Indian Journal of Agricultural Economics 76: 2 (2021):225-244
DOI:10.63040/25827510.2021.02.002

Technical Inefficiency of Maize Farming and Its Determinants in Different Agro-Climatic Regions of Sikkim, India

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ABSTRACT

Using primary data of 200 farm households, the present study aims to examine farm level technical inefficiency of maize farming and its determinants in different agro-climatic regions of Sikkim. In order to check the robustness of results and policy implications thereof both Data Envelopment Analysis (DEA) and Stochastic Frontier Analysis (SFA) are used for measuring technical inefficiency of maize farming in the study area. The results of the analysis indicate that there is substantial scope for enhancing output of maize in the study area by around 40 to 55 per cent through an optimal use of the existing resources. Further, inefficiency is lower among the farmers belonging to Buddhism and those cultivating leased-in land while remoteness from the input market makes them more inefficient. The technical inefficiency was highest among the farmers in tropical agro-climatic region and was lowest among the farmers in temperate agro-climatic region. These results are robust to alternative methodologies and scale assumptions. Given the bottlenecks in the implementation of land reforms in Sikkim some tenancy reforms such as security over land use rights may provide a boost to the tenant cultivators and thereby enhance maize production in the state. The government may also provide incentives to open farm input outlets at the village level which may help the farmers in getting easy and timely access to farm inputs which may help them increase their farm output level.

Keywords: Agro-climatic region, Maize farming, Technical inefficiency.

JEL: Q12, D24

I

INTRODUCTION

Attaining high productivity and efficiency in agriculture is a prime concern of farmers as well as policy makers to meet the rising demand for food and raw materials for industrial needs. Achieving food security for all has become more challenging because of declining average size of agricultural land holding on the one hand, and deterioration of natural resources such as ground water and soil quality resulting from their indiscriminate use on the other. For example, in the process of intensive use of both natural and chemical factors for rice and wheat cultivation the Green Revolution in India has led to serious environmental problems such as reduction in soil fertility, imbalance in nutrient contents of soil, depletion of groundwater, etc. (Bhushan, 2018), all of which has the potential to adversely affect agricultural production. In this context policy decisions should focus on how to increase production from judicious use of the resources at the disposal of the farmers

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The study was carried under the financial support of Sikkim University Research Award, 2017-18.

by enhancing their efficiency and preventing wastage of the resources. Therefore, the study of efficiency in farming has important implications because an improved understanding of the level of productive efficiency of the farmers and the factors that affect it can greatly assist the policy makers so as to obtain the maximum possible output from the efficient use of the available resources and minimising wastage of the same.

The agriculture sector of Sikkim, a hilly state in the north-eastern region of India, is a source of livelihood for more than 64 per cent of its population (IBEF, 2018). During 2017–18 the contribution of agriculture, forestry and fishing to the gross state domestic product (GSDP) of the state was 10.33 per cent at current prices (Government of Sikkim, 2019a). Agricultural land use in the state is strongly influenced by elevation, climate and mountain terrain with nearly 11 per cent of its area being devoted to agriculture out of total geographical area of 7,096 square kilometers (Government of Sikkim, 2014–15). In Sikkim around 91 per cent of the farm households are marginal by the size of land holding (Sharma *et al*., 2016). Maize is the predominant crop of Sikkim sharing 28.44 per cent of gross cropped area (GCA) of the state during 2015-16 followed by other principal cereal crops including paddy, buckwheat, finger millet, barley and wheat (Appendix 1). The importance of maize cultivation in Sikkim can be realised from the fact that it serves as a staple food for the rural population, and as feed and fodder for their animals (Borah *et al*., 2012). Among the farming community maize provides an assurance of food security because of its stated capacity and insurance against crop failure through returns from the intercrops (Basnet *et al*., 2003). Moreover, the demand for maize has been rising in the state with growing population and animal and poultry feed sector besides its use as industrial raw material. However, the productivity of maize has remained low in Sikkim with an average figure of 1674.38 kg/hectare against the national figure of 2385.26 kg/hectare during 2003-04 and 2017-18 (Government of India, 2019a; Government of Sikkim, 2019b). A study by Guha and Ghosh (2017) found that the productivity of maize remained fairly constant across altitudes of Sikkim. Thus, given the limited availability of cultivable land coupled with inaccessibility, fragility and marginality (Subba, 2009) the growing demand for maize in the state is to be met by increasing its output through enhancing the efficiency of the farmers. This is because efficiency improvement is an important determinant of productivity growth, especially in developing agriculture where resources are meagre and opportunities for developing and adopting better technologies are dwindling (Ali and Choudhury, 1990).

The aim of the present study is to measure a particular type of productive inefficiency, namely, technical inefficiency in maize farming in different agro-climatic regions of Sikkim. It further seeks to identify the factors that affect such inefficiency of the farmers so that policy decisions can set right those factors in order to enhance the efficiency of the maize farmers in the study area. More specifically, the principal hypothesis of the study is that status of farm ownership has no association with technical inefficiency of farmers. Since the pioneering work of Aigner *et al*. (1977) and Meeusen and Broeck (1977) the study of technical efficiency of production and its measurement has been a popular area of research and the literature in this area has expanded to include various possible production models and different production systems including agriculture (Bhattacharyya and Mandal, 2016). Bravo-Ureta *et al*. (2007) presents a review of the studies on efficiency of crop growing sector which covers efficiency analysis of various crops such as rice, maize, wheat, potato, cotton and cassava, sugarcane, grains and beans among others. The studies of Kalirajan (1986), Phillips and Marble (1986), Cooke and Sundquist (1989), Kalaitzandonakes and Dunn (1995), Seyoum *et al*. (1998), Paul *et al*. (2004), Liu and Myers (2009), Ogundari *et al*. (2006), Paudel and Matsuoka (2009) Abdulai and Abudulai (2016), Abdulai *et al*. (2017), Zhang *et al*. (2019), Etienne *et al*. (2019) are a few attempts in measuring the efficiency of maize farming. Likewise, some literature on the efficiency of different agricultural and horticultural crops in the plains of India are available by now (Dayal, 1984; Kumar and Mittal, 2006; Coelli and Battese, 1996; Bhende and Kalirajan, 2007, Pradhan and Mukharjee, 2018; Mandal and Maity, 2021). However, there is a research gap in this regard as far as the efficiency of farmers; especially in maize farming in the Eastern Himalayan state of Sikkim is concerned. The novelty of the paper is that it uses a data set that has been collected specially to examine the technical inefficiency of maize farming in Sikkim. This study uses two approaches, viz., Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) to measure technical inefficiency of maize farming and identify its determinants among the sample farms, and check whether the results are robust to these alternative specifications. The results of our analysis indicate that there is substantial scope for enhancing output of maize in the study area by around 40 to 55 per cent through an efficient use of the existing resources. Moreover, the tenant farmers are found to be more efficient than the owner-cultivators, and distance of the farm from the input market reduces efficiency of the farmers. Similarly, the farms located at higher altitude of temperate region are more efficient than those in the lower altitudes of sub-tropical and tropical regions. These results are robust to alternative methodologies used and scale assumptions.

The rest of the paper is organised as follows. Section II gives a description of the study area, data and the sample. Section III discusses the methodology and the empirical models. Section IV reports the results and their discussion while section V concludes along with policy recommendations.

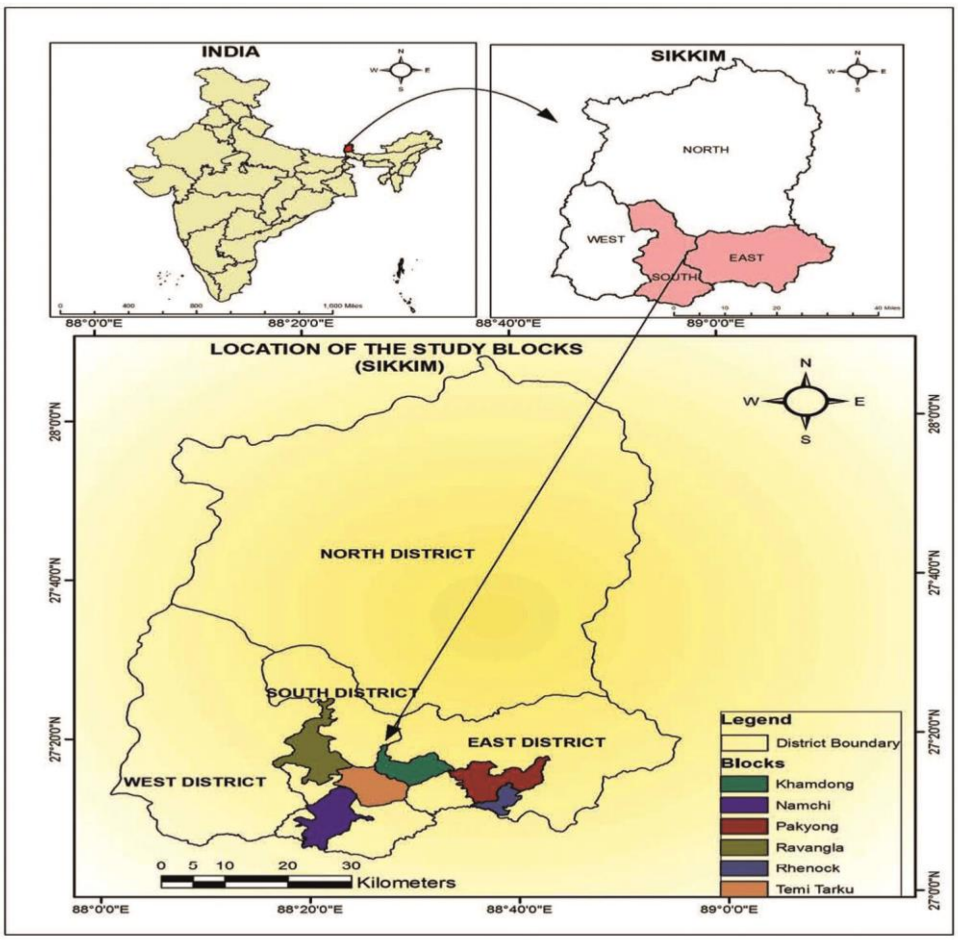
II

STUDY AREA, DATA AND THE SAMPLE

Sikkim is an Eastern Himalayan state of India situated between 27º to 28º North latitudes and 88º to 89º East longitudes. The State occupies a strategic position bordered by Bhutan, Tibet, Nepal and North Bengal. Based on soil and topography the state has been divided into five agro-climatic zones, viz., tropical at elevation level of 610 meters above sea level (MSL) [1]; sub-tropical at elevation level of 610–1524 MSL; temperate at elevation level of 1524–2743 MSL; sub-alpine at elevation level of 2743–3962 MSL; and alpine at elevation level of 3962–8153 MSL (Government of Sikkim, 2014–15). The state has four districts, namely, East Sikkim, West Sikkim, North Sikkim and South Sikkim. Nearly 80 per cent of the rural population of Sikkim depends on agriculture and allied sectors for economic, food, and nutritional security (Government of Sikkim, 2017). Rice, maize, finger millet, pulses, mustard, soyabean are some of the food crops grown in the state, while spice crops such as large cardamom, ginger, turmeric are also grown in the state. Sikkim became the first declared organic agricultural state of the country in 2016. Maize is the predominant crop in the state in terms of acreage share in gross cropped area which has remained the highest among all crops during the 2003–04 to 2015–16 (Appendix 1).

The present study is based on primary data collected from the maize producing farm households using multistage sampling technique during the second half of 2018. Since maize farming in Sikkim is practiced during the *kharif* cropping season, so data on output and farm inputs are collected for the previous farming season (July–October 2017). In the first stage, three agro-climatic regions are selected, viz., tropical, sub-tropical and temperate for their suitability[2] in maize farming. In the next stage two districts, i.e., East Sikkim and South Sikkim are randomly selected[3] that fall in the three agro-climatic regions mentioned (see Figure 1). In the third stage, three development blocks are selected from each sample district. They are Pakyong, Rhenock and Khamdong from East Sikkim district, and Namchi, Ravangla and Temi Tarku from South Sikkim district. In the next stage two villages were randomly selected from each block. Finally 6 –11 per cent of farm households from each village were selected randomly for the primary survey. A total of 200 farm households, thus selected, have been interviewed using a pre-tested question schedule. The survey collected data on output quantities of maize, inputs used in its cultivation, background and other characteristics of the sampled farm households, enabling factors such as distance to input market, and locational characteristics like agro-climatic parameters. The broad field study locations (i.e., development blocks) are shown in Figure 1.

The summary statistics of the variables used in the present study are listed in Table 1. As seen from Table 1 the average sample farm produces 213 kg of maize with 0.22 hectares of land. The point to be noted is that all the sample farms are marginal in size, the highest size being 0.9 hectare. The average quantity of seeds used by a sample farm is 9.28 kg. The average expenditure on wage payment, including imputed wage of family labour, and capital expenditure are INR 2,738 and INR 671 respectively. The low capital expenditure is primarily because of the fact that in the study area the farming activities – from land preparation to harvesting – are usually done manually with traditional methods owing to nearly non-existence of



Source: Rural Management & Development Department, Government of Sikkim (2019c).

Figure 1. Map of Sampled Development Blocks of Sikkim.

farm mechanisation resulting from limited availability of power for agriculture, constrained use of power tiller and difficulty in construction of large irrigation channels for the topography of Sikkim (Government of India, 2019b). The farmers use simple tools such as pedal operated thresher, hand hoe, push-pull weeder, wheel hand hoe, manual dibblers, paddy weeder, improved knapsack sprayers etc. There was no reported case of use of chemical fertiliser among the sampled households of the study area. Under the organic mission of state agricultural policy the farmers in the study area reported to be using organic manure, castor cake, cow dung, green manure, compost and biological pest for farming practices. For an average farm, the amount of expenditure on organic fertiliser was INR 3,716. The farmers in the study area mostly used bullock for their land preparation and the average expenditure on bullock among the sample farm households of the study area was INR 2,777.

TABLE 1. DESCRIPTIVE STATISTICS

Variables (1)	Unit (2)	Mean (3)	Standard deviation (4)	Minimum (5)	Maximum (6)
Non-Categorical Variables					
Production	Kilogram	213	150	25	800
Land	Hectare	0.22	0.14	0.05	0.9
Labour	INR	2,738	1,622	400	9,000
Capital	INR	671	481	0	3,000
Seed	Kilogram	9.28	5.89	2	40
Organic Fertiliser	INR	3,716	2,334	600	12,500
Bullock	INR	2,777	1973	0	12,600
Schooling	Years	4.45	3.92	0	15
Experience	Years	31	14	3	70
Age	Years	52.34	13.62	22	90
Distance	Kilometer	15.47	10.16	0	40
Dummy Variables					(per cent)
Tenureship Status	= 1 if the farming household use own land = 0 if use leased-in land				80.5
Religion	= 1 if the farming household is Buddhist = 0 otherwise				36.0
Temperate	= 1 if the farm is located in Temperate Region = 0 otherwise				34.0
Sub-Tropical	= 1 if the farm is located in Sub-tropical Region = 0 otherwise				33.0
Number of Observations = 200					

Source: Field survey.

The level of formal educational attainment in the study area is found to be very low. As evident from Table 1 the mean years of schooling of the head of the sample farm households is less than 5 years. Maize farming is being practiced in the study area for a considerable period of time where the average experience of maize farming by head of the household is around three decades, and the average age of the head of farm household is 52 years. The distance of the farmland to input market is important for timely availability of inputs which have indirect implications on farm output. It was observed that the distance of input market from the farm land for an average farm household of the study area was 15.47 kilometers.

Nearly 81 per cent of the farmers in the study area use their own land for maize farming and the rest use leased-in land. About 36 per cent of sample households are Buddhists and the remaining are Hindus and Christians. As regards the differential exposure to agro-climatic conditions, it is found that 34 and 33 per cent of the sample farms are located in temperate and sub-tropical agro climatic regions respectively. The rest of the farms are located in tropical agro-climatic region.

III

METHODOLOGY AND MODEL

There are two approaches of measuring technical efficiency in production – data envelopment analysis (DEA) and stochastic frontier analysis (SFA). The present study uses both these non parametric DEA and parametric SFA approaches for measurement of farm level technical inefficiency across different agro-climatic regions of the study area. The purpose is to check whether the results obtained and the policy implications emanating thereof are robust to alternative methodologies. There are a few studies using both SFA and DEA approaches which include Wadud (2003), Kalaitzandonakes and Dunn (1995), Hjalmarsson *et al*. (1996) and Sharma *et al*. (1997), Ferrier and Lovell (1990), Fecher *et al*. (1993) and Sharma *et al*. (1999). It may be noted that both these approaches have their relative merits and limitations. The main advantage of DEA is that it does not require specification of the functional form of the production function and can accommodate scale issues. However, it has the disadvantage of not explicitly accommodating the effects of data noise, attributing all the deviations from the frontier to inefficiencies. Such limitation in estimation is better handled by SFA. The SFA as proposed by Aigner *et al*. (1977) and Meeusen and Van den Broeck (1977) specify a production function for cross sectional data which has a composite error term comprising random errors and technical inefficiency components. In agricultural fields, the SFA is widely used for the efficiency measurement due to its capacity to accommodate statistical noise, such as measurement error, and its parametric specification of technology.

Non-Parametric Specification: DEA Model

Charnes *et al.* (1978) formulated the DEA methodology, which measures the technical efficiency estimators as optimal solutions to mathematical programming problem. Following the similar specification of DEA model as in the empirical work of Theodoridis and Anwar (2011), the present study assumes that there are 'n' decision making units (DMUs), each producing a single output by using 'm' different inputs. The i-th DMU produces y_i units of output using x_{ki} units of the k-th inputs. Thus the variable returns to scale (VRS) output-oriented model for the i-th DMU is expressed as follows:

$$Max_{\theta_i \lambda_j} \theta_i \quad .... (1)$$

Subject to,

$$\sum_{j=1}^{n} \lambda_j y_j - \theta_i y_i \geq 0$$
$$\sum_{j=1}^{n} \lambda_j x_{kj} \leq x_{ki} \quad .... (2)$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0$$

k = 1, 2,...., m inputs ; j = 1, 2,......, n DMUs where, θ_i is the proportional increase in output possible for the i-th DMU; and λ_j is the intensity variable of the j-th DMU. The constant returns to scale (CRS) is obtained by exclusion of the restriction $\sum_{j=1}^{n} \lambda_j = 1$.

The single output-oriented DEA model maximizes the proportional increase in output while remaining within the production possibility set. The i-th farm is efficient, which means that the unit lies on the frontier when $\theta_i = 1$, $\lambda_i = 1$, and $\lambda_j = 0$ for $j \neq i$. The frontier level of production for the i-th farm, denoted by y_i*, is given by;

$$y_i^* = \sum_{j=1}^{n} \lambda_j y_j = \theta_i y_i \quad \text{.... (3)}$$

In the present empirical context the inputs used in the production of maize are – area under cultivation (*Land*), expenditure on labour (*Labour*), expenditure on farm machinery (*Capital*), quantity of seeds (*Seed*), expenditure on organic fertiliser (*Organic Fertiliser*) and expenditure on bullock labour (*Bullock*). The output-oriented measure of technical efficiency of the i-th farm unit, denoted by TE_i can be estimated by equation (4) as follows.

$$TE_i = \frac{y_i}{y_i^*} = \frac{1}{\theta_i} \quad \text{.... (4)}$$

The farm-specific technical inefficiency scores are obtained by subtracting TE_i from one. After obtaining the farm-specific technical inefficiency scores we attempt to identify the factors that affect such inefficiency of the farmers by regressing these scores on a set of exogenous factors.[4] However, a linear regression model is not appropriate here as the dependent variable, i.e., technical inefficiency scores, is bounded between 0 and 1. In fact there are clusters of observations in both the ends where the dependent variable takes the value of 0 and 1. Hence a Tobit model with censoring on both sides has been formulated. The model is formulated with the help of latent variable Y_i* which can take any possible value but is not always observable. Incorporating the explanatory variables the model to be estimated has been formulated as shown by equation (5).

$$\begin{aligned} Y_i^* = {} & \gamma_0 + \gamma_1 (Schooling_i) + \gamma_2 (Age_i) + \gamma_3 (Experience_i) \\ & + \gamma_4 (Tenureship\ Status_i) + \gamma_5 (Religion_i) + \gamma_6 (Distance_i) \\ & + \gamma_7 (Temperate_i) + \gamma_8 (Sub\text{-}Tropical_i) + \varepsilon_i \end{aligned} \quad \text{... (5)}$$

The observed dependent variable Y_i is linked to the latent variable Y_i* as per the following formulation.

$Y_i = 0$ for $Y_i^* \leq 0$
$Y_i = Y_i^*$ for $0 < Y_i^* < 1$
$Y_i = 1$ for $Y_i^* \geq 1$

The explanatory variables are – years of schooling of the head of the farming household (*Schooling*), age of the head of the farm household (*Age*), years of maize farming experience by the household (*Experience*), tenureship status of the farm household (*Tenureship Status*), religion of the farm household (*Religion*), distance of the farm land from input market (*Distance*). Moreover, two location dummies, viz., temperate and sub-tropical are also used in the model while the tropical agro-climatic region is taken as the base region for the purpose of comparison. The random disturbances ε_i s are assumed to be independently normally distributed with zero mean. Finally the maximum likelihood estimates of the parameters have been obtained using STATA 11.

Parametric Specification: SFA Model

For obtaining parametric estimate of the technical inefficiency of maize farming across the sampled households of the study area the stochastic frontier production function, following Battese and Coelli (1995), is formulated as follows:

$$y_i = f(x_i; \beta) \exp(v_i - u_i) \quad \text{....(6)}$$

$$u_i = z_i\delta + \eta_i \quad \text{....(7)}$$

where, $f(x_i; \beta)$ is the frontier production function (usually assumed as Cobb Douglas); y_i is the output of i-th sample farm ; x_i is (1x k) vector of inputs used by i-th farm; β is (1xk) vector of unknown parameters to be estimated . The error term is composed of two parts - one is normally distributed term v_i ($v_i \sim$ iid$N(0, \sigma_v^2)$) and the other is an one-sided disturbance u_i ($u_i \sim iid\ N^+(\mu_i, \sigma_u^2)$) which is non-negative. Here v_i represents random errors like measurement errors, specification errors and random shocks that are not under the control of a producer. u_i represents the technical inefficiency of the i-th farmer that results from managerial problems and co-ordination issues at work. The u_i is assumed to follow a truncated normal distribution; z_i is vector of farm-specific attributes; δ is a vector of parameters to be estimated; $\eta_i \sim$ iid $(0, \sigma_\eta^2)$.

The vector of inputs in the production function (Equation 6) includes the same inputs as used in the DEA model mentioned earlier. They are area under cultivation (*Land*), expenditure on labour (*Labour*), expenditure on farm machinery (*Capital*), quantity of seeds (*Seed*), expenditure on organic fertiliser (*Organic Fertiliser*) and expenditure on bullock labour (*Bullock*). Thus, the Cobb-Douglas stochastic frontier (SF) production function after logarithmic transformation to be estimated can be written as :

$$\ln(Output_i) = \lambda_0 + \lambda_1 \ln(Land_i) + \lambda_2 \ln(Labour_i) + \lambda_3 \ln(Capital_i) + \lambda_4 \ln(Seed_i) + \lambda_5 \ln(Organic\ Fertiliser_i) + \lambda_6 \ln(Bullock_i) + v_i - u_i \quad \text{....(8)}$$

The main focus of this study is to identify the determinants of technical inefficiency of maize farming in Sikkim. Hence, incorporating the same exogenous variables as used in model (5) the model for technical inefficiency (Kumbhakar *et al*., 1991; Huang and Liu, 1994) is formulated as follows:

$$u_i = \delta_0 + \delta_1 (Schooling_i) + \delta_2 (Age_i) + \delta_3 (Experience_i) + \delta_4 (Tenureship\ Status_i) + \delta_5 (Religion_i) + \delta_6 (Distance_i) + \delta_7 (Temperate_i) + \delta_8 (Sub\text{-}Tropical_i) + \eta_i \quad \text{....(9)}$$

For consistently estimating the technical inefficiency scores of every farmer and the effects of exogenous factors on them, equations (8) and (9) have been simultaneously estimated using maximum likelihood method. This method is an improvement over the two-steps method used in literature (Kalirajan and Shand, 1985), as this method allows consistent estimation of the technical inefficiency terms (and parameters) even if they are correlated with the inputs and incorporates the non-positive nature of the inefficiency values (Bhattachrayya and Mandal, 2016). The present study has used output oriented approach in measuring inefficiency because in agricultural studies input choices are made well in advance of output realisation (Karagiannis and Sarris, 2004).

IV

EMPIRICAL RESULTS AND DISCUSSION

IV.1 *DEA Results*

The Tobit regression results of technical inefficiency as obtained from the DEA approach under the assumptions of constant returns to scale (CRS) and variable returns to scale (VRS) are shown in Table 2. It is interesting to note that the coefficient of tenureship status has turned out to be positive and significant. This implies that owner cultivators of maize in the study area are more inefficient compared to the tenant cultivators. Thus, tenurial arrangements play a significant role in determining the farm level inefficiencies. For tenants, insecurity over land use rights and financial constraints are found to be the critical factors dissuading them from investing in activities such as improvements in land and managerial capabilities (Ahmad *et al*., 2002). Nonetheless, the tenants generally operate relatively smaller size of cultivable land and are usually under economic pressure like paying rent or share of crop to the landlord, facing high variable cost and feeding the household members. Therefore, the tenants have no other option but to extract the most out of the cultivated piece of land. This may make the tenant cultivators relatively more efficient in cultivation as compared to owner cultivators. This result is consistent with the findings of Ahmad *et al*. (1999); Ahmad *et al*. (2002); Ahmad (2003); Karagiannis and Sarris (2004). The estimated coefficient of religion dummy being statistically significant with a negative coefficient implies that Buddhist farmers in the study area are more efficient in maize farming as compared to Hindu and Christian farmers. The influence of affiliation to religious communities on technical inefficiency has also been found in previous studies. For example, in separate studies in the context of Assam, Bhattacharaya and Mandal (2016) and Mandal and Maity (2021) found that the Muslim farmers are more efficient than the non-Muslim farmers. The religious beliefs influence the economic outcomes by affecting personal traits such as honesty, thrift, willingness to work hard, and openness to strangers (Barro and McCleary, 2003; Chen, 2005).

TABLE 2. DEA RESULTS OF TECHNICAL INEFFICIENCY

Variables (1)	DEA (CRS) (2)	DEA (VRS) (3)
Schooling	-0.001 (0.003)	-0.003 (0.004)
Age	-0.001 (0.002)	0.0001 (0.002)
Experience	0.001 (0.002)	-0.001 (0.002)
Tenureship status	0.078** (0.029)	0.124*** (0.039)
Religion	-0.105 *** (0.027)	-0.113*** (0.031)
Distance	0.002** (0.001)	0.003* (0.001)
Temperate	-0.098*** (0.028)	-0.096** (0.033)
Sub-Tropical	-0.033 (0.027)	-0.046 (0.034)
Constant	0.601*** (0.069)	0.529*** (0.089)
Log Pseudo likelyhood	68.81	31.02
$F_{8,192}$	7.97***	7.45**
Pseudo R^2	-0.444	-1.523

Notes: ***p < 0.01, **p < 0.05, *p < 0.10; Robust standard errors in parentheses.

The distance of a farm from the nearest input market is found to have a statistically significant and positive impact on the technical inefficiency of maize farming in the study area. This result shows that remoteness of farm location from the input market contributes towards greater technical inefficiency in cultivation. This is quite intuitive because remoteness of the input market prevents the farmers from accessing and using required inputs in time which in turn may adversely affect the output level. The findings of Burki and Khan (2011), Nyariki (2011) and Kurkalova and Carriquiry (2003) are consistent with this result of the present study.

The agro-climatic conditions can have influence on the technical inefficiency of farmers and hence locational dummies have been used in our inefficiency model to see the differential impacts of agro-climatic conditions on the inefficiency of maize farming in the study area. The estimated coefficient of locational dummy for the temperate region is found to be negative and statistically significant. This implies that farmers in the temperate agro-climatic region are less inefficient (i.e., more efficient) in maize farming compared to those in the tropical region (which is taken as the reference category). Such findings suggest that farmers in high elevation areas are more efficient in agricultural production. This differential may be because of the fact that higher altitude regions are cooler and exposed to sunlight for a longer duration than the lower altitude regions, thus benefitting maize growth. This result is consistent with the findings of Guha and Ghosh (2017) where it was observed that the productivity of rice, radish, carrot, ginger and large cardamom was higher at higher elevation levels in the mountains of Sikkim. Cooper (1979) also found a positive relationship between yield and altitude.

The above results are robust to different scale assumptions (i.e., CRS and VRS). Moderately high pseudo R^2 value accompanied by significant F statistic indicate that the estimated regression gives a good fit to the data.

IV.2 *SFA Results*

The estimated results of stochastic production frontier model are presented in Table 4. From the results it is evident that the coefficients of inputs such as land, labour, seed and bullock have turned out as significant with positive elasticities. Thus, incremental use of these inputs helps in raising the maize production in the study area which is quite expected. The expenditures on capital and organic fertiliser, however, did not show any statistically significant influence on maize output in the study area.

Before proceeding to the parameter estimate of the technical inefficiency model, it is important to evaluate the presence of technical inefficiency in the production model. In this regard the estimated likelihood ratio statistic has turned out to be 54.36, which is substantially greater than the χ^2_8 (0.01) critical value of 19.38, thereby rejecting the null hypothesis of absence of technical inefficiency in the model (Table 3). This implies that majority of the farms in the sample suffer from inefficiency in production or operate below the production frontier.

TABLE 3. GENERALISED LIKELIHOOD RATIO TEST OF HYPOTHESIS FOR INEFFICIENCY EFFECT MODEL

Hypothesis (1)	Log likelihood (2)	LR test statistic (3)	Critical value (0.01) (4)	Decision (5)
General model	-114.44	54.36	χ^2_8 (19.384)	Reject H_0
H_0: $\delta_0 = \delta_1 = \delta_2 = \ldots = \delta_7 = \delta_8 = 0$	- 87.26			

Note: Appropriate critical values for Likelihood Ratio Test are drawn from Kodde and Palm (1986).

The estimated SFA results of technical inefficiency of maize farming are reported in Table 4. It is interesting to note that the coefficient of tenureship status is positive and statistically significant. This implies that the owner-cultivators of maize are more inefficient than the tenant cultivators. More specifically, technical inefficiency of the farmers cultivating their own land is higher by 0.34 percentage points as compared to those farmers practicing cultivation on leased-in land. The present results corroborate the findings of Lawin and Tamini (2019) as they found that technical efficiency and productivity were consistently higher among the tenant farmers in Benin.

The estimated coefficient of religion dummy being statistically significant with a negative coefficient implies that the Buddhist farmers in the study area are more successful in reducing technical inefficiency as compared to Hindu and Christians farmers. It is observed that technical inefficiency is lower by 0.25 percentage points among the Buddhist farmers as compared to those belonging to Hindu and Christian communities. The influence of agro-climatic conditions on the technical inefficiency is apparent in the study area as technical inefficiency in the temperate agro-climatic region is lower by 0.34 percentage points than the tropical region. The present findings are in line with Minda *et al*. (2018), Ghosh *et al*. (2014) as they reported higher elevation positively influenced output of potato in Gamo Highlands of Ethiopia and crops other than paddy in North-west Himalayas.

TABLE 4. SFA RESULTS OF TECHNICAL INEFFICIENCY

Variables (1)	Parameters (2)	Coefficients /Others (3)
Stochastic production frontier model		
ln(Land)	λ_1	0.606*** (0.111)
ln(Labour)	λ_2	0.018** (0.009)
ln(Capital)	λ_3	-0.00003 (0.016)
ln(Seed)	λ_4	0.266*** (0.087)
ln(Organic fertiliser)	λ_5	-0.014 (0.074)
ln(Bullock)	λ_6	0.528** (0.203)
Constant	λ_0	2.85 * (1.57)
Technical inefficiency model		
Schooling	δ_1	-0.001 (0.010)
Age	δ_2	0.006 (0.007)
Experience	δ_3	-0.005 (0.008)
Tenureship status	δ_4	0.342** (0.126)
Religion	δ_5	-0.251** (0.099)
Distance	δ_6	0.009** (0.004)
Temperate	δ_7	-0.339*** (0.108)
Sub-tropical	δ_8	-0.070 (0.082)
Constant	δ_0	0.240 (0.370)
Variance parameters		
σ_u	0.331*** (0.06)	
σ_v	0.235*** (0.063)	
Log likelyhood	-87.26	
Wald χ^2 (6)	289.19***	
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.165*** (0.008)	
$\gamma = (\sigma_u^2 / \sigma^2)$	0.665*** (0.450)	

Notes: ***p < 0.01, **p < 0.05, *p < 0.10; Robust Standard errors in parentheses.

The estimated coefficient of distance to input market being positively significant in the inefficiency function implies that greater technical inefficiency was directly associated with remoteness of farmland from input market. Thus, an increased distance from input market increased the technical inefficiency of the farm household by 0.01 percentage points. Such result is consistent with the findings of Andaregie and Astatkie (2020), Beyene *et al*. (2020) as they reported longer distance from input and output market leads to higher transaction cost that reduces the technical efficiency of crop-producing farmers. The estimated value of γ and σ^2 means that inefficiency effects were present in the analysis and that the conventional average production function is not an adequate representation of data (Theodoridis and Anwar, 2011). The estimate of γ indicates that the portion of the one-sided error component in the total variance is as high as 67 per cent. Thus 67 per cent variation in data between farms can be attributed to inefficiency and remaining 33 per cent due to pure noise.

It is interesting to note that the results obtained from SFA model are consistent with those of DEA under its CRS and VRS scale assumptions (see Table 3) as far as the determinants of technical inefficiency of maize farming in the study area are concerned. To be more precise, in case of all the three specifications owner cultivators are less efficient than the tenant cultivator and efficiency decreases with increase in the distance of input markets from the farm location. Similarly, Buddhist farmers are more efficient than others and that farmers in the temperate region are more efficient than those in the tropical region.

The technical inefficiency scores under different methodologies and scale assumptions are indicated in Table 5. The technical inefficiencies under SFA methodology show substantial variability among the farming households ranging between 9 and 79 per cent with mean technical inefficiency of 45 per cent and standard deviation of 16 per cent. This implies presence of considerable technical inefficiency among the sample farms, and hence substantial room for increasing production of maize through improving managerial practices and making deliberate changes in the exogenous factors that are found to adversely influence the productive efficiency of farmers. It is interesting to observe that the mean technical inefficiency of the farmers under SFA methodology was directly related to the altitude level, with average inefficiency scores of 33 per cent in temperate, 49 per cent in sub-tropical and 52 per cent in tropical agro-climatic region of the study area. This is indicative of the differential impact of altitudes and associated climate change on farm efficiency. This differential may be because higher altitude regions are cooler and exposed to sunlight for a longer duration than the lower altitude regions. These results are similar to those obtained from DEA under its scale assumptions.

TABLE 5. FREQUENCY DISTRIBUTION OF TECHNICAL INEFFICIENCY OF MAIZE FRAMING IN SIKKIM

TIS	SFA				DEA (CRS)				DEA (VRS)			
(per cent)	R_1	R_2	R_3	SK	R_1	R_2	R_3	SK	R_1	R_2	R_3	SK
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
0-20	0	4.55	25	10	1.52	1.52	5.88	3	4.55	7.58	5.88	6
20-40	16.67	25.76	44.12	29	4.55	9.09	17.65	10.5	9.09	10.61	27.94	16
40-60	56.06	40.91	23.53	40	16.67	28.79	39.71	28.5	15.15	27.27	38.24	27
60-80	27.27	28.79	7.35	21	69.70	46.97	30.88	49	65.15	43.94	23.53	44
80-100	0	0	0	0	7.58	13.64	5.88	9	6.06	10.61	4.41	7
Mean	0.52	0.49	0.33	0.45	0.64	0.63	0.52	0.60	0.60	0.58	0.48	0.56
SD	0.12	0.16	0.15	0.16	0.13	0.18	0.20	0.18	0.18	0.22	0.21	0.21
Min	0.22	0.17	0.09	0.09	0.18	0	0	0	0	0	0	0
Max	0.73	0.76	0.79	0.79	0.86	0.91	0.93	0.93	0.86	0.9	0.93	0.93

Notes: TIS stands for Technical Inefficiency Score; R_1, R_2 and R_3 represent Tropical, Sub-tropical and Temperate agro-climatic regions respectively, and SK stands for overall sample farms of Sikkim.

The results of SFA in Table 5 show that 40 per cent of the sample farms in Sikkim belong to technical inefficiency scores of 40-60 per cent with only 10 per cent of farms being in the inefficiency interval of 0-20 per cent in the state. Across the agro-climatic regions under consideration nearly 44 per cent farmers of the temperate agro-climatic region have inefficiency score in the range of 20-40 per cent; while the corresponding figures of farmers in tropical and sub-tropical region are 17 per cent and 26 per cent respectively. The number of sample farmers having inefficiency score in the range of 0-20 per cent in temperate region is 25 per cent followed by sub-tropical region with 4.55 per cent while no farmer in the tropical region belonged to this range.

V

CONCLUSION AND POLICY RECOMMENDATIONS

By applying DEA and SFA approach this paper attempts to measure technical inefficiency of maize farming and identify the determinants of such inefficiency in different agro-climatic regions of Sikkim. Using an original farm level survey data set the stochastic frontier function was simultaneously estimated together with the inefficiency model. The results of analysis show that there are substantial production inefficiencies among the sample farmers because the mean technical inefficiency score ranges between 40 per cent to 55 per cent. These results suggest that there is scope to increase production of maize output across the sample farms to a considerable extent (by around 40 to 55 per cent) with the existing technology and resources.

The estimated results show that efficiency in maize cultivation is more among the farmers belonging to Buddhism and those cultivating leased-in land. Moreover, higher technical inefficiency is associated with remoteness of farmland from the input market. The technical efficiency was the highest among the farmers in temperate agro-climatic region and was lowest among the farmers in tropical agro-climatic region. The higher altitude regions are cooler and exposed to sunlight for a longer duration than the lower altitude regions which might have contributed towards such variation in technical efficiency across altitudes of the study area. These results are robust to alternative approaches of SFA and DEA, and even to scale assumptions of production.

From the findings it can be concluded that the tenant farmers are more efficient in maize cultivation than the owner cultivators in the study area. This has special implications in Sikkim where even after 45 years of becoming an Indian state the land reforms measures seem to be inadequate and have failed to ensure distributive justice for its agrarian society as a result of which land distribution is highly skewed (Chakrabarti, 2010). The land possessed by the Lepcha and Bhutia tribes in the state is non-transferrable because of which the amount of surplus land available for distribution is a matter of concern (Chakrabarti, 2009). Given these bottlenecks, any significant reform in the state regarding land distribution seems unviable in the imminent future. Hence, some effective measures with respect to tenancy reforms such as security over land use rights may provide a boost to the tenant cultivators and thereby enhance maize production in Sikkim. Some innovative steps may also be taken in this regard and more in-depth research in this field is called for.

On the other hand, distance of farms from the input market is found to increase inefficiency of the maize farmers. Hence, the public and private initiatives in opening up of farm input outlets at the village level may help the farmers in getting easy and timely access to farm inputs which may help them increase their farm output level.

Received October 2019. *Revision accepted April 2021.*

NOTES

1) Meters Above Sea Level (MSL) is a standard metric measurement in meters of vertical distance (height, elevation or altitude) of a location in reference to a historic mean sea level taken as a vertical datum.

2) The remaining two, namely sub-alpine and alpine agro climatic regions have been excluded from the present study as these two regions are not suitable for maize cultivation. The crops primarily grown in these two regions are barley, vegetables, potato, apple, plum, peach, peas, off-season vegetables and large cardamom, seed potato, herbs and medicinal plants (Rahman and Karuppaiyan, 2011).

3) These two districts accounted for 58.48 per cent of total area under maize farming in the state, producing 59.37 per cent of total maize output of the state during 2017–18 (Government of India, 2019d).

4) The DEA and SFA give efficiency and inefficiency scores respectively. For the sake of comparability of their results DEA scores are subtracted from one to convert them into inefficiency scores.

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APPENDIX 1. AREA (IN ‘000 HECTARE) UNDER CEREAL CROPS IN SIKKIM

Year (1)	Maize (2)	Paddy (3)	Buckwheat (4)	Finger millet (5)	Barley (6)	Wheat (7)	GCA of Sikkim (8)
2003-2004	36.7	14.74	2.01	4.15	1.23	5.74	121
	(30.33)	(12.18)	(1.66)	(3.43)	(1.02)	(4.74)	
2004-2005	36.7	14.74	2.01	4.15	1.23	5.74	123
	(29.84)	(11.98)	(1.63)	(3.37)	(1.00)	(4.67)	
2005-2006	36.7	14.74	2.01	4.15	1.23	5.74	123
	(29.84)	(11.98)	(1.63)	(3.37)	(1.00)	(4.67)	
2006-2007	40.85	14.15	2.04	4.14	1.15	6.38	123
	(33.21)	(11.50)	(1.66)	(3.37)	(0.93)	(5.19)	
2007-2008	39.1	14	2.04	3.76	0.71	4.45	118
	(33.14)	(11.86)	(1.73)	(3.19)	(0.60)	(3.77)	
2008-2009	39.2	13	5.54	3.76	0.5	3.9	118
	(33.22)	(11.02)	(4.69)	(3.19)	(0.42)	(3.31)	
2009-2010	39.5	12.27	5.54	4.25	1	5.2	144
	(27.43)	(8.52)	(3.85)	(2.95)	(0.69)	(3.61)	
2010-2011	40.17	12.14	4.39	3	0.64	2.65	152
	(26.43)	(7.99)	(2.89)	(1.79)	(0.42)	(1.74)	
2011-2012	40.17	12	5	3.5	0.65	2.5	137
	(29.32)	(8.76)	(3.65)	(2.55)	(0.47)	(1.82)	
2012-2013	39.97	11.92	3.56	2.98	0.59	0.52	144
	(27.76)	(8.28)	(2.47)	(2.07)	(0.41)	(0.36)	
2013-2014	39.93	11.16	3.63	2.96	0.58	0.36	147
	(27.16)	(7.59)	(2.47)	(2.01)	(0.39)	(0.24)	
2014-2015	38.91	11.04	3.27	3.07	0.57	0.39	136
	(28.61)	(8.12)	(2.40)	(2.26)	(0.42)	(0.29)	
2015-2016	38.96	10.67	3.57	2.85	0.45	0.32	137
	(28.44)	(7.79)	(2.61)	(2.08)	(0.33)	(0.23)	

Sources: (a) Government of Sikkim (2019), ENVIS Centre: Sikkim; (b) Government of India (2018-19). (c) Government of India (2019c)

Note: GCA stands for Gross Cropped Area, figures in the parenthesis represent percentage share in GCA.