Technical Efficiency in Potato Cultivation in Eastern Himalayas: A Case Study of Arunachal Pradesh, India

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Abstract

This paper analyses the level of technical efficiency in potato (Solanum Tuberosum) cultivation and factors determining it in Arunachal Pradesh, a hilly State of India, situated in the eastern Himalayan ranges. The study was mainly based on household level cross-sectional data collected from 138 randomly selected potato growers. Technical efficiency ratios were obtained by applying the stochastic frontier Cobb-Douglas production function. The logit transformation model was applied to examine the determinants of technical efficiency. The analysis was done in STATA. The mean yield of potato among the surveyed farmers was 7344 kg per hectare which was marginally higher than the average yield of the State (7200 kg in 2015-16). The significant factors which were determining the potato yield was plant nutrient, mainly fertilizer. The average level of technical efficiency among the sample farmers was 88% which indicated that output can be raised by 12% through better use of existing level of inputs and technology. A high proportion of the farmers (92.76%) were having technical efficiency of 80% and above. Marginal farms were more efficient than the small farms. Land size was found to be negatively influencing the technical efficiency and it was statistically significant. The variables family labour, education and experience were found to be positively influencing the level of technical efficiency. The findings of the study imply that the State should focus on encouraging the use of modern inputs like improved seeds, plant nutrients and build up irrigation facilities to raise yield rate. It should also emphasis on providing training and disseminating knowledge to farmers for enhancing the level of technical efficiency.

Keywords: *Potato, yield rate, technical efficiency, stochastic frontier production function*

I. INTRODUCTION

Potato (*Solanum Tuberosum*) is one of most important crops in the world. It is considered as the most important crop after wheat, rice and maize. Potato is a temperate crop and grows well in temperature between 15^0 Celsius to 21^0Celsius. It is best known for its carbohydrate content (Ghose, 2019). It contains starch (16.1 g/100 g), protein (2.1 g/ 100 g), vitamin C (17.1 g/ 100 g), potassium (443 mg/ 100 g), vitamin C and amino acids (Bajracharya and Sapkota, 2017). It contributes to nutritional security, address food insecurity and reduce poverty among the small holder farmers in developing countries. The potential of potato to provide food security has led to remarkable growth in its production in China, the world's largest producer of potato (Su and Wang, 2019). It is preferred by the farmers for its adaptability, stable yield and high demand. Potato is also more productive and profitable than the cereal crops. It is cultivated by farmers both for self consumption and sale in the market for cash income. It is known as the king of vegetables for its popularity and high use in the households across the world (Lama and Rimjim, 2017). It is also highly demanded as an input for producing chips and fries in food processing industries. Thus, it has the potential to contribute to farm household income and reduce poverty in developing countries.

Potato is an important crop grown in India. It occupies an important place in the cropping pattern of the country. It is a temperate crop grown in most parts of the country during winter. The area and production of potato in the country has been growing over the years. In fact, India is the second largest producer of potato in the world. The area under potato in the country has increased from 1.22 million hectares in 2000-01 to 2.18 million hectares in 2016-17. During the same period, production of potato has increased from 22.49 million tonnes to 48.6 million tonnes (Agriculture Statistics at a Glance, 2018). The compound annual growth rates (CAGR) of area, production and yield of potato in the country during 2000-01 to 2016-17 were 3.47%, 4.63% and 1.14% respectively. The increase in production was largely contributed by area expansion as the yield rate grew at low rate.The slow growth in yield rate is a matter of concern as the yield rate of potato in the country is relatively low compared to the other countries. In 2016-17, the yield rate of potato in India was 223

quintals per hectare which was lower than that in other countries.

Potato is widely grown in all the States of India. It is also luxuriantly cultivated in north eastern region of India which comprises of eight States namely, Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. The region accounts for around 10% of the total area under potato in the country (Rimjim and Lama, 2020). The yield of potato in the region as a whole was very poor but the crop was found to be remunerative with more than 97% of the total produce being marketed (Pandit *et. al.* 2006). Potato is one of the major crops grown in Arunachal Pradesh, a hilly State of the region. It is cultivated as an off-season vegetable during February to June for home consumption as well as for market. However, the productivity of potato in the State is relatively low. For instance, in 2015-16, the productivity of potato in the State was 72 quintals per hectare which was only 35% of the national average (GoAP, 2016). The low productivity in the State can be attributed to low level of technology adoption and poor irrigation facilities. The area under irrigation facility is only 26.55 per cent of the gross cropped area (Agricultural Census, 2011-12). The low level of technology adoption is mainly due to low income, low literacy rate of farmers and conservatism. Since the adoption of new technology depends on a number of socio-economic and institutional factors which may take time to change, the productivity of crops can be raised by improving the production efficiency. Hence, it there is a need to focus on improving technical efficiency to increase output.

Technical efficiency is defined as the ration of actual output to potential output. It measures the extent of deviation of actual output from the potential output. It, thus, shows the possibility of increasing the output with the same amount of resources. It is an important indicator of efficient use of resources in agriculture. Several studies have reported that there is a scope to increase crop output in developing countries by improving technical efficiency. For example, Bogale *et. al.* (2005) examined the technical efficiency of farmers in the production of irrigated potato under two schemes in four districts of Awizone, Ethiopia by applying the stochastic frontier production function. The mean level of technical efficiency was found to be 77% for modern scheme and 97% for traditional scheme. The study showed that productivity under modern schemes could be raised by improving technical efficiency. Shanmugam *et.al.* (2006) estimated the technical efficiency of agricultural production as a whole at various districts of India. The study observed that, due to the lack of production efficiency, the agricultural production of India was relatively very low in comparison to international level. Pandit *et.al.* (2007) estimated the technical efficiency of the potato growers of Barpeta District of Assam by applying the data envelopment analysis. The overall technical efficiency of the potato growers was estimated at 78 percent. The study suggested providing irrigation facilities, marketing infrastructure, good quality seed and scientific knowledge to the potato growers to reduce technical inefficiency. Hossain *et. al.* (2008) measured the technical efficiency of potato production in Bangladesh by applying Cobb-Douglas production function. The average level of technical efficiency among the sample farmers was 75%. The important determinants of technical efficiency were training on the potato production, extension linkage and quality of seed. Sharma *et. al.* (2008) used frontier production function to measure resource use and technical efficiency of Himachal farmers. The study revealed that considerable potential output of cereal crops was untapped due to technical inefficiency. Nelson *et. al.* (2015) found that the variables gender, household size, frequency of extension visits, farm size and farming region were significant determinants of technical efficiency of Maize production in Zimbabwe's smallholder farming communities. Lama (2017) reported resource use efficiency in production of selected crops in Arunachal Pradesh to be inefficient. Dube *et. al.* (2018) analysed the technical efficiency and profitability of potato production by smallholder farmers in Bale zone, Ethiopia by using stochastic frontier approach. The study found potato production to be profitable with mean technical efficiency of 89%. Welda (2020) analysed the technical efficiency of small holder oil palm farmers in west Sumatra by applying the Cobb-Douglas stochastic frontier production function. They found the mean technical efficiency of farmers to be 0.73 with individual farmers to be more efficient than partnership farmers.

The literature shows that there is a dearth of study on measures of technical efficiency in potato cultivation in North East India, particularly in Arunachal Pradesh. In this background, this paper is an attempt to examine technical efficiency and its determinants in potato cultivation in Arunachal Pradesh, a hilly State of India. The study was conducted with the following objectives. To analyse the trend and growth in area, production and yield of potato, to examine the productivity of potato and factors influencing it and to measure the level of technical efficiency in potato cultivation and its determinants.

II. The Study Area

Arunachal Pradesh is situated in the Eastern Himalayan ranges between latitude 26^0 28′ N and 29^0 33′ N and longitude 91^0 31′ E and 97^0 30′ E. The State is divided into 25 administrative districts. The study was conducted in two hilly districts of Arunachal Pradesh, namely West Kameng and Tawang. These districts are located in the north western corner of the States and share international

boundary with China and Bhutan. The entire region is hilly and mountainous with elevation ranging from 213 metres to 4114 metres above mean sea level. The agro-climatic conditions and main crops grown in these districts are given in table I.

Table I
Agro-climatic condition and main crops grown

District	Area under potato (% of GCA)	Potato yield (kg/hectare)	Irrigated area (% of GCA)	Mean Rainfall (mm)	Temperature (C)	Main crops
West Kameng	5.06	7962	4.46	1704	- 3 to 30	maize, millet, paddy, wheat, pulses, potato
Tawang	8.78	9976	7.07	915	-5 to 18	millet, wheat, paddy, maize, potato, pulses

Source: kvk.gov.in

It has four major agro- climatic zones; alpine, temperate sub-alpine, subtropical hill and mild tropical hill. The soil type of the district varies from rocky to loamy, clay and sandy loam. On the other hand, Tawang district falls under alpine agro-climate zone. Its soil type is rocky and loamy skeletal texture with depth shallow to medium (kvktawang.gov.in).

These districts are spread over an area of 7422 sq. km and 2172 sq. km respectively and jointly account for 11.45% of the total geographical area of the State. As per the population census 2011, West Kameng and Tawang districts have total population of 87,013 persons and 49,950 persons respectively. Both the districts are sparsely populated with density of only 12 persons and 23 persons per sq. km respectively. The districts, together, accounted for 9.91% of the State's total population. In these districts, about 80% of the people live in rural area and rely on agriculture for their livelihood. The main inhabitants of Tawang are *Monpa* tribe and those of West Kameng are *Monpa, Sherdukpen, Aka, Miji, Bugun and Sartang* tribes which belong to Mongoloid stock. The important crops grown in the area are; paddy, wheat, maize, millet, potato and off-season vegetable crops. Potato cultivation is concentrated in these districts as they account for about 20% of total area under potato in the State (GoAP, 2018). Potato is used both as a staple food and a vegetable. The arable land is quite limited due to hilly and mountainous topography. The terrace cultivation, which is a distinguish feature of hill agriculture, is widely practice in these districts to overcome natural constraints. The level of adoption of new technology is very low. Hence, there is a need to improve productive efficiency through better farm management to raise crop productivity.

III. Materials and Method

A. Data and Sampling

The study is based on both primary and secondary data. The secondary data were collected from the Agricultural Statistics, Ministry of Agriculture, Government of India and Statistical Abstract of Arunachal Pradesh, Government of Arunachal Pradesh. The primary data were collected by conducting field survey in the study area during 2016-17. The survey was based on multi-stage random sampling technique. In the first stage, two hilly districts of the State namely, West Kameng and Tawang were selected. In the second stage, from each district, two blocks were selected on the basis of their distance from district headquarter. From each block, two villages were selected considering their distances from the block headquarter. Finally, random sampling technique was applied to select the farming household for collection of data. The required information was collected from the sample of farmers with the help of structured questionnaire. The questionnaire was designed to collect information related to socio-economic characteristics, area sown and quantity of various inputs (like human labour, seed, fertilizer, manure etc.) used in potato cultivation as well as output of crop. The study adopted personal interview method to collect the data from the farmers. During the interview, sufficient time was given to the respondents. Each interview lasted for 20-25 minutes. The sample size was 138 farmers.

B. Analytical Technique

Technical efficiency (TE)is an important measure of overall resource use efficiency of a farm/firm (Kundu, 2012). The concept of technical efficiency was first proposed by Farell (1957) when he introduced the frontier production function to measure the efficiency of a productive unit. It is defined as the ration of the actual output to the potential output. It measures the maximum output that can be produced with the existing resources. Thus, if the actual output is below the potential (frontier) output, then there is a technical inefficiency indicating that there is scope to increase output with the same inputs through reallocation.

$$TE = \frac{Actual\ output}{Potential\ output}$$

The Stochastic Frontier Approach (SFA) developed by Aigner, Lovell and Schmidt (1977) was used to

estimate the technical efficiency, assuming given technology and prices. The estimation was done by taking the Cobb-Douglas production function. In the Stochastic frontier, the disturbance term consists of two components, one component representing technical inefficiency and the other representing the usual random noise. The actual production function can be written as;

$$Y_i = f(X_i;\beta) \exp(-u_i) \text{ and } 0 < u_i < \infty ; \quad I = 1,2\ldots,n \text{---------- (1)}$$

Where Y_i = Actual output for the i^{th} sample unit; X_i = Vector of inputs used by the farm; β is the vector of parameters that describe the transformation process and u_i is a residual term that captures the effect of inefficiency. If the production unit is inefficient, then its actual output is less than the potential output (Shanmugam and Venkataramani, 2006). Thus, by using equation (1), we can write the measure of the technical efficiency (TE) of the production units as below:

$$TE = Y_i / f(X_i;\beta) = \exp(-u_i)$$
---------- (2)

Thus, if TE is less than one, the actual output is lower than that of potential output and vice versa. Again u_i is zero if the production unit produces the potential output. In order to capture the effect of other omitted variables that can influence the output, a random noise variable v_i is included in the equation (1) i.e.

$$Yi = f(Xi; \beta) \exp(v_i - u_i) \text{ ---------- (3)}$$

Where v_i represents a random noise variable which is assumed to be independently and normally distributed. The parameters of the stochastic frontier production were estimated by using the maximum Likelihood method with the help of software *STATA*.

IV. AREA, PRODUCTION AND YIELD OF POTATO

The analysis of area, production and yield of potato in major potato producing States in India was done to assess the contribution of different States in area and production of potato in the country. The analysis showed that Uttar Pradesh is the largest producer of potato in the country followed by West Bengal and Bihar. In 2016-17, these States together accounted for 67.84% of total potato production and 62.26% of the total area under potato in the country. The details are given in table II.

The yield rate of potato was the highest in Gujarat (309.95 quintals/hectare). Its yield rate was 138.97% of the national average yield rate of 223 quintals per hectare. Among the top potato producing States, the yield rate was the lowest in Assam (73.08 quintals/hectare). Its yield rate was only 32.77% of the national average. The analysis shows a wide inter-State variation in yield rate of potato which can be ascribed to different level of technology adoption.

The trend in area, production and yield of potato in Arunachal Pradesh showed that the State there has been increase in area and production of potato (Table III). The area under potato in the State has increased from 4335 hectares in 2002-03 to 5985 hectares in 2015-16. During this period compound annual growth rate in area under potato was 2.33% which shows that the potato is gaining importance in the cropping pattern of the State. During the same period, the production of potato in the State increased from 30.18 thousand tonnes in 2002-03 to 43.09 thousand tonnes in 2015-16. During this period, the production of potato in the State grew at CAGR of 2.57%. The increase in production was mainly contributed y area expansion as the yield rate of potato grew at slow pace.

Table II
Area, Production and Yield of Potato in Major Producing States of India in 2016-17

States	Area (in '000 hect.)	% to all India	Production (in 000 tonnes)	% to all India	Yield (in quintals/hect.)	Yield Index
Uttar Pradesh	614.35	28.19	15543	31.98	253	113.44
West Bengal	422	19.36	11052.6	22.74	261.91	117.43
Bihar	320.5	14.71	6377.71	13.12	199	89.23
Gujarat	122.53	5.62	3797.82	7.81	309.95	138.97
Madhya Pradesh	162.27	7.45	3461.09	7.12	213.3	95.64
Punjab	97.57	4.48	2423	4.99	248.34	111.35
Haryana	34.53	1.58	896.95	1.85	259.77	116.47
Assam	106.44	4.88	777.83	1.6	73.08	32.77
Chhattisgarh	44.08	2.02	678.57	1.4	153.94	69.02
Jharkhand	52.73	2.42	668.66	1.38	126.81	56.86
Others	202.28	9.28	2927.35	6.02	144.72	64.89
All India	2179.25	100	48604.57	100	223.03	100

Source: Source: Agricultural Statistics at a Glance, 2018

Table III
Trend in Area, Production and Yield of Potato in Arunachal Pradesh

Year	Area (in hectares)	Production (in tonnes)	Yield (in quintals/hectare)
2002-03	4335	30183	69.63
2003-04	4022	29569	73.52
2004-05	3917	27538	65.3
2005-06	3963	29838	75.29
2006-07	3965	31689	79.92
2007-08	3843	29173	75.91
2008-09	4063	33405	82.22
2009-10	4235	36089	86.1
2010-11	4334	35832	82.67
2011-12	4600	40000	86.95
2012-13	4817	38872	80.7
2013-14	4933	40664	82.4
2014-15	5090	42000	82.5
2015-16	5985	43092	72
CAGR (%)	2.33	2.57	0.24

Source: Statistical Abstract of Arunachal Pradesh (2002-2016)

The yield rate of potato in the State improved marginally from 69.63 quintals per hectare in 2002-03 to a peak level of 86.50 per hectare in 2011-12. However, thereafter the yield rate of potato in the State witnessed a declining trend. The yield rate declined to 72 quintals per hectare in 2015-16 which was only 35% of the national average yield rate. During the period under review, the yield rate of potato in the State grew at CAGR of only 0.24% (Figure 1).

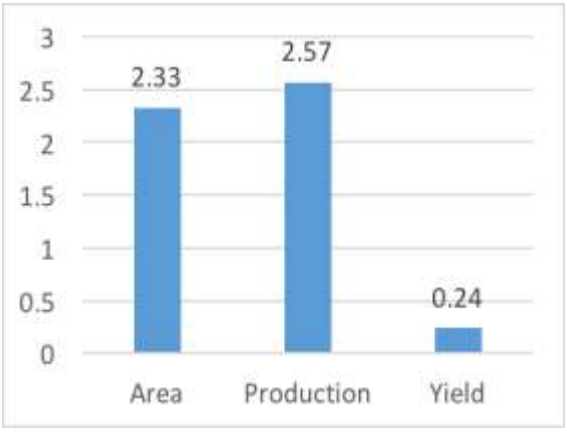

Figure 1: CAGR in area, production and yield of potato in Arunachal Pradesh (2002-03 to 2015-16).

The slow growth in yield rate of potato in the State can be attributed poor irrigation facility, low level of technology adoption (which is due to lack of awareness) and poor extension services. The use of HYV seeds and plants nutrients was found to be very low in the study area.

V. RESULTS AND DISCUSSION

A. Socio-economic Profile of Farmers

The socio-economic characteristics of farmers such as household size, ratio of working to non-working members, education level, size of land holdings etc. influence the production decision of farming households relating to allocation of acreage to different crops, amount of labour to be committed to farm work and leisure, hiring-in and hiring-out of labour and so on. It also determines the efficiency in use of resources. Thorner *et. al.*, (1966) argued that the amount of labour time devoted to farm work was directly related to the ratio of working members to total consumers in the households.

Table IV
Socio-economic Characteristics of Surveyed Farmer

Particulars	Percentage of respondent
Age (in years)	
25-38	21.7
38-51	40.6
51-64	28.3
64-77	9.4
Education level	
Illiterate	77
Literate	23
Household size	
Less than 5	
5 to 9	63.04
More than 9	3.62
Size of holding	
Marginal (less than 1 hectare)	2.17
Small (1-1.99 hectares)	36.23
Semi-medium (2-3.99 hectares)	47.83
Medium (4-9.99 hectares)	13.04
Large (10 hectares and above)	0.72

Source: Field Survey, 2016-17

The size of holdings also influences the use of labour. The farmers with small size of holdings would use labour until its marginal productivity becomes zero.

The socio-economic characteristics of the surveyed farm households are given in the table IV.

The table IV shows that most of the farmers (40.6%) were in the middle age group of 38-51 years. The mean age of the respondents was estimated to be 47 years. Educational level of the surveyed respondent farmers indicated that majority of them were illiterate (77%). The household size of majority of farmers (64.04%) was 5 to 9 persons. The mean household size was 5.28 persons. Most of the farmers had medium size household (63%). Land holdings pattern showed that most of the farmers had semi-medium size and small size of land holdings. The mean size of land holding of the sample farmers was 2.35 hectares with standard deviation of 1.48. The low size of land holding can be attributed to hilly and difficult terrains which have limited the cultivable land in the State.

B. Productivity and Technical Efficiency

The productivity (yield rate) of potato among the farmers varied from 32 quintals to 140 quintals per hectare. The average yield of potato among the farmers was 73.44 quintals per hectare. The yield of potato by farm size showed that marginal holding had higher yield (74 quintals per hectare) than the small holding (59 quintals per hectare). The mean yield of potato among the surveyed farmers of West Kameng and Tawang districts were 85 quintals per hectare and 67 quintals per hectare respectively. The yield of a crop depends on a number of factors. In this study, the productivity of potato was taken to be a function of seed, human labour, fertilizer (proxy of technology adoption) and manure. The relationship between inputs and output and technical efficiency was estimate by applying the stochastic production function assuming Cobb-Douglas production function. The descriptive statistics of the variables are presented in table V.

Table V
Descriptive Statistics of the Variables

Variables	Mean	Std. Deviation	Min.	Max.
Output (in kg/hectare)	7344	238.46	3200	14000
Seed (in kg/hectare)	656	42.21	240	1600
Fertilizer (in kg/hectare)	94	18.34	4	200
Human labour (in man days/hectare)	280	17.92	192	464
Manure (in kg/hectare)	192	29.31	448	1200

Source: Field Survey, 2016-17

The result of the analysis is presented in table VI. The model was found to be fit as indicated by the highly significant Wald Chi^2. The result showed that among the included variables, only fertilizer was significant at 0.01 level. The coefficient of fertilizer was positive which indicated that potato output is elastic to fertilizer. The variables seed and human labour also had positive influence on potato output but these variables were not significant at any level. The variable manure had negative sign but it was also not significant at any level.

Table VI
Result of the Stochastic Cobb-Douglas Frontier Production Function

Log Likelihood = 33.94 Wald Chi2= 104.17
Prob>Chi2 = 0.00

Variables	Coefficient	Std. Err.	t-value	p-value
Seed	0.0186	0.0354	0.53	0.599
Labour	0.0974	0.0672	-1.45	0.15
Fertiliser	0.111*	0.0148	7.71	0.001
Manure	-0.0077	0.01407	-0.55	0.58
Constant	6.9699	0.29518	23.61	0.002
sigma u	0.1627			
sigma v	0.1621			
lambda	1.004			

The technical efficiency in potato cultivation among the sampled farmers varied from 68.28% to 95.28%. The mean technical efficiency was found to be 88.25% which indicated that output of potato can be increased by 12% with the same resources through reallocation of resources (Table VII).

Table VII
Mean Level of Technical Efficiency by Size of Land

Size group	Mean TE (%)	Min	Max	Std.
Marginal	88.49	66.28	96.38	4.25
Small	82.03	74.05	88.09	5.1
All farms	88.25	68.28	95.58	4.43

Source: Field Survey, 2016-17

The analysis of technical efficiency by size of land holdings indicated that the technical efficiency was higher in marginal holding (88.49%) than the small holding (82.03%). This could be due to the fact that smaller land size can be better managed than the larger one.

The distribution of farmers by size of holding and technical efficiency revealed that 48.12% of the marginal farmers had technical efficiency of 80-90% and 45.11% of such farmers had technical efficiency of 90 and above (Table VIII).

Table VIII
Distribution of Farms by Technical Efficiency (in Percentage)

TE level (%)	Marginal	Small	All holdings
60-70	0.75	0	0.72
70-80	6.02	20	6.52
80-90	48.12	80	49.28
90 and above	45.11	0	43.48
Total	133 (100)	5 (100)	138 (100)

Source; Field Survey, 2016-17

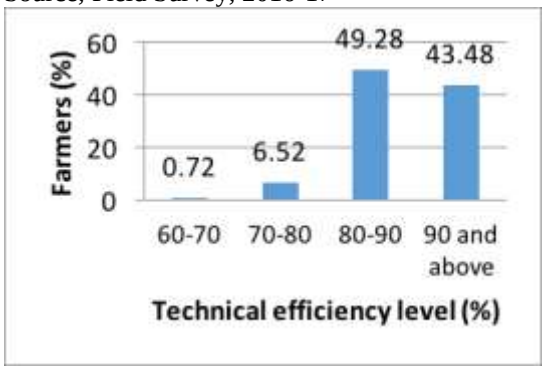

Figure 2: Distribution of farmers by the level of technical efficiency.

It was found that 80% of the small farmers had technical efficiency of 80-90% and 20% of them had technical efficiency of 70-80%.

The distribution of farmers by level of technical efficiency showed that 49.28% had technical efficiency in between 80-90% and 43.48% of them had technical efficiency of 90% and above (Figure 2). Only 0.72% of farmers had technical efficiency in the range of 60-70%. The analysis showed that majority of the potato farmers had fairly high level of technical efficiency. The level of technical efficiency by size of farm showed that marginal farms were better than small farms in respect of technical efficiency.

C. Determinants of Technical Efficiency

The study also made an attempt to examine the factors affecting technical efficiency in potato cultivation. The analysis is important to identify the factors which influence technical efficiency. It, thus, helps to focus on improving those factors for realising the potential output and higher yield. The technical efficiency of a farm depends on a number of factors such as socio-economic characteristics and institutional factors. In this study, technical efficiency was taken to be a function of socio-economic variables such as percentage of family labour used, education and experience (age) and institutional factor, that is farm size.

Since the value of technical efficiency (TE) varies between 0 and 1, a linear regression cannot be applied as it would not ensure the predicted value between o and 1. Hence, the logit transformation model was applied to examine the determinants of technical efficiency. The variable (TE) was transformed into a new variable (Y*), where Y* = In (TE/1-TE), so that the estimation of the parameters could be done by using the Ordinary Least Square (OLS) technique (Kundu, 2012).

The model used to identify the determinants of technical efficiency is as follows.

$$Y^* = \alpha + \beta 1FL + \beta 1FS + \beta 1EDU + \beta 1EXP + \varepsilon_i$$

Where, FL is the percentage of family labour in total labour, FS is the farm size, EDU is the education, EXP is the experience in years (age has been taken as a proxy of experience) and district dummy (to capture the influence of agro-climatic condition). The descriptive statistics of the variables are given in table IX.

Table IX
Descriptive Statistics of the Variables

Variables	Mean	Std. deviation	Min	Max.
Family labour (in percentage)	72.56	28.53	12.9	100
Education (0=illiterate, 1=literate)	0.23	0.4235	0	1
Land size (in hectares)	0.41	2.2743	0.06	1.75
Experience (in years)	47	11.7	25	77
District dummy (1=West Kameng, 2=Tawang)	0.34	0.4756	0	1

Source: Field Survey, 2016-17

The result of the regression for determinants of technical efficiency in potato cultivation is presented in table X.

The Breusch-Pegan/Cook-Weisberg test showed that there was a problem of heteroskedasticity. Hence, the regression was run with robust standard error to overcome this problem. The highly significant F-Statistic indicated good fit of the model. The R^2 was found to be low which implies that there are many other factors which influence technical efficiency.

The result of the regression in table X shows that in family labour and education had positive impact on technical efficiency but both the variables were not significant.

Table X
Determinants of Technical Efficiency in Potato Cultivation

Variables	Coefficient	Robust Std. Err.	t-value	p-value
Family labour	0.0017	0.00137	1.23	0.22
Education	0.0035	0.08614	0.04	0.96

Farm size	-0.05*	0.01507	-3.6	0
Experience	0.002	0.00293	0.64	0.52
District dummy	0.044	0.09181	0.48	0.62
Constant	1.96*	0.3116	6.31	0
F-Statistic	5.58*			
R^2	0.15			

The variable farm size was positively affecting the technical efficiency in potato cultivation and it was significant at 0.01 level. This indicated that smaller farms have higher technical efficiency than the larger ones. This could be due to the fact that small farms can be easily managed well by the family labour and allocated resources efficiently. The variable experience had positive impact on technical efficiency but it not significant. The positive sign of the variable indicates that as the experience increases, farmers become more efficient. The coefficient of district dummy was positive but it was also not significant which indicated that there is no evidence of inter-district variation in technical efficiency in potato cultivation.

VI. POLICY IMPLICATIONS

The findings of the study lead to the following policy implications for improving productivity and technical efficiency in hill regions:

1. The policy should focus on encouraging the use of new inputs to improve yield rate of potato in the State. The State should procure and supply modern inputs such as high yielding variety of seeds and plant nutrients to the farmers.
2. The knowledge about the new technology should be disseminated to farmers by strengthening the extension services. Farmers should be encouraged to judiciously use new inputs by providing trainings. At the same time, there is need to promote the use of organic manure such as vermin compost, farm yard manure and cow dung to raise output and protect its environment.
3. The agriculture in the State is mainly dependent on monsoon rainfall which is erratic and uncertain. Hence, the State should invest more resources to strengthen irrigation facilities in all agricultural zones for improving the crop yield. In the hills, where canal is not suitable, drip irrigation lines may be laid as it has the potential to save water and soil nutrients.
4. The technical efficiency analysis showed that there is a scope to raise output by about 12% through better use of existing inputs. Hence, the policy should be designed to enhance farmers' skill and ability through dissemination of skills and knowledge to improve efficiency of farmers for realising higher yield.

VII. CONCLUSION

Potato is widely grown in Indian as well as north eastern region of India. The crop is also grown well in the State of Arunachal Pradesh, where it is used both as a subsidiary and staple food. The yield of potato in the State was much lower than the national average and had been growing at a very slow rate. The relatively low yield rate of potato in the State was due to low level of use of modern inputs, poor irrigation facilities and traditional method of cultivation as well as inefficiency in resource use. The low level of use of modern inputs is attributable to lack of awareness, low income and conservatism of farmers. The mean yield of potato among the surveyed farmers was 73.44 quintals per hectare. The significant factors which were determining the potato yield was plant nutrient, mainly fertilizer. This calls for encouraging use of plant nutrients in adequate quantity along with improved seeds and irrigation for realising better yield. The stochastic frontier production analysis showed that there is a possibility of increasing output by 12% with the existing level of inputs by improving technical efficiency. The average level of technical efficiency among the sampled farmers was 88%. The efficiency level ranged from 68% to 95% among the farmers. A high proportion of the farmers (92.76%) were found to have technical efficiency of 80% and above, which showed that farmers in the hills are considerably efficient in allocation and management of resources. Among the categories of land holdings, marginal farms were found to be more efficient than the small farms. Technical efficiency was found to be negatively influenced by the size of land and it was statistically significant. The variables family labour, education and experience were positively influencing the level of technical efficiency. The findings of the study imply that there is a need to focus on encouraging the use of modern inputs like improved seeds, and plant nutrients to raise the yield rate of potato. It should also emphasis on providing training and education of farmers for better farm management for enhancing the level of technical efficiency and obtain higher yield.

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