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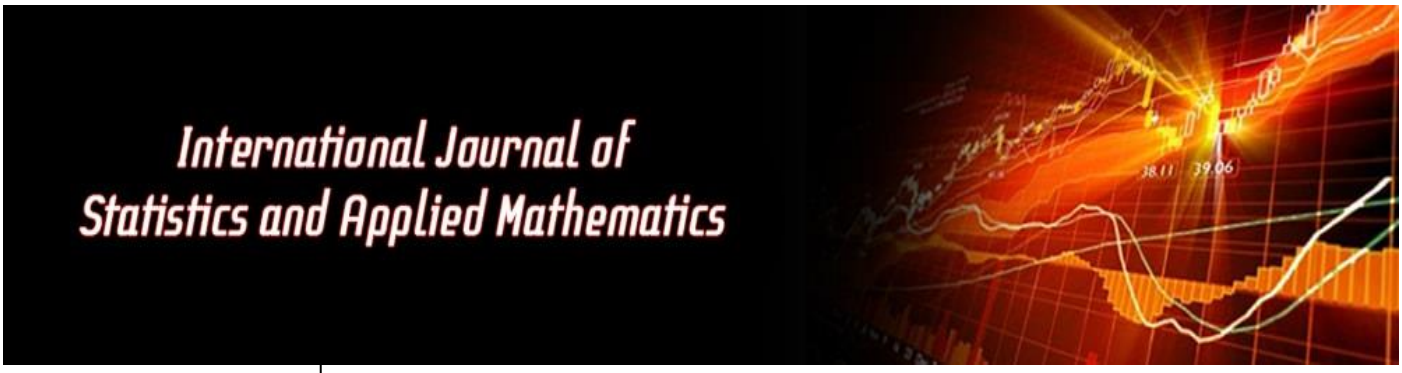

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Technical, allocative and economic efficiency of soybean: A stochastic frontier approach

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Abstract
Increasing the efficiency in production assumes greater significance in attaining the potential output. An attempt has been made in this study to estimate technical, economic and allocative efficiencies of soybean farms using stochastic frontier approach and stochastic frontier profit function. Statistical analysis of study was done by using R software. The mean technical, economic and allocative efficiencies were found to be 82.188 per cent, 70.438 per cent and 86.44 per cent respectively. The result revealed that, the technical efficiency ranges from 43.20 to 97.90 per cent it means the average efficient farmers and least efficient farmers, to achieve the technical efficiency level of the most efficient farmers could only bring about 15.42 per cent and 55.87 per cent increase in production. Similarly the economic efficiency ranges from 16.54 to 94.96 per cent means the average efficient farmers and the least farmers, to achieve the economic efficiency level of the most efficient farmers could bring about 25.83 per cent and 82.58 per cent increase in production. Similarly, the allocative efficiency ranges from 25.70 to 192.34 per cent, the average efficient farmers and the least efficient farmers, to achieve the allocative efficiency level of the most efficient farmers could bring about 55.05 per cent and 86.63 per cent increase in production. Seed is statistically significant and positive value 1.01079 in technical efficiency, indicated that farmers could increase per hectare yield by applying more units of these inputs. One per cent increase in the prices of bullock labour (-0.05628) was found to reduce profit by 0.05 per cent. The coefficient of prices of seed (1.01079) and fertilizer prices (0.36189) showed statistically significant and positive effects on profits in economic efficiency. The study showed that, the mean technical efficiency values of greater than 90 per cent for majority (33.61%) of soybean farmers. While, majority (40.91 per cent) of the farmers in sample operated at economic efficiency levels lied between 70 to 80 per cent and 41.18 per cent of the sample farmers achieved allocative efficiency of above 90 per cent level. Frequency distribution of higher efficiency farmers indicated that, there was little scope for improving the efficiencies with existing technology.

Keywords: Technical efficiency, economic efficiency, allocative efficiency, stochastic frontier approach

Introduction
Agricultural output can be increased through either area expansion or productivity improvements. The concept of efficiency is the core of economic theory. The crucial role of efficiency in increasing agricultural output has been widely recognized by researchers and policy makers alike. The economic efficiency is composed of technical efficiency and allocative efficiency. Technical efficiency (TE) is defined and measured as the ratio of the farm's actual output to its own maximum possible frontier output for a given level of inputs and the chosen technology (Kalirajan and Shand, 1994) [6]. Allocative efficiency reflects the ability of a farm to use the inputs in optimal proportions given their respective prices. Both are important to achieve the overall farm economic efficiency. Soybean (Glycine Max L. Merrill) belongs to family Leguminaceae. In the near future, given the relatively stagnant technology, efficiency improvement at farm level would probably be an appropriate way to increase soybean production. Since the available resources are limited, then it is imperative to determine priorities of alternative activities. The leading countries in terms of soybean production and productivity are United States, Brazil, Argentina, China, India. India's total area under soybean cultivation in 2021-22 is 121.46 million hectares with production 129.86 metric tonnes and productivity is 1069 kg/hectares. The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka and Telangana.

In Maharashtra area under soybean cultivation is 45.95 million hectares with production 55 metric tonnes and productivity is 1197 Kg/ Hectares. This study was therefore designed to investigate the soybean production efficiency of farmers in Vidarbha region of Maharashtra. The objectives of the study was to estimate the technical, economic and allocative efficiency of soybean crop.

Materials and Methods

The nature of the present study was mainly based on primary data. In order to attain the objectives of the study, relevant data for a period of 2021-22 of 119 soybean cultivars for Vidarbha region of Maharashtra have been taken for analysis.

Analytical Methods

In the present study, stochastic frontier production function was used to measure the technical efficiency while stochastic frontier profit function was used to estimate economic efficiency of soybean farms. Allocative efficiencies were estimated by dividing economic efficiency with technical efficiency.

Stochastic production frontier function-

In the present study, the stochastic frontier approach was used to measure the farm specific efficiencies of soybean cultivating farms. (Aigner *et al*., 1977; Kalirajan and Shand, 1889; Sharma and Datta, 1997) [1, 6, 8] The stochastic frontier model is called a 'composed' model because the error term is composed of two independent elements, namely-

$\Sigma i = v_i - u_i \quad i = 1,\ldots n$

The term vi is the symmetric component and permits random variation in output due to factors like weather and plant disease. It is assumed to be identically and independently distributed $v_i \approx N(0, \square^2\square)$. A one-sided component ($u_i \square\square 0$) reflects technical efficiency relative to stochastic frontier $Q_i = Q(Xk_i,,\square)\, e^{vi}$. Thus $u_i = 0$ for any farm lying on the frontier while $u_i > 0$ for any farm lying below the frontier. Hence expression (u_i) represents the amount by which the frontier exceeds realized output. The distribution of u_i is assumed to be half-normal.

Specification of the model

lnYi = □0 + □1lnX1 +□2lnX2 + □3lnX3 +□4lnX4 + □5lnX5 + □6lnX6 + □7lnX7 + (Vi-Ui)

Where,

Y_i = Output of soybean (Quintals ha^{-1})	X_6 = Quantity of pesticides (lit ha^{-1})
X_1 = Area under cultivation (ha)	X_7 = Quantity of fertilizers (kg ha^{-1})
X_2 = Human labour (hrs ha^{-1})	V_i = Random variable
X_3 = Bullock labours (hrs ha^{-1})	U_i = Farm specific technical efficiency related variable
X_4 = Machine hours (hrs ha^{-1})	□0 = Intercept/Constant
X_5 = Quantity of seeds (kg ha^{-1})	

Stochastic profit frontier function

Stochastic frontier profit function was used to estimate economic efficiency of sample soybean farms. (Ali and Flinn, 1989; Rahman, 2003; Galawat and Yabe, 2012) [2, 7, 5]. The stochastic profit frontier function was estimated as-

□i = f (Xi, Pi) + (□i – ui)

where,

□i = Normalized profit at cost-A of the i^{th} farmer.

X_i = The vector of variable input prices divided by output price faced by the i^{th} farm.

P_i = The vector of fixed factor of the i^{th} farm.

V_i = random error due to factors outside the control of the farmers.

U_i = A non- negative random variable associated with economic inefficiency component

The economic efficiency in relation to the stochastic profit frontier is given by,

EEi = exp (ui)

Specification of the model

Ln Πi = β0 + β1lnX1 +β2lnX2 + β3lnX3 +β4lnX4 + β5lnX5 + β6lnX6 +(Vi-Ui)

Where,

Π_i = Normalized profit at cost-A of the i^{th} farmer.

X_1 = Human labour wage rate per hr normalized by output price of i^{th} farm.

X_2 =Bullock labour wage rate per hr normalized by output price of i^{th} farm.

X_3 = Machine wage rate per hour normalized by output price of i^{th} farm.

X_4 = Price of seed per kg normalized by the output price of i^{th} farm.

X_5 = Price of fertilizer per kg normalized by the output price of i^{th} farm.

X_6 = Price of plant protection per liter normalized by the output price of i^{th} farm.

V_i = Random variable

U_i = Farm-specific economic efficiency related variable

□0 = Intercept

Factor price is obtained by dividing the price of input with the output price.

Allocative efficiency was estimated by dividing economic efficiency with technical efficiency for each farm.

$AE_i = EE_i/TE_i$

Results and Discussions

1.1 Estimation of Stochastic Frontier Production Function-

Maximum likelihood estimates (MLE) of stochastic frontier production function along with mean technical efficiency are given in Table 1.

Table 1: Coefficient of stochastic frontier production function of soybean farmer

Variables	Coefficient	Std error
Intercept	-0.63588	0.32665
Area (Ha)	0.02132	0.14276
Human labour (Hrs/Ha)	-0.08129	0.08682
Bullock labour (Hrs/Ha)	-0.00296	0.02703
Machine hours (Hrs/Ha)	0.13583	0.08871
Seed (Kg/Ha)	1.01079***	0.16097
Plant protection (Lt/Ha)	0.06614	0.07734
Fertilizer (Kg/Ha)	-0.00502	0.04276
Sigma-squared	0.00303	
Gamma	0.95721	
Log-likelihood function	53.79683	
Mean TE (%)	82.18	

(*** indicate significance at 1% level of significancy.)

The mean level of technical efficiency has been estimated as 82.188 per cent for farms as a whole, implying that on an average the sample farmers tend to realize around 82 per cent of their technical abilities. Hence, on an average, approximately 18 per cent of technical potentials were not realized.

The results of the stochastic frontier production function estimates for soybean crop are shown. Seed is positive and statistically significant (1.01079). Hence, if the quantity of seed increases by one per cent it could increase the agricultural production by 1.01 per cent. This implies that, seed is an important contributor to improvement of technical efficiency in agricultural production practices. Statistically significant and positive value of the estimated coefficient indicated that farmers could increase per hectare yield by applying more units of these inputs. The area under cultivation, machine hours and plant protection are not significant, and its elasticity is positive. The elasticity of human labour (-0.08129), bullock labour (-0.00296) and fertilizer (-0.00502) present a negative sign and it's statistically non-significant. The gamma value of MLEs of stochastic frontier production model is 0.9572. This value is implying that 95.72 per cent of variability of revenue from agricultural production is attributed to the technical efficiency in agricultural production techniques and rest (4.28 per cent) is due to random noises. The estimate of sigma squared (0.00303) was positive elasticity. The log likelihood function (53.79683) was positive and significantly different from zero indicating a good fit and the correctness of the specific distribution assumption.

1.2 Technical Efficiency of Sample Farms

The frequency distribution of sample farms by the level of technical efficiency in rising the soybean crop is shown in Table 1.2. In the study the technical efficiency ranges from 43.20 to 97.90 with a mean efficiency of 82.80 per cent. For the average efficient farmers in the study, to achieve the technical efficiency level of the most efficient farmers could only bring about (97.90-82.80/97.90) 15.42 per cent increase in production. The least efficient farmers can increase the production of (97.90-43.20/97.90) 55.87 per cent to achieve the required technical efficiency of the most efficient farmers. From table 2, study revealed that number of 3 farmers lied between the efficiency range of 40-50 and 50-60% could increase in production about 53.94% and 44.56% to achieve technical efficiency level of most efficient farmer respectively. Also, 6 farmers lied in 60 to 70% level of efficiency which have to increase about 32.70% of efficiency to achieve the level of most efficient farmer. 30 farmers lied between efficiency range of 70 to 80% in study, to achieve technical efficiency of most efficient farmers could bring about 22.71% increase in production. From the study, it was observed that efficiency range of 80 to 90% and above 90% of technical efficiency having 37 and 40 farmers, could bring about 13.20 and 4.35% increase in production to achieve most efficient level of technical efficiency.

Table 2: Distribution of sample farmers under different levels of technical efficiency (N=119)

TE (%)	No. of Farm	Per centage to total	Average	Per centage to increase production to achieve maximum efficiency
<10	00.00	00.00	00.00	00.00
10.01-20	00.00	00.00	00.00	00.00
20.01-30	00.00	00.00	00.00	00.00
30.01-40	00.00	00.00	00.00	00.00
40.01-50	03.00	02.52	45.09	53.94
50.01-60	03.00	02.52	54.17	44.66
60.01-70	06.00	05.04	65.88	32.70
70.01-80	30.00	25.21	75.66	22.71
80.01-90	37.00	31.09	84.97	13.20
>90	40.00	33.61	93.64	04.35
Mean TE (%)	82.80			
Min TE (%)	43.20			
Max TE (%)	97.90			

From table, it was observed that a majority of the farms (33.61 per cent) were operating close to the frontier with the technical efficiency of more than 90 per cent. 31.09 per cent of the soybean farms lied between 80 to 90 per cent of the technical efficiency level. Further the analysis revealed that, 25.21 per cent of the sample farm lied between 70 to 80 per cent technical efficiency level and only 2.52, 2.52 and 5.04 per cent of the sample farmers were operating at technical efficiency levels of 40 to 50 per cent, 50 to 60 per cent and 60 to 70 per cent respectively.

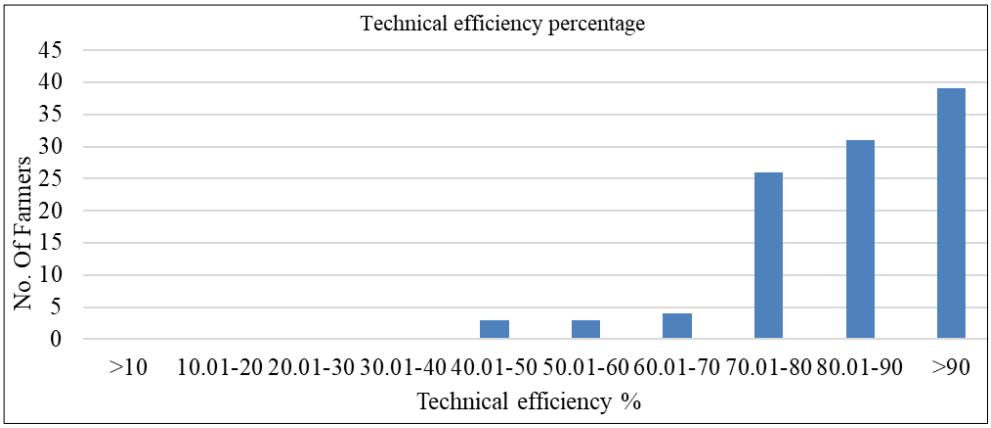

Fig 1: Distribution of sample farmer under different level of technical efficiency

2. Estimation of coefficient of Stochastic Frontier Profit Function

The maximum likelihood estimates of the stochastic profit frontier production function are reported in Table 3. The coefficient of prices of bullock labour (-0.05628) showed a significant negative effect on the profits. The result showed that one per cent increase in the prices of bullock labour reduce the profit by 0.056 per cent.

Table 3: Coefficient of stochastic frontier profit function for soybean in Vidarbha

Variables	Coefficient	Std error
Intercept	3.84358	0.33236
Human labour (Hrs/Ha)	0.47335	0.07548
Bullock labour (Hrs/Ha)	-0.05628***	0.13423
Machine hours (Hrs/Ha)	-0.37746	0.03160
Seed (Kg/Ha)	1.01079*	0.17512
Plant protection (Lt/Ha)	0.05970	0.03802
Fertilizer (Kg/Ha)	0.36189***	0.05164
Sigma-squared	0.23874	
Gamma	0.90086	
Log-likelihood function	-33.95825	
Mean TE (%)	70.438	

Note: *** and * indicate significance at 1% and 10% levels respectively

The coefficient of prices of seed (1.01079) and fertilizer prices (0.36189) showed statistically significant and positive effects on profits. The coefficient of human labour (0.47335) and plant protection (0.0597) are non-significant and its elasticity positive. The coefficient value of machine hour (-0.37746) is negative and non-significant. The estimated value of gamma is 0.90086. The log likelihood function (-33.95825) was negative and significantly different from zero indicating not good fit. The mean economic efficiency of the sample farms was 70.438 per cent which means, in principle that the sample farms can potentially reduce their overall cost of soybean production, on average, by 30 per cent and still achieve the existing level of output. This results indicate the potential to further improve the economic efficiency by 30 per cent.

2.2. Economic efficiency of sample farms

The frequency distribution of sample farms by the level of economic efficiency in rising the soybean crop is shown in Table 4. The economic efficiency ranges from 94.96 to 16.54 with a mean efficiency of 70.43 per cent. For the average efficient farmers, to achieve the economic efficiency level of the most efficient farmers could only bring about (94.96-70.43/94.96) 25.83 per cent increase in profit. The least efficient farmers can increase the profit of (94.96-16.54/94.96) 82.58 per cent to achieve the required economic efficiency of the most efficient farmers.

Table 4: Distribution of sample farmers under different levels of economic efficiency (N=119)

EE (%)	No. of Farm	Per centage to total	Average	Per centage to increase production to achieve maximum EE
<10	00.00	00.00	00.00	00.00
10.01-20	01.00	00.84	16.54	82.58
20.01-30	01.00	00.84	22.46	76.34
30.01-40	00.00	00.00	00.00	00.00
40.01-50	12.00	10.08	46.34	51.20
50.01-60	14.00	11.76	54.60	42.50
60.01-70	20.00	16.81	64.22	32.37
70.01-80	29.00	24.36	74.99	21.02
80.01-90	32.00	26.89	84.49	11.02
>90	10.00	08.40	91.32	03.83
Mean EE (%)	70.89			
Min EE (%)	16.54			
Max EE (%)	94.96			

From above table it was observed that, efficiency range of 10 to 20 and 20 to 30 per cent consisting one farmer could bring about 82.58% and 76.34% increase in profit to achieve level of most economic efficient farmer. 12 farmers lied between 40 to 50% of economic efficiency, to achieve most efficient farmer level bring about 51.20% increase in production. Number of 14 farmers and 20 farmers lied between the frequency of 50 to 60% and 60 to 70% of economic efficiency should bring about 42.50% and 32.37% increase in profit respectively. Also, 29 farmers lied between 70 to 80% of economic efficiency could increase 11.02% production to achieve most efficiency level. Only 10 farmers lied above 90% of economic efficiency, should increase 3.83% of economic efficiency to achieve highest efficiency level. An examination of the table 2.2 indicates that, majority (26.89 per cent) of the farmers in sample operated at economic efficiency levels of 80 to 90 per cent followed by 24.36 per cent of the farmers with economic efficiency of 70 to 80 per cent. Only 8.4 per cent of the farmers achieved higher efficiency levels of greater than 90 per cent. About 0.84, 0.84, 10.08, 11.76 and 16.81 per cent of the farmers registered efficiency levels of 10 to 20, 20 to 30, 40 to 50, 50 to 60 and 60 to 70 per cent respectively.

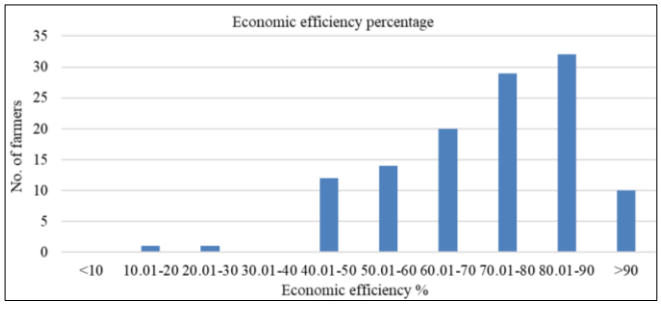

Fig 2: Distribution of sample farmers under different level of Economic efficiency

3. Allocative efficiency of sample farmers

The mean allocative efficiency of the sample farms was 86.44 per cent which means, the potential to further improve the allocative efficiency by 14.66 per cent. The allocative efficiency ranges from 192.34 to 25.70 per cent with a mean efficiency of 86.44 per cent. For the average efficient farmers,

to achieve the allocative efficiency level of the most efficient farmers could only bring about (192.34-86.44/192.34) 55.05 per cent increase in production. The least efficient farmers can increase the production of (192.34-25.70/192.34) 86.63 per cent to achieve the required allocative efficiency of the most efficient farmers. From table 3.1 observed that, only 2 farmers lied between 20 to 30% of allocative efficiency, have to increase 86.52% of production to achieve maximum allocative efficiency level. In between the frequency of 50 to 60% and 60 to 70% consisting about 4 and 13 number of farmers, to achieve maximum allocative efficiency level could bring about 71.39% and 65.90% increase in production respectively. 20 farmers lied between 70 to 80% allocative efficiency, bring about 61.10% increase in production to achieve most efficient farmer level. 31 farmers lied between 80 to 90% and 49 farmers lied in above 90% of allocative efficiency, to achieve most allocative efficient farmer level could bring about 55.94% and 46.54% increase in production respectively.

Table 5: Distribution of sample farmers under different levels of allocative efficiency (N=119)

AE (%)	No. of Farm	Per centage to total	Average	Per centage to increase production to achieve maximum EE
<10	00.00	00.00	00.00	00.00
10.01-20	00.00	00.00	00.00	00.00
20.01-30	02.00	01.68	25.91	86.52
30.01-40	00.00	00.00	00.00	00.00
40.01-50	00.00	00.00	00.00	00.00
50.01-60	04.00	03.36	55.01	71.39
60.01-70	13.00	10.92	65.57	65.90
70.01-80	20.00	16.80	74.82	61.10
80.01-90	31.00	26.05	84.73	55.94
>90	49.00	41.17	102.82	46.54
Mean AE(%)	86.44			
Min AE (%)	25.70			
Max AE (%)	192.34			

An examination of table 3.1 indicates that majority (41.17 per cent) of the sample farmers achieved allocative efficiency of above 90 per cent followed by 26.05 per cent of the sample farmers achieved 80 to 90 per cent efficiency level. Also, 16.80 per cent and 3.36 per cent of the sample farm achieved efficiency level between 70 to 80 per cent and 50 to 60 per cent. Only 1.68 per cent and 0.92 per cent achieved efficiency level between 20 to 30 per cent and 60 to 70 per cent.

Conclusion

1. The mean level of technical efficiency has been estimated as 82.188 per cent. Therefore, it is possible to improve the yield by 18 per cent by following efficient crop management practices without increasing the level of input application.
2. The mean economic efficiency of the sample farms was 70.438 per cent. The results indicate the potential to further improve the economic efficiency by 30 per cent.
3. The mean allocative efficiency of the sample farms was 86.44 per cent which means, the potential to further improve the allocative efficiency by 14.66 per cent.
4. The technical efficiency ranges from 43.20 to 97.90 per cent. For the average efficient farmers, to achieve the technical efficiency level of the most efficient farmers could only bring about 15.42 per cent increase in production. The least efficient farmers can increase the production of 55.87 per cent to achieve the required technical efficiency of the most efficient farmers.
5. The economic efficiency ranges from 16.54 to 94.96 per cent. For the average efficient farmers, to achieve the economic efficiency level of the most efficient farmers could only bring about 25.83 per cent increase in profit. The least efficient farmers can increase the profit of 82.58 per cent to achieve the required economic efficiency of the most efficient farmers.
6. The allocative efficiency ranges from 25.70 to 192.34 per cent. For the average efficient farmers, to achieve the allocative efficiency level of the most efficient farmers could only bring about 55.05 per cent increase in production. The least efficient farmers can increase the production of 86.63 per cent to achieve the required allocative efficiency of the most efficient farmers.
7. Seed is statistically significant and positive value 1.01079 in technical efficiency, indicated that farmers could increase per hectare yield by applying more units of these inputs.
8. The coefficient of prices of bullock labour showed a significant negative effect on the profits. The result showed that one per cent increase in the prices of bullock labour will reduce the profit by 0.056 per cent. The coefficient of prices of seed (1.01079) and fertilizer prices (0.36189) showed statistically significant and positive effects on profits.
9. Frequency distribution of sample farmers, was observed that a majority of the farms (33.61 per cent) were operating close to the frontier with the technical efficiency of more than 90 per cent. While majority (26.89 per cent) of the farmers in sample operated at economic efficiency levels lied between 80 to 90 per cent and 41.17 per cent of the sample farmers achieved allocative efficiency of above 90 per cent level.

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