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Research Article

Profitability and Resource-Use Efficiency of Foxtail and Kodo Millet in Cuddalore District of Tamil Nadu

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Abstract

Minor millets are increasingly recognized for their nutritional benefits, climate resilience, and suitability for sustainable agriculture in rainfed regions. However, empirical evidence on the comparative profitability and resource-use efficiency of foxtail millet and kodo millet cultivation in Tamil Nadu remains limited. The present study evaluated the cost structure, profitability, and allocative efficiency of major production inputs in minor millet cultivation in Cuddalore district of Tamil Nadu. Primary data were collected from 80 millet farmers during 2021 using a multistage random sampling technique. The study employed the Cobb–Douglas production function and Marginal Value Product (MVP)–Marginal Factor Cost (MFC) approach to assess resource-use efficiency. The results revealed that foxtail millet cultivation was relatively more profitable, with a net income of Rs. 17,942 ha^{-1} and an input-output ratio of 1.48, compared to Rs. 9,737 ha^{-1} and 1.32, respectively, for kodo millet cultivation. The regression analysis indicated that fertilizers, seeds, and irrigation significantly influenced millet productivity. The estimated return to scale coefficient was 2.04 for foxtail millet, indicating increasing returns to scale, while kodo millet exhibited approximately constant returns to scale (0.959). The MVP–MFC analysis showed that seeds and fertilizers were underutilized in both millet crops, whereas human labour and machine labour were over utilized in kodo millet cultivation. Diagnostic tests confirmed absence of serious multicollinearity among explanatory variables, with Variable Inflation Factor (VIF) values ranging from 1.25 to 1.63. The findings suggest that improving seed and fertilizer use efficiency through targeted extension and input support policies can substantially enhance millet productivity and farm profitability. Strengthening extension support, market infrastructure, and millet promotion programmes can further enhance the economic viability of millet cultivation and contribute to nutritional security, climate resilience, and sustainable agricultural development in semi-arid regions.

Keywords: Cobb-Douglas production function, Cost and Returns, Minor Millets, MVP-MFC, Resource-use Efficiency

1. Introduction

Millets are small-seeded cereal crops cultivated predominantly in arid and semi-arid regions due to their inherent tolerance to drought, heat stress, and low soil fertility. In India, millets have been an integral component of traditional food systems for centuries and are increasingly recognized for their role in ensuring nutritional security, climate resilience, and sustainable agricultural development. Rich in dietary fibre, essential minerals, antioxidants, and bioactive compounds, millets offer significant health benefits and are considered climate-smart crops requiring relatively low external inputs compared to major cereals (Satyavathi *et al.,* 2024; Sikdar *et al*., 2025).

In recent years, renewed policy attention, including the observance of the International Year of Millets 2023, has enhanced awareness regarding their potential contribution to sustainable food systems, livelihood security, and environmental sustainability. The production of millets in India was estimated at 17.57 million tonnes during 2023–24, reflecting their continued contribution to the country's food grain production and nutritional security initiatives (APEDA, 2025).Millets are being utilized as a source of nutraceutical components for nutritional enrichment of processed food products toaugment their proposed health benefits. Consumption of millet-based diet is known to regulate plasma glucose levels on account of its high fibre content(Islam and Manaloor, 2021). Further, the presence of anti-nutritional factors in millet-based diets has been reported to reduce overall starch digestibility and thus result in lower absorbability (Verma and Mishra, 2011).Millets are reported to possess cholesterol-lowering properties owing to their high dietary fibre, phytosterols and phenolic compounds, which contribute to improved lipid metabolism and reduced risk of cardiovascular diseases. Regular consumption of millet-based diets has been associated with reductions in total cholesterol, low-density lipoprotein cholesterol (LDL-C) and other cardiovascular risk factors (Jacob*et. al.,* 2024).

Minor millets include kodo millet (*Paspalum scrobiculatum*), foxtail millet (*Setaria italica*), little millet, proso millet, and barnyard millet. These crops contribute significantly to household food security, especially in dryland areas (Padulosi *et al.,* 2009).However, the cultivation of minor millets has declined due to a shift in dietary preferences, urbanization, and the promotion of rice and wheat under public distribution systems. To revive millet farming, the Government of India declared 2018 as the National Year of Millets and 2023 as the International Year of Millets. These initiatives aim to increase awareness and support for millet production. Despite their nutritional and ecological advantages, millet consumption remains limited due to changing dietary preferences, inadequate processing infrastructure, and limited availability of consumer-friendly value-added products (Anbukkani *et al*., 2017; Kumar *et al.,* 2018). However, growing awareness regarding nutritional security and climate-resilient agriculture has renewed policy interest in millet promotion. Consequently, millets such as sorghum, pearl millet, and finger millet are increasingly being considered for inclusion in public food distribution and nutrition programmes.

Several studies have analysed the economics and profitability of millet cultivation in India, with emphasis on major millets such as finger millet, pearl millet, and sorghum. Previous research has primarily focused on production performance, cost of cultivation, adoption of improved technologies, and nutritional benefits of millets. However, empirical studies examining resource-use efficiency and allocative efficiency in minor millets, particularly foxtail millet (*Setaria italica*) and kodo millet (*Paspalum scrobiculatum*), remain limited. Furthermore, farm-level comparative analyses employing Cobb–Douglas production function and Marginal Value Product–Marginal Factor Cost (MVP–MFC) approaches under rainfed production systems are scarce in Tamil Nadu. In Cuddalore district, where minor millets are cultivated under diverse resource conditions, information on the efficiency of input utilization and profitability is largely unavailable. Therefore, the present study evaluates the cost and returns, resource-use efficiency, and allocative efficiency of foxtail millet and kodo millet cultivation in Cuddalore district of Tamil Nadu.

This study focuses on the resource use efficiency of minor millets in Cuddalore district, Tamil Nadu. The selected district is a major producer of kodo and foxtail millets, particularly in rainfed areas. Understanding input efficiency is critical for improving productivity and profitability for smallholder farmers. The objective of the study is,

To estimate the cost and returns of foxtail and kodo millet cultivation in Cuddalore district.

1. To analyse the resource-use efficiency of major production inputs using the Cobb–Douglas production function.

2. To estimate allocative efficiency through MVP–MFC analysis.
3. To suggest policy measures for improving millet profitability and input-use efficiency.

2. Methodology

Cuddalore district in Tamil Nadu (11.75° N and 79.75° E) is characterized by a tropical climate with significant areas under dryland cultivation. The district is divided into 13 blocks, and major millet cultivation occurs in Panruti, Vridhachalam, and Tittakudi taluks.

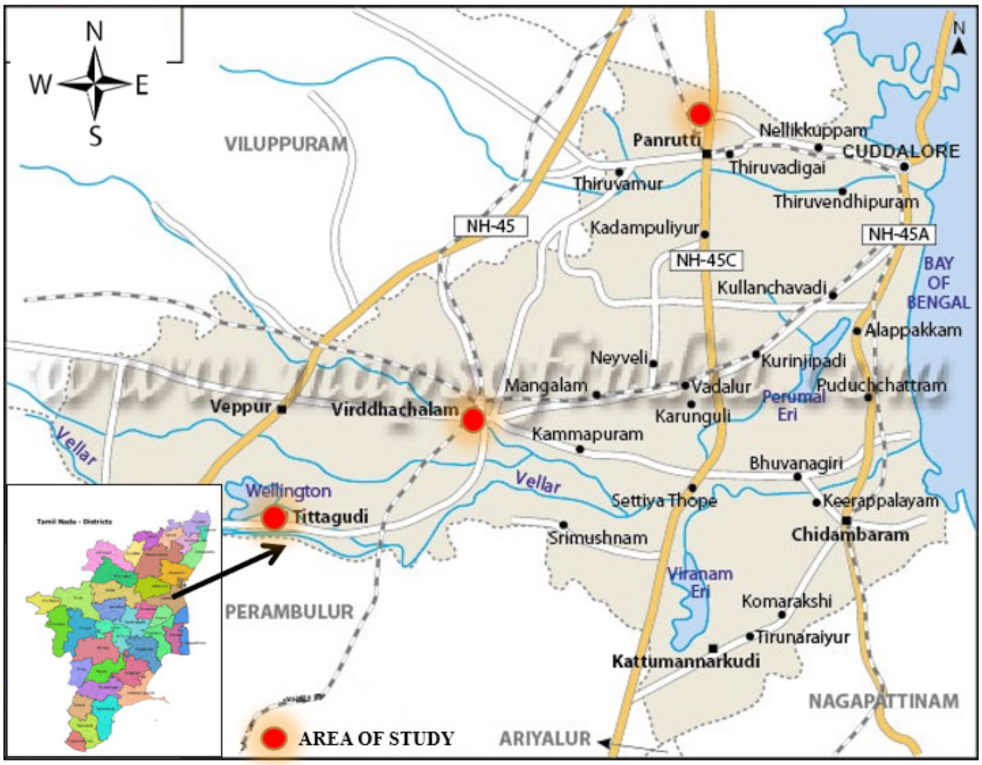

Fig .1 Map of Study area

A multistage random sampling technique was used. Multistage sampling is a widely accepted probability sampling procedure in survey research and does not have a single identifiable developer. The methodology follows the principles described by Cochran (1977) and Kothari (2004).From the selected taluks, six villages (Veppur, Maathur, Vaiyankudy, Vathistapuram, Melpattampakkam and Kolapakkam) were chosen based on area under kodo and foxtail millet. A total of 80 farmers were selected: 40 each for kodo millet and foxtail millet cultivation. The minimum large sample size of 80 farmers was considered adequate for farm-level econometric analysis, as previous studies have suggested that sample sizes ranging from 30 to 100 observations are generally sufficient for estimating production functions and resource-use efficiency models in agricultural economics (Gujarati, 2012; Wooldridge, 2016).Although the sample size was adequate for farm-level econometric estimation, the findings may not be generalized beyond similar agro-climatic regions. Primary data were collected using a structured, pre-tested interview schedule during March-April 2021. Secondary data on crop statistics for the year 2020-21 were obtained from the Department of Economics and Statistics, Tamil Nadu.

2.1 Cost and returns

The various cost components (Cost A1, Cost A2, Cost B1, Cost B2, Cost C1 and Cost C2) were calculated to derive the cost of cultivation and related income measures. The cost and returns of crops were calculated based on CACP (Commission on Agricultural Costs and Prices) cost concepts.

Cost A1: Cost A1 Includes:

i. Value of hired human labour (temporary and permanent)

ii. Value of owned and hired bullock labour

iii. Value of owned and hired machine power

iv. Value of owned and purchased seed

v. Value of owned and purchased manures

vi. Value of fertilizers

vii. Value of plant protection chemicals

viii. Value of herbicides

ix. Depreciation on farm implements, farm buildings etc.

x. Irrigation charges

xi. Interest on working capital

xii. Land revenue, cess and other taxes paid and

xiii. Other miscellaneous expenses.

Cost A2: Cost A1 + Rent paid for the leased-in land.

Cost B1: Cost A1 + Interest on the value of owned capital assets (excluding land)

Cost B2: Cost B1 + Rent paid for the leased-in land + Rental value of the owned land(net of land revenue)

Cost C1: Cost B1 + Imputed value of family labour.

Cost C2: Cost B 2 + Imputed value of family labour (Cost of cultivation)

Income measures

a) Net income = Gross income – total cost (C_2)

b) Family labour income = Net income + total family labour

c) Farm business income = Family labour income + rental value of owned land + interest on owned capital

2.2 Resource use efficiency

Cobb-Douglas type of production function (per hectare) was used to assess the resource use efficiency in minor millets production(Ravi *et al.*, 2017; Verma and Mishra, 2011). Linear regression of the Cobb-Douglas type of production function was employed. The Cobb-Douglas production function was linearized through transformation into a double log. Ordinary least square (OLS) was used for estimating minor millet production function. The Ordinary Least Squares (OLS) method was first introduced by Legendre (1805) and later theoretically developed and justified by Gauss (1877).

The specification of the equation for Foxtail millet and Kodo millet is given in the equation.

$$Y = aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}D_1^{b5}D_2^{b6}\ e^u$$

Where,

Y = Yield (quintal)

X_1 = Human labour (Man days)

X_2 = Machine labour cost (₹)

X_3 = Seeds (kg)

X_4 = Fertilizer quantity (kg)

D_1 = Dummy for farm yard manure applied (1= yes; 0 = no)

D_2 = Dummy for Irrigation (1 = irrigated; 0 = rainfed)

a = Intercept

u = Random variable

b_1 to b_6 indicate regression coefficients of respective inputs and implicitly represents the elasticity of production of respective inputs.

The equation was transformed into the logarithmic form (log linear) and the same is represented as follows,

$$\text{Log } Y = \log a + b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + b_5 D_1 + b_6 D_2$$

Diagnostic tests were performed to examine the reliability of the estimated regression model. Multicollinearity among explanatory variables was tested using the Variance Inflation Factor (VIF). The estimated VIF values ranged from 1.25 to 1.63, which were well below the critical threshold value of 5, indicating absence of serious multicollinearity among the explanatory variables. The goodness of fit of the model was assessed using R^2 and F-statistics (Gujarati, 2012).

2.2.1 Marginal Value Product (MVP)

The estimated coefficients were used to compute the MVP. By studying the marginal value product of factors of production, we can assess their relative importance. Marginal value Product of X_i, the i^{th} input is estimated by the following formula,

$$MVP = b_i * (\text{Geometric mean of output / Geometric mean of } i^{th} \text{ output}) * P_y$$

b_i = regression coefficient of i^{th} input.

P_y = price of output

2.2.2 Marginal factor cost (MFC)

Per unit cost of input was taken for those variables expressed in terms of units and 1 was taken for the variables expressed in monetary terms (Rs.).

2.2.3 Resource use efficiency (r)

The model was estimated as follows,

$$r = \frac{\text{Marginal Value Product (MVP)}}{\text{Marginal Factor Cost (MFC)}}$$

Where, r = efficiency ratio

Based on economic theory, a farm maximizes profits with regards to resource use when the ratio of the marginal return to the opportunity cost is one (Heady and Dillon, 1961). The values are interpreted thus,

If r is <1; resource is excessively used or over utilized (no scope to increase the use) hence, decreasing the quantity use of resource increases the profits.

If r > 1; resource is under used or being underutilized (there is a scope to increase the use) hence, increasing its rate of use will increase profit level.

If r = 1; it shows the resource is efficiently used, that is optimum utilization of resource hence the point of profit maximization.

Finally, the relative percentage change in MVP was calculated using following way:

$D = (1\text{-MFC/MVP}) \times 100$ or,

$D = (1\text{-}1/r) \times 100$

Where, D= absolute value of percentage change in MVP of each resource.

3. Results and Discussion

3.1 Cost and Returns

The cost of cultivation of foxtail millet (Cost C_2) was estimated at ₹25,826 per hectare, comprising operational costs of ₹21,770 (84.29 per cent) and fixed costs of ₹4,056 (15.71 per cent). Since no leasing activity was observed among the sample farmers, Cost A_1 and Cost A_2 remained the same. Hired human labour constituted the largest share of the total cost (26.70 per cent), followed by machine labour (20.50 per cent) and rental value of land (13.25 per cent), which is in line with the findings of Devika (2017) and Makadia *et al.* (2012). Recent studies have also reported that labour and machinery charges account for a major proportion of millet cultivation costs due to rising wages and increased mechanization (Yadav *et al.,* 2024; Felix *et al.,* 2024). Fertilizers accounted for 9.81 per cent of the total cost, highlighting the importance of nutrient management in millet production (Xing *et al.,* 2023), while the remaining cost components contributed relatively smaller shares to the total cost of cultivation.

Table 1. Cost of cultivation of foxtail and Kodo millet

(Rs.ha^{-1})

Particulars	Foxtail Millet	Kodo Millet
Variable cost		
Family labour	1578	1450
Hired Human labour	6896	8372
Machine labour	5294	7438
Seeds	608	1341
Manures	1138	1219
Fertilizers	2534	3103
PPC	56	72
Transportation	1997	1738
Interest on working capital	1669	1743
Total Variable cost	21770	26474
Total fixed cost	4056	3604
Total Cost of Cultivation	25826	30,078

The cost of cultivation of kodo millet (Cost C_2) was estimated at ₹30,078 per hectare, of which operational costs accounted for ₹26,474 (88.02 per cent) and fixed costs for ₹3,604 (11.98 per cent). Among the various cost components, hired human labour constituted the largest share (27.83 per cent), followed by machine labour (24.73 per cent), fertilizers (10.32 per cent), rental value of land (7.93 per cent), and interest on working capital (5.79 per cent). The predominance of labour and machinery costs indicates the labour-intensive nature of millet cultivation and the increasing dependence on mechanization for timely farm operations. Similar findings were reported in studies on kodo millet and other minor millets, where human labour and machinery charges accounted for a major share of the total cultivation cost (Mahajan, 2017; Sreedhar *et al.,* 2024). Further, rising labour wages and mechanization expenses have increased the share of these inputs in cereal and millet production systems in recent years (Lamba *et al.,* 2026). Fertilizers also formed a significant component of total cost, reflecting the growing importance of nutrient management in improving millet productivity under rainfed conditions.

The gross income estimated in the cultivation of foxtail millet was Rs. 43768 per hectare (Table 2). Foxtail millet farmers realized a net income of Rs. 17942 per hectare in the study area. Farm business income is a measure which indicates return for owned resources like land, labour and capital and this amounted to Rs. 19728 per hectare. Family labour income is another measure of farm efficiency which represents the returns to farmer's owned labour and family labour and this amounted to Rs. 15785 per hectare. On an average, the yield of main product was 9.09 quintals and the value of by-product (straw) was Rs. 2408 per hectare. The cost of production per quintal was Rs. 2987 per hectare.

The gross income estimated was Rs. 39815 per hectare. Kodo millet farmers realized a net income of Rs. 9737 per hectare in the study area. Farm business income amounted to Rs. 14529 per hectare. Family labour income represents the returns to farmer's owned labour and family labour and this amounted to Rs. 11025 per hectare. On an average, the yield of main product (grain) was 19.92 quintals and the value of by-product (straw) was Rs. 2981 per hectare. The cost of production per quintal was Rs. 1368 per hectare.

Table 2. Measures of farm income for foxtail and Kodo millet production

Particulars	(Rs. ha^{-1})	
	Foxtail Millet	**Kodo Millet**
Yield (quintal/ha)	9.09	19.92
Main product	41359	36834
By product	2408	2981
Gross income (Rs.)	43768	39815
Net income (Rs.)	17942	9737
Family labour income	15785	11025
Farm business income	19728	14529
Input-output ratio	1.48	1.32

3.2 Resource use efficiency

The estimated Cobb–Douglas production function for foxtail millet and kodo millet cultivation is presented in Table 3. The coefficient of determination (R^2) for foxtail millet was 0.84, indicating that 84 per cent of the variation in output was explained by the explanatory variables included in the model. The F-value (29.40) was statistically significant at one per cent level, confirming the overall goodness of fit of the model. Similarly, the R^2 value for kodo millet cultivation was 0.64, implying that 64 per cent of the variation in output was explained by the selected explanatory variables. The F-statistic (9.94) was also significant at one per cent level, indicating adequacy of the estimated model. The Variance Inflation Factor (VIF) values ranged from 1.25 to 1.63, which were well below the critical threshold value of 5,indicating absence of serious multicollinearity among the explanatory variables (Salmeron *et al.,* 2024). Residuals were examined for model adequacy and no serious econometric violations were observed.

In foxtail millet cultivation, the regression coefficients of human labour, machine labour, seeds, fertilizers, Farm Yard Manure (FYM), and irrigation were positive, indicating positive contribution of these inputs towards crop output. Among these variables, fertilizer application was significant at one per cent level, while seeds and irrigation were significant at five per cent level. Machine labour was significant at ten per cent level. The positive and significant coefficient of fertilizer indicated that improved nutrient application substantially enhanced millet productivity under rainfed conditions, reflecting nutrient deficiencies in farmers' fields. Recent studies on foxtail millet have similarly reported that balanced nutrient application significantly increases grain yield and productivity through improvements in soil nutrient availability and crop growth characteristics (Duan *et al.,* 2024; Xing *et al.,* 2023).

Similarly, the positive response of seed quantity suggested that farmers were operating below optimum seed rates, and increasing seed use could improve plant population and yield performance. Studies on foxtail millet cultivation have shown that appropriate seed rates and plant spacing significantly influence tiller production, biomass accumulation, and grain yield, indicating that sub-optimal seed use can constrain productivity (Chaturvedi *et al.,* 2025). The positive effect of irrigation highlighted the importance of supplemental irrigation even in predominantly rainfed millet cultivation systems. Recent evidence indicates that pre-sowing and supplemental irrigation substantially improve yield stability and productivity of foxtail millet by reducing moisture stress during critical growth stages, particularly under dryland conditions (Ma *et al.,* 2026). The positive coefficient of machine labour further suggests that mechanized farm operations such as land preparation, sowing, and intercultural practices contribute to improved timeliness of operations and efficient resource utilization, thereby enhancing crop productivity under labour-scarce conditions.

The return to scale for foxtail millet cultivation was estimated at 2.04, excluding dummy variables (FYM and irrigation), indicating increasing returns to scale. This implied that a proportionate increase in all production inputs would result in a more than proportionate increase in output. The relatively high return to scale may be attributed to low baseline input use and limited adoption of improved production practices among farmers, suggesting considerable scope for productivity enhancement through efficient input management and technological interventions (Ravi *et al.,* 2017).

In the case of kodo millet cultivation, the regression coefficients of all explanatory variables were also positive. Irrigation was statistically significant at one per cent level, while seeds and fertilizers were significant at five per cent level. Human labour was significant at ten per cent level. The positive coefficient of seeds indicated that optimum seed rate played an important role in improving crop productivity. Similar findings were reported by Ravi *et al.* (2017) in finger millet cultivation in Karnataka, where seed and fertilizer application positively influenced crop yield and resource-use efficiency. The significant effect of irrigation further emphasized the role of moisture availability in enhancing millet productivity under dryland conditions.

The estimated return to scale for kodo millet cultivation was 0.96,excluding dummy variables (FYM and irrigation), indicating approximately constant returns to scale. This implied that proportionate changes in all production inputs would result in nearly proportionate changes in output. The finding suggested that farmers were operating near the rational stage of production and that balanced use of inputs could sustain productivity and profitability in kodo millet cultivation.

The estimated MVP–MFC ratios for foxtail millet cultivation indicated that human labour, machine labour, seeds, and fertilizers were underutilized, as their ratios were greater than one (Table 4). The MVP–MFC ratios for these inputs were 1.82, 1.89, 58.60, and 7.11, respectively, suggesting that increasing their use would increase returns by more than the additional costs incurred. The high ratio for seeds indicated considerable scope for improving productivity through the use of quality seeds and optimum seed rates (Hariprasanna, 2023; Warisa*et al.,* 2025).

Table 3. Estimation of Cobb-Douglas production function in foxtail millet and Kodo Millet production

Independent Variables	**Regression coefficient (b_i)**	
	Foxtail Millet (N=40)	**Kodo Millet (N=40)**
Intercept	-6.30 *** (1.56)	-1.46 (2.78)
Human labour in Man-days (X_1)	0.39 (0.29)	0.25 * (0.15)
Machine labour in Rs. (X_2)	0.25 * (0.14)	0.13 (0.32)
Seeds in kg (X_3)	0.90 ** (0.29)	0.42 ** (0.20)
Fertilizer in kg (X_4)	0.50 *** (0.08)	0.17 ** (0.06)
Dummy for Farm Yard Manure (FYM) (D_1)	0.07 (0.05)	0.07 (0.04)
Dummy for irrigation (D_2)	0.18 ** (0.05)	0.18 *** (0.05)
R^2 value	0.84	0.64
F-Value	29.40***	9.94***
Return to scale	2.04	0.96

(Figures in the parentheses indicate standard errors)

Note: '***' significant at 1% level, '**' significant at 5% level, '*' significant at 10% level

Similarly, the higher MVP–MFC ratio for fertilizers suggested that farmers were applying fertilizers below the optimum level, and improved nutrient management could enhance yield (Xing et al., 2023). The results also showed that increased use of human and machine labour could improve productivity through timely farm operations. Similar findings on the underutilization of inputs in millet cultivation were reported by Verma and Mishra (2011).

In kodo millet cultivation, the MVP–MFC ratios for seeds and fertilizers were greater than unity, indicating underutilization of these resources, whereas human labour and machine labour recorded ratios below unity, indicating overutilization. The MVP–MFC ratios for human labour, machine labour, seeds, and fertilizers were 0.86, 0.62, 11.79, and 2.11, respectively (Table 5). The overutilization of labour resources suggested inefficiencies in labour allocation and possible dependence on traditional cultivation practices with limited mechanization efficiency. On the other hand, the underutilization of seeds and fertilizers indicated scope for increasing productivity through improved input application. Similar findings were reported by Ibitoye et al. (2015), who observed inefficient allocation of production resources in crop cultivation systems.

Overall, the results indicated that there exists considerable scope for improving resource-use efficiency and profitability in minor millet cultivation through balanced input utilization, improved seed distribution, scientific nutrient management, and efficient labour use. Strengthening extension support and promoting location-specific input recommendations could substantially improve millet productivity and farm income in the rainfed regions of Tamil Nadu.

Table 4. Resource use efficiency in Foxtail millet cultivation

Variables	Input use at geometric mean level (X)	Coefficient	MVP	MFC	MVP/ MFC (r)	D-value	Efficiency
Human labour in Man-days (X_1)	35.16	0.39	436.56	240	1.82	45.02	Underused
Machine labour in Rs. (X_2)	5218.32	0.25	1.89	1.00	1.89	46.96	Underused
Seeds in kg (X_3)	10.20	0.90	3472.70	59.26	58.60	98.29	Underused
Fertilizer in kg (X_4)	205.30	0.50	95.85	13.49	7.11	85.93	Underused

Note: Geometric mean (Y) of foxtail millet production was 8.65 quintals per hectare and its price (P_y) was Rs.4550 per quintal

MVP – Marginal Value of Product, MFC – Marginal Factor Cost

Table 5. Resource use efficiency in Kodo millet cultivation

Variables	Input use at geometric mean level (X)	Coefficient	MVP	MFC	MVP/ MFC (r)	D-value	Efficiency
Human labour in Man-days (X_1)	45.98	0.24	199.98	240	0.86	22.22	Overused
Machine labour in Rs. (X_2)	7788.1	0.07	0.64	1	0.62	69.77	Overused
Seeds in kg (X_3)	27.08	0.35	580.08	49.2	11.79	91.20	Underused
Fertilizer in kg (X_4)	213.22	0.20	30.55	14.51	2.11	49.72	Underused

Note: Geometric mean (Y) of kodo millet production was 19.68 quintals per hectare and its price (P_y) was Rs.1850 per quintal

MVP – Marginal Value of Product, MFC – Marginal Factor Cost

Conclusion

The study assessed the profitability and resource-use efficiency of foxtail millet and kodo millet cultivation in the rainfed regions of Cuddalore district, Tamil Nadu. Both crops were found to be economically viable, with foxtail millet generating higher returns than kodo millet. The production function analysis showed that seeds, fertilizers and irrigation significantly influenced millet productivity. Resource-use efficiency analysis revealed that seeds and fertilizers were underutilized in both crops, indicating potential for increasing productivity through their optimal use, while human and machine labour were overutilized in kodo millet cultivation. The estimated returns to scale suggested increasing returns in foxtail millet and nearly constant returns in kodo millet cultivation.The study identified constraints such as limited access to quality seeds, inadequate mechanization and poor market infrastructure. Therefore, improving input supply, extension services, and marketing support is essential to enhance millet productivity and overall, efficient resource use and supportive policies can strengthen millet-based farming systems and contribute to sustainable agriculture and nutritional security in rainfed regions.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Author Contributions

Lakshmipathy Thirumurugan Thirumarudhan: Conceptualization, data collection, analysis and manuscript preparation, data validation and manuscript review.

N. Swaminathan: Supervision, Statistical guidance and methodology.

G. Harshavardhini Gopal: Review and editing.

Ethical Approval

The study involved survey-based data collection from farmers. Participation was voluntary and informed consent was obtained from all respondents.

Declaration on AI Use

During the preparation of this manuscript, the authors used generative AI tools only for language improvement and grammatical editing. The authors reviewed and edited the content and take full responsibility for the final manuscript.

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