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Technical Efficiency of Pecan nut Production in J & K: Application of Stochastic Frontier Model

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A B S T R A C T

Pecan nut is one of the emerging nut crops of Jammu and Kashmir, drawing attention of government functionaries as well as the stakeholders involved in horticulture in UT of Jammu and Kashmir. The production from pecan nut trees started after 8 years with subsequent increase every year. The pay-back period of pecan nut orchard was 22.20, 24.11 and 26.18 years at 8, 10 and 12 percent of discount rate respectively. The net present value was ₹ 43,12,022, ₹ 19,85,900 and ₹ 6,72,510 at 8, 10 and 12 percent of discount rate respectively. At the same rate of 8, 10 and 12 percent of discount rate, the profitability index was 10.81, 5.61 and 2.60 respectively. The internal rate of return of pecan nut orchard was 14 per cent which shows that investing in pecan nut orchard will be a profitable venture until the market interest rate remains below 14 per cent. The value of gamma parameter was 0.00001 and was insignificant, reflecting the absence of technical efficiency in pecan nut production. The results highlighted the need for introduction of technical innovations without compromising the quality and uniqueness of the traits.

Key words: Pecan nut, Stochastic frontier model, Technical efficiency, Poonch

Pecan nut (*Carya illinoinensis*) is exclusively grown under intermediate hills of Poonch district of Jammu region of UT of Jammu & Kashmir. The success of a crop having long gestation period depends upon the optimum allocation of resources and thus the question arose, as whether the existing pecan nut growers under intermediate hills of Jammu & Kashmir were efficient in the allocation of their production resources or not? Pecan nut tree belongs to the hickory family that often grow to a height of over 70 feet with a spread of greater than 80 feet. Ares *et al.* (2006) studied production and economics of native pecan silvopastures in central United States and found that the nut crop had a pattern of biennial bearing with a mean tree age of 37 years and forage production varied between 1500 and 4600 kg DM ha^{-1}. Ferencz and Notari (2010) found that the payback period was extremely long for canopy form; the SX spindle in Pecan nut orchard due to the high historical cost. The rate of returns was very unfavourable and low annual income determined weak profitability. Springer *et al.* (2011) determined that an irrigated improved pecan orchard was economical and found that the improved pecan orchard is more profitable than competitive enterprises after a twenty-year time frame, but is sensitive to pecan price, pecan yield and attitude toward risk. Benucci *et al.* (2012) also studied mycorrhizal inoculation of pecan seedlings with some marketable truffles. Pecan nut is a relatively newly introduced crop in Jammu & Kashmir and government agencies are making every effort to expand the area under the crop. However, the success of adoption always depends upon the efficiency of factors used in production, keeping their prices into consideration. There are very limited studies conducted on different aspects of pecan nut, whereas the scope is immense as carried out in other fruit crops by Singh

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and Patel (2014), Bhut *et al.* (2017). The present study however was conducted to assess the production of pecan nut under intermediate hills of Poonch district of UT of Jammu & Kashmir, India using stochastic frontier model.

MATERIALS AND METHODS

Poonch is located on the Southern slopes of the Pir Panjal range and as such is rugged with spurs and valleys. It lies between 33°25’ to 34°10’ North latitude and 73°58’ to 74°35’ East longitude. Pecan nut is grown over an area of 283 hectare in Poonch district with an annual production of 5 metric tonnes (Economic Survey of J&K 2017-18). The district Poonch having maximum area under pecan nut in Jammu region of UT of Jammu & Kashmir was purposively selected for the present study. The cost, production and return data were collected for assessing capital investment, resource use and profitability index of pecan nut crop in the year 2014-15. A list of pecan nut growers in the Poonch district was procured from the office of Chief Horticulture Officer, Poonch and 50 farmers from the list were selected randomly without replacement for collecting the requisite data.

Efficiency of crops in scientific trials, as reported by Sharma and Dwivedi (2020), Arora *et al*. (2018), Sharma and Parkash (2015), Singh *et al*. (2016), Rana *et al*. (2017) has always been better than the actual field conditions. Modelling is an essential part of study for description of casual relationship and depends upon the problem in hand, factors associated and crop to be studied e.g. Roy (2018) applied Binary logistic regression to find out the factors affecting farmers’ decision on paddy straw burning in Punjab. Farrell (1957) introduced the theory of efficiency representing a company’s capacity to produce a given quantity of output with as little quantity of inputs as possible. The efficiency can be classified into technical efficiency and allocative efficiency; the product of both yields economic or cost efficiency.

The stochastic frontier model

Aigner *et al*. (1977), Mueeusen and Van den Broeck (1977) introduced the basic frontier model which was reviewed then by Battese (1991), Bravo-Ureta and Pinherio (1993), Coelli (1995). For the present study, stochastic frontier efficiencies of pecan nut at individual farm levels were estimated using Battese and Coelli specification model (1995).

Specification of the technical function model

A Cobb-Douglas functional form was employed to model the stochastic frontier production function which has been presented as below:

$$Y_i = f(X_i;\beta)e^{V_i - U_i}$$

Where,

Y_i = Output of the ith farmer

X_i = (1 × K) vector of input quantities used by ith farmer

β = (K × 1) vector of parameters to be estimated

V_i = random variations due to factors outside farmer’s control, it is an independently and identically distributed random error component (statistical noise), and usually assumed to follow the standard normal distribution with zero mean and constant variance σ_v^2.

U_i = error due to inefficiency i.e. technical inefficiency,

The explicit form of the above model has been expressed as below:

$$\ln Y = \beta_0 + \sum \beta_i \ln X_i + (V_i - U_i)$$

Specification of the cost function model

A Cobb-Douglas functional form was employed to model the stochastic frontier cost function and presented as below:

$$C_i = g(P_i;\alpha)e^{V_i + U_i}$$

Where

C_i = total input costs of the ith farm

P_i = (K × 1) vector of input prices and output of ith farm

α = vector of unknown parameters

V_i = random variations due to factors outside farmer’s control, it is an independently and identically distributed random error component (statistical noise), and usually assumed to follow the standard normal distribution with zero mean and constant variance σv2.

U_i = error due to inefficiency i.e. cost inefficiency, a non-negative producer specific inefficiency error term that follows certain distributional assumptions. A 100% cost efficient firm means that it is operating on the stochastic cost frontier and thus $U_i$will be zero. The explicit form of the above model has been expressed as below:

$$\ln C = \alpha_0 + \sum \alpha_i \ln P_i + (V_i + U_i)$$

The cost efficiency {exp (U_i)} of an individual farm was estimated as the ratio of actual cost (C_i) to the predicted minimum cost i.e. the stochastic frontier cost. The {exp (U_i)} can take the value of 1 or higher, where ‘1’ defining the most cost-efficient farm.

The ‘FRONTIER Version 4.1’ of “The University of New England” was used to obtain Maximum Likelihood Estimates for both stochastic frontier production as well as frontier cost functions.

Hypotheses 1

The hypotheses framed in context of the present study have been presented as below:

H_0: Technical inefficiency effects in pecan nut production are not present

H_1: Technical inefficiency effects in pecan nut production are present

Hypotheses 2

The hypotheses framed in context of the present study have been presented as below:

H_0: Cost inefficiency effects in pecan nut production are not present

H_1: Cost inefficiency effects in pecan nut production are present

RESULTS AND DISCUSSION

Descriptive statistics of socio-economic characteristics of pecan nut growers

Table 1 Descriptive statistics of socio-economic characteristics (n = 50)

Particulars	Unit	Min	Max	Mean	Variance
Qualitative socio-economic variables					
Non-farm income	No. (%)	23 (46.00)			
Member of social organization	No. (%)	03 (6.00)			
Kisan credit card holders	No. (%)	10 (20.00)			
Quantitative socio-economic variables					
Age	Years	33.00	68.00	51.34	8.64
Formal Education	Years	8.00	20.00	13.00	2.84
Land Holding	Acres	0.75	5.62	2.06	1.28

The socio-economic indicators of pecan nut growers studied in the present study include age, formal education, land holding, non-farm income (dummy variable), member of social organization (dummy variable) and kisan credit card holders (dummy variable). The descriptive statistics of both qualitative and quantitative socio-economic variables of pecan nut growers has been presented in (Table 1). The average age of sampled growers was 51.34 years with minimum of 33 years and maximum of 68 years. The average formal education of sampled pecan nut growers was 13 years with minimum of eight and maximum of 20 years. The average size of land holding was 2.06 acres with minimum of 0.75 acres and maximum of 5.62 acres.

Table 2 Descriptive statistics of major inputs and output of Pecan nut

Particulars	Unit	Minimum	Maximum	Mean	Variance
Descriptive statistics of quantity of inputs and output					
Area under Pecan nut	acres	0.62	3.50	1.57	0.41
No. of trees	number	3.00	10.00	5.42	2.86
Human labour	days	113.76	204.04	154.28	458.82
Yield	quintals	3.30	11.75	6.37	3.80
Descriptive statistics of cost of inputs					
Cost of land	rupees	4,868	32,000	12434	6016
Cost of trees	rupees	60	230	121	32
Cost of human labour	rupees	36,104	54519	42599	4049
Total cost	rupees	2,58,438	1464598	594704	264633

Descriptive statistics of inputs and output in pecan nut production

The descriptive statistics of inputs and output related to pecan nut production in study area has been presented in (Table 2). The mean area under sampled pecan nut orchards was 1.57 with minimum area of 0.62 and maximum of 3.50 acres per farm. The average number of trees in the sampled farms was 5.42 with minimum of three and maximum of 10 trees per farm. The average human labour days used was 154.28 with minimum of 113.76 and maximum of 204.04 days. The average production of pecan nut under sampled farms was 6.37 quintals with minimum of 3.30 and maximum of 11.75 quintals per farm.

The average cost of land for sampled pecan nut orchards was ₹ 12,434 with minimum of ₹ 4,868 and maximum of ₹ 32,000. The average cost of pecan nut trees in sampled orchards was ₹ 121 with minimum of ₹ 60 and maximum of ₹ 230 per farm. The average cost of human labour under sampled orchards was ₹ 42,599 with minimum of ₹ 36,104 and maximum of ₹ 54,519. The estimated mean total cost of pecan nut production in sampled area over a period of 44 years was ₹ 5,94,704 with minimum of ₹ 2,58,438 and maximum of ₹ 14,64,598. Ike and Chukwuji (2007) revealed a high gross margin of 36.79% of sales receipt or 58.19% of total variable cost (TVC) in case of cashew nut in Enugu State, Nigeria.

Table 3 Capital appraisal of pecan nut orchard

Measures of investment	Discount rate @ 8%	Discount rate @ 10%	Discount rate @ 12%
Pay-back period (years)	22.20	24.11	26.18
Net present value (₹)	43,12,022	19,85,900	6,72,510
Profitability index	10.81	5.61	2.60
PI-1	9.81	4.61	1.60
Internal rate of return (IRR)		14%	

Capital appraisal of pecan nut production

The capital appraisal of one acre of pecan nut for a period of 44 years was conducted and the same has been presented in (Table 3). The pay-back period of pecan nut orchard was 21.14, 23.62 and 28.22 years at 8, 10 and 12 percent of discount rate respectively. The net present value was ₹ 42,40,141, ₹ 19,63,808 and ₹ 6,65,621 at 8, 10 and 12 percent of discount rate respectively. At the same rate of 8, 10 and 12 percent of discount rate, the profitability index was 10.75, 5.52 and 2.53 respectively. The internal rate of return of pecan nut orchard was 14 per cent. Verma *et al.* 2014 estimated cost benefit ratio for cashew nut kernel processing technology in Bastar region of India to be higher in case of machine extraction (1.57) as compare to traditionally practiced (0.169).

Technical efficiency of pecan nut production under stochastic frontier model

The ordinary least squares (OLS) estimates and maximum likelihood estimates (MLE) of the stochastic frontier production function for pecan nut are presented in (Table 4). The estimated coefficients under OLS and MLE method were 0.152, 0.007 and 0.920 for human labour, area under pecan and plant population respectively. The function coefficient was 1.079. The coefficients of all the inputs were positive. The value of sigma square and gamma in MLE was 0.0013 and 0.00001 respectively. As the coefficients and log likelihood value for MLE were similar as obtained using OLS, we could not reject null hypothesis and thus conclude that technical inefficiency effects in pecan nut production were not present in the study area. The estimated coefficients under OLS and MLE method were same and significant at 1 per cent level for human labour and plant population. The coefficients of all the inputs were positive which means that increase in all the inputs will result in increase of output. The function coefficient was 1.079 indicating increasing returns to scale which means that increase in inputs will result in more than increase in output. The value of gamma parameter was 0.00001 and was insignificant, reflecting again the absence of technical efficiency in pecan nut production. Bhattacharyya and Mandal (2016) also found lower inefficiency for rice farming in the frequently flood prone areas of Assam due to availability of government support.

Table 4 Cobb Douglas model and stochastic production frontier for pecan nut

	Production function (Corrected Ordinary Least Square Estimates)				Production frontier (Maximum Likelihood Estimates)		
Variables	Coefficient	Standard error	t- ratio	VIF	Coefficient	Standard error	t- ratio
Constant	6.437***	0.264	24.410		6.437***	0.254	25.32
Human labour	0.152***	0.059	2.584	2.15	0.15***	0.055	2.71
Area under pecan	0.007	0.016	0.433	1.32	0.007	0.01	0.45
Plant population	0.920***	0.030	30.668	2.37	0.92***	0.027	4.93
F statistic		844.55***				-	
Function coefficient		1.079				1.077	
σ^2		0.0014			0.0013***	0.0002	4.93
Gamma		-			0.00001	0.01	0.0011
Log likelihood function		94.15				94.15	

***Significant at 1% level of significance

Cost efficiency of pecan nut production under stochastic frontier model

The ordinary least squares (OLS) estimates and maximum likelihood estimates (MLE) of the stochastic frontier cost function for pecan nut are presented in (Table 5). The estimated coefficients under OLS were 0.024, 0.03 and 0.93 for material cost, human labour cost and pecan nut yield respectively. The estimated coefficients under MLE method were 0.085, -0.06 and 0.92 for material cost, human labour cost and pecan nut yield respectively. The value of sigma square and gamma in MLE was 0.22 and 0.80 respectively. As the log likelihood value 1.21 is less than tabulated value of 5.412 at 1% level and with one number of restriction; we could not reject null hypothesis and thus conclude that cost inefficiency effects in pecan nut production were absent in the study area. The estimated coefficient of yield of pecan nut was the only variable found to be significant at 1% level under both OLS and MLE method. The cost elasticity with respect to all variables was positive. The value of log likelihood function under OLS estimates was 15.78 and under MLE, it was 15.18. The value of gamma parameter was 0.80 and was significant; reflecting that 80% of variation in total cost of pecan nut production among the sampled farmers was due to differences in their cost efficiencies. But these variations were not much significant, as the hypothesis for presence of cost inefficiencies was already rejected. Price *et al.* (2017) found no significant differences in cost efficiency across regions, treatment technologies, output, or turbidity levels for Canadian water utilities. Akanni and Adams (2010) recommended reduction of costs incurred on various physical aspects in marketing system of cashew nuts.

Table 5 Cobb Douglas model and stochastic production frontier for pecan nut

	Production function (Corrected Ordinary Least Square Estimates)				Production frontier (Maximum Likelihood Estimates)		
Variables	Coefficient	Standard error	t- ratio	VIF	Coefficient	Standard error	t- ratio
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Human labour	0.152***	0.059	2.584	2.15	0.15***	0.055	2.71
Area under pecan	0.007	0.016	0.433	1.32	0.007	0.01	0.45
Plant population	0.920***	0.030	30.668	2.37	0.92***	0.027	4.93
F statistic		844.55***				-	
Function coefficient		1.079				1.077	
σ^2		0.0014			0.0013***	0.0002	4.93
Gamma		-			0.00001	0.01	0.0011
Log likelihood function		94.15				94.15	

***Significant at 1% level of significance

The absence of technical inefficiencies in pecan nut production highlighted the need for introduction of technical innovations in their production so that its productivity can be enhanced without compromising the quality and uniqueness of traits. The production of pecan nut was confined to rainfed undulated areas of the farms. It was primarily grown as organic with negligible use of chemical fertilizers. Therefore, an organic package of practices is essential for management of diseases and pests to sustain the productivity of pecan nut. On the other hand, the absence of cost inefficiencies indicated limited use of external inputs in production of pecan nut. Therefore, the farmers should be made aware about management of inputs and should be trained in scientific management of trees, including pruning and training at right intervals. The provision of quality planting material along with remunerative incentives for production of niche crop like pecan nut must also be ensured for diversifying farming in intermediate hills of J & K.

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