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EVALUATING THE TECHNICAL EFFICIENCY OF SMALLHOLDER VEGETABLE FARMS IN DIVERSE AGROECOLOGICAL REGIONS OF NEPAL

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Abstract

Enhancing the efficiency of vegetable farms is crucial to increase the vegetable outputs for meeting the demand for growing population. This study evaluated the technical efficiency and explored factors determining the efficiencies of smallholder vegetable farms in diversified agro-ecological regions using Stochastic Frontier Analysis (SFA) with cross-section data collected in 2013. The results revealed that average technical efficiency was found to be 0.77 and the variance parameters were highly significant indicating that the inefficiency existed in vegetable farms. The inefficiency gap could improve by operating the farms at the frontier level. The input variables consisting of land, labor, animal power, fertilizer, compost, pesticide, and capital were proved to be the important factors in determining the level of outputs. Meanwhile, the major sources of the inefficiencies identified were: age of farmer, training to the farmers, and infrastructure development. The efficiency in vegetable production can be improved by allocating input resources at the optimum levels, encouraging younger farmers in vegetable production, increasing training and extension activities, enhancing market access to the farmers, and developing infrastructures with regard to vegetable production.
Keywords: *Technical efficiency, vegetable farms, stochastic frontier, infrastructure underdevelopment index*
JEL Codes: D24, Q12, Q16

1. Introduction

Vegetable farming is a strategic sector to provide employment opportunities, increase income, improve livelihood for the landless and smallholder farmers and can help alleviate poverty. Agriculture sector is the major source of Nepalese economy, which contributes about 33% of the gross domestic product (GDP), and the vegetable sector shares 14% of the agriculture gross domestic product (AGDP). According to Brown and Kennedy (2005), vegetable farming provides 11 times higher income than rice farming that inspired farmers to enhance in vegetable production. The vegetable production was estimated to be 3.64 million tons in 0.593 million acres of land in 2011 with annual average growth rate 5.6% since 1991 to 2011in Nepal (MOAD, 2012). The production quantity is insufficient to meet the demand of vegetables for ever growing population in the country. As a result, Nepal imported vegetables from different countries mainly from India at US$ 77.4 million (NRs. 86.93 = 1 US$ as of 2012) (MOAD, 2012). This figure shows that there is a need to enhance vegetable production for meeting domestic demand and exporting vegetables to the neighbor countries.

Nepalese vegetable farms are of small-scale with average size of land holding at 1.73 acres (CBS, 2011); however, a larger number of farmers have been shifting towards commercialization, particularly in the peri-urban areas or areas with better accessed to road and markets. The farmers have adopted integrated farming practices where different types and varieties of crops (cereals, vegetables, pulse crops, for example) are grown on a small parcel of land. Indeed, such types of integrated farming is more resource conserving and productive because they cope with and even prepare for climate change, adopt soil conservation practices, minimize crop failure, mixed cropping system, water harvesting techniques (Altieri et al., 2011). This leads to increasing efficiency in production, consequently, smallholding integrated agriculture could be the best strategy for food security and livelihood.

Nepalese vegetable farming practices are characterized by working on farmers' group or cooperatives, majority of the farmers cultivate vegetables in their own land, while limited numbers of commercial oriented farmers cultivate in rented land, and they utilize both manual and animal power intensively. In general, farmers cultivate vegetable mainly during winter and summer seasons, however, commercial oriented farmers grow throughout the year. The common vegetable crops grown by farmers are cauliflower, tomato, cabbage, radish, bean, gourds, pumpkin, cucumber, cowpea, and eggplant (CBS, 2010).

Nepal possess highly diversified agroecological regions consisting of tropical, hill, and mountain, and offers huge opportunities in producing different types of vegetable crops. It brings comparative advantage in vegetable production that can contribute not only to meet domestic demand but also to earn foreign currency by exporting fresh vegetables to the international markets. In fact, Nepalese vegetables would have additional importance in the global markets for being uniqueness of Himalayan topographical and associated agro-climatic flavor and taste. Therefore, a study on agroecology-based farming system could be one of the strong pathways in formulating policies to enhance the productivity and efficiency in agriculture. The accessibility of resources to the farmers differ in by agroecological regions; the tropical areas have better access to infrastructures, road networks, input and output markets, extension services, and other public services than the hills; and the hills have better in this respect than the mountain region. Thus, the productivity and efficiency varies in the respective regions. Indeed, vegetable farmers are embarrassed by inadequate and weak agriculture road networks, poor irrigation facilities, rudimentary market infrastructures, and ineffective extension services (Pokhrel, 2010; USAID, 2011) that rendered the vegetable sector less productive. These are the critical issues to be addressed in order to improve the technical efficiency. The technical efficiency refers to the ability of a farm to produce the optimum level of outputs with a set of input bundles and technology or to produce the current level of outputs with the lowest level of inputs (Tonsor and Featherstone, 2009), while, the inefficiency exists when the actual output from a given input mix is less than the maximum possible level of production (Parikh et al., 1995; Silva and Stefanou, 2007).

The government policies, Agriculture Perspective Plan (APP) (NPC, 1995), National Agriculture Policy-2004 (MOAD, 2004), Agribusiness Promotion Policy-2005 (MOAD, 2005), and successive periodic development plans, have been focused on transferring subsistence agriculture into commercial system, particularly the high value crops. Nepalese agriculture is suffered from four challenges: low productivity, inefficiency, less competitiveness, and scarcity of resources in achieving the goals set forth in the government plans, which reinforce the agriculture research system (NPC, 1995; MOAD, 2004; MOAD, 2005; NARC, 2010). Additionally, the mid-term review of APP pointed out that the set objectives were failed to attain the targets because of weak policy design in inputs supply, output marketing, and failed in incorporating socio-economic environmental factors that might be affecting on vegetable production (NPC, 2006).

Numerous studies have been carried out analyzing the efficiency of agricultural commodities (Binam et al., 2004; Bozoğlu & Ceyhan, 2007; Ojo et al., 2009; Nisrane et al., 2011; Bakhsh, 2012) using the parametric approach in different countries. A similar approach was adopted by Pudasaini (1984), Dhungana et al. (2004), Bhatta et al. (2006), Paudel and Matsuoka (2009) in Nepalese agriculture, while these studies ignored the vegetable sector. Therefore, we measured the technical efficiency of smallholder vegetable farms on agroecological perspectives and determined factors affecting the inefficiency using Stochastic Frontier Analysis (SFA) in this study. The outcomes of this study would be inferential for making the vegetable sector more productive, competitive, and efficient in the areas with similar agroecological, agro-climatic, and socio-economic environmental conditions of different countries.

2. Methodology of the Study

2.1. Sampling Design and Study Areas

A multi-stage sampling technique was adopted to collect cross-section data during July-August, 2013. Firstly, we purposively selected the central part of Nepal because this region contributed the highest level of production estimated at 40% of the total vegetable production (3.3 million tons) under 38% of the total area of cultivation (0.61 million acres) in 2011 (MOAD, 2012). Secondly, we purposively selected four districts (Dhanusha, Dhading, Lalitput, and Dolakha) (Figure 1) representing three agroecological regions (tropical, hill, and mountain).

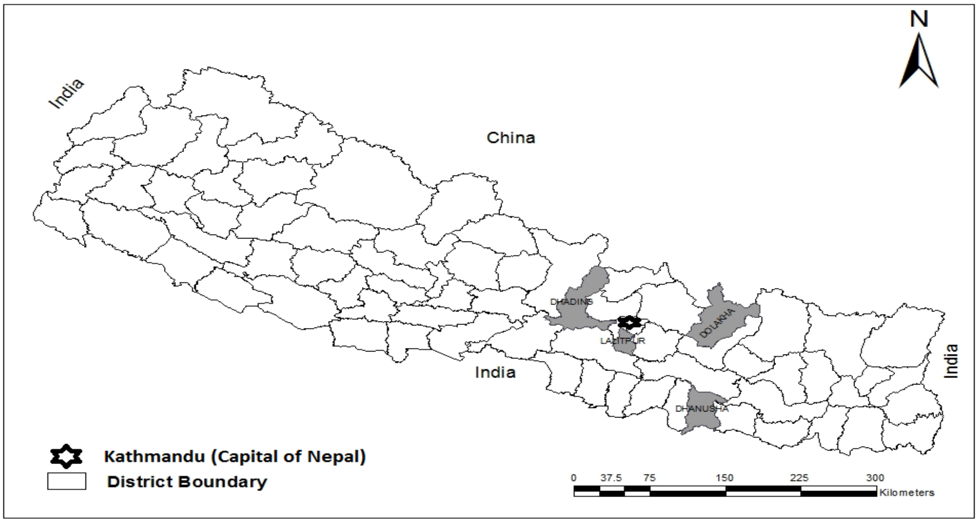

Figure 1. Map of Nepal Showing Study Areas

Dhanusha district represents the tropical, Dhading and Lalitpur the hills, and Dolakha the mountain agroecology. The altitude of Dhanusha ranges from 150m-400m, Dhading 800m-1500m, Lalitpur 900m–1800m, and Dolakha 2000-2600m from the sea level. We selected two districts- Dhading and Lalitpur from the hills in order to represent relatively larger quantity of vegetable production in the hill areas. Thirdly, we randomly selected three major Village Development Committees (VDC), a lower administrative part of Nepal, in terms of vegetable production in each sampled district. Fourthly, we randomly selected 326 sample units of vegetable farmers in the sampled VDCs from the profile of respective District Agriculture Development Offices (DADO) in order to collect data on inputs quantity, cost of production, outputs, and different socio-economic environmental parameters associated in the vegetable farms.

2.2. Empirical Analysis

We adopted the Stochastic Frontier Analysis (SFA), a parametric approach, to measure the technical efficiency of vegetable farms and to identify influential factors on the inefficiency (equation 1), assuming that the market was perfectly competitive. In applied production economics, a parametric efficiency analysis is one of the most effective and appropriate investigating tools that decomposes error into stochastic random error, and inefficiency error because of technical inefficiency in production process (Sauer, 2006). The parametric approach is the most suitable in efficiency analysis; when the study is based on farm level cross-section data that might have measurement error, missing variables, and weather (Coelli, 1995). Within the parametric approach, two models can be used; either one-step or two-step. According to Wang and Schmidt (2002), a “one-step model” specifies both stochastic frontier and one-sided half normal error can be estimated in a single step, while two steps approach become biased. In using two-steps model, estimate the technical inefficiency, then regress the technical inefficiency by socio-economic environmental variables. In this model, the first step procedure is biased for regression parameters when input variables (X) and socio-economic variables (Z) are correlated. Even if X and Z are uncorrelated, when estimated inefficiencies are regressed by Z, this renders the second-step estimate biased. Under the consideration of these facts, we adopted the stochastic frontier production function with one-stage approach where output is considered as a function of inputs and environmental factors (Battese and Coelli, 1995; Coelli et al., 2005).

$$ln(Y_i) = \ln(X_i)\beta + v_i - u_i \qquad \text{i} = 1 \ldots\ldots \text{n} \qquad (1)$$

Here, Y_i is the value of vegetable production of the ith farm, X_i is the inputs used for ith farm, β is the unknown parameter to be estimated, ln is natural logarithm, and v_i is random variable assumed to be independently and identically distributed with $N(0, \sigma_v^2)$. While u_i is a non-negative random variable that account for technical inefficiency in vegetable production, which is assumed to be independently and identically distributed as truncations.

The value of vegetable output was considered as the dependent variable. The value of output was considered as the function of land, labor, animal power, seed, fertilizer, compost, pesticide, and capital in this study. We defined the inefficiency effect as $u_i = z_i\delta$, where (z_i) represent for environmental explanatory variables that may influence the technical inefficiency of a vegetable farms and (δ) is unknown parameter to be estimated.

In this study we considered five environmental variables; for instance, age of farm household head, farmers’ association (farmers’ group or cooperatives), and number of trainings received by farm household head, market access, and index for underdevelopment of infrastructure. The index for underdevelopment of infrastructure was introduced in order to analyze the effects of inaccessibility of infrastructures in the vegetable farms.

A computer program FRONTIER, version 4.1, developed by Coelli (1996) was adopted to estimate the Maximum Likelihood Estimates (MLE) of the parameters. We defined the technical efficiency of vegetable farms as the ratio of the observed output to the frontier output that could be produced by a fully efficient farm (equation 2) where the inefficiency effect is assumed to be zero. The value of the technical efficiency of vegetable farms occurs between zero and one, and is inversely related to the inefficiency effect (Coelli and Battese, 1996).

$$TE_i = \frac{\exp(X_i)\beta + v_i - u_i}{\exp(X_i)\,\beta + v_i} = \exp(-U_i\,) \qquad (2)$$

We estimated the variance parameters: sigma squared (σ^2), and gamma (γ) using equation 3 and 4 (Battese and Corra, 1977).

$$\sigma_s^2 = \sigma_v^2 + \sigma_u^2 \qquad (3)$$

$$\gamma = \sigma_u^2 \,/\, (\,\sigma_v^2 + \sigma_u^2) \qquad (4)$$

We applied Likelihood Ratio (LR) test statistics (equation 5) hypothesizing that the vegetable farms were technically efficient ($\gamma = 0$). The LR test statistics have an approximately Chi-square distribution with the parameter equal to the number of parameters assumed to be zero in the null hypothesis (H_0), provided H_0 is true (Battese and Coelli, 1995).

$$\lambda = -2[\ln\{likelihood\ (H_0)\} - \ln\{likelihood\ (H_0)\}] \qquad (5)$$

2.3. Data Management

We considered the dependent variable, value of output, was estimated by aggregating the output value of all the vegetable crops produced in sampled farms. The gross output of vegetables was calculated by adding farm use as a seed, household consumption, sales, and gift. The output value was normalized dividing by average farm gate price of the vegetable products. The input variables such as land, labor, animal power, vegetable seed, chemical fertilizer, compost, and pesticide were introduced in this study. The land was estimated in acres, labor in man-days, and capital as costs incurred in temporary bamboo-plastic tunnel, thatch, and simple equipment. The animal power, vegetable seed, chemical fertilizer, compost, and pesticide were estimated in cash expenditure as used in vegetable farming.

The environmental variables such as age of household head, farmers' association, and number of trainings received by farmers, market access, and index for underdevelopment of infrastructure were introduced in order to analyze the effects of these environmental variables on the productive efficiency of vegetables. The age of household head (years) was considered, hypothesizing that the younger farmers perform more efficiently than those of elder one. According to Tauer (1995), middle age (35-44 years) farmers are more efficient than those of younger and elder farmers. However, the older farmers are more likely to have had more farming experience; they are also likely to be more conservative and thus less willing to adopt new practices (Coelli & Battese, 1996). Farmers' group or cooperative approach has been adopted as a main model in Nepalese agriculture development for more than four decades. Studies focused on the effects of farmers' group on vegetable production efficiency are yet to be conducted. Therefore, we introduced an independent variable, farmers' association, referred as farmers working in groups or in cooperatives. The farmers' association was considered as 1 if the farmer worked in association and 0 otherwise. Similarly, we introduced farmers' training assuming to have positive impacts on the efficiency of vegetable production by disseminating improved farming technology to the farmers. Total number of trainings received by household head of the sampled farms in vegetable farming from either government agencies or private sector or any development institutions was considered to determine the effects of number of agriculture training on vegetable production efficiency.

The market access to the farmers is one of the central issues in enhancing vegetable sector in the developing countries where vegetable produces in small-scale. We defined market access as market infrastructure facilities (vegetable collection centers, daily or weekly markets, cooperative markets, wholesale markets, for example) where farmers could sell their products without any restriction. The market access was considered 1 if the farmer accessed to market and 0 otherwise in order to analyze its effect on production efficiency of vegetables.

Agriculture based infrastructures such as agriculture road networks, irrigation and electric power, extension services, financial facilities, and academic education systems are the major components in enhancing vegetable sector. We adopted the index for underdevelopment of infrastructure, estimated by aggregating six infrastructure elements: agriculture road network, irrigation, electricity, agriculture service center (ASC), financial institution, and location of school near the vegetable farms. ASC is a government institution responsible for disseminating technology to the farmers at field level. The cost of access approach was used where each of these element indexed from 1 weak access to 5 strong access, thereby aggregating index range from 6 (minimum) to 30 (maximum). The index was believed to a positive relationship with inefficiency in vegetable production as higher the index, lesser the infrastructure development, and lower the efficiency level. According to Rahman (2003), underdevelopment in infrastructure significantly influenced profit inefficiency in Bangladeshi rice farms. We introduced this variable to analyze the influence of underdevelopment of infrastructures on Nepalese vegetable farming using stochastic frontier. As the heteroskedasticity problem is frequently faced by cross-section data (Hill et al., 2011), we tested this problem using the White's test. Thus, the value was found to be 101.05, which was less than $\chi^2_{(0.90,102)} = 120.678$, and confirmed that the heteroskedasticity problem did not exist in the dataset.

3.1. Descriptive Statistics of the Variables

The vegetable farming in the study areas was in small-scale. The average size of vegetable farm was estimated to be 0.98 acres, the average labor used 94 man-days, and the mean of capital US$116.34. The average value of outputs of vegetable farms was found to be US$1139.69, range from US$172.55 to US$7483.03 (Table 1). The variable cost structure was estimated to be higher in compost, followed by animal power, fertilizer, pesticide, and seeds. It indicates that farmers in the study areas rear animals for the purpose of making compost and drag animal power for ploughing farm land.

Table 1. Descriptive statistics of the variables used in vegetable farms

Variable	Mean	Standard deviation	Minimum	Maximum
Output value (US$)[a]	1139.69	923.48	172.55	7483.03
Land (acres)	0.98	0.76	0.13	5.44
Labor (man-days)	94.06	75.80	14.00	584.00
Animal power (US$)	133.35	124.06	6.90	741.98
Seed (US$)	105.01	84.29	11.50	666.05
Fertilizer (US$)	129.77	105.68	3.28	727.02
Compost (US$)	141.74	96.76	17.26	611.99
Pesticide (US$)	108.17	89.55	5.06	897.27
Capital (US$)	116.34	85.99	4.60	638.44
Age of farm household head (years)	42.51	9.21	18.00	70.00
Farmers' association (dummy)	0.71	0.46	0.00	1.00

Trainings received by household head	1.52	2.05	0.00	15.00
Market access (dummy)	0.71	0.46	0.00	1.00
Index for underdevelopment of infrastructure	18.00	4.33	7.00	29.00

[a]Nepali currency Rs.86.93 equivalent to 1 USD during study period.

The average age of farm household head was estimated to be 42.5 years, which is economically active age group and more productive for vegetable farming. The majority of the farmers (71%) were involved in farmers' groups or cooperatives, particularly for vegetable farming activities. The average number of trainings received by the household head was 1.52. Mostly, the vegetable farmers (71%) access to market facilities; they sell their products at the farms (to commission agents or traders), local markets (daily or weekly markets), cooperative markets, or wholesale markets. Furthermore, the average index for the underdevelopment of infrastructure was 18 (60%) of the total index (30) indicating that farmers relying on poor infrastructure conditions,especially on road, irrigation, electricity, ASC, financial institutions, and schools.

3.2 Estimation of Stochastic Frontier Production Function

The results of maximum likelihood estimates (MLE) are presented in Table 2. The variance parameters were found to be highly significant (Table 2) indicating that there was inefficiency in vegetable production. The coefficient of gamma (γ) was found to be much higher (0.73) and significant at 1% level, which revealed that about 73% of the inefficiency in vegetable production was attributed by technical inefficiency, and small portions (27%) by random error generated by weather and natural calamities. We tested the null hypothesis of technically efficient ($\gamma = 0$) usingthe likelihood-ratio test. The null hypothesis was strongly rejected at 1% level (LR statistics $9.095 > \mathrm{X}^2_{(1,0.99)} = 7.879$), which also reconfirmed that the inefficiency existed in vegetable farming.

Table 2. Maximum likelihood estimates of stochastic frontier production function

Independent variable	**Coefficient**	**Standard error**	**t-value**
Production function			
Constant	0.169	0.599	2.820***
lnLand	0.196	0.075	2.631***
lnLabor	0.316	0.072	4.373***
lnAnimal power	0.112	0.041	2.744***
lnSeed	0.015	0.038	0.390
lnFertilizer	0.087	0.032	2.756***
lnCompost	0.163	0.047	3.450***
lnPesticide	0.103	0.036	2.834***
lnCapital	0.126	0.031	4.105***
Sum of elasticity of inputs	1.118		
Variance parameters			
Sigma-squared (δ^2)	0.167	0.025	6.767***

Gamma (γ)	0.733	0.088	8.315***
Likelihood Ratio (LR) test	9.095***		
Inefficiency effects model			
Age of household head	0.003	0.002	1.878**
Farmers' association	-0.026	0.039	-0.672
Training of household head	-0.014	0.009	-1.565*
Market access	-0.072	0.039	-1.871**
Index for underdevelopment of infrastructure	0.015	0.004	3.529***

Note: ***, **, * indicate significant at 1 percent, 5 percent, and 10 percent levels, respectively

All the input variables except seed were highly significant, and consistent with expected signs (upper part of Table 2). The sum of the elasticity found to be more than one (1.118), confirmed that there was increasing returns to scale, implying that as increases in inputs increases the outputs in vegetable farming. The elasticity was much higher for labor, followed by land, compost, capital, animal power, pesticide, and fertilizer, and indicated that these variables have major effects in vegetable production.

3.3 Sources of Inefficiencies

In inefficiency effect model (lower part of Table 2), all the socio-economic variables except farmers' association were significant, and consistent in the expected signs of the coefficients. The positive effect of age supported the hypothesis that younger farmers are more efficient than those of elder one. This result was not different from the past studies (Bozoğlu & Ceyhan, 2007; Hussain et al., 2012). However, it had an important implication for the Nepalese context that younger people could be involved in vegetable farming instead of migrating to foreign countries seeking employment. In fact, a larger number of younger Nepali workers (annually about 350 thousand) have been migrating abroad for employment (CBS, 2010) even if the salary is relatively lower than the amount that could be earned from vegetable farming because of demotivation in agriculture farming occupation. This trend of out-migrating of younger people from the country can profoundly damage for sustainable economic development process in the country. As the younger farmers are productive, dynamic, and updated in information, they can promptly grasp and adopt improved technologies that helps to reduce cost per unit, eventually enhancing efficiency.

Farmers' association, farmers' training, and market access were negatively affected on the inefficiency and consistent as expected. The negative estimation of training of household head was significant, and implying that providing training to the farmers could help to reduce the inefficiency. The result was consistent with the finding of Ojo et al. (2009), and Enwerem and Ohajianya (2013) that inefficiency declines as the number of training and extension programs to the farmer increases. Training and extension programs disseminate improved technologies on farming practices that help to enhance production efficiency by improving farmers' decision-making ability, and significantly increase net farm income (Akobundu et al., 2004). In particular, farmers' field school of agriculture extension has been instrumental in developing technical competencies of the farmers to improve their efficiency and agricultural productivity (Joshi & Karki, 2010). Thus, increase in extension activities would enhance competencies of farmers and that improve the efficiency in vegetable production.

The statistically significant coefficient of market access confirmed the hypothesis of positive relationship of market with efficiency in vegetable farming. Market access to farmers would create opportunities in getting reasonable price for their products in competitive condition, and eventually improve the efficiency level. Group marketing or cooperative marketing are common in agricultural markets in supporting smallholder commercialization and marketing performance, especially for the fresh-products (Bernard & Spielman, 2009; Lemeilleur & Codron, 2011). However, Nepalese vegetable farmers are handicapped on market access in two ways: first, limited market infrastructure facilities nearby the production areas; second, the government rules and regulations restrict farmers from getting entry into the markets to sell their products. The government rule, Agriculture Market Regulation Directives 1996, provides market space to the traders rather than the producers for conducting their business. The market environment needs to be farmers-friendly to ensure that the producers have access to the market where government role is imperative in order to create conducive marketing environment.

The index for underdevelopment of infrastructure was statistically significant and consistent with the hypothesis of positive relationship with the inefficiency, which implies that improving infrastructures would help to enhance vegetable production efficiency. Among six infrastructure elements, the overall index was higher in ASC, followed by road network, financial institution, school, irrigation, and electricity (Table 3).

Table 3. Average index for underdevelopment of infrastructures by agroecological region

Agroecological region	Road network	Irrigation	Electricity	ASC	Financial institutions	School
Tropical region	4.05	2.45	3.11	3.76	4.13	3.90
Hill region	3.23	2.53	2.19	3.56	3.03	2.20
Mountain region	3.47	2.59	2.13	3.66	2.73	2.64
Mean	3.58	2.52	2.48	3.66	3.30	2.91
Rank	2	5	6	1	3	4

Note: Each infrastructure element has a value of 1 to 5; higher index represents less development

The higher index in ASC indicates that institutions assigned for providing extension services were poorly developed; thus farmers were unable to get enough extension facilities, and consequently affected on the inefficiency in vegetable production. Garrett (2001) argued that a larger number of extension institutions provide educational services at a lower cost that contribute to increase the efficiency. We suggest policy makers to establish ASC adjacent to the vegetable farming areas and disseminate improved technologies on vegetable farming practices and provide technical assistance to the farmers. The underdevelopment of road network adversely affected farmers in delivering the inputs and outputs required from and to the markets that made the product more expensive and inefficient. Rudimentary rural road network not only adds to the cost of the product but also increases the marketing losses. Adequate agriculture road network is essential for vegetable sector development. The existence of inadequate number of financial institutions in rural areas compelled farmers to avail credit from informal financial sources such as local moneylenders, traders, relatives, and friends. About 72% of the households borrow credit from the informal sectors despite the much higher interest rates up to 42%, while banks charge 8 to10% annually, because borrowers prefer faster lending process even if the interest rate is higher (Ferrari et al., 2007). This situation limits the accessibility of the required credit, reduces the inputs use by the farmers, and adversely affects vegetable production (Kumar et al., 2013). Thus, establishment of financial institutions in rural areas and disbursement of credit to the farmers with competitive interest rate can help to access financial resources and can contribute inimproving the efficiency in vegetable production.

3.4 Technical Efficiency of Vegetable Farms

The mean of the technical efficiency score was found to be 0.77, ranged from 0.30 to 0.94 (Figure 2). It showed that a wide range and great extent of inefficiency was found in Nepalese vegetable farms. The main implication of these efficiency scores is that vegetable farmers could improve the efficiency level, and substantially increase additional outputs (23%) by improving farm management practices at the frontier level within the existing technology. The best farming practices provides higher yields than the average farm that leading to be the frontier level of efficiency. About 97% of the farms exhibited below the highest level of benchmarking implying considerable scope for improving the efficiency by learning the best allocation decisions from the efficient farms.The frequency distribution of efficiency showed that 23% of the farms exhibited less than 0.70 score, majority of the farms (74%) had a range of 0.71 - 0.90 scores, andonly 3% farms exhibited more than 0.90 score.

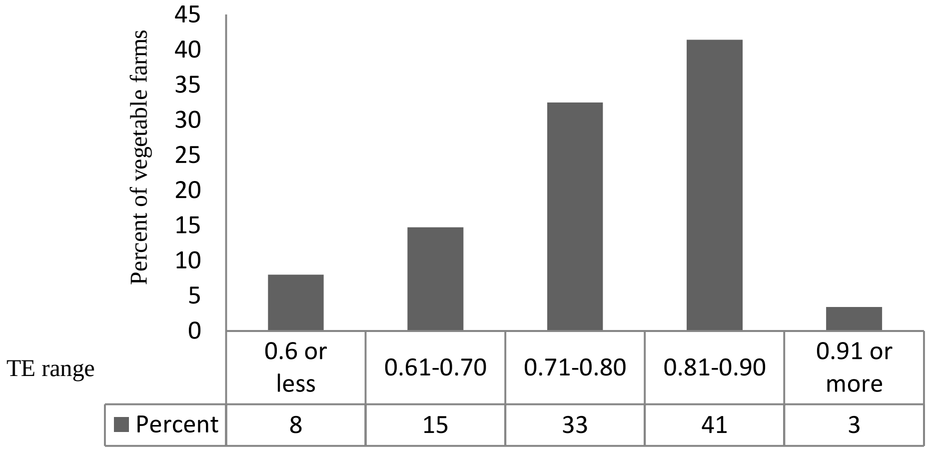

Fig. 2. Technical Efficiency Score Distribution of Vegetable Farms

The vegetable farms were categorized into two groups: large (≥0.98 acres), and small (<0.98 acres). The technical efficiency was found to be quite high in larger farms compared to small farms (Table 4). This support the principle of economics of scale; as larger the farm size, lower the cost, and higher the efficiency. This finding was consistent with the results of Ogundari and Ojo (2007) and Nyagaka et al. (2010), and contradictory to Enwerem and Ohajianya (2013), and Altieri et al. (2011). The policy implication of higher efficiency of larger scale farm is that the land size for vegetable farming should be increased in order to contribute for commercialization and enhance efficiency in the vegetable production.

Table 4. Technical efficiency of vegetable farms by farm size

Farm size	Number of farm	Technical efficiency	Standard deviation	Minimum	Maximum
Small farms (< 0.98 acres)	207	0.77	0.105	0.42	0.94
Large farms (≥ 0.98 acres)	119	0.78	0.105	0.30	0.93

3.5 Technical Efficiency of Vegetable Farms by Agroecological Regions

Agroecology perspective analysis is crucial for ecology-based agricultural development that would have a meaningful impact on the livelihood and food security of smallholder farmers. The results revealed that vegetable farming in tropical region was more efficient than in the hill and mountain regions, and hill farming was more efficient than that in the mountain (Table 5).

Table 5. Technical efficiency of vegetable farms by agroecological regions

Agroecological region	Observation	Mean TE	Standard deviation	Minimum	Maximum
Tropic	80	0.784	0.096	0.524	0.932
Hill	180	0.780	0.111	0.300	0.941
Mountain	86	0.747	0.098	0.425	0.888
All locations	326	0.772	0.105	0.300	0.940

The higher efficiency in tropical vegetable farming could be explained by fairly more productive land, more access to infrastructures, and effective extension services. The efficiency gap was much higher in hill vegetable farms than in the tropical and mountain.Vegetable production could considerably increase in all the agroecological regions,and more specifically in the mountain and the hill region by increasing technical efficiency operating thefarms atthefrontier level.

3.6 Technical Efficiency, Optimum Outputs and Output-Loss in Vegetable Farms

The average of technical efficiency level, actual output, optimum potential output and output-loss in vegetable farms are presented in Table 6. The optimum level (maximum) of vegetable outputs can be aattained by operating the farms at the frontier level. The optimum level was estimated by dividing the actual output by the technical efficiency scores of individual farms. The output-loss is defined by the amount that have been lost due to the inefficiencies in vegetable production given prices and fixed factor endowments. It was calculated by multiplying the optimum level of outputs with the technical inefficiency scores.

As the Table 6 demonstrated that each vegetable farmer has been lost outputs by about 24 % (US$932.00 per farm) because of the inefficiencies in vegetable farming. If the farms had been operated with best practices at the frontier levels, the farmers would have increased that lost outputs. Thus the additional outputs would be used for rural economic development activities.

Table 6. TE, Actual Output, Optimum Output, and Output-Loss at Household Level Vegetable Farms

Variables	Mean TE	Actual output (US$)	Optimum -output (US$)	Output-loss (US$)	Output -loss (%)
Output-loss by technical inefficiency					
Lower TE (<0.77)[b]	0.67	2741.61	4126.80	1385.20	33.57
Higher TE (≥ 0.77)	0.84	3215.44	3818.35	602.90	15.79
t-ratio (lower vs. higher TE)	-23.538***	3.955***	1.908**	11.889***	
Output -loss by farm size					
Small-size (< 0.40ha)[c]	0.77	3174.78	4158.19	983.41	23.65
Large-size (≥ 0.40 ha)	0.78	2744.65	3579.70	835.053	23.33
t-value (very small vs. small)	-0.721	3.487***	3.541***	1.846**	
Output-loss by age of manager					
Younger farmer (>42.51 years)[d]	0.78	3083.43	4006.24	922.814	23.03
Elder farmer (≥42.51 years)	0.77	2957.52	3892.69	935.17	24.02
t-value (younger vs. elder)	0.469		0.708	-0.158	
Output-loss by farmers' association					
Non-member	0.78	2985.86	3911.06	925.196	23.66
Member	0.77	3030.89	3961.82	930.93	23.50
t-value (non-member vs. member)	0.302	-0.34	-0.28	-0.07	
Output-loss by number of trainings					
Less training	0.77	2834.12	3712.35	878.23	23.83
More training	0.77	3305.54	4314.75	1009.22	23.44
t-value (less vs. more)	0.150	-3.88***	3.74***	1.65**	
Output-loss by market access					
Market not access	0.77	2603.69	3418.45	814.76	23.83
Market access	0.77	3190.60	4167.65	977.05	23.44
t-value (not access vs. access)	-0.071	4.56***	4.38***	-1.91**	
Output-loss by infrastructure index					
Less infrastructure (<18 index)[e]	0.77	2786.62	3654.60	867.98	23.75
More infrastructure (≥ 18 index)	0.77	3217.22	4199.35	982.13	23.39
t-value (less vs. more infrastructure)	0.090	-3.62***	-3.45***	-1.47*	
Average		2,991.00	3,923.00	932.00	23.71

Note: [b]Mean of technical efficiency 0.77; [c]mean of farm size 0.40 ha; [d]mean of age of farmers 42.51 years; [e]mean of index for under development of infrastructure 18.00.

The technical efficiency was positively correlated with output levels; as higher the efficiency, higher the outputs, and lower the losses. The larger farms had higher efficiencies with lower output-losses than small-size farms. The younger farmers had higher levels of efficiencies, and lower output-losses than those that of elder farmers. The mean of outputs was higher to the farms operated by the farmers who were associated with farmers association. The numbers of trainings to the farmers did not show significant effects on efficiency and output levels.

4. Conclusions and Policy Implications

We measured the technical efficiency of vegetable farms and determined factors that influenced the inefficiency in different agroecological regions using stochastic frontier analysis with cross-section data. Based on the results, the technical efficiency score was found to be 0.77, revealed that there was substantial scope to increase vegetable outputs with existing technology. Operating the vegetable farms at the frontier level would release surplus input resources that could be used in alternative economic activities to generate extra income for the farm families.

The productive input variables (land, labor, animal power, fertilizer, compost, pesticide, and capital) proved as important factors influence the total value production differential. This implied that policymakers should focus on increasing farm size and making land more productive, developing efficient and skillful labor, upholding animal power making it more productive, promoting compost for plant nutrients, and making more accessible and affordable fertilizers, pesticides, and capital to the farmers.

The age of household head, training to farmers, market access, and infrastructure development were confirmed to be the major parameters determining the levels efficiency in vegetable farming. The positive relationship of younger farmers with vegetable production implied that policies should encourage younger farmers with adequate incentive packages incorporating extension services, training programs, and financial access that help to enhance efficiency. Different types and levels of training program focus on crop management, insect-pest control, input management, and market management need to be implemented.

In addition, market access to the farmers reduces the inefficiency in vegetable farming. Policies should give priority in greater access of market to the farmers that would require government support for providing adequate resources in establishing market infrastructures, and endorse farmer-friendly rules and regulations instead of the traders.

The development in infrastructures such as establishment of agriculture service centers at the field level, agriculture road networks, and financial institutions were seen to be the key infrastructure components in enhancing efficiency in vegetable production. Policymakers need to pay serious attention to formulate policies and programs in prioritizing these specific infrastructure components that entail huge budgetary resources. But scarcity of resources could be a problem for a resource-poor country like Nepal. Therefore, exploring the local resources and its utilization through participatory development approach aligned with the international funding sources could be one better alternative for necessary resource managementand developing infrastructures.

Those farms, accessed with markets and more infrastructure facilities, performed the higher levels of outputs. The larger farms, farms managed by younger farm manager, farmers associated with farmers' association, farms accessed with markets, and farms associated with well-developed infrastructure, performed the higher levels of technical efficiencies, higher levels of vegetable outputs, while less level of output lost.

Finally, we recommend the following policies: (i) encourage younger farmers in vegetable farming; (ii) increasethe numberof trainings and extension programs integrating them with younger farmers' participation; (iii) provide greater accessof the farmers to the markets; and

(iv) develop infrastructures,especially focus on the establishment of agriculture service centersin the vegetable production areas, construction of agriculture road networks between the production areas and markets, and establishment of financial institutions in the rural areas.

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