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Analysis of Resource-use Efficiency of Mulberry Cocoon Production in Karnataka State- A Stochastic Frontier Approach

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ABSTRACT

The study seeks to analyse resource-use efficiency and technical efficiency in mulberry sericulture using data of 220 sericulture farmers in Karnataka during 2022-23. Economic efficiency indicated that increase in use of inputs such as animal labour, dfls, fertilizers, FYM, human labour would increase cocoon yield by 0.008 percent, 0.434 percent, 0.091 percent, 0.241 percent and 0.467 percent, respectively. The technical efficiency of 43 percent of sample farmers was above 80 percent, indicating the possibility of increasing the yield of cocoon by adopting better technology. The study has suggested measures to increase productivity and income of farmers in Karnataka state.

Keywords: Mulberry Sericulture, Technical Efficiency, Resource-use Efficiency, Cocoon Yield

JEL Code: Q12, Q16, D24, O13, R11

I

INTRODUCTION

Resource use efficiency in agriculture refers to how effectively farmers utilize resources such as land, labour, water, and capital to achieve maximum output at minimum cost in a sustainable manner. It broadly includes technical efficiency, allocative efficiency, and economic efficiency in allocating resources optimally to maximize income (Haque, 2006). In simple terms, it reflects the ability to obtain the highest possible output per unit of resource. Efficient use of resources is crucial for addressing the challenges of food security, especially in the context of increasing population and rapid urbanization, which is leading to the conversion of agricultural land into non-agricultural uses (Ishtiaque *et al*., 2017).

Resources are defined as the stock or supply of money, materials, labour, and other assets that can be utilized effectively for production (Rahman and Lawal, 2003). According to Heady and Egbert (1964), resources are considered efficiently used when the marginal productivity of the last unit of each resource is equal. Analysis of resource use efficiency helps in identifying whether inputs are overused, underused, or optimally utilized. Inefficient use of resources increases the cost of production and results in lower returns.

Sericulture, the practice of silk production, is an important agro-based enterprise that provides quick returns to farmers, often within a short period of around 30 days (Likitha, 2022). It is commonly practiced in rural areas alongside agriculture. The process involves three main stages: mulberry cultivation (moriculture), silkworm rearing, and silk reeling. Karnataka plays a major role in silk production, contributing

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32.31 per cent of the country's mulberry raw silk production (11,823 MT) during 2022-23, with mulberry cultivated over 1.12 lakh hectares. The silk industry also generated employment for about 9.2 million people during the same period. Additionally, bivoltine silk production increased by 12.1 per cent, from 7,941 MT in 2021–22 to 8,904 MT in 2022–23 (GOI, 2023).

Several studies have examined the cost and efficiency aspects of sericulture. Kumaresan et al. (2008) observed in the Udumalpet area of Coimbatore district that large farmers incurred higher costs of cocoon production per kilogram compared to small farmers, mainly due to greater use of labour. Similar findings were reported by Dandin *et al.* (2005), Balasaraswathi *et al.* (2010), and Priyadarshini and Kumari (2017). Elumalai *et al.* (2020) reported that the maintenance cost of mulberry gardens in Krishnagiri and Salem districts of Tamil Nadu during 2019-20 was Rs. 1,24,260.07 per hectare, with major expenditure on farmyard manure (24.57%) and leaf harvesting (17%). The cost of production per kilogram of mulberry leaf was ₹ 3.27. The total cost of silkworm rearing for 2,500 dfls per year was ₹ 2,71,612.50, while the gross income was ₹ 5,36,887.50, yielding a return of ₹ 2.97 per rupee of expenditure.

In West Bengal, mulberry cultivation is mainly practiced on small and marginal farms with an average holding of 0.66 acre. The cost of production per kilogram of cocoons was ₹ 283, and the return per rupee of expenditure was 1.47 (Manjunatha et al., 2020). Anil Kumar *et al.* (2022) studied cocoon production in the North Eastern Karnataka region and found that labour usage was highest in Kalaburagi compared to Raichur and Ballari. Variable costs constituted more than 81 per cent of the total cultivation cost. Similarly, Madhu (2021) reported that the average net returns from rearing 300 dfls were ₹ 55,819.

Dyavappa et al., (2016) estimated the cost of mulberry cultivation per acre in North Karnataka at ₹ 12,699.82 for rearing 300 dfls, with 77.95 per cent as variable cost, mainly labour. However, the gross returns from mulberry leaves and stalks were ₹ 9,472.91. Choudhari *et al.* (2020) reported that the gross return from one hectare of mulberry garden was ₹ 2,63,182.50 against a cultivation cost of ₹1,30,680.20, resulting in an output-input ratio of 2.09, with cocoon production cost at ₹ 215.82 per kg.

Resource use efficiency studies further indicate imbalances in input utilization. Srinivas et al., (2008) found that labour was often overused, while fertilizers and disinfectants were underutilized in certain regions like Chamarajanagar and Kolar districts. Inputs such as farmyard manure, fertilizers, disinfectants, and leaf quantity showed a positive relationship with output. The study suggested increasing the use of these inputs to improve efficiency and income. Similarly, Likhitha *et al*. (2024) observed that increasing the use of fertilizers, farmyard manure, and irrigation could enhance productivity, as the production function indicated increasing returns to scale.

With advancements in technology and improved adoption of modern practices, cocoon yield and overall production have increased in recent years. However, this progress also highlights the need to understand how efficiently resources are being utilized across different regions. Such an understanding is essential for creating awareness among sericulture farmers and helping them improve their returns through better resource management. In this context, assessing the existing levels of resource-use efficiency and technical efficiency in cocoon production becomes highly important. Therefore, the present study was undertaken with the overall objective of evaluating the efficiency of cocoon production in mulberry sericulture in Karnataka. This study captures location-specific variations in technical and economic efficiency within Karnataka, identification of input misallocation by distinguishing between underutilized and overutilized inputs and also behavioural insights into farmer decision-making.

The specific objectives of the study are as follows:

i. To evaluate the costs and returns of mulberry sericulture
ii. To analyse resource-use efficiency in cocoon production across southern states
iii. To estimate the technical efficiency of mulberry farms

II

DATA AND METHODOLOGY

2.1. Sampling Design and Distribution

The present study was conducted in the state of Karnataka for the year 2022-23. For collection of primary data, stratified random sampling design was adopted. Under Cluster Promotion Programme (CPP) being implemented in the state to promote the bivoltine silk production, there are 11 sericulture clusters *viz.*, Bangalore Rural, Tumkur, Ramanagara, Kolar, Chitradurga, Haveri, Koppal, Jamkhandi, Madduru, Mysuru and Bidar) across the state. From each cluster, 20 sericulture farmers were selected at random, thus a total of 220 farmers were selected for the study.

2.2. Analytical Framework

A. Costs and Returns Analysis

The cost and returns earned by the farmer are worked out by using the costs, *i.e.* variable costs and fixed costs (Madhu, 2021 and Likhitha, 2022). Returns from the main product (cocoon) and by-product were considered. Returns are worked out by using gross returns and net returns.

a) Operational and fixed cost in mulberry cultivation

b) Operational and fixed cost in cocoon production

The returns per rupee investment was worked out as the

$$Returns\ per\ rupee\ investment = \frac{Gross\ Returns}{Total\ Cost} \qquad \text{.........}(1)$$

2.3 Resource (Technology) Use Efficiency in Mulberry Sericulture

2.3.1 Production Function

The resource-use efficiency of the inputs used by the sericulture farmers was estimated using Cobb-Douglas (CD) production function, as given below:

$$Y = a\, X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} e^{u} \quad \ldots\ldots(2)$$

Where,

Y is the cocoon yield obtained (kg/acre/ annum),
a denote intercept
X_1 denote animal labour (pair days),
X_2 denotes the number of dfls reared per annum per acre,
X_3 denotes quantities of fertilisers (kg/acre),
X_4 denote quantities of FYM (tractor load),
X_5 denotes cost of chemicals for mulberry and silkworm protection (Rs.),
X_6 denotes the human labour (man days/acre/annum)
b_i denotes elasticity coefficients of inputs
e^u = Error term

2.4 Resource Use Efficiency

The estimated coefficients of significant independent variables were used to compute the marginal value products (MVPs) and the resources-use efficiency (r) was worked out using Equation (3) (Rahman and Lawal, 2003, Baldeep 2024):

$$r = \frac{MVPi}{MFC} \ldots(3)$$

$$MVPi = bi \frac{\bar{Y}}{\bar{Xi}}\, p_y$$

Where,

MVP_i = Marginal value product of the i^{th} input,
$\bar{Y}$= Geometric mean of the value of output,
$\bar{X}i$= Geometric mean of the i^{th} input,
b_i = Estimated co-efficient (or) elasticity of the i^{th} input, and
p_y = Price of output.

2.5. Stochastic Frontier Production Function

Given the inherent nature of sericultural production in the Karnataka state, stochastic frontier production function was employed to assess the technical efficiency of sericultural farmers.

The model for cross-sectional data as defined by Aigner *et al.* (1977); Meeusen and Broeck (1977); Battese and Coelli (1988) is given in Equation (5):

$$Y_i = f\,(X_i\,;\beta)\, e^{(Vi\text{-}Ui)} \ldots (5)$$

Where,

Y_i = Output of the i^{th} farmer,

X_i = $(1 \times K)$ vector of input quantities used by the i^{th} farmer,

β = $(K \times 1)$ vector of parameters to be estimated,

e = A stochastic error-term consisting of two independent components U_i and V_i

The symmetric component V_i accounts for random variations in output, *i.e.* due to factors outside the farmer's control such as weather and occurrence of pests and diseases. It is assumed to be independent and identical as $V_i \approx N\,(0, \sigma^2{}_v)$. A one-sided component that captures deviations from the frontier due to inefficiency (U_i> 0) is assumed to be non-negative of the N (μ_i, σ^2) distribution (half normal distribution) or has exponential distribution.

The variance of ε is given by

$$\sigma^2 = \sigma^2{}_u + \sigma^2{}_v$$

Where,

σ^2 is the variance parameter that denotes the total deviation from the frontier,

$\sigma^2{}_u$ is the deviation from the frontier due to inefficiency,

$\sigma^2{}_v$ is the deviation from the frontier due to stochastic noise.

$$\gamma = \sigma^2{}_u / (\sigma^2{}_u + \sigma^2{}_v)$$

Where,

γ is an indicator of relative variability of U_i and V_I that differentiates the actual yield from the frontier.

When $\sigma_v{}^2$ tends to zero, it implies that U_i is the predominant error, then $\gamma = 1$. This means yield difference is mainly due to non-adoption of best practice or technique. When $\sigma_u{}^2$ tends to zero, it implies that the symmetric error-term, V_i is the predominant error and γ will be tending to zero. This means that yield differences from the frontier yield is mainly due to either statistical error or external factors that are not included in the model.

2.6 The Model

The stochastic frontier production function used in the study is given by Equation (6):

$$\ln(Y_i) = \alpha_0 + \alpha_1 \ln(X_1) + \alpha_2 \ln(X_2) + \alpha_3 \ln(X_3) + \alpha_4 \ln(X_4) + \alpha_5 \ln(X_5) + \alpha_6 \ln(X_6) + \alpha_7 \ln(X_7) + V_i - U_i \ldots (6)$$

The model for assessing technical inefficiency is given by Eq. (7):

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + W_i \ldots (7)$$

Where,

U_i = technical inefficiency in the i^{th} farm,

Z_1 = experience in silkworm rearing (in years),

Z_2 = education of a farmer (in years),

Z_3 = farm size (in acres),

δ_1, δ_2, δ_3 = inefficiency parameters

W_i = Random error term

The technical efficiency of individual farm was worked out using formula (8):

$$TEi = \frac{Yi}{Yi*} = e^{-Ui} \dots (8)$$

Where,

Y_i* = frontier yield

Y_i = actual yield.

III

RESULTS AND DISCUSSION

3.1 Economics of Cocoon Production

Cocoon production in sericulture is a combination of two main activities-mulberry cultivation and silkworm rearing. Mulberry is a perennial crop that requires about one year for establishment and starts yielding economically from the second year onwards (Kumaresan *et al*., 2008). In the present study, the inputs and labour required for cocoon production using leaves from one acre of mulberry plantation were analyzed. The total variable cost incurred for cocoon production was estimated at ₹2.79 lakhs per acre per annum, accounting for 72.06 per cent of the total cost. Among these, human labour constituted the largest share (32.67%), indicating its critical role in sericulture operations. Expenses on crop protection chemicals included costs related to pest and disease management in both mulberry cultivation and silkworm rearing.

Silkworm rearing also requires substantial fixed investments, such as the construction of rearing sheds and procurement of equipment like rearing stands, humidifiers, mountages, and sprayers. These fixed costs, including depreciation of assets, contributed about 27 per cent of the total cost. Additionally, the apportioned establishment cost of the mulberry garden (₹15,712) was also included under fixed costs. Similar findings were reported by Architha and Murthy (2022) and Manjunatha *et al.* (2020), who observed that labour cost forms the major component of total production cost, especially in small and marginal farms.

In the study area, on an average farmers reared seven silkworm crops per year by brushing about 1,285 dfls. The average cocoon yield was 85 kg per 100 dfls, resulting in a total production of 1,093.63 kg of cocoons annually. The cocoon yield among farmers in Karnataka showed noticeable variation, ranging from 924 kg to 1105 kg per acre, with an average productivity of 85.09 kg per 100 dfls. This variation reflects differences in management practices, input use, and farm-level efficiency across farmers. The cost of cocoon production was estimated at ₹ 354.54 per kg, while the average market price realized was ₹ 609 per kg. Most farmers marketed their produce at the Ramanagara cocoon market in Karnataka, which is known for offering better prices. The return per rupee of investment was calculated to be 1.74, indicating that sericulture is a highly profitable enterprise in the region. This finding aligns with the results of Mallikarjuna *et al.* (2008), who reported that sericulture is more profitable compared to other crops in the Mandya region of Karnataka. Overall, sericulture emerges as a remunerative agro-based enterprise, offering higher returns relative to costs and holding strong potential to attract more farmers, particularly in rural areas.

TABLE 1. COST OF COCOON PRODUCTION PER ACRE PER YEAR IN KARNATAKA

Particulars	Amount (₹)
A. Variable costs	
Chawki Charges	43062.35 (11.10)
Animal labour	2895.8 (0.74)
Machine Labour	3317.7 (0.85)
Human Labour	126662.46 (32.67)
FYM	17875.11 (4.61)
Chemical Fertilizers	7376.22 (1.90)
Cost of crop protection chemicals	22638.79 (5.84)
Irrigation costs	1893.38 (0.48)
Other costs (Transportation & Marketing)	20970.72 (5.41)
Interest on working capital (10%)	32649.89 (8.42)
Total variable cost	279342.42 (72.06)
B. Fixed costs	
Apportion cost of establishment of mulberry garden	15712.51 (4.05)
Depreciation/Maintenance cost of rearing building, equipments, machinery, etc.	92583.86 (23.88)
Total fixed cost	108296.37 (27.93)
Total cost (A+B)	387638.7 (100.00)
Cost per kg of cocoon	354.45
Average cocoon price per kg	609.64
Income from cocoons	666720.34
Income from by-products, sale of leaf etc	8366.83
Gross returns	675087.17
Net returns	287448.37
Returns per rupee of investment	1.74

**Figures in parenthesis indicate percentage share to the total*

Sericulture, as a commercial activity, follows a relatively short production cycle. Typically, one silkworm crop takes about 35 days, starting from the hatching of silkworm eggs to the marketing of cocoons, including the time required for cleaning and disinfection of the rearing house and equipment. However, instead of rearing silkworms from eggs, many farmers prefer to purchase young larvae from specialized centres known as Chawki Rearing Centres (CRC), which helps save time and ensures better survival and uniform growth. Under normal conditions, the availability of mulberry leaves limits farmers to rearing about five silkworm crops per year. To overcome this constraint and make better use of available resources, farmers adopt improved management practices. One such practice involves dividing the mulberry garden into two equal portions and scheduling pruning in a staggered manner. This ensures a continuous and adequate supply of leaves for silkworm feeding.

By adopting this approach, farmers are able to rear upto 10 crops annually, as each portion of the garden supplies leaves alternately for successive batches. This system also allows for more efficient utilization of fixed infrastructure such as rearing houses and equipment. In the study area, however, farmers were found to rear an average of seven silkworm crops per year using this method of dividing their mulberry fields and managing them strategically.

3.2 Resource Use Efficiency of Cocoon Production

Resource use efficiency reflects the ability of sericulture farmers to utilize available inputs in a way that maximizes output and profitability, given the prevailing prices and production technology. It combines both technical efficiency (efficient use of inputs) and allocative efficiency (optimal allocation of inputs), thereby providing an overall measure of economic efficiency in cocoon production. The estimated results of resource use efficiency were presented in Table 2. The coefficient of determination (R^2) was found to be 0.73, indicating that about 73 per cent of the variation in cocoon yield is explained by the variables included in the model. The estimated production elasticities reveal that human labour (0.467) and DFLs (0.434) were the most influential factors affecting cocoon production. This clearly highlights the labour-intensive nature of sericulture. A one per cent increase in these inputs results in a relatively higher increase in output compared to other inputs such as farmyard manure (0.241), fertilizers (0.091), and animal labour (0.008), which show comparatively lower responsiveness. The positive and significant coefficients of most inputs indicate that increasing their usage can lead to higher cocoon yield.

The higher elasticity and underutilization of labour also point towards a strong demand for labour in sericulture, which has positive implications for rural employment generation. However, since labour constitutes a major share of the total cost, continuous increases in wage rates may eventually encourage farmers to adopt labour-saving technologies and mechanization to sustain profitability. The presence of increasing returns to scale further suggests that expanding the use of inputs can result in proportionately higher output, thereby enhancing overall efficiency. Achieving optimal resource allocation, where the marginal value product equals the marginal cost of inputs is essential for maximizing profitability and ensuring efficient resource use in mulberry sericulture.

TABLE 2. RESOURCE USE EFFICIENCY IN COCOON PRODUCTION

Variable	Regression coefficients	Standard error	t-stat
Constant	1.802		
Animal labour (pair days)	0.008NS	0.0734	0.112
DFLs (No./acres/yr)	0.434**	0.0564	7.691
Fertilisers (Kg)	0.091 NS	0.121	0.752
FYM (tractor load)	0.241**	0.043	5.611
Chemicals for mulberry and silkworm crop protection (₹)	0.081NS	0.0714	1.134
Labour (man days)	0.467**	0.0652	7.162

Note: R^2 = 0.73** $\bar{R}^2$ = 0.71** F- ratio = 12.12, N = 220
**Significant at 1 per cent level, *Significant at 5 per cent level, NS - Non-significant

Farmers in the study area were observed to follow improved management practices such as timely and adequate feeding of silkworms, maintaining optimal bed space, proper use of disinfectants, and careful control of temperature, humidity, and ventilation. They also adopted appropriate mounting techniques. These practices help in increasing cocoon yield and farmers' income without necessarily increasing input costs. The availability of family labour further supports timely operations such as feeding and maintaining hygiene in silkworm rearing. However, any disruption in these practices due to labour shortages can adversely affect cocoon yield and overall production performance.

3.3 Economic Efficiency

Economic efficiency in cocoon production was assessed using the ratio of marginal value product (MVP) to marginal factor cost (MFC) (Table 3), it was found that the MVP–MFC ratios for inputs such as DFLs, fertilizers, plant protection chemicals, and human labour were greater than one. This indicates that these resources are being used below their optimal levels, and increasing their use could further enhance cocoon yield and profitability. In contrast, inputs like farmyard manure (FYM) and animal labour recorded ratios less than one, suggesting that they are being overutilized and need to be rationalized. To address this imbalance, farmers are being encouraged to adopt soil test-based application of FYM and fertilizers to achieve optimal mulberry productivity. Given that sericulture is a labour-intensive activity, the adoption of mechanization is becoming increasingly important to reduce dependence on human and animal labour, thereby lowering production costs and improving net returns.

TABLE 3. RESOURCE USE EFFICIENCY IN SERICULTURE IN KARNATAKA

Variable	Parameter	Mean of inputs	Regression coefficients	MVP	MFC	MVP/ MFC Ratio
No.of observations	220					
Intercept	A		1.802			
Animal labour (pair days)	X_1	2.24	0.008	23.77	2885.90	0.01
Dfls (No./acre/year)	X_2	1285	0.434	2.25	1.24	1.82
Fertilisers (Kg)	X_3	1043.00	0.091	0.58	0.19	3.01
FYM (tractor load)	X_4	2.68	0.241	598.58	1616.84	0.37
Chemicals for plant and crop protection (₹)	X_5	21347.00	0.081	0.03	0.02	1.27
Labour (mandays)	X_6	370.00	0.467	8.40	5.55	1.51
Returns to scale			1.322			
Coefficient of multiple determination (R^2)			0.73			
Adjusted R^2			0.72			

The estimated production elasticities provide useful insights into farmers' input use behaviour. The relatively high elasticity of human labour (0.467) indicates that labour plays a crucial role in enhancing productivity. This reflects farmers' reliance on both family and hired labour for essential operations such as feeding, bed cleaning, and maintaining suitable environmental conditions. Similarly, the high elasticity of DFLs (0.434) highlights the importance of biological inputs directly linked to cocoon output, suggesting that farmers respond positively to increasing the scale of silkworm rearing. On the other hand, the lower elasticities of fertilizers (0.091) and animal labour (0.008) indicate limited responsiveness, which may be due to either near-saturation levels of use or lack of precise input management. The MVP–MFC ratios further support these observations. Ratios greater than one for key inputs suggest that farmers are operating below the profit-maximizing level, possibly due to constraints such as limited access to credit, risk aversion, or inadequate technical knowledge. Conversely, the overuse of FYM and animal labour reflects traditional practices that are not fully aligned with economic efficiency principles.

The estimated returns to scale (1.322) indicate increasing returns to scale in cocoon production. This means that a proportional increase in all inputs leads to a more than proportional increase in output, suggesting that farmers are currently operating below the optimal scale. Expanding input use can therefore significantly enhance productivity and reduce average costs. These scale economies arise from better utilization of fixed resources such as rearing infrastructure and improved coordination of inputs at higher levels of operation. From a practical perspective, larger or more intensive production systems tend to achieve higher efficiency and profitability. However, since sericulture is predominantly practiced by small and marginal farmers, expanding landholding may not always be feasible. Instead, farmers can achieve scale advantages through intensification such as increasing the number of rearing cycles using the two-plot system in mulberry cultivation, improving input management, and adopting better technologies.

While the high elasticity and underutilization of labour suggest strong potential for rural employment generation, the rising cost of labour may encourage farmers to gradually adopt labour-saving technologies. In the short run, increased labour use can support production, but in the long run, selective mechanization becomes essential to reduce costs and maintain profitability.

The underutilization of key inputs like labour and fertilizers highlights the need for stronger extension services to guide farmers on optimal input use. Training programmes on soil test-based fertilization and improved rearing practices can help farmers achieve better efficiency. Additionally, access to institutional credit and timely input supply can enable farmers to expand production and benefit from increasing returns to scale.

To address input imbalances, reducing the excessive use of FYM and animal labour, while promoting the use of productivity-enhancing inputs, should be a key focus of advisory services and development programmes. Overall, improving economic efficiency in mulberry sericulture requires aligning farmers' input use decisions with marginal productivity principles through better access to technology, institutional support, and market opportunities. This will not only enhance profitability but also ensure the long-term sustainability of the enterprise.

3.4 Technical Efficiency in Cocoon Production

The technical efficiency in cocoon production was estimated using the stochastic frontier production function through the Maximum Likelihood Estimation (MLE) method, and the results are presented in Table 4. The estimated variance parameter (γ) was 0.81, indicating that nearly 81 per cent of the variation in cocoon output is attributable to differences in farmers' practices and managerial efficiency, rather than random factors such as weather or measurement errors. The high gamma value further confirms that much of the variation in production is due to differences in farmers' efficiency rather than external factors like weather or chance. This highlights the significant scope for improving productivity through better farm management.

The results further reveal that among all the inputs, DFLs (disease-free layings) emerge as the most influential factor. Farmers who used more quality DFLs were able to achieve significantly higher output, highlighting how crucial seed quality is in sericulture. Animal labour and human labour also play an important role in sericulture, their positive and significant effects suggest that sericulture continues to be a labour-intensive enterprise where timely operations-such as feeding, maintenance, and harvesting-directly affect productivity. This also indicates that both availability and efficient use of labour remain key to improving outcomes.

TABLE 4. ESTIMATED STOCHASTIC FRONTIER PRODUCTION FUNCTION FOR COCOON PRODUCTION

Variables	Regression coefficient	Standard error	t-stat	p-value
Frontier production function				
Constant	-0.970	0.704	-1.384	0.167
Animal labour	0.2104***	0.043	4.892	0.000
Dfls	0.4756***	0.052	9.151	0.000
Fertilisers	0.1834*	0.102	1.810	0.072
FYM	0.2415	0.421	0.572	0.568
Chemicals for plant and crop protection	0.5474	0.511	1.072	0.285
Labour	0.1824**	0.089	2.056	0.040
Technical inefficiency effects				
Constant	-0.140	0.325	-0.432	0.667
Education	-0.124***	0.011	-11.274	0.000
Farm size	0.021	0.014	1.526	0.134
Farming experience	0.004	0.006	0.672	0.503
Diagnosis statistics				
Sigma square (σ^2)	0.064**	0.0112	5.712	0.000
Gamma (γ)	0.810**	0.0614	13.191	0.000
Log likelihood	41.32			
Mean technical efficiency (per cent)	74.14			

Note: N = 220, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$, NS = Not significant.

The role of fertilisers is positive but only moderately significant, indicating that while nutrient application helps improve mulberry yield, farmers may not always be using the right quantity or combination. On the other hand, FYM and plant protection chemicals did not show a significant impact. This could be due to improper application methods, inconsistent usage, or lack of awareness about recommended practices.

When it comes to inefficiency, farmers with higher levels of education tend to operate more efficiently, possibly because they are better at understanding new technologies, following scientific practices, and making informed decisions. In contrast, factors like farm size and farming experience did not show a strong influence, suggesting that efficiency is less about scale or years of practice and more about knowledge and management. The estimated technical efficiency of about 74 per cent indicates that farmers are performing reasonably well, but there is still significant gap of around 26 per cent to improve output without increasing input use.

The findings suggest that improving technical efficiency in cocoon production is largely within the control of farmers and can be achieved through targeted interventions. Since a major share of output variation is due to management practices, strengthening extension services is crucial. Regular training and capacity-building programmes should be conducted to promote scientific rearing practices, including optimal feeding, hygiene maintenance, and environmental control.

The significance of inputs such as DFLs and fertilizers indicates the need to ensure timely availability and proper usage of these inputs. Policies should focus on improving access to quality inputs through efficient supply chains and subsidies where necessary. Encouraging soil test-based fertilizer application and balanced nutrient management can further enhance mulberry productivity.

Although labour plays a critical role in cocoon production, rising labour costs may affect profitability in the long run. Therefore, promoting selective mechanization such as improved rearing equipment and labour-saving devices can help reduce dependency on manual labour without compromising productivity. The influence of farm size suggests that economies of scale can improve efficiency. However, since most sericulture farmers are smallholders, policies should emphasize intensification rather than expansion. Practices such as the two-plot mulberry system, increased rearing cycles, and better input management can help small farmers achieve higher productivity within limited land. It can be concluded that improving access to institutional credit is essential to enable farmers to invest in quality inputs, infrastructure, and technology. Integrated support involving extension, credit, input supply, and market access will be key to enhancing technical efficiency and ensuring the sustainability of mulberry sericulture.

3.5 Distribution of Technical Efficiency among Farmers

The distribution of farmers based on their level of technical efficiency in cocoon production is presented in Figure 1. The results show that only 12.73 per cent of the farmers fall under the highly efficient category, with efficiency levels above 90 per cent. A larger proportion, about 42.73 per cent, belong to the 81–90 per cent efficiency group. This indicates that while a considerable number of farmers are performing reasonably well, only a small share were operating very close to the production frontier.

The average (mean) technical efficiency was estimated at 80.21 per cent. This suggests that, on average, farmers are achieving about 80 per cent of the maximum possible output under the given technology and resource conditions. In other words, there exists a gap of nearly 19.79 per cent between the current level of production and the potential (frontier) output. This gap represents the scope for improvement through better management practices, efficient use of inputs, and adoption of improved technologies without necessarily increasing the quantity of inputs.

These findings imply that most farmers are not fully utilizing the available technology and resources to their maximum potential. Factors such as lack of technical knowledge, improper input management, labour constraints, and inadequate extension support may contribute to this inefficiency. The results are in line with several earlier studies conducted in different crops, which also reported relatively high but not optimal

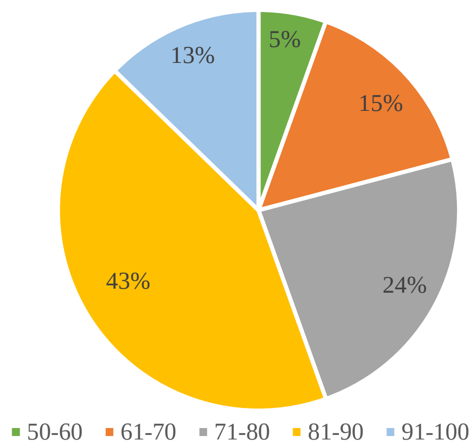

FIGURE 1. DISTRIBUTION OF THE FARMERS BASED ON THE TECHNICAL EFFICIENCY SCORES

levels of technical efficiency. For instance, mean technical efficiency was found to be around 86 per cent in sorghum (Bhendi and Kalirajan, 2007), 84 per cent in turmeric (Karthick et al., 2013), and similar levels in crops like rice (Konja et al., 2019; Sani et al., 2020), groundnut (Devi et al., 2020), potato (Sapkota and Bajracharya, 2018), garlic (Ahmed et al., 2011), and maize (Wakili, 2012). This consistency across studies suggests that while farmers generally perform at a reasonably efficient level, there is always a margin for improvement. Even a modest improvement in efficiency levels can significantly enhance cocoon production and farmers' income without requiring additional resources. It highlights the need of bridging the efficiency gap by strengthening extension services, promoting best management practices, and improving farmers' access to knowledge and technology.

IV

CONCLUSION

Efficient use of resources is essential for increasing production and maximizing returns in sericulture. The study revealed that key inputs such as DFLs, fertilizers, human labour, and crop protection chemicals are underutilized, while FYM and animal labour are overused, leading to inefficient resource allocation. Hence, proper adjustment in input use is necessary to improve profitability. The results also showed that about two-thirds of farmers achieved more than 80 per cent technical efficiency, indicating good performance but with scope for further improvement. Enhancing technical efficiency, especially among less efficient farmers, can increase output without additional resource use. Education of farmers could significantly influence efficiency, highlighting the need for better technical knowledge and training.

From a policy perspective, there is a need to promote optimal input use through extension services, soil test-based recommendations, and targeted input subsidies. Improving access to credit can help farmers invest adequately in essential inputs. Additionally, promoting labour-saving technologies and establishing custom hiring centres can reduce labour costs. Encouraging cluster-based approaches, such as farmer producer organizations and shared infrastructure, can help small farmers achieve economies of scale. Overall, improving resource use efficiency through better management, institutional support, and technology adoption is key to enhancing productivity and income in mulberry sericulture in Karnataka.

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