EFFICIENCY AND PRODUCTIVITY ANALYSIS OF HIGH-TECH COTTON-MELON MULTIPLE CROPPING SYSTEMS IN PUNJAB, PAKISTAN

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ABSTRACT: *This research entails the efficiency analysis of multiple cotton-melon cropping systems under tunnels in Punjab, Pakistan. With population growth and a loss of land to urbanization, innovative farms are needed to maintain production. The adoption of multiple cropping systems under a tunnel is one of the ways to increase farm production on the same space and time. The data were collected from 150 cotton-melon multiple cropping system farms. Results reveal that most of the farmers are moderately technical efficient, with a mean technical efficiency of 85 percent. On 76 percent of cotton-melon farms, the technical efficiency varies between 0.80 to greater than 0.90. Technical efficiency calculations indicate that the improvement in performance is possible by using balanced quantities of inputs. Also, it can be improved by making and analyzing agricultural policy in order to adopt and improve the productivity of cotton-melon cropping systems under tunnels. However, farmers will have to make strenuous efforts in terms of inputs and maintenance to get the targeted output.*

INTRODUCTION

Why is sustainable agriculture pertinent for Pakistan and how has it served the country? The answer is food. Food happens to be the most strategic of self-sustainable production. Countries who understand the significance of territory try their best to achieve self-sufficiency in food. The non-realization of self-sufficiency, on the other hand, makes such countries dependent. The role of the agricultural sector in Pakistan has been far-reaching and its growing value in this century can't be ignored. Pakistan has a suitable weather environment that plays a momentous role in the attainment of high agricultural production that contributes towards self-sufficiency goals.

There are a number of real and monetary links, originating from the agricultural sectors, which affect the economic performance of the general economy. These relationships often are referred to as backward linkages. In other words, the agricultural sector has backward links with other economic sectors. On the other hand, long-term and short-term real and monetary impacts affect quantity, price, income and outcomes from the agricultural sector directly. Agriculture provides raw material for other sectors and meets consumer needs for food and fiber as well as contributes to national income [1].

'Multiple cropping systems' refers to growing two or more crops at the same time in a particular area. Multiple cropping is beneficial as it swaps essential soil nutrients, it can produce more than one crop in a year and these crops help each other in diverse ways. In this system, each farm manager adopts their own best suitable multiple crop combination. Growing more than one crop on the same space and time can result in higher levels of farm output and manifold earnings to the farm manager.

Admittedly, multiple cropping systems are more complex than the mono-cropping system. However, there are some advantages of multiple cropping systems, like the planning of the season with the right selection of crops, which can benefit other crops. Generally, this system demands a trained and larger labor force. Lack of training and information regarding multiple cropping systems causes economic losses and lower income to the farm manager. Under this system, mechanization for cultivation, harvesting and application of fertilizers, herbicides and pesticides are also complicated. The farm management issues, particularly in case of a complex farming system play a major role in technical efficiency variation from one farm to another and consequently result in production gaps [2].

For the determination of returns on investment, the efficiency analysis of multiple cropping systems under tunnels transmits high importance. The introduction of new technology works as a distinctive differing factor between traditional and modern cropping systems and also enhances the efficiency of production systems [3].

[4] Estimated the performance of multiple cereal crop production in Ethiopia by using the Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) techniques. The results from the parametric and non-parametric approaches revealed the existence of technical inefficiency in multiple cropping systems. The major factors that influenced the technical efficiency of cereal crop production were poor access to credit and extension services, and timely availability of inputs. [5] Estimated the technical efficiency of the inter-cropping system of Ethiopia. The result of the study suggested that farm efficiency could be improved by innovative intensification and adoption of appropriate technologies. [6] Articulated the technical efficiency of multiple-cropping systems of Nigeria. Farmers, who had greater access to extension systems, education and credit availability, were found to be more efficient than those who did not have these facilities. The technical efficiency in resource utilization can be increased under the mixed cropping system, by better utilization of land, a proper combination of crops and improvement in farm level activities [7].

The literature in Pakistan is lacking any study conducted on efficiency analysis of high-tech multiple cropping systems. Such an analysis, if done, would be helpful in specifying the future changes in the production practices of food and cash crops. It would also enlighten the challenges and hurdles faced by farm managers in attaining the optimum production with this intensified and high-tech farming system. Therefore, this study is an attempt to estimate the performance of multiple cropping farms under tunnels, using DEA and SFA techniques, from the selected sample of farmers from Punjab, Pakistan.

MATERIAL AND METHODS

The purposive sampling technique was adopted to identify the areas to be sampled. Within the selected areas, the simple random sampling technique was used. A total of 150 farms were selected with a cotton-melon cropping system. Most of the tunnel farming practices are done in the Punjab Province of Pakistan. Within the Punjab Province, most of the tunnel farming practice has been carried out in the Faisalabad division. The cities sampled, and the corresponding number of farms selected from each city includes Faisalabad (5), Mureed Wala (2), Sumundri (33), Tandnian Wala (19), Toba Tek Singh (10), Gojra (4), Kamalia (13) and Mammo Kanjan (64).

In the present study, SFA, a renowned parametric technique, is applied to calculate the efficient technical frontier in cotton-melon cropping systems. [8] Proposed the stochastic frontier production model in line with the works of [9] and [10] to cross-sectional data to determine the efficiency of cotton-melon cropping systems under tunnels in Faisalabad, Pakistan. The maximum likelihood is a considerable choice utilizing the Frontier 4.1 software program [11]. [8] Established a stochastic frontier production function, whose effects are disseminated as reduced normal random variables where some of the variables affect inefficiency variables.

The SFA technique holds the advantage of controlling measurement and other types of statistical errors, which might cause disruption in production variables. It also works better in a situation of external shock faced by agricultural yield, as is the case of Pakistan. This approach supposes that deviation from the frontier occurs because of measurement and statistical errors, effect of non-systematic factors and importantly technical inefficiency.

It is necessary to make standard assumptions for the stochastic frontier model estimation of the distribution of variance parameters, such as v_i and u_i.

$$\gamma = \frac{\sigma_v^2}{\sigma_u^2} \qquad 1$$

The gamma (γ) parameter has been introduced by [12]. The major reason behind introducing the γ parameter is its value remains between zero and one. Hence, if the value of γ equals zero, it indicates that difference between farms' output is only because of random error and if γ is equal to one it means that the entire variation in farm output is due to technical inefficiency.

Keeping in view our objectives, a Cobb-Douglas stochastic frontier production function is applied. The Cobb-Douglas empirical functional form is written as

$$LnY_i = \alpha_0 + \sum_{i=1}^{7} \alpha_{1i} \ln X_i + u_i - v_i \qquad 2$$

where α is the unknown parameters and Y_i is the yield and has been constructed using the quantity index. The quantity index is given by

$$Y_{ij} = \sum_{j=1}^{2} W_{ij} X_{ij} \qquad 3$$

Where $i = (1,2,3...,150)$, $j = (1,2)$, j show the cotton-melon crops and W represents the weight given to the quantity of each j_1 and j_2 crops over the i^{th} farm and is given by

$$W = Output\, of\ j_1 crop / [\{total\ value\ of\ j_1\ and\ j_2\ crop\}] \quad 4$$

The separate quantity indices have been developed for the cotton-melon combination of crops under multiple cropping. The yield of each harvest has been converted to kilograms.

These indices have been developed for having combined quantity produced per acre for the selected crops' combination in the multiple cropping systems. The combination for which the index has been developed is cotton and melon. This was the description of the dependent variable. Now we turn to the description of the independent variables of the production models.

X_1 is land preparation hours. This variable shows the time spent in land preparation before the seed sowing process. The farming tools used for the preparation of cotton-melon field were deep plougher, rotavater, cultivator, land leveler, plougher and planker, and bed-shedder, X_2 is the application of cotton seed in grams per acre. X_3 is the application of melon seed per acre in grams. X4 is the numbers of pesticide spray application per acre. X_5 is the Nitrogen, Phosphorus and Potassium (NPK) ratio per acre. X_6 is the labor hours per acre. X_7 is the number of irrigations per acre during the whole season.

The inefficiency model of cotton-melon cropping systems follows:

$$U_i = \delta_0 + \sum_{m=1}^{n} \delta_m Z_{mi} + W_i \qquad 5$$

Where the U_i denotes the technical inefficiency of cotton-melon cropping system, δ_m are the unknown parameters to be estimated, Z_i represents the socioeconomic, farm-specific and management factors of cotton-melon multiple cropping farms under tunnels. A description of Z_i variables in the model is given below:

Z_1 is the age of the farmer in years. Z_2 represents the farmer's education in years. Z_3 captures the farm distance from the main market in kilometers. Z_4 is a dummy variable for access to credit which takes the value of one if the credit was available to the farmers and zero otherwise. Z_5 represents the owner-cum tenant dummy variable. It takes the value one if the farmer is an owner-cum tenant, and zero otherwise. Z_6 represents the tenant variable. This is also a dummy variable, which takes the value of one if the land is cultivated by just the tenant and zero otherwise. Z_7 is the variable for tractor ownership is a dummy variable. The value of one indicates that the farmers owns the tractor and zero otherwise. Z_8 is the area under the crops per acre. Z_9 is the total number of tunnels per acre. This variable captures the effect of change in the per acre number of tunnels on the cotton-melon farms' technical efficiency.

HYPOTHESES TESTING

Examining and analyzing the null hypotheses is essential prior to the model estimation. Several hypotheses were tested to fulfill that objective, and a number of restrictions were imposed after finalizing the model specification. The generalized likelihood ratio test was used to testing the validity of the hypotheses of this study.

$$LRTest = [\ln H_0 - \ln H_1] \quad 6$$

Equation. 6 is the likelihood ratio test, where H_o and H_1 represent the null and alternative hypotheses, respectively. The hypotheses result of the Cobb-

Douglas stochastic frontier model's parameters and

TABLE 1. HYPOTHESIS TESTING OF COTTON-MELON CROPPING SYSTEMS

Hypotheses	Log-Likelihood Value	Test Statistics Value	Critical Value $\chi^2 0.05$	Decision
$H_0 : \gamma = \delta_\circ ....\delta_9 = 0$	45.8	106	5.1-19.0	Rejected
$H_0 : \delta_1 ... \delta_9 = 0$	57.5	84.2	18.3	Rejected

parameters for the inefficiency model are reported in Table 1. The first hypothesis imposed on the cotton-melon cropping production functions describes that there is no technical efficiency effect present in the cotton-melon production model. To check the first hypothesis of no technical efficiency effects present in cotton and melon cropping system, the Ordinary Least Square (OLS) and stochastic frontier production function were estimated.

The log likelihood values of the Cobb-Douglas and OLS production models for the cotton-melon cropping system were 99.1 and 45.8, respectively. The tabulated value of chi-square at 5 percent of significance level is 5.1-19.0 and the calculated value of the LR test is 106, which is greater than tabulated value. Hence, the value of likelihood test statistics rejected the null hypothesis of no technical effect present in the cotton-melon cropping system. Hence, Ordinary Least Square (OLS) production model is found inadequate for the demonstration of cotton-melon sample data. The second null hypothesis tested on inefficiency model of cotton-melon cropping system. This hypothesis is specified that socioeconomic and farm specific factors have no influence on technical inefficiency.

The results obtained from LR test rejected the null hypothesis in favor of the alternative hypothesis. The calculated value of LR test is 84.2, which is greater than the tabulated value of Chi-square, which is 18.3. This result implies that socioeconomic and

Farm specific factors have substantial influence on the technical efficiency of cotton and melon growers in Pakistan.

DESCRIPTIVE ANALYSIS OF COTTON-MELON CROPPING SYSTEMS

In multiple cropping systems, the balanced application of inputs has an imperative impact on cotton-melon production. Land preparation is the initial step and all the later steps of the production activities depend on this initial step. Hence, improved farm management skills result in improved quantity and quality of cotton-melon production. On average, farmers spend around 22 to 23 days for cotton-melon land preparation, table 2. The land preparation activities that have been carried out under tunnels include deep ploughing, leveling, bed shedding, use of rotavator and cultivator, and ploughing and planking. Relative to other farming systems, multiple cropping under tunnels is highly water demanding. In the work area, the number of irrigations for the cotton-melon system is approximately 21 per season.

TABLE 2. AVERAGE OUTPUT AND APPLICATION OF INPUTS PER ACRE ON COTTON-MELON CROPPING SYSTEMS

Inputs (application per acre)	Average	St.dev
Land preparation days	22.7	6.2
Land Preparation hours	3.3	0.9
Number of times deep ploughing	1.1	0.3
Number of leveler used	1.0	0.0
Number of times rotavator used	1.1	0.3
Number of times bed-shedder used	1.0	0.0
Number of times cultivator used	3.2	0.6
Number of ploughing and planking	1.2	0.4
Number of irrigations	20.7	3.4
Application of urea (Bags)	4.5	1.0
Application of DAP (Bags)	4.4	1.2
Application of SOP (Bags)	1.1	0.4
Number of pesticide sprays	17.9	4.0
Cotton seed application (Grams)	2,586.6	541.8
Melon seed application (Grams)	310.8	36.2
Average Cotton-Melon Output (acre)		
Cotton yield (Kg)	1,318.1	282.4
Melon yield (Kg)	10,415.5	3,029.3

Balanced application of chemical fertilizers also plays a fundamental role in cotton-melon multiple cropping under tunnels. Chemical fertilizer can be conducive in enhancing farm output. However, employed in unnecessarily large amounts with intensive production, fertilizer can be adulterated and this will culminate in soil and land quality and resulted in productivity loss [13]. Hence, balanced application of fertilizer is essential to achieve the highest level of cotton-melon production. Three types of fertilizers are mainly employed on the sample farms. These are Urea, Diammonium phosphate (DAP) and Sulfate of Potash (SOP). In a cotton-melon cropping system, farmers applied on average 4.49, 4.37 and 1.12 bags of Urea, DAP and SOP, respectively. In the case of pesticides, two types of sprays, namely insecticide and fungicide are mostly applied in the cotton-melon cropping system. The sampled farmers on average applied pesticides 17.91 times. In the case of tunnel farming, each tunnel requires a specific quantity of seeds. Across the sampled area, the manual sowing method is used in cotton-melon multiple cropping under tunnels. The cottonseed application under the tunnels is on average around 2,587 grams per acre and melon seed application on average is approximately 311 grams per acre in the study area. In the cotton-melon cropping system, the average yield of cotton crop is around 1,318 kg per acre. On the other hand, the average yield of melons is around 10,415 kg per acre. The cotton and melon crop combination is quite novel and can be more productive by employing the upgraded farm management techniques.

COTTON-MELON PRODUCTION FRONTIER ANALYSIS

TABLE 3. COBB-DOUGLAS STOCHASTIC PRODUCTION FRONTIER

Maximum Likelihood Estimation				
Variables	**Parameter**	**Coeff**	**Std.er**	**t-ratio**
Intercept	β0	0.081	0.753	0.10
Number of labor hours	β1	0.163	0.072**	2.27
Number of irrigation	β2	0.374	0.075***	4.93
Number of pesticide spray	β3	0.052	0.072	0.73
Cotton seed	β4	0.042	0.052	0.80
Melon seed	β5	0.970	0.121***	8.01
Number of and preparation hours	β6	0.508	0.054***	9.37
NPK	β7	-0.122	0.048***	-2.51
Sigma-squared		0.052	0.019***	27.36
Gamma		0.903	0.065***	136.98
Log likelihood Function				99.10

*:10%significance; **: 5%significance; ***: 1%significance

In stochastic production frontier, a total of 16 variables were calculated out of which 7 were in the C-D production frontier model (Table 3) and 9 were in the technical inefficiency model (Table 4).

The results of the present study indicate that labor is one of the most important inputs used in multiple cropping systems under tunnels, as the production under tunnels requires a lot of consideration. The result illustrates that the production of cotton-melon crops under the tunnels is much dependent on laborers' farming skills. It is estimated that the one percent increase in the number of labor hours increases the cotton-melon production by 16.3 percent. Hence, it is pragmatic that the use of labor increases productivity if it is properly utilized. If the labor is better aware of crop requirements, proper combination, and proper application timing of inputs, the farm productivity will rise. It is worth understanding that more than one crop is produced under tunnels in multiple cropping. Labor is required to use the inputs and combination in time such that it causes no harm to the other crop being grown under the same tunnel. The more care and time is devoted by the labor to the multiple farming, the more profitable the crops will be.

Earlier studies also assessed how labor affect the productivity of a farm and revealed that labor contributed positively to enhance farm productivity [14-22]

By using the Cobb-Douglas production function and stochastic frontier model, the results have revealed that the total number of irrigations affect positively and significantly the cotton-melon cropping system. Irrigation is an important determinant for multiple crops grown under tunnels. The water requirement of these crops is greater relative to those crops grown without a tunnel. The timing of irrigation is also important. Timely availability and application of water enhances the performance of other inputs. The optimum combination of seeds, fertilizers and other inputs with water can manifold the cotton-melon production. The farmers, well acquainted with the proper timing of water application and proper combination of inputs with water are more efficient in crop production. Earlier studies illustrate that crops' productivity is positively and significantly linked with number of irrigations [14,16,24,25].

It has been observed that the pesticide application is quite common among the tunnel farmers. Application of pesticide positively affects the cotton-melon cropping system, but is insignificant.

The input of seed is an important determinant of the cotton-melon cropping system. The result of the study reports that the seed rate of both crops transmits the positive sign. Application of melon seed under tunnels is highly significant; however, it is insignificant in case of the cotton crop. Application of seeds under the tunnels requires an appropriate quantity of seed and most importantly, quality. Accessibility to seed technology and reduction in prices can act as an incentive to adopt improved technology. The findings of previous studies illustrate that the use of improved seed had a positive impact on the crops technical efficiency. Nevertheless, improved planting materials if not utilized in the recommended proportion could reduce a farmer's productivity [2,14,22,27,28,29,36].

Land preparation also plays a decisive role in cotton-melon crop production under tunnels. Land preparation is done in a more beneficial way with the help of a tractor, plougher, planker, rotavatar, bed-shedder, cultivator and deep ploughing. The results of the study demonstrated that the increase in cotton-melon productivity is directly proportional to the time spent in land preparation. The land preparation coefficient is positive and highly significant. Improved land preparation practices aid in the application of other farm inputs that would subsequently enhance the production of the cotton-melon cropping system.

The application of NPK nutrients is also common in the cotton-melon multiple cropping system under tunnels. The application of NPK affects the cotton-melon crops negatively and significantly. The major reason behind this negative coefficient sign is that the farmers apply the quantities of NPK, without getting prior information about the specific quantities of these nutrients required by the soil. This may result in excess amount of some nutrient and deficiency of other nutrients in the soil. Such practices deteriorate the soil quality and subsequently decrease the cotton-melon output. The practice of getting prior information regarding soil requirement of specific nutrient may be lucrative for the farmers. Hence, optimum application NPK can result in cost reduction and profit elevation. Earlier studies also report the inverse and significant relationship between the fertilizer application and farm output [26,30,31].

COTTON-MELON TECHNICAL INEFFICIENCY MODEL

Farm management and accomplishment of highest technical efficiency is a challenging job for farmers. It requires a lot of hard work and commitment. Efficient farm management requires that the farmers should be well equipped with the knowledge of entrepreneurship as well as agricultural science. Farm management practices would be inefficient if managers are devoid of knowledge of either of the two fields stated above.

In most studies, technical efficiency is associated with farmers' age, farmers' education, access to credit, operational holding, tenancy status, market access and farmers' access to improved technologies such as fertilizer, pesticide sprays, tractors, tube wells and improved seeds either through the market or public policy interventions. The stochastic production frontier model also gives the estimates of inefficiency effects to identify the factors influencing the farmer's technical inefficiency that are reported in Table 4.

In the inefficiency model, the farmers' age variable has been incorporated to understand the impact of farmers' age on the technical efficiency of cotton-melon cropping system. The estimated result of coefficient of farmer's age is positive and insignificant. Hence, age of farmer in cotton-melon cropping system has no significant impact on increasing or decreasing the technical efficiency of a cotton-melon cropping system. This result is in line with the former studies such as [32,33,34].

The coefficient of the farmers' education reports the inverse and significant relationship with technical inefficiency of a cotton-melon cropping system.

Education plays an integral role in enhancing the technical efficiency in any occupation. In case of the farm sector, the better-educated farmers have better knowledge about the seed varieties available and newly introduced in the market. They are also well aware of newly introduced farm related technologies and the market trends. Hence, with better education, a farmer selects those farm technologies and inputs combinations that augment the farm technical efficiency and productivity. Therefore, it is easier for the better-educated farmers to adopt the innovative cotton-melon multiple cropping pattern under tunnel technology. This result is also in line with the previous studies, such as [2,25,32,33,35,36]

The coefficient of distance from the main market carries a positive and significant relationship with technical inefficiency. It depicts that as the distance from the main market increases the technical inefficiency of cotton-melon farmers also increases. The access to roads and transport are compliant in improving the farm technical efficiency. In the study area, most of the roads from the farms to the markets are rough. The horticultural products are dented, smashed and spoiled being transported through these roads. Consequently, the quality and the quantity of these products is degraded and reduced. The wretched conditions of roads negatively affect the farming sector [37].

The coefficient of access to credit is insignificant and positive, showing that the influence of farm credit in enhancing the technical efficiency of a cotton-melon production system is uncertain. One important point regarding the positive sign of coefficient of credit is its inappropriate use. In the sampled cotton-melon farms, farmers usually use credit for meeting daily expenses or on enlarging farmland instead of resultantly improved productivity and technical efficiency.

TABLE 4. COTTON-MELON CROPPING SYSTEMS INEFFICIENCY MODEL

Variables	Parameters	Coeff	Std-er	t-ratio
Age of Farmer	δ1	0.009	0.035	0.27
Farmer's education	δ2	-0.050	0.015***	-3.26
Distance from main Market	δ3	0.078	0.028***	2.78
Access to credit	δ4	0.045	0.100	0.44
Tractor ownership	δ5	-0.403	0.127***	-3.17
Tenant	δ6	-0.039	0.099	0.03
Own cum-tenant	δ7	0.005	0.102	0.54
Operational holding	δ8	0.274	0.012**	2.20
Total.no. of Tunnels	δ9	-0.009	0.012	-0.75

*:10% significance; **:5% significance; ***1%significance

The factor of tenancy status is linked with the land ownership status of the farmers. The base category is the farm owner. The variables, tenant and owner-cum tenant variables have the positive coefficients in the cotton-melon technical inefficiency model. This result indicates that tenant and owner-cum tenant farmers have a positive relationship with technical inefficiency, compared to the farm owner. [39] found out that farmers having ownership of the land on which they farmed were more productive than the ones who did not. However, a precise conclusion on the impact of these variables on technical efficiency has not been reached, as both variables are insignificant.

The effect of the operational holding on technical inefficiency of cotton-melon cropping system farmers is positive and significant. This result illustrates that as the operational holding under cotton-melon cropping system increases, it also increases the technical inefficiency of the farmers. The major reason behind this positive and significant relation is the nature of crop combination, where cotton is a cash crop and melon is a horticultural crop. Consequently, management of both crops is relatively complex. Those farmers that have a small operational holding, perform farm management practices better than the large farms. Hence, the small farm size farmers are more technical efficient compared to the large farms in the cotton melon cropping system under tunnels.

The number of tunnels variable shows an inverse relationship with technical inefficiency, but it is insignificant. Due to the insignificance of this variable the impact of this variable on technical inefficiency of a cotton-melon cropping system is unidentified.

TECHNICAL EFFICIENCY FREQUENCY DISTRIBUTION OF COTTON-MELON CROPPING SYSTEM

The technical efficiency scores of cotton-melons cropping system, obtained from the SFA are shown in figure 1. The result of the study revealed that technical inefficiency present in the cotton-melon multiple cropping systems. The gamma value obtained from the estimation of stochastic frontier analysis is around 0.90 and significant as well. Hence, the farm-specific, management and socioeconomic factors have explained 90% of variation in cotton-melon cropping system yield.

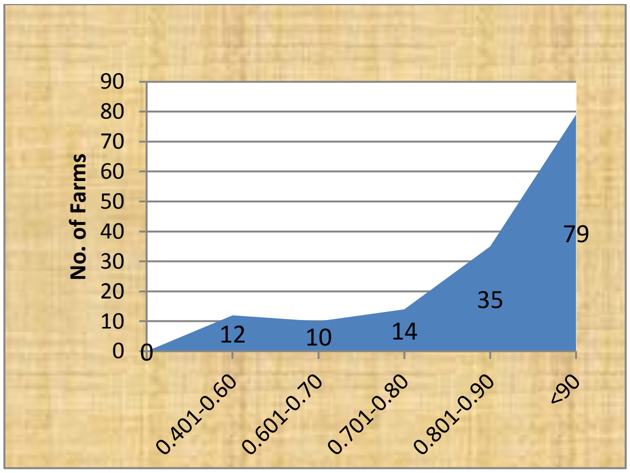

Figure 1. Technical Efficiency Distribution of Cotton- Melon Cropping Systems

Technical efficiency scores obtained from SFA reports that the average technical efficiency of cotton-melon cropping system is about 0.85. The highest technical efficiency score of cotton-melon cropping systems is 0.98 and the lowest one is 0.41. The calculated technical efficiency frequency distribution varies between 0.80 to 0.98 and around 76 percent of farms fall into that category with the mean efficiency value of 0.85. Only eight percent of the cotton-melon farms fall within the efficiency range of 0.41-0.50 while the technical efficiency of 0.51-0.60 categories is around 6.7 percent. About 9.3 percent of the farms fall within the efficiency range of 0.71-0.80 of the cotton-melon cropping system.

The efficiency measurement technique highlights the technical inefficiency present in the sampled cotton-melon cropping systems under tunnels. This means that there exists a wide variation in the technical efficiency of sampled farms within and across their scales of operations, thus determining the factors that cause the variability is necessary. The findings are not surprising keeping in view the fact that the former incorporates both multiple cropping systems and it's under the tunnels. The present result of the study suggests that there is greater potential for efficiency improvement through better farm management practices.

CONCLUSION

Technology defines the mix of inputs, knowledge and the practices for the farm management. These are employed simultaneously and combined with productive resources for obtaining the output level that is desired. Apart from conveying information and skills relevant to the technology to the potential farm managers, the transfer of technology also helps them to take advantage of these farm technologies. If the farmer is risk taking, determined and profit oriented, the1n he might be interested in acquiring all the skills and knowledge necessary to run the farm efficiently. If the farmer has contentment with the moderate profits and just a respectable life, then he may improve his skills a little bit.

This is the first study in Pakistan that analyzed the technical efficiency of the high-tech multiple cropping systems under the tunnels in Punjab, Pakistan. The previous studies examined the efficiency analysis of mono-cropping systems, due to several reasons, such as ease of data availability, ease of empirical analysis and simplicity of the mono-cropping system. Hence, there is considerable space for new research projects concerning the multiple cropping system under the tunnels. In future research for further comprehensive analysis can be instigate by using time series or panel data on multiple cropping systems under the tunnels across the provinces of Pakistan. The end results of this sort of research will give the clearest and extensive findings and inference for multiple cropping system under tunnels.

Multiple cropping systems under tunnels require added farm management skills. This farming system requires extra effort and commitment from the cotton-melon farm manager and support from the public research centers concerning the application of farm inputs. In the present study, on average, the cotton-melon farming system is facing 15 percent technical inefficiency. For accomplishing the objectives of higher level of output, it is needed that farmers ensured balanced application of farm inputs and save redundant overheads of using unreciprocated fertilizers and pesticide spray that yield no return. On the other hand, agricultural extension and programs for educating the farmers are vital policy instruments of government, seeking to improve the technical efficiency of the high-tech cropping system, while protecting the environment. However, many have observed poor performance in the operation of extension and informal education systems, due to bureaucratic inefficiency, deficient program design, and some generic weaknesses that are inherent in publicly operated staff-intensive information delivery systems.

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