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Production efficiency of chillies in peri-urban areas of Coimbatore district

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Abstract
In this paper, resource use efficiency and technical efficiency of chillies were measured in Coimbatore district of Tamil Nadu. The study was conducted in peri-urban villages of Coimbatore district. Three peri-urban cluster village each in Thondamuthur, Madukkarai and Karamadai blocks were selected. From each village, thirty sample farmers were selected to form a sample size of 90. Cobb-douglas production function and Data Envelopment Analysis were used to measure the resource-use efficiency and technical efficiency respectively. The average yield of the sample farms was nine tonnes per hectare with the coefficient of variation of 24.44 per cent. The net return from chillies cultivation was Rs. 30728 with the BC ratio of 1.29. The study also revealed that plant population, human labour and number of irrigations had a positive and significant influence on the yield. The ratio of MVP to MFC was greater than one for all the significant variables indicating the underutilization of resources and there exists the possibility of enhancing their yield by increasing their use. The overall mean technical efficiency was 0.89, which indicated the possibility of increasing the yield of chillies by adopting better technology and cultivation practices.

Introduction
Tamil Nadu state is the second largest producer of vegetables in South India. The area under vegetables was 2.89 lakh hectares in 2015-16 and the production was 8.68 million tonnes. The important vegetable crops grown in the state are tomato, onion, drum stick, brinjal, ladies-finger and chillies. The state has achieved the highest average vegetable productivity in the country with 30 tonnes per hectare in 2015-16 and it is also close to the worlds' highest average productivity of 32.5 tonnes per hectare reported by United States (Government of India, 2017). Chilles is the one of the important crops in the state cultivated in 41.4 thousand hectares and produced the output of 11.2 thousand tonnes. With horticultural crops gaining such momentum over the decade at both national and state level, the analysis of their resource use efficiency and technical efficiency would provide a better insight about the efficient utilization of the resources through which productivity can be improved further. Enhancing and sustaining productivity on the other hand would help to meet out the growing urban demand in the state. With this background, the present study was carried out the overall objective of assessing the production efficiency of major horticulture production in Coimbatore district.

Materials and Methods
Sampling
Coimbatore district was purposively selected for the study. At first stage, three blocks were purposively selected based on the area under horticultural crops. The blocks selected for the study were Thondamuthur, Madukkarai and Karamadai. In each block, one peri-urban cluster village was selected. From each cluster, 30 farmers were selected at random and the total sample size was 90. The sample farmers were personally interviewed and the data were obtained using structured interview schedule.

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Analytical Framework
Production Function
The Cobb-Douglas production function was fitted to establish the input-output relations and to calculate the efficiency of the inputs used. The dependent and independent variables used in the model are given below.
The model is specified as follows:

$$Y = \beta_0 X_1^{\beta_1} X_2^{\beta_2} X_3^{\beta_3} X_4^{\beta_4} X_5^{\beta_5} X_6^{\beta_6} X_7^{\beta_7} X_8^{\beta_8} X_9^{\beta_9} e_U$$

The logarithmic expression of the model is

$$ln\ Y = \beta_0 + \beta_1\ ln\ X_1 + \beta_2\ ln\ X_2 + \beta_3\ ln\ X_3 + \beta_4\ ln\ X_4 + \beta_5\ ln\ X_5 + \beta_6\ ln\ X_6 + \beta_7\ ln\ X_7 + \beta_8\ ln\ X_8 + \beta_9\ ln\ X_9$$

Y- Output of the chillies crop (t/ha),
$\beta_0 \ldots \beta_9$ - Parameters to be estimated,
X_1 - Quantity of seed (kg/ha) or number of seedlings
X_2 - Machine labour (hrs/ha)
X_3 - Human labour (man-days/ha)
X_4 - Farm yard manure (tonnes/ha)
X_5 - Quantity of nitrogen (kg/ha)
X_6 - Quantity of phosphorous (kg/ha)
X_7 - Quantity of potassium (kg/ha)
X_8 - Plant protection chemicals (Rs. /ha)
X_9 - Irrigation (No. /ha)

Resource-Use Efficiency
Marginal productivity analysis was done to study the efficiency of various resources used for production. The efficiency of resources is determined as follows

$$r = Marginal\ Value\ Product\ (MVP)/Marginal\ Factor\ Cost\ (MFC)$$

Where,
r = Efficiency ratio
MVP = Product of marginal physical product and unit price of output (MPP. P_Y)
MFC = Cost of one unit of a particular resource
If, $r = 1$, it implies efficient use of the particular resource.
$r < 1$, it implies inefficient (over-utilizing resources) use of the particular resource.

Technical Efficiency
Technical efficiency refers to the farm's ability to produce the maximum possible output from a given combination of inputs and technology. Data envelopment analysis (DEA) advocated by Charnes *et al*., (1978) [3] was used in the present study to examine the technical efficiency.

Data Envelopment Analysis (DEA)
The DEA method is a frontier method that does not require specification of a functional or distributional form, and can accommodate scale issues. This approach was first used by Farrell (1957) [6] as a piecewise linear convex hull approach to frontier estimation and later by Boles (1966) [2] and Afriat (1972) [1]. In the present study, Data Envelopment Analysis (DEA) technique was employed to estimate the technical and allocative efficiencies of the various crops raised by the peri-urban farms.
The DEA was applied by using both classic models CRS (constant returns to scale) and VRS (variable returns to scale) with input orientation, in which one seeks input minimization to obtain a particular product level.

Constant Returns to Scale
Under the assumption of constant returns to scale, the linear programming model for measuring the efficiency of farms are:
$Min\ _{\theta, \lambda}\ \theta$
Subject to
i) $\ -y_i + Y\lambda \geq 0$
ii) $\ \theta x_i - X\lambda \geq 0$
iii) $\ \lambda \geq 0$ …………………..… (1)

Where,
y_i is a vector (m × 1) of output of the ith farm,
x_i is a vector (k × 1) of inputs of the ith farm,
Y is the output matrix (n × m) for n farms,
X is the input matrix (n × k) for n farms,
θ is the efficiency score, a scalar whose value will be the efficiency measure for the ith farm. If $\theta = 1$, the farm will be efficient; otherwise, inefficient, and λ is a vector (n × 1) whose values are calculated to obtain the optimum solution.
For an inefficient farm, the λ values will be the weights used in the linear combination of other, efficient farms, which influence the projection of the inefficient farm on the calculated frontier.
The specification of constant returns is only suitable when the farms work at the optimum scale. Otherwise, the measures of technical efficiency can be mistaken for scale efficiency, which considers all the types of returns to production, i.e., increasing, constant and decreasing.

Variable Returns to Scale
The CRS model was reformulated by imposing a convexity constraint. The measure of technical efficiency obtained in the model with variable returns is also named as 'pure technical efficiency', as it is free of scale effects. The following linear programming model estimated it:
$Min\ _{\theta, \lambda}\ \theta$
Subject to
i) $\ -y_i + Y\lambda \geq 0$
ii) $\ \theta x_i - X\lambda \geq 0$
iii) $\ N_1\ \lambda = 1$
iv) $\ \lambda \geq 0$ …………………………. (2)

Where, N_1 is a vector (n × 1) of ones.
When there are differences between the values of efficiency scores in the models CRS and VRS, scale inefficiency is confirmed, indicating that the return to scale is variable, i.e. it can be increasing or decreasing (Färe and Grosskopf, 1994) [5].
The scale efficiency values for each analyzed unit can be obtained by the ratio between the scores for technical efficiency with constant and variable returns as follows:

$$\theta s = \theta_{CRS}\ (X_K, Y_K)\ /\theta_{VRS}\ (X_K, Y_K) \ ……………… (3)$$

Where,
θs = Scale efficiency,
$\theta_{CRS}\ (X_K, Y_K)$ = Technical efficiency for the model with constant returns, and
$\theta_{VRS}\ (X_K, Y_K)$ = Technical efficiency for the model with variable returns.
It could be seen that model (2) makes no distinction as to whether the farm is operating in the range of increasing or decreasing returns (Coelli *et al.*, 1998) [4]. The only information one has is that if the value obtained by calculating the scale efficiency in Equation (3) is equal to one, the farm

will be operating with constant returns to scale. However, when θs is smaller than one, increasing or decreasing returns can occur. Therefore, to understand the nature of scale inefficiency, it is necessary to consider another problem of linear programming, i.e. the convexity constraint of model (2), $N_1\lambda = 1$, is replaced by $N_1\lambda \leq 1$ for the case of non-increasing returns, or by $N_1\lambda \geq 1$, for the model with non-decreasing returns. Therefore, in this work, the following models were also used for measuring the nature of efficiency.

Non-increasing returns:

Min $_{\theta, \lambda}$ θ

Subject to

i) $-y_i + Y\lambda \geq 0$

ii) $\theta x_i - X\lambda \geq 0$

iii) $N_1 \lambda \leq 1$

(iv) $\lambda \geq 0$ ………………………..… (4)

Non-decreasing returns:

Min θ, λ θ

Subject to

i) $- y_i + Y\lambda \geq 0$

ii) $\theta x_i - X\lambda \geq 0$

iii) $N_1 \lambda \geq 1$

iv) $\lambda \geq 0$ ………………………..… (5)

It is to be stated here that all the above models should be solved n times, i.e. the model is solved for each farm in the sample. The quantity produced (t/ha) was used as an output

(Y) in the present case and total labour days (man days), machine power (hours), seeds/plant population (No.), farm yard manure (t), plant nutrients N (kg), P (kg), K (kg) separately, capital inputs (Rs) on plant protection, other input costs and fixed input costs as inputs (X). The models were solved using the DEAP version 2.1 taking an input orientation to obtain the efficiency levels (Murthy et al., 2009) [8].

Results and Discussion
Input use in Chillies Cultivation
Input use in Chillies cultivation in selected blocks of Coimbatore district is presented in Table 1. The seedlings used for planting chillies were the lowest of 14829 numbers in Karamadai block and highest in Thondamuthur block with 16920 numbers. The machine labour usage was ranged from 3 to 3.5 hours among sample farms. Similarly, the human labour usage varied from 62 man-days to 74 man-days for chillies cultivation among sample farms. The nitrogenous fertilizer usage was ranged from 80 Kgs to 120 Kgs per hectare. The phosphorus and Potassium usage were ranged from 60 kgs to 95 kgs per hectare and 85 kgs to 100 kgs per hectare respectively. The overall fertilizer usage was less among the Karamadai block farmers. The Madukkarai block farmers used more of plant protection chemicals with the cost of Rs.7566 per hectare than the other block farmers. However, the Thondamuthur Block farmers used comparatively less value of plant protection chemical (Rs.5754) than others.

Table 1: Input use in Chillies Cultivation in Selected Blocks of Coimbatore District

S.No	Particulars	Karamadai Block	Madukkarai Block	Thondamuthur Block
1	Seedlings (Nos)	14829	16920	16920
2	Machine labour (hours)	3	3	3.5
3	Human labour (man days)	62	74	69
4	Farmyard manure (tonnes)	-	-	-
5	Nitrogen (kgs)	80	120	100
6	Phosphorous (kgs)	60	80	95
7	Potassium (kgs)	85	85	100
8	Plant protection chemicals (Rs.)	7410	7566	5754

Yield of Chillies Crop among the Sample Farms
The yield of chillies among the sample farmers of selected blocks of Coimbatore District is presented in Table 2. The average yield of chillies was nine tonnes per hectare among the selected sample farms in the district. However, the yield varied from 5 tonnes per hectare to 12 tonnes per hectare. The yield variability was the highest among the Thondamuthur block farmers with the coefficient of variation of 24.44 per cent.

Table 2: Yield of Chillies among the Sample farms in Selected Blocks of Coimbatore Districts (tonnes/ha)

S.No	Block	Minimum	Maximum	Average	C.V. (%)
1.	Thondamuthur	5	12	9	24.44
2.	Madukkari	5	10	9	20.66
3.	Karamadai	8	10	9	11.11

Costs and Returns
The cost and returns of chillies crop among the sample farms of Coimbatore district is presented in Table 3. The total cost of cultivation of chillies was the highest in Karamadai block (Rs.1.10 lakhs /ha) and lowest in Thondamuthur block (1.04 lakhs /ha). However, the gross return remains the same for all sample farms. However, the net return from chillies

cultivation was the highest among Thondamuthur block farms (Rs. 30728) with the benefit cost ratio of 1.29.

Table 3: Costs and Returns of Chillies crop among the sample farms of Coimbatore District Rs. /ha)

S.No	Block	Total cost of cultivation	Gross returns	Net returns	B-C ratio
1.	Thondamuthur	104272	135000	30728	1.29
2.	Madukkarai	105482	135000	29518	1.28
3.	Karamadai	110089	135000	24911	1.23

Resource-Use Efficiency in Chillies
The results of the production function analysis for chillies are presented in Table 4. It could be seen from table that the adjusted R^2 value is 0.828 which indicates that about 83 per cent of the variation in chillies yield is explained by the selected variables included in the model. The co-efficient of plant population, human labour and number of irrigations are significant at one per cent level and positively contributed to the yield. The co-efficient of human labour and irrigation are 1.2248 and 1.8383 which imply that increase in the use of these resources by one per cent would increase the yield by about 1.22 and 1.83 per cent respectively.

Table 4: Production function estimates of chillies

S. No	Particulars	Co-efficient	t-value
1	Constant	-14.1819	-4.58
2	Plant population (X1)	0.8158*	3.75
3	Machine labour (X2)	0.0796 NS	0.82
4	Human labour (X3)	1.2248*	3.91
5	Nitrogen (X4)	-0.0046 NS	-0.20
6	Phosphorous (X5)	-0.0918 NS	-0.49
7	Potassium (X6)	-0.2547 NS	-4.03
8	Plant protection chemicals (X7)	-0.0627 NS	-0.85
9	Irrigation (X8)	1.8383*	6.03
	Adjusted R2	0.8280	

Note: * - 1% level of significance, NS - Non Significant

Marginal Productivity Analysis

The efficiency in the use of the various resources is estimated using marginal productivity analysis and are presented in Table 5.

Table 5: Resource use efficiency in chillies

S.No	Variables (units/ha)	Geometric mean	Regression co-efficient	MVP	MFC	Ratio of MVP to MFC
1	Plant population (No)	16829	0.8158	5.05	0.6	8.42
2	Human labour (days)	73	1.2248	1745.4	600	2.91
3	Irrigation (No.)	12	1.8383	14716	250	58.86

It is evident from the table that MVP is greater than MFC for plant population, human labour and number of irrigations. This clearly indicates that these resources were under-utilized and that the farmers still had the scope of increasing the yield per hectare by increasing the use of these resources.

Technical Efficiency in Chillies Production

Out of the 90 sample farms, 30 farms raised chillies. The technical efficiency for these farms was calculated and the results are presented in Table 6.

Table 6: Efficiency Measures and Descriptive Statistics for Chillies Producing Farms

S.No	Descriptive statistics	CRSTE	VRSTE	SE
	No. of Efficient Farms (≥ 0.90)	15 (50.00)	30 (100.00)	15 (50.00)
1	Mean	0.82	0.99	0.83
2	Standard Deviation	0.18	0.01	0.19
3	Minimum	0.42	0.96	0.45
4	Maximum	1.00	1.00	1.00

Note: Figures in parentheses indicate percentages to total number of farms (n=30)

CRSTE: Technical Efficiency under Constant Returns to Scale; VRSTE-Technical Efficiency under Variable Returns to Scale; SE - Scale Efficiency

Overall Technical Efficiency

It could be observed from table that only 50 per cent of the chillies producing farms were efficient in terms of overall technical efficiency under the assumption of Constant Returns to Scale (CRS) and the remaining farms were technically inefficient with respect to input allocation in crop production. The overall technical efficiency of the farms ranged from 0.42 to 1.00 with mean technical efficiency of 0.82. This implies that the technical efficiency could be increased by 18 per cent through better use of the resources, with the given technology.

Pure Technical Efficiency

The pure technical efficiency as calculated by using variable returns to scale model ranged from 0.96 to 1.00 with mean efficiency score of 0.99. Farms with pure technical efficiency score more than 0.90 (50 per cent) increased to 100 per cent and the mean technical efficiency increased to 0.99 from 0.83 as compared to constant returns to scale model.

Scale Efficiency

About 50 per cent of the farms were found with the scale efficiency of more than 0.90 and the remaining were operating in a less than optimal scale size. The scale efficiency among the farms ranged between 0.45 and 1.00 with mean scale efficiency score of 0.83. The above result indicates that the farms which were operating in less than optimal scale size (scale inefficiency) could increase their scale efficiency by 17 per cent by operating in optimal scale size under current technology which enables the small farms to operate in optimal scale size.

Scale of Operations

It is interesting to note that the sample farms cultivating chillies were operating either with increasing returns to scale or constant returns to scale. The details are given in Figure 1.
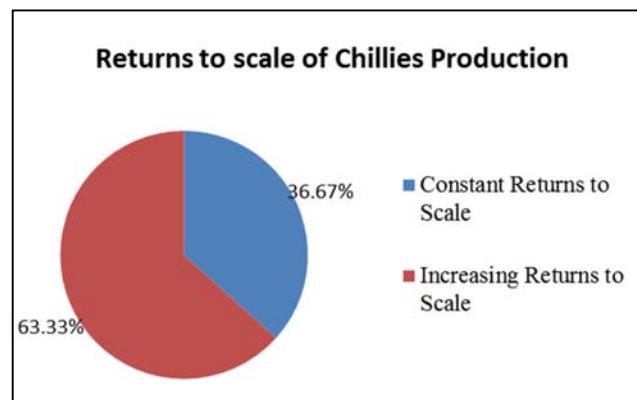
Fig 1: Returns to Scale of Chillies Production

Conclusion

The average productivity of chillies among the sample farms was nine tonnes per hectare and the yield variation was 24.44

per cent. The highest net return was Rs. 30728 per hectare in Thondamuthur block with the benefit cost ratio of 1.29. The increased usage of plant population, human labour and number of irrigations could increase the retunes in chillies production. The overall technical efficiency of the sample farms ranged from 0.42 to 1.00 with mean technical efficiency of 0.82. This implies that the technical efficiency could be increased by 18 per cent through better use of the resources, with the given technology.

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