Data envelopment analysis in estimating economic efficiency of farm credit for adopting good agricultural practices in mango cultivation in Tamil Nadu

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DATA ENVELOPMETN ANAYLSIS IN ESTIMATING ECONOMIC EFFICIENCY OF FARM CREDIT FOR ADOPTING GOOD AGRICULTURAL PRACTICES IN MANGO CULTIVATION IN TAMIL NADU

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Abstract

Good Agricultural Practices in mango production is essential to enable farm produce to be internationally competitive with sufficient institutional credit. Economic efficiency was 0.45 and 0.68 for conventional and GAP farms implied that there existed scope to increase mango output by 55 and 32 per cent respectively by optimum allocation of resources. The highest return invested by GAP borrowers might be due to efficient use of resource and GAP. The extension workers should develop strategies to increase income through adoption of good agricultural practices, efficient use of resources, strengthening loan delivery mechanism to enhance mango production.

Key Words: Credit, Efficiency, Mango, Production, Resource.

Introduction

Agricultural investment, when appropriately structured, can lead to capital deepening, technology transfer, and accelerate broader economic development of the country. India is being the second largest producer of horticultural crops[1]; it is in a position to supply to worldwide market in the presence of shortage of planting material, infrastructure constraints and lack of proper post harvest management facilities to become a reliable exporter [2]. The challenge today is to recast horticulture in the new environment of globalization, rising prices, growing domestic demand and greater private sector involvement [3]. The high capital cost involved in establishing an orchard or a plantation, or rejuvenation of existing old unproductive plantation poses serious constraint in area expansion under perennial crops as it require greater investments. The institutional credit has been perceived as an important key determinant in the agricultural development of India [4]. The financial institutions supplying the substantial credit which enabled the rapid growth of infrastructure across our country and also upgraded the absorption capacity of the farm credit. The situation becomes all the more difficult in view of the large number of small holdings devoted to these crops which are essentially owned by weaker section, who have no means to invest, nor can afford to stand the burden of credit even if available[5]. This calls for liberalized credit facilities in easy instalments for repayment in the form of soft loans to small and marginal farmers to be introduced if the benefits of the horticulture industry are to be fully exploited.

India is world famous for its diverse collection of mango types and each of them having its own distinctive flavour, texture and aroma[6]. The Indian mango is a special produce that validates the high standards of quality and plentiful nutrients packed in it.

India is the largest producer and also an eminent exporter of fresh mangoes to other parts of the world. India has exported 27,872.78 mt of fresh mangoes to other countries which having worth of Rs. 327.45 crores during the year 2021-22[7]. Mechanization, diversification and commercialization of horticulture and changing demand pattern resulted in the increased area and production under mango. Although credit has played vital role in mango production yet regional and farm-category wise disparity has also taken place. Few farmers with better resource endowments and access to financial and other institutions have marched faster while others could not do so. Furthermore, multiplicity of lending institutions together with the liberal deployment of credit for mango production through various on going schemes including micro-financing saved rural dwellers from the clutches of money lenders. The market potential can also be realized by reforming agricultural practices and making its produce internationally competitive in quality and food safety. To enable farm produce to be internationally competitive innovative farming practices incorporating the concept of globally accepted Good Agricultural Practices (GAP) within the framework of commercial agricultural production for long term improvement and sustainability is essential. GAP in addition to improving the yield and quality of the products, also has environmental and social dimensions. Implementation of GAP would promote optimum utilization of water resources such as pesticides, fertilizers, water and eco-friendly agriculture. Its social dimension would be to protect the agricultural workers' health from improper use of chemicals and pesticides. It is a particularly opportune time to promote GAP when second generation of reforms in agriculture which would have a critical impact on Indian agriculture, are planned by the Indian Government. In this context, the need for affordable, sufficient and timely supply of institutional credit to adopt the Good Agricultural Practices has assumed critical importance. By encouraging cooperatives, the government is also helping framers to reduce risk of farming by encouraging them to do bulk purchase of inputs and selling of yields, as well as negotiate jointly for credit from financial institutions that are willing to use the wealth of numbers as a form of collateral. The crop loan system or the production oriented system of lending was evolved and conceived as the most appropriate mechanism for mass disbursement of production credit. In this context, the present study was taken up to evaluate the impact of credit or owned capital on returns to investment and also to the farm investment.

Methodology

Krishnagiri district in the state of Tamil Nadu is the leading region in mango cultivation and mango processing activity. In Krishnagiri district, the area under mango cultivation is around 30885 ha with total production of four lakh tonnes per annum[8]. The National Horticultural Mission has already identified the potential in this region, and has identified Krishnagiri for promoting mango cultivation. Hence, it was decided to study the economics and credit impact of the mango cultivation in this district. Among the ten blocks in Krishnagiri district, Bargur, Kaveripattinam and Mathur blocks were selected purposively for the present study, as production and processing are concentrated in these blocks. The sample mango farmers who borrowed credit for crop production purposes for the year 2017-18 from institutional sources of credit were classified as borrower farms and the sample farmers who did not borrow credit from any source and who used up their own savings were classified as non-borrower farms. These two categories of mango farmers were adopting conventional mango cultivation practices. The third category of mango farmers was referred as GAP farmers who were adopting Good Agricultural Practices (GAP) in the study period. All GAP farmers were borrowers in the study area and there were no farms without credit under GAP. All farms were certified for GAP by the concerned processing firms. The total number of respondents was finalized at 270 mango farms which are selected from Bargur, Kaveripattinam and Mathur blocks. From each block, three villages were selected and for each of selected villages a sample of 30 mango growers was selected at random. Out of these 30 farmers, 10 farmers were selected from each category of conventional borrowers, 10 from conventional non-borrowers and 10 from GAP farmers. The sample size of the conventional borrowers, conventional non-borrowers and GAP farmers were fixed at ninety each (Table 1).

Tools of Analysis

Data collected were coded, processed and classified into tables in order to bring out generalization of facts from which meaningful inference could be drawn. Based on survey, mango producing period of the sample farms were fixed at 20 years for conventional borrowers, 15 years for conventional non-borrowers and 30 years for GAP farmers. Data Envelopment Analysis (DEA) was employed to study the technical efficiency of GAP farmers over conventional farmers.

Data Envelopment Analysis

Data Envelopment Analysis **(**DEA) is a methodology of measuring the relative efficiency of the decision making units[9]. Data Envelopment Analysis is a linear programming technique, which used input and output data for a set of mango farms to construct non-parametric piece-wise linear production frontier for each farm in the sample. The frontier surface is constructed by the solution of a sequence of linear programming problems for each farm in the sample. An output oriented DEA model is used to find the production frontier. It seeks the maximum proportional increase in output, given the levels of input. Production function explores the relationship that describes the maximum possible output for the given combination of inputs[10]. A production function estimated by applying ordinary least squares (OLS) method shows an average response of the model and does not represent the frontier. Deterministic approach is used[11] in which he estimated a cost frontier by using linear programming (LP), requiring all observations toile on or above the cost frontier. Farrell's cost frontier was transformed into a production frontier[12]. It was noted that all the observations lay on or below the production frontier. The deterministic frontier was converted into a probabilistic frontier function as the outliers under a deterministic approach affect the results[13,14,15]. This deterministic approach removes outliers or extreme observations until the estimated coefficients are established and hence, the above probabilistic approach has been used in the study.

Measuring Technical Efficiency

Using Ordinary Least Square technique, the usual means by which production functions are estimated. It results in the specification of "average production function", represented by the curve I (OLS average function) for the factor – product situations in Figure 1. The envelope curve (Curve II in Figure 1) often referred as "Maximum Technologically Possible Output" function (Deterministic Frontier) meets the theoretical definition of a production function[16].

If the production function is defined as the envelope curve

$$Y_i = f(X_i) \qquad \text{---------} (1)$$

Then the j[th] farm output may be specified as

$$Y_j = f(X_i) + u_j \qquad u_j \leq 0 \qquad \text{--------- (2)}$$

Where u_j is the diffrence between the output obtained by the j^{th} farmer (Y_j) and output estimated from the envelope curve in equation (1). By definition, equation (1) is the MTPO which implies that u for farm j will be negative or zero. If the farm uses best practice techniques and maximizes output for a given bundle of inputs then the farm lies on the MTPO and u will be zero (point B in Figure 1) . If a farmer does not employ best practice techniques, u will be negative, and the farm will lie below the MTPO (point A in Figure 1). The magnitude of u will vary among farmers, depending on their individual technical efficiency. A higher value of u_j indicates higher technical inefficiency. If u_j is zero then the farmer is perfectly technically efficient. The deterministic frontier is defined as the maximum output attainable from a given set of measured inputs and technology.

. **Empirical model for measuring efficiency in mango farms**

The estimated Cobb – Douglas production function is estimated as

$$\ln(Y) = \beta_0 + \beta_1 \ln A + \beta_2 \ln M + \beta_3 \ln F + \beta_4 \ln L + \beta_5 \ln P + e \qquad \text{------- (2)}$$

where,

Y = Yield per hectare (kg)

A = Age of the mango tree (Years)

M = Farmyard Manure (tonnes)

F = Fertilizer (kg)

L = Labour (man days)

P = Plant protection chemicals (kg)

The production function in equation (2) was first estimated by OLS method. It was transformed into a deterministic frontier production function as follows:

The objective function is to minimize

$$\beta_0 (1) + \beta_1 \ln \bar{A} + \beta_2 \ln \bar{M} + \beta_3 \ln \bar{F} + \beta_4 \ln \bar{L} + \beta_5 \ln \bar{P} + e \qquad \text{------- (3)}$$

Subject to

$$\beta_0 (1) + \beta_1 \ln A_1 + \beta_2 \ln M_1 + \beta_3 \ln F_1 + \beta_4 \ln L_1 + \beta_5 \ln P_1 \geq Y_1$$

$$\beta_0 (1) + \beta_1 \ln A_2 + \beta_2 \ln M_2 + \beta_3 \ln F_2 + \beta_4 \ln L_2 + \beta_5 \ln P_2 \geq Y_2 \qquad \text{------- (4)}$$

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$$\beta_0 (1) + \beta_1 \ln A_{90} + \beta_2 \ln M_{90} + \beta_3 \ln F_{90} + \beta_4 \ln L_{90} + \beta_5 \ln P_{90} \geq Y_{90}$$

Where, $\bar{A}, \bar{M}, \bar{F}, \bar{L}$ and $\bar{P}$ are mean values of the respective inputs. The deterministic function co efficients used in estimating efficiencies were obtained from equation (3) after deleting outlier observations until the estimated efficiencies were stabilized. In the analysis, stabilization was obtained after deleting five observations one by one.

From the deterministic function co efficient, farm specific technical efficiency (TE) was measured as follows:

$$TE = AF_i / MF_i \qquad \text{----------- (5)}$$

Where, AF_i is the actual farm output and MF_i is the maximum possible output and it is estimated by substituting i^{th} farm's resources into the deterministic frontier production function. Farm specific allocative efficiency (AE_{ji}) in the use of a factor (j) is

$$AE_{ji} = MF_i / OF_i$$

Where, MF_i is the maximum possible output and it is estimated by substituting i^{th} farm's resources into the deterministic frontier production function. OF_i is the output as the optimum level of j^{th} input, with all other inputs remaining at the level at which the i^{th} farm used them. The optimum input level is calculated by equating marginal value product of an input with its marginal cost.

The allocative efficiency (AE_i) of all inputs on the i^{th} farm is estimated to be

$$AE_i = MF_i / GF_i \qquad \text{---------- (6)}$$

Where, MF_i is the maximum possible output and it is estimated by substituting i^{th} farm's resources into the deterministic frontier production function. GF_i is the farm's output at the optimum level of all inputs.

Individually, these efficiency measures are averaged over a number of observations to arrive at a single value for measuring technical and allocative efficiency. Farm specific Economic efficiency is estimated using equation (7).

$$EE = TE \, . \, AE \qquad \text{----------- (7)}$$

Economic inefficiency is calculated by deducting economic deficiency measure from one.

Results and Discussion

Data Envelopment Analysis (DEA) was attempted to determine which of the mango farms are most efficient, and to point out specific inefficiencies of the other farms. The core part of DEA analysis lies in creating the best mango producing farms for each real mango producing farms. All the producers can then be combined to form a composite producer with composite inputs and composite outputs. Since this composite producer does not necessarily exist, it is called a best producer. The producer is considered as efficient if best output is more than actual output for a given input level. The phenomenon is known as output-oriented technical efficiency.

OLS, Deterministic Cobb –Douglas production frontier for mango conventional borrower farms

In case of conventional borrower farms, the regression coefficients in Table 2 clearly indicate that the marginal effects of factors affecting mango productivity vary across two estimating procedures, demonstrating the importance of allowing for threshold effects of the explanatory factors.

It could be inferred from the OLS estimation that the plant protection chemicals were influenced the dependent variable more at 10 per cent significant level when compared to other inputs in mango production. The co – efficient value of plant protection chemicals was 0.29 which showed that the major contribution of plant protection chemicals to the total yield. The plant protection chemicals to control weeds and insects, and their effect on significant increases in agricultural products have been reported[17]. Farm yard manure was influenced the mango yield at 5 per cent significant level. Number of Saplings, fertilizer and labour were influenced the mango yield at 10 per cent significant level except fertilizer which was not significant. These four variables had showed less contribution to the mango yield when compared to plant protection chemicals in this category of conventional borrower farms. In this category, most of the co – efficients in the deterministic frontier function have shifted, implying that the frontier envelops shifts vertically. The deterministic frontier function showed that the response to the best practice of the progressive farmers in the category of conventional farmers.

OLS, Deterministic Cobb –Douglas production frontier for mango GAP borrower farms

The OLS estimates for GAP borrower farms implied that number of saplings; farmyard manure, fertilizer and labour were significant factors of production except plant protection chemicals in these sample mango farms (Table 3). It might be due to under use of resources of by the ‘average’ farmers. These ‘average’ farmers were operating in the first stage of production curve and so these input elasticities were significant. The OLS function portrayed the response of the ‘average’ farmers while the frontier function reflected response of the ‘best practice’ farmers. In addition, most of the co – efficients in the deterministic frontier function have shifted, implying that the frontier envelops shifts vertically. The deterministic frontier function showed that the response to the best practice of the progressive farmers.

Efficiency co-efficients in sample Mango Conventional Borrower farms

From the deterministic function through data envelopment analysis farm specific technical efficiency, allocative efficiency and economic efficiency for conventional borrower farms were estimated and presented as follows.

The mean technical efficiency estimated for conventional borrower farms was 0. 64. Therefore, the technical inefficiency was 0.36. The mean technical efficiencies of the DEA models indicate that there is substantial inefficiency for the conventional borrower mango farms in the sample, which confirms the expectations. It revealed that there existed as 36 per cent potential for increasing mango yield at the existing level of resources by adopting the technology followed by frontier farms. It highlighted the need to strengthen the existing farm extension services so that the available conventional practices could be disseminated from progressive farms to average farms. The overall was allocative efficiency 0.71 and allocative inefficiency was 0.29 which showed that the output could be increased by 29 per cent by optimum allocation of all inputs. Economic efficiency was 0.45 for conventional borrower farms which implied that there existed scope to increase mango output by 0.55 per cent by adopting the conventional practices of progressive farms and by optimum allocation of all resources.

Efficiency co-efficients in sample Mango GAP farms

The deterministic frontier function was selected for estimating efficiency measures since it was selected for outliers. From the deterministic function through data envelopment analysis farm specific technical efficiency, allocative efficiency and economic efficiency for GAP borrower farms were estimated and presented as follows.

From Table 5, it is found that technical efficiency estimated for GAP farms was 0.89. Therefore, the technical inefficiency is given as 0.11.The mean technical efficiencies of the DEA models indicate that there is substantial inefficiency for the GAP mango farms in the sample, which confirms the expectations. It had revealed that there existed 11 per cent potential for increasing mango yield at the existing level of resources by adopting the technology followed by frontier farms. It highlighted the need to strengthen the existing farm extension services so that the available Good Agricultural Practices could be disseminated from progressive farms to average farms. The overall was allocative efficiency 0.76 and allocative inefficiency was 0.24 which showed that the output could be increased by 24 per cent by optimum allocation of all inputs. Economic efficiency was 0.68 for GAP borrower farms which implied that there existed scope to increase mango output by 32 per cent by adopting the Good Agricultural Practices of progressive farms and by optimum allocation of all resources.

Conventional borrower mango farms under different efficiency measures

Number of conventional borrower mango farms under different efficiency measures is presented in Table.5.40. It clearly stated that there were 27 farms coming under the category of technical efficiency less than 60 per cent. More number of conventional borrower farms (i.e) 68.89 per cent of the total conventional farms was attained technical efficiency of 60 – 80 per cent and only one farm was under the category of greater than 80 per cent of technical efficiency. In case of allocative efficiency, only one farm was coming under the category of technical efficiency greater than 80 per cent. There was 45.56 and 53.33 per cent of the farms belonging to the category of less than 60 per cent and 60 – 80 per cent respectively. It was also observed from Table 6 that 74.44 per cent, 23.33 per cent and 2.22 per cent of the conventional farms were economically efficient at less than 60 per cent, 60 – 80 per cent and greater than 80 per cent respectively.

GAP borrower mango farms under different efficiency measures

Number of GAP borrower mango farms under different efficiency measures is depicted in Table 7. It clearly explained that no farms were under the category of technical efficiency less than 60 per cent. More number of GAP borrower farms (i.e) 78.89 per cent of the total GAP farms was attained technical efficiency greater than

80 per cent. In case of allocative efficiency, only 2 farms were coming under the category of technical efficiency less than 60 per cent. There were 34.44 and 63.33 per cent of the farms belonging to the category of 60 – 80 per cent and greater than 80 per cent respectively. It was also observed from Table.7 that 4.44 per cent, 40 per cent and 55.56 per cent of the GAP farms were economically efficient at less than 60 per cent, 60 – 80 per cent and greater than 80 per cent respectively. More than 60 per cent of the sample farmers having scale efficiency indicated that majority of farmers are not working at the optimal scale and they are operating much far away from the frontier efficiency [18].

Conclusion

The role of credit in mango cultivation has been significant. In modern agriculture, farming has now become complex and needs careful planning to achieve success. Transformation of traditional farming to modern commercialization farming needs credit availability. Access to credit to more mango farmers and appropriate quantity and quality of agricultural credit are crucial for realizing the full potential of mango cultivation as a profitable activity. The results clearly depicted that improvement in credit supply for mango cultivation could considerably assist to increase the income from the given set of resources. The extension workers should analyze the resource position of the farms and suggest suitable solutions to increase the farming efficiency by adopting the Good Agricultural Practices for progressive farms and by optimum allocation of all resources. Because economic efficiency was 0.45 for conventional borrower farms and it was 0.68 for GAP borrower farms which implied that there existed scope to increase mango output in the study area. The cost structure of the crop may be used by the bankers as guidelines for fixing the scale of finance. The role of credit can be further enhanced by much greater financial inclusion by involving of region-specific market participants, and credit suppliers ranging from public sector banks, co-operative banks, the new private sector banks and micro-credit suppliers, especially self-help groups.

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Acknowledgements

We thank our professor Dr.T.R.Shanmugam for his guidance, support and encouragement. His critical remarks and suggestions have always been very helpful in improving skills and for strengthening our manuscript. We owe a great deal of appreciation and deep sense of gratitude to Dr.K.Govindarajan, Professor. Our sincere thanks also go to Dr.S.Padma Rani, Professor for her timely support, constructive criticism and her extensive discussions around my work.

Table 1. Sample Villages and Number of Mango Producers

Sl.	Block	Village	Conventional	Conventional	GAP	Total

No			Borrowers	Non-Borrowers	Borrowers	
1.	Bargur	Kullanoor	10	10	10	30
		Pochampalli	10	10	10	30
		Kosapatti	10	10	10	30
2.	Kaveripattinam	Malathampatti	10	10	10	30
		Panagamutlu	10	10	10	30
		Kadhampatti	10	10	10	30
3.	Mathur	Kunnathur	10	10	10	30
		Rangampatti	10	10	10	30
		Sivampatti	10	10	10	30
	Total		90	90	90	270

Table 2. Estimates of OLS, Deterministic Cobb –Douglas production frontier for mango Conventional borrower farms

Sl.	Parameters	Average Function	Deterministic Frontier

No.		estimated through OLS estimation	estimated through DEA
1.	Intercept	0.3658	0.3301
2.	Number of Saplings	0.1431*	0.1515
3.	Farmyard Manure	0.1701**	0.1782
4.	Fertilizer	0.1643NS	0.1725
5.	Plant protection chemicals	0.2903*	0.3061
6.	Labour	0.1489*	0.1594
	N	**90**	**90**

Notes: *** significance at 1 per cent,** significance at 5 per cent, * significance at 10 per cent and NS non significant

Table 3. Estimates of OLS, Deterministic Cobb –Douglas production frontier for mango GAP borrower farms

Sl. No.	Parameters	Average Function estimated through OLS	Deterministic Frontier estimated

		estimation	through DEA
1.	Intercept	0.5823	0.4822
2.	Number of Saplings	0.2764*	0.2928
3.	Farmyard Manure	0.3808**	0.3904
4.	Fertilizer	0.1123*	0.1212
5.	Plant protection chemicals	0.2493NS	0.2613
6.	Labour	0.3268***	0.3409
	N	**90**	**90**

Notes: *** significance at 1 per cent,** significance at 5 per cent, * significance at 10 per cent and NS non significant

Table 4. Efficiency co-efficients in sample Mango Conventional Borrower farms

Sl.No.	**Types**	**Efficiency measures**	**Inefficiency measures**
1.	Technical efficiency	0.6391	0.3609
2.	Allocative efficiency	0.7104	0.2896
3.	Economic efficiency	0.4540	0.5460

Table 5. Efficiency co-efficients in sample Mango GAP farms

Sl. No.	**Types**	**Efficiency Measures**	**Inefficiency Measures**

1.	Technical efficiency	0.8862	0.1138
2.	Allocative efficiency	0.7644	0.2356
3.	Economic efficiency	0.6774	0.3226

Table.6. Number of Conventional borrower mango farms under different efficiency measures

Sl. No.	Types	< 60 per cent	60– 80 per cent	> 80 per cent	Total
1.	Technical efficiency	27 (30.00)	62 (68.89)	1 (1.11)	90 (100.00)
2.	Allocative efficiency	41 (45.56)	48 (53.33)	1 (1.11)	90 (100.00)
3.	Economic efficiency	67 (74.44)	21 (23.33)	2 (2.22)	90 (100.00)

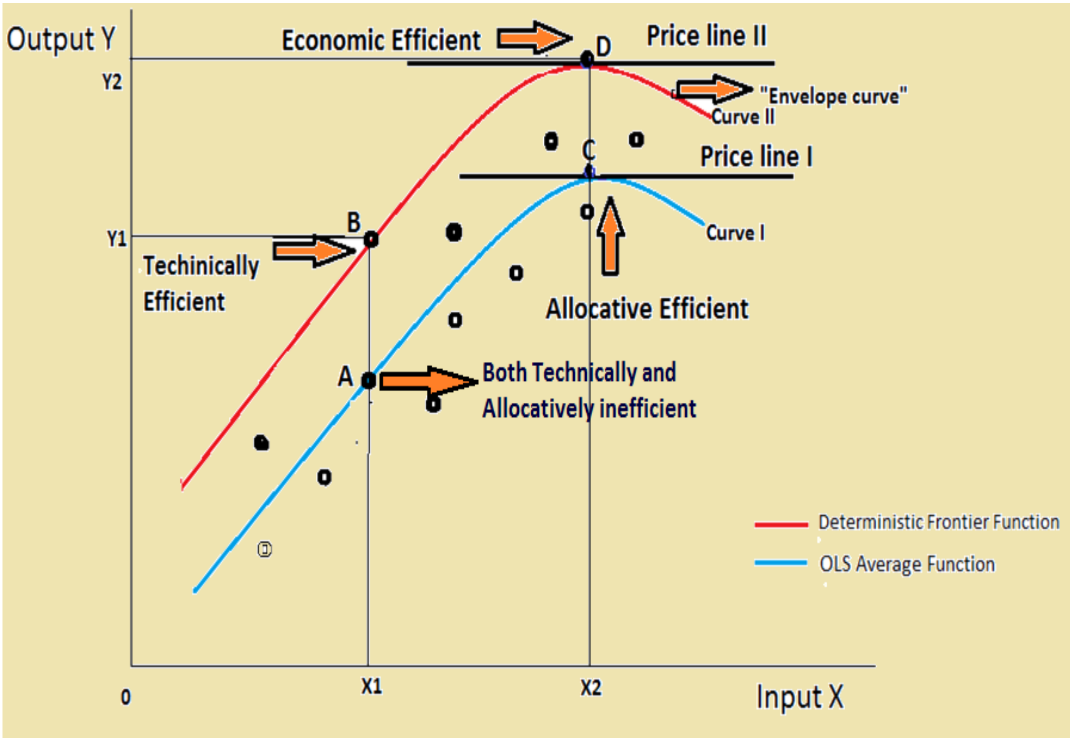
(Figures in parentheses indicate percentage to the total)

Table 7. Number of GAP borrower mango farms under different efficiency measures

Sl. No.	Types	< 60 per cent	60– 80 per cent	>80 per cent	Total
1.	Technical efficiency	0 (0.00)	19 (21.11)	71 (78.89)	90 (100.00)
2.	Allocative efficiency	2 (2.22)	31 (34.44)	57 (63.33)	90 (100.00)
3.	Economic efficiency	4 (4.44)	36 (40.00)	50 (55.56)	90 (100.00)

(Figures in parentheses indicate percentage to the total)

Figure 1: Schematic Presentation of a Stochastic Frontier & Average Production Function


Output Y
Economic Efficient
D
Price line II
Y2
"Envelope curve"
Curve II
C
Price line I
B
Y1
Curve I
Techinically
Efficient
Allocative Efficient
A
Both Technically and
Allocatively inefficient
Deterministic Frontier Function
OLS Average Function
0
X1
X2
Input X