation	Z_6	-1.385	0.656	-2.11**
Membership	Z_7	-3.996	1.182	-3.38***
Access to Credit	Z_8	-4.838	1.605	-3.01***

*, **, *** significant at 10%, 5%, 1% significance levels, respectively.
Source: Sample Survey, 2021

According to the result of the model, the farmer's age was highly significant at 1% level of significance and positively correlated with technical inefficiency. This suggests that younger farmers tend to be more technically efficient than older farmers in the study area. Like other occupations, farming also requires accumulated knowledge, skills, and physical capability. Although these factors typically increase with age, they tend to decline after reaching a certain age limit. Hence, it is evident that older farmers have less physical capacity to perform farming activities as efficiently as younger farmers. Moreover, younger farmers are more skilled in adopting modern technology, so they can access market information more easily than older farmers. This result is consistent with the findings of Chirwa (2007), Bozoglu and Ceyha (2007), Shumet (2011), and Khan et al. (2022). The farming experience showed a negative coefficient value and was significant at 5% level of significance, implying that an increase in the number of years of farming may enable farmers to develop better managerial skills and capabilities, which, in turn, could help minimize inefficiencies and achieve a higher level of technical efficiency. This finding aligns with the results reported by Bozoglu and Ceyhan (2007), Viengpasith et al. (2012), Biam et al. (2016), Kariyawasam et al. (2019), and Khan et al. (2022). The level of education was found to have a positive and significant effect (at 10% level of significance) on farmers' technical inefficiency in production, indicating that higher education levels may cause increased inefficiency. This could be attributed to educated farmers redirecting their attention toward alternative income-generating opportunities, leveraging their skills in other sectors. This finding diverges from prior studies conducted by Bozoglu and Ceyhan (2007), Idiong (2007), and Kariyawasam et al. (2019), which have suggested a negative correlation between education and technical inefficiency. However, our study revealed a positive association between farmers' level of education and technical inefficiency.

The findings disclosed that family size negatively influenced technical inefficiency and was highly significant at 1% level of significance, indicating that farmers with more family members are more technically efficient than farmers with fewer family members. Having a large family is an advantage for farmers as they could use their family members for cinnamon cultivation activities such as fertilizer application, weed management, and other maintenance activities without incurring additional expenses on hiring labor from outside. This result is in line with the findings of Shumet (2011) and Thayaparan and Jayathilaka (2020). The coefficient of age of cinnamon plants showed a positive value and was significant at the 5% level of significance, suggesting that older plants contribute to higher inefficiency levels. Conversely, younger plants contribute to enhanced technical efficiency thereby yielding higher cinnamon output. Thus, farmers managing younger cinnamon plants in their plantations demonstrate greater technical efficiency compared to those overseeing older plants.

According to the results of the model, occupation was found to be significant at 5% level of significance and negatively correlated with technical inefficiency. This elucidates that farmers who are permanently involved in cinnamon cultivation demonstrate higher levels of technical efficiency compared to those who are not fully dedicated to this sector. This is because farmers engaged full-time in cinnamon cultivation can devote more time and attention to farming activities, in contrast to those involved on a part-time basis. A similar result was reported by Basnayake and Gunaratne (2002). Membership showed a negative coefficient value and was significant at the 1% level of significance, suggesting that farmers who are members of any cinnamon cultivators' union, group or association tend to be more technically efficient than non-members. This finding implies that holding membership in a farming group may motivate farmers to access up-to-date information on market changes and acquire new knowledge on cinnamon cultivation practices, ultimately aiding them in achieving maximum level of production. Similar findings were reported by Idiong (2007), Raphael (2008), and Viengpasith et al. (2012). The results revealed that credit access was significant at 1% level of significance and negatively correlated with technical inefficiency, indicating that farmers with higher access to credit facilities tend to be more technically efficient than those with no access. This is likely because of credit availability which relaxes cash constraints, enabling farmers to make timely purchases of the inputs and other resource necessary for their cultivation activities. This result is consistent with the findings of Bozoglu and Ceyhan (2007), Idiong (2007) and, Viengpasith et al. (2012).

Estimates of technical efficiency

To address the third objective of the study, the technical efficiency of farmers in the sample was estimated using the formula outlined in the methodology section (Equation 10). Table 5 presents the frequency distribution of technical efficiency of cinnamon farmers in the study area.

Table 5: Frequency distribution of technical efficiency estimates

Range of technical efficiency (%)	Number of farmers	Percent
Less than 40	4	5.0
40 - 60	22	27.5
60 - 80	6	7.5
80 -100	48	60.0
Total	80	100.0
Mean	0.7483	
Minimum	0.1440	
Maximum	0.9951	

Source: Sample Survey, 2021

The study found that the majority (60%) of farmers achieved a technical efficiency level exceeding 80%, showcasing effective resource utilization. Moreover, a smaller percentage operate within lower efficiency ranges, with only 7.5% falling between 60% and 80%, and 5% recording a technical efficiency level below 40%. The overall results indicated that the mean technical efficiency level of cinnamon farmers in Galle District was 74.8% with the minimum and maximum efficiency levels of 14.4% and 99.5%, respectively. Furthermore, it disclosed that cinnamon farmers have the potential to increase output by 25.2% given the existing inputs and technology levels. This suggests that eliminating this 25.2% of inefficiency could empower farmers to attain maximum cinnamon production through effective utilization of available resources and the current state of technology.

Conclusion

This study utilizes the Cobb-Douglas stochastic frontier production function model alongside the technical inefficiency effect model to assess technical efficiency and sources of inefficiency in the cinnamon cultivation sector in the Galle District, Sri Lanka. The key findings indicated that except land size all input variables such as labor and fertilizer positively and significantly influenced cinnamon output, suggesting that increasing any of these factors could lead to an expansion of cinnamon production. Moreover, the study revealed that farmer's age, farming experience, level of education, family size, age of cinnamon plants, occupation, membership, and access to credit were significant determinants of technical inefficiency in the study area. The mean technical efficiency of cinnamon farmers in the Galle District was 74.8%, indicating potential for increasing the level of output by 25.2% without increasing available input levels.

Based on the results of the study, the following recommendations are made for policy implications. Given the study's emphasis on labor as the most significant factor influencing cinnamon output, it is essential to devise new strategies aimed at enhancing labor productivity. This can be accomplished by replacing traditional cultivation methods with modern farming techniques, enabling farmers to utilize their labor resources more effectively and efficiently, thereby increasing yields. Considering the substantial impact of fertilizer on output, it is crucial to instruct farmers on preparing appropriate fertilizer mixtures and provide guidance on proper application methods to attain optimum yield. Thus, establishing comprehensive advisory or extension services is of utmost importance to facilitate improvement in farming practices and ultimately obtain higher yields. The findings suggest that younger farmers exhibit greater technical efficiency, highlighting the importance of fostering youth involvement in cinnamon cultivation. Thus, strategies should focus on altering young people's attitude towards farming and guiding them towards exploring international market opportunities. Moreover, demonstrating the potential for earning higher levels of foreign exchange earnings by providing high-quality cinnamon products to the world can serve as a compelling incentive for their engagement in the sector. In addition, the policies should be aligned to retain educated farmers within the sector as the findings suggested educated farmers may opt to transition to other sectors in pursuit of higher income opportunities. It is suggested to raise awareness among farmers about the benefits of replacing old cinnamon plants with new ones, as younger plants tend to yield more than older ones. Hence, it is imperative for authorities to prioritize the implementation of incentive schemes for cinnamon replanting or new planting alongside providing comprehensive guidance to farmers, ensuring the attainment of maximum yield from their plantations. Another suggestion is to encourage farmers to become members of farmers' unions, which can inspire them to achieve higher levels of efficiency in their production. Moreover, strategies should focus on increasing farmers' access to credit. Hence, government should provide support to cinnamon farmers through an adequate legal and regulatory framework to ensure proper access to credit facilities. In light of the aforementioned findings and recommendations, which encompass enhancing labor productivity, optimizing fertilizer use, establishing extension services, engaging youth in farming, retaining educated farmers, rejuvenating cinnamon plantations, strengthening farmer unions, and improving access to credit, it is suggested that policy initiatives in the country should prioritize improving the technical efficiency of farmers, as this is the most feasible strategy for increasing the productivity and export competitiveness of the cinnamon cultivation sector in Sri Lanka.

Acknowledgements: The authors wish to thank the Editorial Board of CEJ for accepting this paper for publication and express their deep gratitude to the two anonymous independent reviewers for their insightful comments and constructive suggestions.

References

Adeoye, I. B., Fashogbon, A. E., & Idris, B. A. (2014). Analysis of technical efficiency of pepper production among farmers under tropical conditions. *International Journal of Vegetable Science*, *20*(2): 124–130. https://doi.org/10.1080/19315260.2012.762964

Ahmad, M., Chaudhry, G. M., & Iqbal, M. (2002). Wheat productivity, efficiency, and sustainability: A stochastic production frontier analysis. *Pakistan Development Review*, *41*(4): 643–663. https://doi.org/10.30541/V41I4IIPP.643-663

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21–37. https://doi.org/10.1016/0304-4076(77)90052-5

Aluthgamage, H. N., Kumari Fonseka, D. L. C., & Nakandalage, N. (2023). Enhancement of high-quality cinnamon quill production through agronomic approaches: a review. *Academia Biology*. https://doi.org/10.20935/acadbiol6025

Amos, T. T. (2007). An analysis of productivity and technical efficiency of smallholder cocoa farmers in Nigeria. *Journal of Social Sciences*, *15*(2), 127–133. https://doi.org/10.1080/09718923.2007.11892573

Barnes, A. (2008). Technical efficiency estimates of Scottish agriculture: A note. *Journal of Agricultural Economics*, *59*(2), 370–376. https://doi.org/10.1111/j.1477-9552.2008.00156.x

Basnayake, B. M. J. K., & Gunaratne, L. H. P. (2002). Estimation of technical efficiency and it’s determinants in the tea small holding sector in the Mid country

Wet zone of Sri Lanka. *Sri Lankan Journal of Agricultural Economics*, *4*, 137–150. https://doi.org/10.22004/AG.ECON.205930

Battese, G. E., & Coelli, T. J. (1992). Frontier production functions, technical efficiency and panel data: With application to paddy farmers in India. *Journal of Productivity Analysis*, *3*(1), 153–169. https://doi.org/10.1007/BF00158774

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, *20*(2), 325–332. https://doi.org/10.1007/BF01205442

Battese, G. E., & Corra, G. S. (1977). Estimation of a production frontier model: With application to the Pastoral Zone of Eastern Australia. *Australian Journal of Agricultural Economics*, *21*(3), 169–179. https://doi.org/10.1111/J.1467-8489.1977.TB00204.X

Bhavan, T., & Maheswaranathan, S. (2012, December). *Technical efficiency of paddy farmers in Batticaloa District of Sri Lanka* [Paper Presentation]. Sri Lanka Economic Research Conference (SLERC-2012), International Symposium, University of Colombo, Sri Lanka.

Bhende, M. J., & Kalirajan, K. P. (2007). Technical efficiency of major food and cash crops in Karnataka, India. *Indian Journal of Agricultural Economics*, *62*(2), 176–192.

Biam, C. K., Okorie, A., & Nwibo, S. U. (2016). Economic efficiency of small scale soyabean farmers in Central Agricultural Zone, Nigeria: A Cobb-Douglas stochastic frontier cost function approach. *Journal of Development and Agricultural Economics*, *8*(3), 52–58. https://doi.org/10.5897/JDAE2015.0688

Binam, J. N., Tonye, J., Wandji, N., Nyambi, G., & Akoa, M. (2004). Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. *Food Policy*, *29*(5), 531–545. https://doi.org/10.1016/j.foodpol.2004.07.013

Bozoglu, M., & Ceyhan, V. (2007). Measuring the technical efficiency and exploring the inefficiency determinants of vegetable farms in Samsun Province, Turkey. *Agricultural Systems*, *94*(3), 649–656. https://doi.org/10.1016/J.AGSY.2007.01.007

Bravo-ureta, B. E., & Evenson, E. (1994). Efficiency in agricultural production: The case of peasant farmers in Eastern Paraguay. *Agricultural Economics*, *10*, 27–37.

Central Bank of Sri Lanka. (2018). *Annual Report*. Central Bank of Sri Lanka, Colombo. https://www.cbsl.gov.lk/en/publications/economic-and-financial-reports/annual-reports/annual-report-2018

Chaovanapoonphol, Y., Singvejsakul, J., & Sriboonchitta, S. (2022). Technical Efficiency of Rice Production in the Upper North of Thailand: Clustering Copula-Based Stochastic Frontier Analysis. *Agriculture (Switzerland)*, *12*(10), 1–13. https://doi.org/10.3390/agriculture12101585

Chirwa, E. W. (2007). *Sources of technical efficiency among smallholder maize farmers in Southern Malawi* (Working Paper No. 172). African Economic Research Consortium, Research Department. http://publication.aercafricalibrary.org/handle/123456789/399

Cochran, W. G. (1977). *Sampling Techniques* (3rd edi.). Wiley.

Coelli, T. J. (1995). Recent developments in frontier modelling and efficiency measurement. *Australian Journal of Agricultural Economics*, *39*(3), 219–245. https://doi.org/10.1111/j.1467-8489.1995.tb00552.x

Darshanee, H.L.C., Jayasinghe, G.G., Wijesinghe, K.G.G., & Gunaratne, W. D. L. (2007). Effects of different weed control methods in cinnamon, *Proceedings of the 21st Asian Pacific Weed Science Society Conference*, *October*, 78–81.

Department of Export Agriculture. (2018). *EAC stat book: Export agricultural statistics*.

Ellis, F. (1993). *Peasant economics: Farm households and agrarian development* (2nd edi.). Cambridge University Press.

Esham, M. (2014). Technical efficiency and determinants of maize production by smallholder farmers in the Moneragala District of Sri Lanka. *Mediterranean Journal of Social Sciences*, *5*(27), 416–422. https://doi.org/10.5901/MJSS.2014.V5N27P416

Forsund, F. R., Lovell, C. K., & Schmidt, P. (1980). A survey of frontier production functions and of their relationship to efficiency measurement. *Journal of Econometrics*, *13*(1), 5–25.

Idiong, I. C. (2007). Estimation of farm level technical efficiency in small scale swamp rice production in Cross River State of Nigeria: A stochastic frontier approach. *World Journal of Agricultural Sciences*, *3*(5), 653–658.

Illukpitiya, P., & Yanagida, J. F. (2004). Improving agricultural production through technical efficiency: A case study of small-holder paddy farming in Sri Lanka. *Tropical Agriculture*, *81*(1), 1–7. https://journals.sta.uwi.edu/ojs/index.php/ta/article/view/1235

Institute of Policy Studies of Sri Lanka. (2017). *Analysis of cinnamon, pepper and cardamom value chains in Sri Lanka*. https://www.ips.lk/analysis-cinnamon-pepper-cardamom-value-chains-sri-lanka

Jayasinghe, G. G., Ketakumbura, K. H. M. P. K., Wijesinghe, K. G. G., Hemachandra, K. S., & Weligamage, S. (2016). Relationship between pest and disease incidences and agronomic operations implemented by farmers in Cinnamon (Cinnamomum zeylanicum Blume) fields in Southern Sri Lanka. *Sri Lanka Journal of Food and Agriculture*, *2*(1), 35–40. https://doi.org/10.4038/SLJFA.V2I1.23

Jha, R., Nagarajan, H. K., & Prasanna, S. (2005). *Land fragmentation and its implications for productivity: Evidence from Southern India* [*ASARC Working Papers No.2005-01]*. The Australian National University, Australia South Asia Research Centre. https://ideas.repec.org/p/pas/asarcc/2005-01.html

Kalaitzandonakes, N. G., Wu, S., & Ma, J. (1992). The relationship between technical efficiency and firm size revisited. *Canadian Journal of Agricultural Economics*, *40*(3), 427–442. https://doi.org/10.1111/J.1744-7976.1992.TB03705.X

Kariyawasam, L. G. T. W., Dharmadasa, R. A. P. I. S., Rudrigo, C., & Amarakoon, A. M. C. (2019). Estimation of farm level technical efficiency and its socio-economic determinants in vanilla production in Kandy District, Sri Lanka. *Sri Lankan Journal of Business Economics*, *8*(1), 46–66. https://journals.sjp.ac.lk/index.php/sljbe/article/view/3932

Karunarathna, M. (2014). Estimating technical efficiency of vegetable farmers in Anuradhapura District in Sri Lanka. *Sri Lanka Journal of Economic Research*, *2*(2), 55–67. https://doi.org/10.4038/SLJER.V2I2.92

Khan, S., Shah, S. A., Ali, S., Ali, A., Almas, L. K., & Shaheen, S. (2022). Technical Efficiency and Economic Analysis of Rice Crop in Khyber Pakhtunkhwa: A Stochastic Frontier Approach. *Agriculture (Switzerland)*, *12*(4). https://doi.org/10.3390/agriculture12040503

Khatiwada, D., & Yadav, P. (2022). Technical Efficiency of Ginger Production in Ilam District of Nepal: A Stochastic Production Frontier Approach. *Advances in Agriculture*, *2022*. https://doi.org/10.1155/2022/3007624

Kibaara, B. W. (2005). *Technical efficiency in Kenyan's maize production: An application of the stochastic frontier approach* [Master's thesis, Colorado State University].

Legesse, H., Bekele, Y., Bayissa, M., & Lemma, T. (2020). Technical efficiency of smallholder honey farmers in Jimma zone, Ethiopia. *RUDN Journal of Economics*, *28*(1), 7–22. https://doi.org/10.22363/2313-2329-2020-28-1-7-22

Mairabo, A., Jibrin, S., Audu, H., Salihu, M. Y., & Elisha, Y. (2023). Technical efficiency of soybean production in Niger State, Nigeria. *FUDMA Journal of Sciences (FJS)*, *4*(1), 88–100

Meeusen, W., & Van den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, *18*(2), 435–444. https://doi.org/10.2307/2525757

National Export Strategy of Sri Lanka. (n.d.). *Spices and concentrates strategy*. Retrieved January 26, 2024, from https://www.scribd.com/document /373296376/Spices-and-ConcentratesStrategy-National- Export-Strategy-2018-2022

Ngango, J., & Kim, S. G. (2019). Assessment of technical efficiency and its potential determinants among small-scale coffee farmers in Rwanda. *Agriculture*, *9*(7), 1–12. https://ideas.repec.org/a/gam/jagris/v9y2019i7p161-d250592.html

Piyasiri, K. H. K. L., & Wijeratne, M. (2016). Comparison of the cultivated area and the production trends of Ceylon Cinnamon with the main competitors in the worlds' total Cinnamon market. *International Journal of Scientific and Research Publications*, *6*(1), 476–480.

Raphael, I. O. (2008). Technical Efficiency of cassava farmers in South Eastern Nigeria: Stochastic frontier approach. *Agricultural Journal*, *3*(2), 152–156. https://medwelljournals.com/abstract/?doi=aj.2008.152.156

Shumet, A. (2011). *Analysis of technical efficiency of crop producing smallholder farmers in Tigray, Ethiopia* [MPRA Paper No.40461]. University Library of Munich, Germany. https://ideas.repec.org/p/pra/mprapa/40461.html

Thayaparan, A., & Jayathilaka, D. M. P. I. L. (2020, October 27). *Technical efficiency of paddy farmers and its determinants: Application of translog frontier analysis* [Paper Presentation]. International Conference on Business Research, University of Moratuwa, Sri Lanka.

Tridge. (2020). *Analysis on the Cinnamon industry in Sri Lanka*. https://www.tridge.com/intelligences/cinnamon/LK

Udayanganie, A. D. D., Prasada, D. V. P., Kodithuwakku, K. A. S. S., Weerahewa, J., & Little, D. C. (2006). *Efficiency of the agrochemical input usage in the paddy farming systems in the Dry Zone of Sri Lanka* [Paper Presentation]. Annual Meeting of the Canadian Agricultural Economics Society in Montreal, Quebec. https://doi.org/10.22004/AG.ECON.34181

Viengpasith, V., Yabe, M., & Sato, G. (2012). Analysis of technical efficiency of smallholder maize farmers in Northern Lao PDR: Case study of Paklay district, Sayaboury province. *Journal of the Faculty of Agriculture, Kyushu University*, *57*(1), 309–315.

Wijesinghe, R., Perera, S., & Wijesinghe, P. (2017). *Present situation and prospects of Cinnamon industry in Sri Lanka*.