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# TECHNICAL EFFICIENCY OF SEED POTATO FARMERS OF BADAKSHAN PROVINCE OF AFGHANISTAN

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**ABSTRACT: Potato is the second staple food after wheat in Afghanistan. International Centre for Agricultural Research in the Dry Areas (ICARDA) and International Potato Centre (CIP) introduced high yielding potato variety Kufri Chandramukhi (KCM) and its production technology to develop an efficient seed production system that helped in reducing poverty and increasing food production in Bahrak district of Badakhshan province of Afghanistan. Purposive and multistage sampling technique was used for selecting the sample seed potato farmers for the present study. The economic benefits and technical efficiency levels of farmers were estimated using the data collected from the participating and non-participating farmers in the intervention. A high degree of inefficiency (76%) in the production of seed potato was observed indicating that there is scope for farmers to increase the potato production by 76% just by way of realizing technical efficiency. As the efficiency levels are low, efforts to improve technical efficiency and correct adoption of seed potato production technology would be more productive and cost effective through more trainings, field days, *etc*.**

**KEYWORDS:** potato; frontier production function; determinants, Afghanistan

## INTRODUCTION

Potatoes help alleviate hunger and malnutrition in less developed countries (Guenthner, 2010 and Thiele *et al.,* 2010) and the crop is attaining higher importance at faster rate in many of the Asian countries (Scott and Suarez, 2011; 2012). In Afghanistan, potato is the second most important staple food crop after wheat. It is grown in an area of 21,900 ha producing 333,600 t at an average productivity of 15.23 t/ha (FAOSTAT, 2012). It is grown in provinces like Bamyan, Ghazni, Helmand, Kunduz, Badakhshan, Wardak, Parwan, *etc*. Protracted war resulted in technological erosion, loss of seed material and market infrastructure as evident from the report of the Future Harvest Consortium to Rebuild Agriculture in Afghanistan (FHCRAA, 2002) and Kugbei *et al.,* (2005). This report also noted that potato production in the country is constrained by the low yields, highly degenerated local seed, poor seed storage infrastructure and no or limited scientific seed production knowledge of potato growers. Thiele *et al.* (2010) have argued that the best way to reach the poor is to ensure that new varieties are intrinsically pro-poor having characteristics such as yield stability and resistance to diseases such as late blight and virus vectors. Also an urgent need exists for quick transfer of new agricultural technologies to increase efficiency and to enable farmers to improve their productive capacity.

If producers are not making efficient use of existing technology, efforts to improve efficiency would be more cost effective than introducing new technologies as a means of

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increasing agricultural output (Shapiro, 1983). If producers are efficient in input use, costs will be minimized, profits will be maximized, thereby contributing to greater competitiveness in food crop production and food security (Bravo-Ureta and Everson, 1994; Bravo-Ureta and Reiger, 1991; Xu and Jeffery, 1998).

## ICARDA-CIP intervention

Based on ICARDA's successful model of Village Based Seed Enterprises in Afghanistan and in other countries (Bishaw and van Gastel, 2008; Srinivas *et al.,* 2010), a team of scientists of ICARDA-CIP worked with 15 agriculture co-operatives collectively having more than 4,000 members to introduce seed potato cultivation as an alternative livelihood to opium in Bahrak district of Badakhshan province during 2008-09. Fifteen seed producer groups involving 213 farmers were organized and introduced a new and high-yielding potato variety Kufri Chandramukhi along with a set of recommended seed production technologies and trained in quality seed production. The variety was introduced through establishing participatory demonstrations. Four specialized trainings were conducted to enhance the capacity of the farmers and other stakeholders in quality seed production, storage and marketing. Fifteen semi-underground country stores each with a storage capacity of 25 t of seed potato were constructed for the farmers' co-operatives. These stores minimized the storage losses from present 45-50% to less than 5%. For sustainable quality seed production, "Quality Control and Certification Groups" (QCCG) were constituted and trained in field inspection and in evaluation of seed quality. The increase in the seed to ware potato ratio for the participating farmers to 63:37 from 31: 69 can solely be attributed to this intervention.

The team also undertook a study to understand the level of technical efficiency of local seed potato farmers in comparison to the participating farmers. The aim was to quantify the economic benefits attained by the farmers that participated in ICARDA-CIP intervention in comparison to those of non-participating farmers in Bahrak district. It included the following specific objectives:

1. To estimate and compare the cost of cultivation of seed potato between participating and non-participating farmers.
2. To assess the technical efficiency of seed potato farmers and to identify the factors determining the technical efficiency.

## METHODOLOGY

Purposive and stratified random sampling technique was used to select a sample of 60 farmers (30 participating and 30 non-participating farmers) from four villages in Baharak district of Badakhshan province. Four villages were selected purposively on the basis of concentration of potato cultivation. A sample of 15 seed potato growers from each village was selected in such a way that participating and non-participating farmers of the ICARDA-CIP intervention were represented in equal proportion. Cost of cultivation and socio-economic data were collected from the sample using a pre-tested questionnaire. The study pertains to the agricultural year 2008-09 (April-May to November-December 2008). Data were analyzed using cost concepts, tabular and percentage analysis to estimate the cost of cultivation.

## Production function

In the present study, the Stochastic Frontier production function approach was used to measure technical efficiency of seed potato farms. Technical efficiency is the effectiveness with which a given set of inputs is used to produce an output. A firm is said to be technically efficient if a firm is producing the maximum output from the minimum

quantity of inputs, such as labor, capital and technology. The concept of technical efficiency was elaborated by Farrell (1957) and treated technical efficiency relative to best practices in the group under consideration. A score of unity indicates technical efficiency and any score less than unity indicates technical inefficiency.Later Aigner *et al*., (1977) and Meeusen and van Den (1977) suggested the stochastic frontier model as a means for estimating the technical efficiency. Many researchers such as Kutala (1983); Taylor and Shonkwiller (1986); Kalirajan and Shand (1989); Sharma and Datta (1997); and Reddy and Sen (2004) had estimated the technical efficiency using stochastic frontier model, based on the cross-sectional as well as time series data.

## Model specification

In the present study, stochastic production function of Cobb-Douglas form was specified, which is defined in logarithmic form as,

$$ln\ Y_i = b_0 + b_1 lnX_{1i} + b_2 lnX_{2i} + v_i - u_i \quad \text{.....(1)}$$

where,

$Y_i$ = Gross income per ha in Afghanis (Afs)

$X_1$ = Material costs per ha in Afs

$X_2$ = Labour costs per ha in Afs

b's = Elasticity coefficients

$v_i$-$u_i$ = Error term

$v_i$ = Symmetric component of error term which captures randomness outside the control of the farmer, such as droughts, floods, *etc*.

$u_i$ = Non-negative random variable which is under the control of the farmer

Since the frontier is stochastic in nature, permitting random variations of the production frontier across observations, the technical inefficiency which is captured by the one-sided error component, *i.e.*, $u_i \geq 0$ is relative to the stochastic frontier.

The technical efficiency of individual farmer lies between zero and one and was estimated as

Technical Efficiency (TE) = exp ($-u_i$)

The above model was estimated by Maximum Likelihood Estimate (MLE) method using LIMDEP software.

## Determinants of technical efficiency (TE)

Socioeconomic and technical variables are incorporated into the model to evaluate their relation with efficiency/ inefficiency based on the literature and on data availability. To account for human capital we included the age of the farm household head, and education a dummy variable that is equal to 1 if the sample farmer is educated. The following variables were included to account for household characteristics: Participation- a dummy variable that is equal to 1 if the sample farmer participated in the project intervention; family members above 18 years age involved in different agricultural operations. Size of the farm and distance from the market was also included anticipating to influence the efficiency of farmers. Participation in the trainings imparted to enhance the knowledge on cultivation, plant protection and marketing is expected to improve the technical efficiency of the seed potato farmers and therefore included as one determinant in the model.

Multiple linear regression of the following model was used to determine the factors influencing technical efficiency of seed potato farms.

$$TE_i = a_0 + a_1 FA_i + a_2 E_i + a_3 D_i + a_4 T_i + a_5 A_i + a_6 FM_i + a_7 P_i + u_i \quad \text{……..……} \quad (2)$$

Where,

$TE_i$ = Technical efficiency of $i^{th}$ farm

FA = Age of farm household head in years

E = Farmer's education dummy (1 = educated farmer; 0 = otherwise)

D = Distance from market in km

T = Number of trainings attended by sample farmer during the last year

A = Area under seed potato in ha

FM = Family members involved in agricultural operations

P = Participation in the intervention dummy (1 = participation in the intervention; 0 = otherwise)

a's are coefficients

## RESULTS AND DISCUSSION

### Cost of cultivation

Cost of cultivation of seed potato by participating and non-participating farmers is presented in **Table 1**. Participating farmers incurred a gross cost of US $ 2,886 to cultivate one ha of potato. Of this 72% accounted for material costs *viz.*, seed, fertilizers, insecticides and gunny bags while labour costs (family and hired) accounted for only 20% of the cost. Out of the gross cost of US $ 1,546 for non-participating farmers, 62 and 30% was accounted for material and labour costs respectively. The remaining eight per cent was the interest on the working capital in both the cases. Thus, the material costs accounted for more in the gross costs compared to labour costs in both the cases.

High material cost for the participating farmers was due to use of new potato variety seed that was costing more than the local seed (the average cost of seed potato was Afs 20.65 and Afs 13.29 per kg seed potato for participating and non-participating farmers respectively) and use of recommended dose of fertilizers (**Table 2**). Similar result was indicated by Okoboi in 2001 in his study on the marketing potential of potatoes in Uganda and market opportunities for Rwanda. Seed potato is usually the most expensive input to potato cultivation, accounting for from 30

**Table 1. Cost of cultivation of potato by participating and non-participating farmers.**

| Particulars | Participating farmers (US $/ha) | | | Non-participating farmers (US $/ha) | | |
|---|---|---|---|---|---|---|
| | Family labour | Hired labour | Total | Family labour | Hired labour | Total |
| Total labour costs | 541.13 | 45.67 | 586.80 (20.33) | 462.80 | 7.73 | 470.53 (30.43) |
| Total material costs | | | 2,085.14 (72.26) | | | 961.04 (62.16) |
| Interest on working capital @ 8% | | | 213.76 (7.41) | | | 114.53 (7.41) |
| Gross cost | | | 2,885.70 (100.00) | | | 1,546.10 (100.00) |
| Seed potato yield (t/ha) | | | 18.69 | | | 4.39 |
| Ware potato yield (t/ha) | | | 10.95 | | | 9.61 |
| Market price of seed (US $ per t) | | | 285.00 | | | 285.00 |
| Market price of ware (US $ per t) | | | 213.00 | | | 213.00 |
| Gross income | | | 7,660.00 | | | 3,296.00 |
| Net income | | | 4,774.00 | | | 1,750.00 |
| Cost of production/t | | | 97.35 | | | 110.50 |
| Benefit cost ratio | | | 2.65 | | | 2.13 |
| Total labour days (No.) | | | 127.33 | | | 105.50 |

Note: Figures in the parenthesis indicate % to gross cost of cultivation; One US $=52 Afs in 2012.

**Table 2. Material costs for participating and non-participating farmers in quantity and value terms (per ha).**

| Materials | Participating farmers | | | | Non-participating farmers | | | |
|---|---|---|---|---|---|---|---|---|
| | Quantity/ ha (kg/No.) | Std. deviation | Value/ ha (US $) | Std. deviation | Quantity/ ha (kg/ No.) | Std. deviation | Value/ ha (US $) | Std. deviation |
| Seed | 3250 | 0.00 | 1342.25 | 0 | 2176 | 302.89 | 577.87 | 4728.57 |
| Urea | 250 | 0.00 | 100.00 | 0 | 250 | 0.00 | 98.40 | 98.79 |
| DAP | 250 | 0.00 | 196.00 | 0 | 250 | 0.00 | 193.53 | 166.99 |
| Plant protection chemicals | na | na | 48.00 | 0 | na | na | 2.80 | na |
| Gunny bags | 1247 | 215.20 | 398.89 | 3443.18 | 280 | 37.34 | 88.44 | 864.17 |
| Total material costs | | | 2085.14 | | | | 961.04 | |

to 50% of production costs[5]. Seed rate used by the participating farmers was as per the recommendation (3.25 t/ha) while the non-participating farmers were using less seed rate due to lack of knowledge on scientific cultivation practices which also contributed in less yield (2.17 t/ha). There was no difference in the fertilizers (time of application and quantity) applied between the groups. However there existed a difference in the cost of fertilizers used by both the groups. The project provided the inputs to participating farmers where as non-participating farmers purchased the inputs on their own. The quality of fertilizers applied by the non-participating farmers might also have played role in the yield differences between both the groups.

In Afghanistan where no formal seed supply system exists, farmers have devised their own *ad hoc* method for selecting seed tubers: they sell the largest potatoes for cash, eat the medium-sized ones at home, and keep the smallest as future planting material[6]. This practice resulted in poor per ha yield of potato crop. As a result of participation in the training programmes on production and marketing seed potato and field days the knowledge in the scientific cultivation and grading of potato into seed and ware categories improved that is reflected in the increased ratio of seed and ware potato produced from 31:69 to 63:37 in case of participating farmers. Further, a yield difference of 15.64 t/ha was also realised by the participating farmers over non-participating farmers. A net income difference of US $ 3,024/ ha was recorded between the two groups due to high seed yield for participating farmers and seed potato prices. It is evident that cultivation of potato using improved variety and associated practices resulted in the low per tonne cost of production (US $ 97.35) compared to local varieties and traditional practices (US $ 110.50). Kumar *et al*., (2000) in their study on economics of seed potato production in Western Uttar Pradesh found the viability of seed potato production enterprise since benefit-cost ratio in seed potato production was 1.25 on non-certified seed potato farms and 1.29 on certified seed potato farms while *Uddin et al.,* (2010) reported a benefit cost ratio of 1.37 for potato in Bangladesh. Thus, in spite of additional cost due to adoption of the introduced technology, high net income from its adoption is worth mentioning.

[5]http://www.potato2008.org/en/potato/cultivation.html.
[6]http://www.agriculturedictionary.com/definition/ware-potatoes.html.

A total of 127.33 labour days (family and hired labour)[7] were used by the participating farmers compared to 105.50 labour days by the non-participating farmers. Thus the intervention increased employment opportunities to the tune of 21.83 labour days per ha on operations such as rouging, application of insecticides and irrigation in potato cultivation which resulted in high (seed and ware) potato yield, over non-participating farmers. Such employment generating livelihood options are the present need of the hour in Afghanistan to effectively engage the returning refugees in productive activities.

## Technical efficiency of farmers

Mean of the labour and material costs in the sample farms is presented in **Table 3**. Production elasticities of potato cultivation in Baharak district estimated by Cobb-Douglas production function are presented in **Table 4**. When gross income was regressed with expenditure on seed, fertiliser and labour, the fit was found to be significant and expenditure on seed and fertilizers showed positive and significant influence.

The estimates of technical efficiency (**Table 5**) indicated a high degree of inefficiency in the production of potato in Badakhshan province. The stochastic frontier estimates of technical inefficiency was worked out to be 76% indicating that there is scope for farmers to increase the potato production by 76% by way of realizing technical efficiency. It further showed that 87% of observed inefficiency was due to farmer's inefficiency in decision making and 13% of it was due to random factors outside their control.

In **Table 5**, $\lambda$ measures the degree of asymmetry in the distribution of the composite error term ($E_i=v_i-u_i$). The value of $\lambda$ was more than one implying the dominance of one-sided component $u_i$ in $E_i$ and thus indicated high degree of technical inefficiency. In other words, inefficiency component was not dominated by the random factors outside the control of farm.

The mean of one-sided E (u) implied the percentage of output on an average, below the frontier which turned out to be 19%. The discrepancy parameter ($\theta$) explained that 87% inefficiency was due to the factors which were under farmer's control.

**Table 3. Mean values of socio-economic variables and cost of labour and material inputs used in the potato cultivation.**

| Parameter | Mean values | | |
|---|---|---|---|
| | Participating | Non-participating | All |
| Gross income (US $) | 7,660.00 | 3,296.00 | 5,532.00 |
| Labour cost (US $) | 587.00 | 471.00 | 514.00 |
| Material cost (US $) | 2,085.00 | 961.00 | 1,523.00 |
| Age of farmer (years) | 48.27 | 43.23 | 45.80 |
| Distance from market (km) | 2.60 | 2.60 | 2.60 |
| Trainings attended (No.) | 1.97 | 0.43 | 1.20 |
| Family labour participation (No.) | 2.10 | 2.80 | 2.50 |
| Area under potato (ha) | 0.10 | 0.17 | 0.13 |
| Owned area (ha) | 1.27 | 1.26 | 1.30 |

[7]Family labour measured as the total number of worker days (8 hrs) that family members work in the farm; hired labour measured as the amount paid to hired workers (ware-potatoes.html).

**Table 4. Production elasticities of potato cultivation in Baharak district (Cobb-Douglas Production function).**

| Variable | Regression coefficients (bi) | Standard error |
|---|---|---|
| Constant | -32.845* | 15.677 |
| Labour costs | 0.020 | 0.088 |
| Seed costs | 0.887*** | 0.082 |
| Fertilizer costs | 6.195* | 2.789 |
| Adjusted $R^2$ | | 0.77 |
| F | | 67.951** |

Note: ***indicates significance at one percent probability level; * indicates significance at five percent probability level.

**Table 5. Maximum Likelihood estimates of stochastic frontier production function.**

| Parameters | Estimates |
|---|---|
| Material cost | 1.2733*** (0.1284) |
| Labour cost | -0.0808 (0.0700) |
| Log Likelihood | 7.8878 |
| Sigma-squared (v) | 0.0134 |
| Sigma-squared (u) | 0.0963 |
| λ | 2.6800 |
| E(u) | -0.1946 |
| Var (u) | 0.0963 |
| Discrepancy parameter (θ) | 0.8778 |
| Mean Technical Efficiency | 0.2385 |

Note: Figures in the parentheses indicate the standard error.
*** Significant at one per cent probability level.

Technical efficiency of seed potato farmers (participating and non-participating) presented in **Table 6** indicated that the technical efficiency was very low as only 16% of sample farms could realize more than 40% efficiency while 84% of sample farms realized less than 40% efficiency level. Only seven per cent of sample farmers (participating) were in the efficiency level of above 60%. The mean TE is 24% suggesting considerable inefficiency levels among the sample potato farmers. This indicates that lot of scope exists for improving their efficiency.

## Determinants of technical efficiency

Among the determinants included in the model, only distance from market was found to be influencing the technical efficiency for participating potato farms and for all potato farms (**Table 7**) while none of the other determinants considered in the analysis were found significant. Adoption of any new production technology that involves additional inputs depends on the distance of the village from the input/output markets. Therefore farmers who are situated closer to markets are likely to adopt any new technology which in turn improves their technical efficiency. Lyubov and Jensen (1998) confirmed that distance from a farm location to the nearest city (market) is a determinant of the technical efficiency of grain producers in Ukraine. Bhasin (2002) noted that for pepper growers, technical efficiency decreases only as distance

**Table 6. Frequency distribution of technical efficiency of potato farmers.**

| Efficiency range | Number of farmers | % |
|---|---|---|
| <0.20 | 30 | 50 |
| 0.20-0.40 | 20 | 34 |
| 0.40-0.60 | 8 | 13 |
| >0.60 | 2 | 3 |
| Total farmers | 60 | 100 |
| Mean efficiency | 0.24 | |
| Minimum technical efficiency | 0.0528 | |
| Maximum technical efficiency | 0.6402 | |
| Std. deviation of technical efficiency | 0.1427 | |

**Table 7. Determinants of technical efficiency of seed potato farmers in Afghanistan.**

| Determinants | Potato farmers | | | | | |
|---|---|---|---|---|---|---|
| | Participating | | Non-participating | | All | |
| | Coefficients | Std. error | Coefficients | Std. error | Coefficients | Std. error |
| Constant | -0.1434 | 0.2024 | 0.2430 | 0.1329 | 0.1699 | 0.1123 |
| Age of farmer | 0.0037 | 0.0028 | 0.0025 | 0.0029 | 0.0025 | 0.0022 |
| Farmer's education | 0.0481 | 0.0552 | -0.0851 | 0.0662 | -0.0020 | 0.0428 |
| Distance from market | 0.0503*** | 0.0179 | -0.0111 | 0.0155 | 0.0205* | 0.0124 |
| Trainings attended | 0.0300 | 0.0110 | -0.0025 | 0.0114 | -0.0077 | 0.0080 |
| Participation in the intervention dummy | - | - | - | - | 0.0072 | 0.0822 |
| Area under potato | - | - | - | - | -0.3741 | 0.3717 |
| Family labour participation (No.) | - | - | - | - | 0.0014 | 0.0171 |
| $R^2$ | | 0.31 | | 0.11 | | 0.11 |
| F | | 2.80** | | 0.80 | | 0.97 |

Note: *** Significant at one per cent probability level; ** Significant at five per cent probability level; * Significant at ten per cent probability level.

to market increases. Hine and Ellis (2001) reported a general tendency for heavier crops (such as tubers) to be grown only around the farmstead and collection points.

Dummy on the participation of the potato farms in the ICARDA-CIP intervention though not significant, was found to be positively influencing the technical efficiency of potato farms.

Though not significant, scientific knowledge imparted through trainings given to the participating farmers was found to be positively influencing the technical efficiency. Similar results were reported by Kalirajan and Shand (1985) in their study that education and training have a strong and positive relationship with TE, especially among low-income farmers. No or less number of schooling years of non-participating farmers resulted in negative but non-significant influence of education on technical efficiency. Stefanou and Saxena (1988) found that education and experience have significant positive effects on the level of efficiency. As the education level of farmers is very poor and the knowledge gained by participating in the trainings imparted by the intervention is likely to take some more years

to reflect its impact in improving the TE of farmers, participation dummy showed only positive but not significant influence on the technical efficiency. Lack of education and non-participation in the trainings resulted in decrease in the technical efficiency of non-participating farmers. Pandit *et al*., (2007) suggested that farmers' efficiency can be improved by strengthening their knowledge of scientific potato production practices through capacity building and extension efforts.

## CONCLUSIONS

The study indicated that there is a large scope to improve the potato productivity in Baharak district through enhancement of technical efficiency without significant increase in the quantity of inputs. Improvement in the knowledge on scientific cultivation of potato growers through their participation in field days, trainings and contacts with extension workers can help achieving still higher productivity through correct adoption of the recommended production technologies and thereby high gross income as evident from the determinants of technical efficiency. Lack of knowledge, unavailability and high price of quality seed material limit the adoption and spread of technologies on high yielding varieties and their cultivation practices. It is therefore necessary to develop a sustainable supply chain for quality seed potato to farmers at affordable prices and capacity building of extension and agriculture officials in the Ministry of Agriculture, Irrigation and Livestock (MAIL). The production and multiplication of disease-free seed potato is found economical and feasible to the farmers and the benefit cost ratio of 2.65 can easily convince/induce non-participating farmers to start producing healthy potato seed. Thus the participating farmers can be the future source of quality potato seed for the district as well as for the province.

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