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Resource-use Efficiency in Raw Cashew Nut Production in Kerala, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: To analyze the Resource use efficiency related to raw cashew nut production in Kerala
Study Design: Data was collected using a structured questionnaire administered to 120 randomly selected respondents.
Place and Duration of Study: The study was conducted in the Kannur and Kollam districts of Kerala from 2023-2024.
Methodology: The analysis employed production function analysis through the Ordinary Least Squares (OLS) method using the mathematical form of the Cobb-Douglas production function. The simple descriptive statistics were used to analyze the Socio-economic profile of sample farmers.
Results: The findings revealed that most farmers were elderly and dependent on agriculture (72.5%), with marginal (47.5%) followed by small farmers (31.7%), and had a good literacy

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level. The study stated that manure (p-value; 1.4E-13), and human labour, (0.032), were found to be significant and positively impacted cashew output, and the age of plants (0.019) was found to be significant but negatively related to the yield. This states that with an increase in the age after reaching the yield decreasing phase i.e. of age (> 30 years) the yield starts declining. The analysis also indicated inefficiencies in resource use: manures were underutilized (r>1 i.e. 3.65) whereas labour (r<1 i.e. 0.143) was overused.

Conclusion: Raw cashew cultivation efficiency was analyzed using the Cobb-Douglas function, showing organic manure and labour as significant factors. With increasing returns to scale, better resource use can boost production. Extension programs can enhance farmers' knowledge, improve labour efficiency, reduce costs, and increase profitability. Youth involvement is vital for sustaining cashew production.

Keywords: Resource use efficiency; cobb-douglas; raw cashew nut, yield.

1. INTRODUCTION

The cashew tree (*Anacardium occidentale*) was introduced to Goa from Brazil in the early 1500s and later transplanted to Kerala's Malabar Coast (Palei et al., 2019). India ranks as the second-largest producer following Cote d'Ivoire and exporter of cashew nuts, holding a market share of over 15%, with Vietnam coming next in global cashew exports in 2023. The top destinations for India's cashew exports include the United Arab Emirates, the Netherlands, Japan, and Saudi Arabia. Major cashew-producing states in India are Maharashtra, Andhra Pradesh, Odisha, Karnataka, and Tamil Nadu. India's cashew exports primarily consist of cashew kernels, The country has exported 65808.42 MT of Cashew Kernels to the world, with smaller quantities of Cashew Nut Shell Liquid (CNSL) accounting for 3508.18 MT and 9714.12 MT of cardanol (purified and distilled CNSL) during the year 2023-24 (MoCI, 2024). Initially grown to prevent soil erosion now recognized as a commercial crop due to its export potential, generating farm employment and significant foreign exchange (Nair, 2020).

The inputs required for cashew farming include planting material, labour, capital, fertilizer, manures, and pesticides. Efficient resource utilization refers to making the best use of inputs at the lowest possible cost. To boost productivity, attention is often given to whether farmers are adopting improved technologies. However, it is essential to determine if farmers are fully utilizing their existing resources. This assessment ensures that new technologies are applied effectively and economically to boost output. Since farmers aim to maximize profit while minimizing costs, evaluating resource use efficiency is essential. (Tambo & Gbemu, 2010). Efficient resource use and technology adoption are key to sustainability, addressing environmental and socioeconomic challenges. Cashew production is primarily a smallholder activity, serving as a source of income and enhancing the livelihood of the farmers and other stakeholders engaged in its cultivation and marketing. The OLS regression analysis confirms the significant positive relationship between cashew farming and improved income and food security. (MC, et al., 2024). Agricultural policies now focus on optimizing resource allocation for long-term benefits. The present study was conducted to study the production function and resource use efficiency of raw cashew nut production in Kerala (Albala, 2014).

2. MATERIALS AND METHODS

Kannur and Kollam districts were purposively selected where Kannur district ranked highest in the area under cashew which is 17157 ha and accounting for 53 percent of total production, during 2021-2022 (GOK, 2022). Kollam district is a hub of cashew processing industries and is emerging in cashew production. From the districts, two blocks with the maximum area under cashew i.e., Iritty and Irikkur from Kannur district; and Anchal and Kottarakara from Kollam were purposively selected. Three panchayats were randomly chosen from each of the selected blocks. The proportionate sampling was undertaken based on the area under cashew cultivation in the selected districts. In Kannur, from each panchayat, 15 cashew growers were selected randomly making a sample of 90 farmers, and 5 farmers from six randomly selected panchayats were selected making a sample of 30 from Kollam, resulting in a total sample of 120 cashew farmers. The sample was taken from the list of farmers maintained by the Directorate of Cashew nut and Cocoa Development (DCCD)/Kerala Agricultural

University (KAU)/Krishi Bhavan. The farmers from the Kannur district were only selected for production function analysis as the Kollam district has plantations at the early yielding or establishment phase.

The socioeconomic profile of the cashew farmers was estimated using descriptive statistics and percentages were calculated. In the economic analysis of issues about empirical estimation in industry and agriculture, the Cobb-Douglas production function is one of the common models. (Sankhayan, 1988). Using this function, the resource-use efficiency of cashew plantations was assessed, providing insight into how the sample farmers allocate their resources. The production function was estimated using the Ordinary Least Squares (OLS) method, and a statistical significance test was conducted on the estimated regression coefficients.

$$Q=f\,(A\,LK) \ldots. \qquad (1)$$

Where Q is the production output, which is a function of the capital (K) and the labour force (L) used for the production. A production function may be defined as a mathematical equation showing the maximum amount of output that can be realized from a given set of inputs. The mathematical form of the Cobb-Douglas production function is given as:

$$Q=AL^{\alpha}K^{\beta} \ldots. \qquad (2)$$

Here, Q represents output, A denotes the technology used in production, L is the labour input, K is the capital input, and α and β represent elasticity. The functional relationship is defined to assess the impact of available resources on farm-level cashew production in Kerala.

$$Y = a\,X_1^{\ b1}X_2^{\ b2}X_3^{\ b3}X_4^{\ b4}\,X_5^{b5}\,X_6^{b6}\,e^{u} \qquad (3)$$

(Sankhayan, 1988).

Y: Yield of raw cashew nut (Kg/ha)

X_1: Age of the plant (years)

X_2: Farming experience (years)

X_3: Number of labourers (man days)

X_4: Quantity of manures (kg/ha)

X_5: Quantity of fertilizers (kg/ha)

X_6: No. of plants/ha

According to (Goni. *et al.,* 2007*),* The econometric model is specified using the double-log Cobb-Douglas production function as follows:

$$lnY = ln\beta_0 + ln\beta_1 + ln\beta_2 + ln\beta_3 + ln\beta_4 + ln\beta_5 + ln\,\beta_6 + u \ldots .(4)$$

For the resources under consideration, it was written as: $lnY = ln\beta_0 + ln\beta_1$ *age* $+ ln\beta_2$ *farming experience* $+ ln\beta_3$ *labour+* $ln\beta_4$ *manures* $+ ln\beta_5$ *fertilizer* $+ ln\,\beta_6$ *No. of plants/ha* $+u$ … . (5)

Data on pesticide usage in the study area was limited, as most farmers opted not to apply pesticides, so this factor was excluded from the model. Using the Ordinary Least Squares (OLS) method, coefficients for the identified variables were estimated. To employ OLS in this study, the Cobb-Douglas production function was transformed to satisfy the Classical Linear Regression Model (CLRM) and to ensure it met the standard assumption of the Best Linear Unbiased Estimator (BLUE) (Gujarathi, 2003).

3. RESOURCE USE EFFICIENCY

As stated by Goni et al. resource use efficiency is given as

$$r\ \frac{Marginal\ Value\ Product}{Marginal\ Factor\ Cost}$$

Where, r = efficiency ratio

MVP= Marginal value product of a variable input,

MFC Marginal factor cost (Price per unit input).

The value of MVP was estimated using the regression coefficient of each input and the output price.

MVP= MPP x_i × Py (The unit price of output)

Where, Px_i= Unit price of input x_i

The value of resource use efficiency is interpreted as

If r <1, the resource is excessively used or overutilized, which implies decreasing the quantity of input used will increase the profits.

r >1, the resource is underutilized and profits will increase by increasing the quantity of inputs used.

r =1, it indicates that the resource is efficiently utilized and profit maximization is attained.

For the calculation of return to scale from cashew, the Cobb-Douglas production function was used and calculated using the formula;

$RTS = \sum b_i$

Where, b_i = regression coefficient of i^{th} variables.

The sum of b_i from the Cobb-Douglas production function indicates the nature of return to scale. Return to Scale decision rule (Subba, et al., 2018)

RTS<1; Decreasing return to scale

RTS=1; Constant return to scale

RTS>1; Increasing return to scale

Again the relative percentage change in MVP of each resource required to obtain optimal resource allocation i.e r =1 or MVP = MFC was estimated using the equation below;

$D= (MFC/MVP)*100$

Where, D = absolute value of percentage change in MVP of each resource (Manjunath et al, 2013; Acharya, et al., 2014) and r= efficiency ratio.

Miah et al., (2006) concluded that under perfect competition, farmers maximize profit and optimize resource use when their marginal value product equals their marginal factor cost.

4. RESULTS AND DISCUSSION

4.1 Socio-economic Profile of Cashew Farmers

Evidence from the descriptive analysis of the socio-economic characteristics of respondents in the study area in Table 1 shows that 89.1% of the sampled cashew farmers were males and 10.9% were females. The results showed that most cashew trees or farms are owned by men (90%) while the other is divided among women (10%). Around 52.5 percent of families have 2 to 4 persons. The majority of the farmers (71.7%) were between the age group of forty (40) and sixty (60) years, this is found familiar (Wongnaa & Ofori, 2012), (Danso-Abbeam, *et al.,* 2021), followed by greater than sixty (60) years. From the study, it was realized that a higher percentage of cashew farmers are literate about (86.67%) of cashew farmers in ended up at the SSC level found similar to (MC SC, Chandran et al., 2024). In the study area (72.5%) farmers were dependent on agriculture as a primary source of income with marginal and small farmers being predominant. Most farmers had high experience with an average of around 36 years (Sajeev & Manjusha, 2016). Around (60%) of the farmers were in contact with Krishi Bhavan for planting materials, technical information, etc. It was observed that no farmer selling cashew apples even had the potential to generate income due to no prevalent markets.

Table 1. Socio-economic profile of the sample respondents

Characteristics	Frequency	Characteristics	Frequency
Age		**Occupation**	
30-40	9(7.5)	Agriculture	87(72.5)
40-60	86(71.7)	Public sector	9(7.50)
>60	25(20.8)	Private sector	13(10.8)
		Self-employed	11(9.2)
Gender		**Landholding**	57(47.5)
Male	107(89.1)	Marginal	38(31.7)
Female	13(10.9)	Small	21(17.5)
		Semi-medium	4(3.3)
		Medium	
Family size		**Annual income**	
1-2	8(6.7)	50,000-75,000	17(14.2)
2-4	63(52.5)	75,000-1,00,000	36(30.0)
4-6	34(28.3)	1,00,000-2,00,000	58(44.3)
>6	15(12.5)	>2,00,000	9(7.5)

Characteristics	Frequency	Characteristics	Frequency
Educational Qualification		**Source of information**	
Upto SSC level	104(86.67)	Krishi Bhavan	73(60.8)
Degree	14(11.67)	CPCRI	11(9.1)
Postgraduate	2(1.66)	KAU	10(8.4)
		DCCD	8(6.7)
		KSDCC	18(15.0)
Farming experience		**Economic part of cashew sold**	
<10	7(5.8)	Raw cashew nut	
10-30	26(21.7)	Cashew apple	120(100)
20-40	63(52.5)		0(0.0)
40 and above	24(20.0)		

Source: Field survey 2023
SSC-Secondary School Certificate
**CPCRI- Central Plantation Crops Research Institute*
**KAU-Kerala Agricultural University*
**DCCD- Directorate of Cashew nut and Cocoa institute*
**KSDCC-Kerala State Cashew Development Corporation Limited*

The independent variables considered for the regression analysis encompassed the average age of the plants, farmers' experience, the number of man-days, the quantities of manure fertilizers, and plants per hectare. Table 2. reveals that out of the five explanatory variables analyzed in the production function, three had a statistically significant effect on the yield of raw cashew nuts. The age of the plants was significant at the 1% level, while labour and manure showed significance at the 5% level. The R^2 value of 0.65 indicates that 65% of the variation in cashew yield can be attributed to the included input factors. The adjusted R^2 of 0.63 confirms that, after adjusting for the number of predictors, 63% of the variation is still explained.

The F-statistic confirms that the overall regression model is significant at the 1% level, indicating that at least one of the independent variables has a meaningful impact on cashew output. The coefficients represent the elasticity of the inputs. Both manure (0.592) and human labour (0.214) positively influenced the yield, indicating that a 1% increase in the utilization of manure and human labour results in a 0.592% and 0.214% rise in cashew yield, respectively. Similar results were found in cocoa plantations with labour being found significant ($p<0.01$) and positively influencing yield (Adeyemo, *et al*., 2020). while the age of the plants exhibited a negative impact as the age increased the yield started declining, i.e. a one percent increase in the age of the plants resulted in a decrease in yield by -0.061 percent as most of the plants were almost near to yield declining phase. The summation of these regression coefficients (b_i) for all input variables offers an immediate assessment of the returns to the scale (RTS). The estimated return to scale in Kannur district, Kerala, was 1.011 suggesting a scenario of increasing returns to scale. It was found to be on par with the result of (Wongnaa & Ofori, 2012). It was found similar to the RTS estimated at 1.103, indicating increasing returns to scale in large cardamom plantations (Ghimire, et al., 2025).

Table 2. Estimates of the Cobb- Douglas production function analysis

Explanatory variables	Regression coefficients	Standard error	t- value	Sign.
Age of plants (years)	-0.061***	0.025801	-2.38386	**0.019**
Experience (years)	-0.066	0.040152	-1.66115	**0.100**
Human labour (man days)	0.214**	0.098399	2.180234	**0.032**
Manures (Kg/ha)	0.592***	0.066418	8.918338	**1.4E-13**
Fertilizers (Kg/ha)	0.002	0.004486	0.495347	**0.621**
No. of plants/ha	-0.076	0.052981	-3.14652	**0.594**
Intercept	2.967***	0.529181	5.607246	**2.91E-07**
R^2	0.65			
Adjusted R^2	0.63			
F value	**30.21*** **			**3.12893E-17**

****denotes significant at 1 percent level, ** denotes significant at 5 percent level; Source: Field survey data 2023*

Table 3. Values of estimates of efficiency parameters of dependent variables (ln yield)

Particulars	Mean	Coefficients	MPP	MVP	MFC	r
Human labour (man days)	175	0.098399	0.26	24.1	168.16	0.143
Manure application (Kg/ha)	362	0.066418	0.7	63.1	17.25	3.65

Source: Field survey data 2023

Table 4. Adjustments in MPVs for optimal resource use

Particulars	MPP	MVP	MFC	r	D- value	Efficiency
Human labour (man days)	0.26	24.1	168.16	0.143	697.75	Over-utilized
Manure application (Kg/ha)	0.7	63.1	17.25	3.65	47.78	Under-utilized

Source: Field survey data 2023

The Resource Use Efficiency (r) values indicated a significant impact on yield, with values of 0.14 for human labour and 3.65 for manure. An r value below one for human labour indicates overutilization, suggesting the need to reduce excessive use, especially in terms of labour days. Labour exhibited a low Marginal Physical Product (MPP) of 0.26, indicating inefficient utilization, which aligns with the observations made by Wongnaa and Ofori (2012). On the other hand, an r value greater than one for manure application indicates underutilization, suggesting there is potential to increase manure application to achieve higher yields. The resource use efficiency related to manure application in cardamom plantation was found to be under-utilized whereas labour was contrary to our study (Ghimire, et al., 2025) According to (Azeez & Olabanji, 2024) the cashew yield gap in West Africa is mainly due to poor adoption of good agricultural practices, especially inadequate fertilization, and pest control. The values are represented in the given Table 3.

As shown in Table 4, raw cashew nut production requires a reduction of approximately 697.75% in human labor due to overutilization, Eze et al., (2010), (Wongnaa & Ofori, 2012) obtained similar results for labour. The manure application was found to be underutilized. FYM and organic manures are required to increase by 47.78 percent in cashew production. (Wongnaa & Ofori, 2012) with 28% increase in the fertilizer was needed for efficient resource use in cashew. The result related to manure under-utilization in coffee plantations was under-utilized (Acharya et al., 2014),

5. CONCLUSION

The efficiency of raw cashew cultivation was analyzed using the Cobb-Douglas production function. Organic manure and human labour were significant at one and five percent levels, respectively. Returns to scale exceeded one, indicating increasing returns. Efficient resource use can boost production, while extension programs can enhance farmers' knowledge of fertilizers, manures, application and pest control. These programs can also improve labour efficiency, reducing costs and increasing profitability. Encouraging youth involvement is crucial for sustaining cashew production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Srilakshmi C*, Prema. A hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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