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Efficiency of small scale vegetable farms: policy implications for the rural poverty reduction in Nepal

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Abstract: Poverty and hunger reduction are intertwined challenges and enduring issues in the world, particularly in developing countries. Improvement in the efficiency in vegetable farming helps the farmers increase the per capita income, reduce poverty and eventually improve the livelihood of smallholder farmers. This paper evaluates economic efficiency of vegetable farms in Nepal using a non-parametric data envelopment analysis (DEA) approach. The results show evidence to suggest that vegetable farms in Nepal have a considerable potential for improving the vegetable production efficiency with a greater access to improved seed, agricultural credit, and training and extension services. Some policies options with regard to the vegetable production technology, and support services for farmers in general and women farmers in particular, are suggested to increase the farm efficiency. While some of these support services are currently available, we suggest that a more focus be given to creating the improved market access, to the women focused extension, and to training packages for the sustainable production. These support services can lead to increases in the farm income and to reduce poverty.

Keywords: DEA, improve efficiency, vegetable production, women participation

Poverty and hunger reduction are intertwined challenges and enduring issues in the world, particularly in developing countries. The United Nations Organisation, through its Millennium Development Goal, MDG 1, and the World Bank put a high priority on ending the poverty in the world by 2030 (World Bank 2014). The feasibility of achieving an absolute poverty reduction (based on the $1 a day poverty line) depends on the rate of the average income growth and the level of income inequality (Mehta and Shah 2003). Asia, where more than half of the world's poor live, has a disproportionate distribution of the poor with almost three-quarters of the continent's poor residing in South Asia (SAARC 2014). Furthermore, the distribution of the poverty incidence within the South Asian Association for Regional Cooperation (SAARC) members (eight countries) is also disproportionate and Nepal has the fourth highest incidence of poverty (25.2%) after Afghanistan (38.5%), Pakistan (33.8%), and Bangladesh (31.5) (SAARC 2014). In Nepal, the poverty incidence varies by geography, it is higher in the mountainous region of the country (43.3%) and lower in the hilly and terai regions (Southern tropical plain) with rates hovering around 25%.

For a majority of the people in South Asia, agriculture is the mainstay and agriculture development is thus vital in achieving any poverty and associated hunger reduction targets (Binswanger and Quizon 1986; Islam 2008). Poverty alleviation and food security have been major goals in the successive development plans in Nepal (NPC 1995; MOAD 2004, 2014). In particular, the Thirteenth National Development Plan has a target of reducing the poverty head count ratio (HCR) below 18% with the annual economic growth sustained at 6.0% (agriculture: 4.5, non-agriculture: 6.7) and employment growth at 3.2% (NPC 2014). To realize these objectives, high-value crops including vegetables are identified as the priority areas. Indeed, vegetables play an important role in reducing hunger and malnutrition for billions of people around the world (AVRDC 2010), and offer great opportunities for the poverty reduction through employment and income generation (Weinberger and Lumpkin 2007; Tiwari et al. 2008). However, standing in the way of achieving the expectations of the periodic plans (discussed above), particularly the vegetable farming sector faces several constraints related to farm level inefficiencies.

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Recently, an increasing number of Nepalese farmers are going into the commercial production of vegetables, especially in the peri-urban areas or areas with good roads and market access (Sapkota 2004). However, more rural farm households in Nepal, like those in many other developing countries, are constrained by a low literacy, low rates of technology adoption, and an inefficient use of resources. This leads to high costs of production and the loss of cost advantages compared to imported vegetables. However, with improvements in efficiency, Nepal could improve its comparative advantage in the vegetable production and marketing. Such increased efficiency could help to close the current productivity gap in the vegetable productivity (currently 12.8 mt/ha, but potentially 17 mt/ha) (MOAD 2014) allowing vegetable farmers not only to meet the increasing domestic demand for vegetables but also to export vegetables to the neighbouring countries.

Nepal has diverse agro-ecological conditions (Southern tropical plain to Northern temperate mountainous regions) and this climatic variation offers Nepalese farmers a rare opportunity to produce vegetables throughout the year. However, to improve their comparative advantage, Nepalese vegetable producers must achieve a higher farm productivity and efficiency. Some reports indicate that the poor quality seeds, inadequate fertilizers, and a poor access to credit and markets limit the productivity of vegetable producers (NARC 2010; MOAD 2014). While this is undoubtedly true, such generalized statements do not provide any specific policy prescriptions for a country where vegetables are grown in every seasons and in the diversified agro-econlogical regions. Therefore, there is a need for empirical studies that analyse the relationship between inputs, farm-specific characteristics, socio-economic factors and efficiency in the vegetable production. Only a focused research of this nature can be the basis of policies that promote productivity and efficiency at the household level. The goal of this study, therefore, is to evaluate the economic efficiency of vegetable farms for winter vegetables and to suggest a few high priority areas for the policy intervention designed to improve the efficiency of the vegetable production, and lead to substantial and sustainable increases in the income and decreases in the rural poverty in Nepal.

MATERIALS AND METHODS

Study areas and sampling design

The geographical focus of this study is the Central region (one of five development regions of the country). This region was selected because it represents the largest region in terms of area (38% of 0.25 million hectares) and contributes the largest vegetable production (40% of 3.3 million tonnes) in 2012 (MOAD 2013). Four districts were selected for this study such that they represent all three agro-ecological regions (mountain, hill, and terai) of the country (Figure 1).

We selected two districts from the hilly region because there is a large number of districts in this region which grow vegetables. For each of these four disticts, a list of major villages was prepared in con-

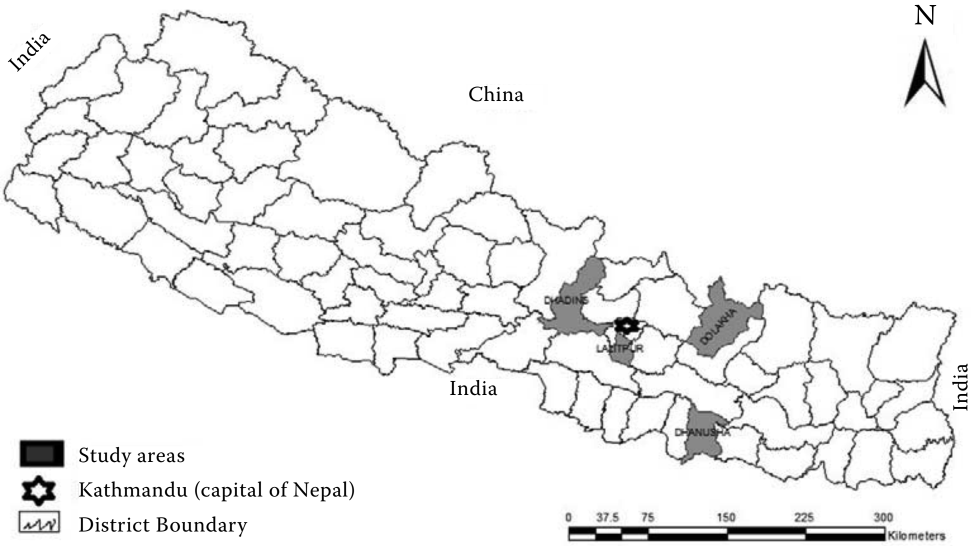

Figure 1. Map of Nepal showing study area

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Table 1. Study areas and their characteristics

District	Villages	Sample size	Geography
Dolakha	Boach Bhimeshowar Kavre	90	Mountain: Characterized by higher altitudes (2000m to 2600m), cold weather, steep land, lack of basic infrastructure (irrigation, roads and market facilities) and weak access to public services including extension services.
Lalitpur	Luvu, Jharuwarasi Devichor	88	Hills: Characterized by moderately cool weather with moderate altitude (1000m to 1900m), upland and valley with terraced land, and relatively better access to roads, market infrastructure, extension services, irrigation facilities, and education facilities.
Dhading	Jeevanpur Benighat Dhusa	165	
Dhanusa	Dhalkebar Bengadabar Digambarpur	159	Terai: Characterized by lower altitudes (250m to 500m), hot climate, mostly lowland, and with better access to roads, markets, irrigation facilities, and extension services.

Source: author's composition

sultation with the District Agriculture Development Offices (DADO). Three villages in each district were randomly selected to be surveyed (Table 1). Next, using the profile of each district obtained from the DADO, we randomly selected 502 farms, from all farms which produce vegetables for sale after the home consumption, to be included in the study.

Although the winter season is characterized by a dry and cold weather, less rain, and less irrigation facilities, a majority of the Nepalese farmers cultivate vegetables during this season compared to summer, when the cereal crop like paddy is the prime focus. Therefore, in this study, we considered the winter season vegetables (harvested in September–February) which include cauliflower, tomato, cabbage, radish, bean, and cowpea. The data on costs of production inputs, the quantity of production, farm gate prices and the information on farm household characteristics were collected from vegetable farms during July and August, 2013.

Theoretical and empirical analysis

Efficiency is defined as the maximum of ratios of weighted outputs to weighted inputs subject to the condition that similar ratios for every decision making unit (DMU) are less than or equal to unity (Cooper et al. 2011). The efficiency of each DMU then is relative to the output to input ratio of the most efficient farm. In general, there are two measurement methods of efficiency analysis, the parametric and non-parametric one. Parametric approaches provide a consistent framework to analyse efficiency (Chavas and Aliber 1993); however, a weakness of the parametric approaches is that the stated hypothesis can never be detected directly (Varian 1984). A non-parametric deterministic mathematical programming approach was developed by Farrell (1957), which attributes all the deviations away from the frontier technology to inefficiency. This approach does not require any specific functional forms and does not impose a priori parametric restrictions on the underlying technology. In addition, this non-parametric approach can be used for technologies involving multiple inputs and multiple outputs, and it can estimate the technical, allocative, pure technical, economic and scale efficiencies. A number of studies have been carried out to analyse the efficiency of agriculture using the DEA. Examples of such studies include Chavas and Aliber (1993), Sharma et al. (1999), Dhungana et al. (2004), Murthy et al. (2009), and Watkins et al. (2014). There is a particular dearth of studies that should analyze the economic efficiency of smallholder vegetable farms.This study is an attempt to evaluate the efficiency of farms so as to be able to generalize the findings at the national level. To make it possible to generalize the results at the national level, we considered a random sample of farms from all three agro-ecological regions of the county. In this regard, this is quite unique.

In this study, we evaluate the efficiency of vegetable farms under both the constant returns to scale (CRS), as in Charnes et al. (1978), and the variable returns to scale (VRS) as in Banker et al. (1984). The constant returns to scale (CRS) assumption proposed by Charnes et al. (1978) gives the overall technical efficiency score by solving Equation 1, which is the objective function of a linear programming model. Suppose n decision making units (DMUs), in this

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case vegetable farms produce a single type of output by using different inputs, m. Here, Y_i is the output produced; X_i is the vector of inputs ($m \times 1$); Y is the vector of outputs ($1 \times n$), and X is the ($m \times n$) matrix of inputs of DMUs. Then the problem can be stated as follows:

$$\min \theta_i^{CRS}$$
$$\theta_i^{CRS}\lambda \quad (1)$$
$$\text{Subject to: } Y_i \leq Y\lambda$$
$$\theta_i^{CRS}X_i \geq X\lambda$$
$$\lambda \geq 0$$

Here, θ_i^{CRS} is the technical efficiency score of the i^{th} DMU under the CRS and λ is ($n \times 1$) vector of the weights attached to each of the efficient DMUs. A separate linear programing problem is solved to obtain the technical efficiency score for each of the DMUs. For any DMU, if $\theta^{CRS} = 1$, then the DMU is on the frontier and is technically efficient assuming the CRS; and if $\theta^{CRS} < 1$, the DMU lies below the frontier and is considered technically inefficient. The technically efficient cost of production of the i^{th} DMU is given by $W_i'(\theta_i^{CRS}X_i)$ for the CRS model. Technical efficiency (TE) refers to the ability of a farm to either produce the optimum level of outputs from the given bundle of inputs, or to produce the given level of outputs from the minimum amount of inputs for the given technology. It may help in exploring the potential benefits of promoting the most efficient of existing technologies in use by the Nepalese vegetable farmers. Allocative efficiency (AE), also called the price efficiency, measures the degree to which the farm equates the marginal value product with the marginal cost.

An alternative approach developed by Banker et al. (1984) assumes variable returns to scale (VRS), which commonly exists in agriculture. Given this possibility, we analysed the efficiency of the Nepalese vegetable farms using both the CRS and the VRS DEA approaches. In order to derive the overall economic efficiency (EE), we can solve the cost-minimizing DEA model (Equation 2) under CRS assumption, which is the objective function of a linear programming model (Fare et al. 1985, 1994).

$$\min W_i' X_i^*$$
$$x_i^*\lambda \quad (2)$$
$$\text{Subject to: } Y_i \leq Y\lambda$$
$$X_i^* \geq X\lambda$$
$$\lambda \geq 0$$

where the cost-minimizing or economically efficient input vector for the i^{th} DMU is X_i^*, given its input price vector, W_i, and the output level, Y_i. The overall economic efficiency score for the i^{th} farm was computed as the ratio of the minimum cost to the observed cost and it is comparable to the economic efficiency score (Equation 3), where $EE = 1$ indictes economically efficient, and $EE < 1$ indicates economically inefficient. The economic efficiency for a DMU can also be defined as the product of the technical and allocative efficiency (Farrel 1957).

$$EE_i = \frac{W_i'X_i^*}{W_i'X_i} \quad (3)$$

The allocative efficiency index is the ability of a farm to choose its inputs in a cost minimizing way (Equation 4).

$$AE_i = \frac{EE_i}{\theta_i^{CRS}} = \frac{W_i'X_i^*}{W_i'(\theta_i^{CRS}X_i)} \quad (4)$$

where $AE = 1$ indicates that the farm is allocatively efficient, and $AE < 1$ indicates the maximum proportion of cost that the technically efficient farm could save by behaving in a cost minimizing way (Chavas and Aliber 1993).

The overall technical efficiency can be disaggregated into its components: the pure technical efficiency (PTE) and the scale efficiency (SE) by solving a VRS DEA model, which is obtained by imposing the additional constraint, $\sum_{j=1}^{n}\lambda_j = 1$ on the Equation (1) (Banker et al. 1984). When separating the scale effect from the technical efficiency, the pure technical efficiency is obtained from the VRS DEA. Scale efficiency is defined as the most efficient scale of operation in the sense of maximizing average productivity. Therefore, the technical efficiency score under the VRS is denoted by θ_i^{VRS}, and the technically efficient cost of production of the i^{th} DMU under the VRS is equal to $W_i'(\theta_i^{VRS}X_i)$. The technical efficiency measure from the VRS DEA, (θ_i^{VRS}) is equal to, or greater than the CRS measure (θ_i^{CRS}) for the i^{th} DMU because the VRS analysis is more flexible and envelops the data in a tighter way than the CRS analysis. The scale efficiency was computed as the ratio of the overall technical efficiency measure under the CRS (θ_i^{CRS}) of i^{th} DMU to the corresponding measure under the VRS (θ_i^{VRS} in Equation 5) (Chavas and Aliber 1993).

$$SE_i = \frac{\theta_i^{CRS}}{\theta_i^{VRS}} \quad (5)$$

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where *SE* = 1 indicates that the farm is operating at the efficient scale, and *SE* < 1 indicates the scale inefficiency (i.e. that the farm could increase productivity by increasing or decreasing its scale). The potential for scale inefficiency exists due to the presence of either increasing or decreasing returns to scale, which can be estimated by solving the non-increasing returns to scale (NIRS), $\Sigma_{j=1}^{n}\lambda_j \leq 1$ or the non-decreasing returns (NDRS), $\Sigma_{já=1}^{n}\lambda_j \geq 1$.

We hypothesized that vegetable farms were efficient ($\gamma = 0$) using the likelihood ratio (LR) test (Equation 6).

$$\gamma = -2[\ln\{likelihood\ (H_0)\} - \ln\{likelihood\ (H_0)\}] \quad (6)$$

The LR test statistics have an approximately Chi-square distribution with the degrees of freedom 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).

Tobit analysis

After the calculation of the efficiencies using the DEA, we adopted a two-limit Tobit model (Maddala 1985) to determine the determinants of vegetable farm efficiencies (farm variables related to the technology and socio-economic characteristics). The dependent variables in the regression Equation (7) have censored distributions rather than normal distributions because their efficiency scores are bounded between zero and unity and the OLS estimates using a censored sample give an inconsistent estimation. Thus, we estimated the following Tobit regression model using the maximum likelihood approach (Tobin 1958).

$$\begin{aligned} E_i^* &= \beta_0 + \sum_{m=1}^{M} \beta_m Z_{im} + \varepsilon_{i,} \qquad \varepsilon_i \sim ind(0, \sigma^2) \\ E_i &= 1 \ if \ E_i^* \geq 1 \\ E_i &= E_i^* \ if \ 0 \leq E_i^* \leq 1 \\ E_i &= 0 \ if \ E_i^* \leq 0 \end{aligned} \quad (7)$$

where, E_i^* is a latent variable representing the efficiency score for the i^{th} DMU that is expressed in terms of the observed variable E_i (efficiency score estimated from the DEA); β_0 *and* β_m are unknown parameters to be estimated; Z_{im} are explanatory variables associated with the vegetable farms; and ε_i is an error term that is independently and normally distributed with zero mean and the constant variance $(0, \sigma^2)$.

In addition, we tested for heteroskedasticity using the White's test (Hill et al. 2011). The estimated value was found to be less than critical, and we conclude that there is no heteroskedasticity problem.

Data and variables specification

Vegetable production was modelled as a function of land, labour, traction power, seed, organic matter, chemical fertilizers and other variable costs. The quantity (kg) of the vegetable output was the dependent variable; the fixed factor was land (in hectares); labour and traction power (man-days); organic matter (kg); and the variable input costs of seed, chemical fertilizer, and other inputs estimated in Rupees (Rs 86.96 = 1 USD as of February 2013) on the basis of prices paid by the farmers. For the analysis of the EE and AE, the land charge was estimated assuming 20% of the vegetable output value; labour, traction power, and organic matter (Rs); and seed, and fertilizer (kg). The household member who was responsible for the decision-making regarding the vegetable farming was considered the farm manager. The seed type (improved or local) was treated as a dummy; 1 if the farmers used improved seed and 0 otherwise. Extension activities, especially the training program plays a key role in disseminating information to the farmers. The number of trainings received by the farm manager was included to determine the effect of information regarding new technology and farming practices on the efficiency of the vegetable production.

Because of the lack of access to financial resources, rural farmers frequently depend on the informal sources (money lenders, relatives and friends), which usually charge higher interest rates. Ferrari et al. (2007) reported that about 72% of the farm households get credit from the informal sectors despite the much higher interest rates (up to 42% versus 8–10% charged annually by banks), primarily because of the lack of formal financial institutions in rural areas. This credit constraint leads to the reduced application of inputs in the vegetable farming and that has negative impacts on the vegetable production (Kumar et al. 2013). Therefore, we included the credit access as a dummy; 1 if the farmer availed credit and 0 otherwise. Rural smallholders are constrained by the lack of the access to markets for fresh products and to account for this in our model, we introduced a market access dummy variable; 1 if the farmer is satisfied with the access to market and 0 otherwise.

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The government of Nepal, in collaboration with the donor partners, has been investing a huge amount of resources, especially since 1990s in the vegetable production and marketing. To analyse the effects of these support services on the farm efficiency, we introduced an external support index consisting of seven components: fertilizers, irrigation, seeds, pesticides, production material (ploughing, digging, sprayer material), extension material (leaflets, posters and mass communication from newspaper, radio and television) and post-harvest material (packaging, harvesting, weighing, drying material). Each of these components was indexed from zero to one; one if the farmer was satisfied with the support and zero otherwise. Thus, the total index of each farm household ranged from zero to seven.

Vegetable farming is very labour-intensive, and women are typically the major source of labour in the agriculture production and food systems (ILO 2008). However, rural women are less likely than men to have access to financial services, technology, education and markets (Spieldoch 2011). Gender inequality limits the economic growth and diminishes the effectiveness of the poverty reduction programs and policies. Thus it is important to include gender in the analysis of efficiency in agriculture (Bozoğlu and Ceyhan 2007). Therefore, we introduced two gender related indicators in our model. The first is the dummy variable, gender of the farm manager, measured 1 if the farm manager was male and 0 otherwise. The second is a women participation index, which captures five types of contributions: (1) land preparation, (2) plantation, (3) crop management (irrigation, insect-pest management, fertilization and weeding), (4) harvesting and marketing, and (5) decision-making with regard to the vegetable farming. Each of these five contributions was scored from one to five (minimal participation of women received a one and the highest participation received a five). Thus, the aggregated index ranged from 5 (minimum) to 25 (maximum) for the farm household.

RESULTS AND DISCUSSION

Descriptive statistics for the variables used in this study

The summary statistics of the variables used in this study are presented in Table 2. The mean of the farm size was quite small (0.128 ha), and the average vegetable production was more than 2 tonnes per farm. The major variable costs were for the chemical fertilizer, seed, organic matter, and other inputs. A minority of farmers (23%) used the improved seed varieties, the average number of trainings received

Table 2. Descriptive statistics for variables used in this study

Variables	Units	Mean	Std. dev.
Output	kg/farm	2 121.082	1 685.297
Land	hectare/farm	0.128	0.091
Labour	man-days/farm	30.705	20.917
Traction power cost	man-days/farm	3.764	2.502
Seed cost	Rs[1]/farm	2 806.325	2 173.769
Organic matter	kg/farm	283.705	183.409
Chemical fertilizer cost	Rs/farm	3 305.329	2 666.143
Other variable costs	Rs/farm	5 558.386	2 983.499
Seed type	dummy	0.229	0.421
Training of farm manager	number	1.213	1.855
Credit access	dummy	0.333	0.472
Market access	dummy	0.775	0.418
External support index	number	5.277	1.479
Gender of farm manager	dummy	0.819	0.386
Women participation index	number	15.721	3.906

[1]Nepali currency (Rupees) Rs 86.96 = 1USD as of February 2013.

Source: survey conducted during July–August, 2013

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Table 3. Ordinary least square estimates and standardized coefficients in vegetable farms

Variables	Ordinary least square		Standardized coefficient	
	coefficient	std. error	beta value	rank
Constant	2.733[a]	0.653		
lnLand	0.159[a]	0.060	0.153	4
lnLabor	0.286[a]	0.067	0.243	1
lnTraction power	0.104[b]	0.045	0.091	5
lnSeed	0.059[b]	0.033	0.056	6
lnOrganic matter	0.257[a]	0.042	0.214	3
lnChemical fertilizer	0.200[a]	0.030	0.239	2
lnOther variable input cost	–0.016	0.038	–0.012	7
Sum of elasticities	1.049	–		

[a], [b], [c] indicate significant at 1, 5 and 10 % levels, respectively

Source: survey conducted during July–August, 2013

by farm managers was quite low, less than 35% of the farmer availed credit, 77% of the farmer accessed markets, and the average external support index was 5.3 out of 7.0. A larger number of farms (82%) were managed by women managers, and the average women participation index was more than 16 out of 25, which indicated that there was a considerable contribution of women labour in the vegetable farming.

Ordinary least square estimation

The results of the ordinary least square estimation (OLS) and the standardization of coefficients of the variables used in this study are reported in Table 3. All the variables, except other variable input costs were found to be significant in determining the vegetable outputs. The sum of coefficients, 1.049, is almost in unity which indicates that there are near constant returns to scale in the vegetable production. The output elasticities, in decreasing order, were for labour, organic matter, chemical fertilizer, land, traction power and seed. With regard to the standardized coefficients (Table 3), labour, chemical fertilizer and organic matter, these are the three inputs with a greater effect on vegetable outputs.

Economic, technical, allocative and scale efficiency scores for vegetable farms

The average economic, technical, allocative, and scale efficiency scores in the vegetable production estimated with the DEAP 2.1 program (Coelli 1996) are summarized in Table 4. Results show that there is a big gap between the observed and frontier efficiency scores under both approaches. The farmers in the study are using a number of different technologies, most of which are inefficient. To reduce the inefficiencies, many of the farmers would have to adopt superior technologies. The average economic, technical and allocative efficiency scores were higher under the VRS than the CRS assumption, which was consistent with the previous findings (Sharma et al. 1999; Dhungana et al. 2004; Murthy et al. 2009).

The mean of the EE was found to be 0.30 under the CRS, and 0.39 under the VRS assumptions, which is far from the frontier efficiency level. This indicates that there is a great deal of inefficiency in the Nepalese vegetable farms and that substantial reductions in the costs of variable inputs are possible without reducing the production. Few vegetable farms (less than 1%) had efficiency scores more than 0.91 under the VRS, while a majority of the farms (92% under the CRS, and 82% under the VRS) had efficiency scores equal to, or less than, 0.50. The mean TE score were found to be 0.62 under CRS and 0.73 under VRS; less than 15% of farms under the CRS and 26% farms under the VRS exhibited efficiency scores more than 0.91. A majority of the farms (more than 53%) showed efficiency scores between 0.51 and 0.90 under both approaches, whereas less than 32% farms had efficiency scores equal to, or less than, 0.50. The mean of the AE scores were 0.50 and 0.55 under the CRS and the VRS, respectively, while very few vegetable farms (around 1%) achieved efficiency scores more than 0.91 under either approach. Forty-six percent of farms under the CRS and 58% under the VRS exhibited the AE scores between 0.51 and 0.90, and

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Table 4. Economic, technical, allocative, and scale efficiency for vegetable farms under CRS and VRS DEA models

Efficiency score	EE	TE	AE	SE
≤ 0.40	78.29 (60.96)	20.32 (6.97)	28.69 (21.51)	3.98
0.41–0.50	13.35 (20.92)	11.75 (7.37)	24.70 (19.52)	4.58
0.51–0.60	5.38 (8.57)	18.13 (16.33)	20.72 (21.51)	5.18
0.61–0.70	1.79 (4.78)	12.55 (17.73)	16.33 (18.73)	6.97
0.71–0.80	0.80 (2.19)	9.96 (12.15)	6.37 (12.15)	8.96
0.81–0.90	0.20 (1.58)	12.35 (13.55)	2.79 (5.38)	13.94
> 0.91	0.20 (1.00)	14.35 (25.9)	0.40 (1.20)	56.37
Mean efficiency	0.30 (0.39)	0.62 (0.73)	0.50 (0.55)	0.85
Standard error	0.140 (0.157)	0.235 (0.203)	0.156 (0.169)	0.19

EE = economic efficiency, TE = overall technical efficiency, AE = allocative efficiency; SE = scale efficiency; figures in parenthesis are under VRS DEA

Source: survey conducted during July–August, 2013

53% of farms under CRS and 41% under the VRS scored equal to, or less than, 0.50. The average SE was found to be 0.85, indicating that 15% of the costs the vegetable farms could be eliminated by changing the scale of farms under the existing technology. Most of the farms (56%) exhibited scale efficiency scores of more than 0.91, about 35% farms had scale efficiency scores between 0.51 and 0.90, and less than 10% of farms scored less than 0.50 on the scale efficiency.

In general, the estimated levels of economic and technical inefficiencies suggest that significant reductions in the variable input costs can be achieved in the vegetable farming. While the adjustments in the scale of farms offer limited opportunities for increased efficiencies, significant cost savings could be achieved by moving the farms towards the frontier isoquant through a more efficient use of inputs (technical efficiency) and the reallocation of inputs (allocative efficiency). As Table 4 indicates, the technical inefficiency and the allocative inefficiency contribute about equally to the overall economic inefficiency, especially when the scale effects are used to adjust the technical inefficiency.

Factors affecting efficiency in vegetable production

In order to determine if there were any underlying causes (like technology, and support services including extension, training or infrastructure services) for the inefficiencies of vegetable farms, various explanatory factors were regressed on the EE, TE, AE, PTE and SE using a two-limit censored Tobit model. The coefficients of parameters used in the model are presented in Table 5. As the last row of Table 5 indicates, we are able to reject the null hypothesis of no relationship between the explanatory variables and the economic efficiency, technical efficiency, allocative efficiency, pure technical efficiency, and the scale efficiency in vegetable production. We conclude therefore that there is evidence that the inefficiencies are at least partially related to the explanatory variables indicated in Table 5.

There is a number of interesting significant relationships identified in Table 5.The seed type used by the farmer was significant and positive in the EE and AE Equations, implying that the improved seed varieties increase the economic and allocative efficiency in the vegetable farming. Improved varieties can potentially be technically more efficient though a higher productivity and play an important role in overcoming the poverty and food insecurity for the smallholder poor farmers (Fuwa 2007; da Silva Dias 2010). The number of trainings taken by the farm manager was not significant but it still showed positive effects on the EE, AE, and PTE in vegetable farming. Extension and training programs help farmers in the decision-making, particularly for the varietal selection, farming practices, and marketing activities (Akobundu et al. 2004). In the recent years, farmers' field schools have been established to develop the farmers' competencies in crop management practices focusing on the integrated pest management (IPM) (Joshi and Karki 2010). Since the IPM approach is focused on encouraging the use of inputs appropriately and minimizing the use of toxic chemicals, it helps to improve the health of produc-

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Table 5. Factors affecting economic, technical, allocative, pure technical, and scale efficiency in vegetable production

Variables	EE	TE	AE	PTE	SE
Constant	0.217 (0.049)[a]	0.463 (0.082)[a]	0.517 (0.055)[a]	0.519 (0.071)[a]	0.958 (0.0547)[a]
Seed type	0.021 (0.015)[c]	–0.025 (0.025)	0.046 (0.017)[a]	–0.024 (0.024)	–0.008 (0.020)
Training of farm manager	0.004 (0.004)	–0.001 (0.006)	0.003 (0.004)	0.006 (0.005)	–0.005 (0.005)
Credit access	0.020 (0.013)[c]	–0.027 (0.022)	0.044 (0.015)[a]	–0.004 (0.019)	–0.033 (0.017)[b]
Market access	0.021 (0.016)[c]	–0.007 (0.027)	0.029 (0.018)[c]	–0.017 (0.023)	0.014 (0.022)
External support index	0.010 (0.005)[b]	0.018 (0.008)[a]	–0.003 (0.005)	0.013 (0.007)[b]	–0.016 (0.007)[b]
Gender of farm manager	–0.036 (0.019)[b]	–0.055 (0.031)[c]	–0.003 (0.021)	0.017 (0.027)	–0.091 (0.025)[a]
Women participation index	0.002 (0.002)[c]	0.008 (0.003)[a]	–0.002 (0.002)	0.008 (0.003)[a]	0.001 (0.002)
Sigma	0.136 (0.004)	0.229 (0.007)	0.153 (0.005)	0.200 (0.006)	0.182 (0.006)
Log likelihood	285.893	26.671	224.564	93.073	140.763
LR	23.53	26.16	18.63	15.64	38.76

EE = economic efficiency, TE = overall technical efficiency, AE = allocative efficiency; PTE = pure technical efficiency SE = scale efficiency; values in parentheses are asymptotic standard errors; superscripts [a], [b], [c] indicate significant at 1, 5 and 10 % levels, respectively

ers and consumers (Atreya 2007), and ultimately to contribute to reducing poverty.

Credit access had a significant positive effect on the EE and AE, which suggests that having an access to credit allowed farmers to get the inputs necessary to be more productive. This result was consistent with the finding of the previous studies (Gbigbi 2011; Khan and Ali 2013). The negative relationship between the access to credit and the scale efficiency may simply mean that the farmers operating at a more efficient scale were less likely to need the outside capital. The coefficient of the market access was statistically significant with a positive effect on the EE and AE, which implies that providing market access to the farmers would improve the economic and allocative efficiency. In developing countries, small-scale vegetable farmers are frequently constrained by the poor market access because of the lack of market facilities and inappropriate or ineffective marketing regulations (Minten et al. 2010). Adequate market structures and farmer-friendly market regulations help farmers to sell their products and ultimately to reduce rural poverty. Direct marketing or cooperative marketing approaches could improve the efficiency of smallholder farmers (Bernard and Spielman 2009; Lemeilleur and Codron 2011; Jia et al. 2012; Kim et al. 2014).

Table 6. External support index in vegetable farming

Components	Average index	Rank
Fertilizer	0.75	1
Irrigation	0.09	6
Seed	0.20	5
Pesticide	0.05	7
Production material	0.23	4
Extension service	0.60	2
Post-harvest material	0.52	3

Index: one (supported), zero (not supported) for each component in the farms.

Source: survey conducted during July–August, 2013

The significant and positive effect of the external support on the EE and TE in the vegetable production indicates that supports from the government, non-governmental organizations (NGOs) or donor partners are effective ways of increasing the efficiency of the vegetable farming. The composition of the external support index showed that the support was more focused on fertilizer followed by extension services, post-harvest materials, production materials, seed, irrigation, and pesticide (Table 6).

The gender of the farm manager had a statistically significant negative effect on the EE, TE and SE, implying that women managers are more effective than their male counterparts. This result was consistent with the findings of other researchers (Rahman 2000; Gbigbi 2011). The statistically significant positive effect of the women participation index on the EE, TE and PTE in vegetable farming implies that a greater involvement of women in vegetable farming activities improves the efficiency in the vegetable production. The mean of the women participation index was found to be 63%

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Table 7. Women participation index in vegetable farming

Variable	Average index	Rank
Land preparation	2.98	4
Vegetable plantation	3.45	1
Crop management	3.35	2
Harvesting and marketing	3.29	3
Decision-making	2.66	5
Total index	15.72	

Index: one (minimum women participation), five (maximum women participation) for each component in the farms.

Source: survey conducted during July–August, 2013

Table 8. Standardized coefficients of explanatory variables on economic efficiency in vegetable production

Variables	Beta value	Rank
Seed type	0.062	6
Training of farm manager	0.057	7
Credit access	0.067	4
Market access	0.063	5
External support index	0.102	1
Gender of farm manager	–0.099	2
Women participation index	0.068	3

Source: survey conducted during July–August, 2013

in this study, which was consistent with the results of a FAO (2011) study where the women labour accounted for between 60 and 80% of agricultural labour in developing countries. Higher levels of the women participation were found in the vegetable plantations followed by the crop management, harvesting-marketing, land preparation, and decision-making activity in the whole vegetable production process (Table 7). In average, women were more involved in the vegetable cultivation activities than in the decision-making, which could explain some of the inefficiency in the vegetable farming in Nepal. The IFAP (2010) argued that women farmers are indispensable in building the world's sustainable future through their contribution to the food security and poverty reduction, whereas they are often barely visible in the decision-making processes. Therefore, women reaching at the decision-making levels, and the access to resources and opportunities is very important in the vegetable sector development in developing economies.

The results of standardized coefficients of the explanatory variables are presented in Table 8. The coefficient was higher for the external support index followed by the gender of farm manager, the women participation index, the credit access, market access, seed type, and training of farm manager orderly, indicating that these variables are the most effective factors for improving economic efficiency in the vegetable production.

Potential cost reduction in vegetable farms

The study produced a surprisingly rigorous empirical evidence of the inefficiency in the vegetable farms. Effective information and a better understanding of the cost composition are crucial for developing the effective policy for enhancing efficiency in the vegetable production. The average economic efficiency, the actual cost, the minimum cost or the economically efficient cost, and the potential cost reduction in vegetable farms are presented in Table 9. The minimum level of cost is the amount that the farms could have spent if the farms have operated at the frontier level given price and the fixed factor endowments, which was estimated by multiplying the actual costs by the economic efficiency scores of the individual farms. The potential costs reduction is the amount that have been lost due to the technical and allocative inefficiencies in the vegetable farming, given the price and fixed factor endowments, which was computed by multiplying the actual costs by the inefficiency indexes. We found that the sample vegetable farmers would be able to reduce their actual costs by 75% by operating their vegetable farms at the full technical and allocative efficiency.

Significantly higher levels of the economic efficiency and lower levels of the potential cost reduction were identified for very small-size farms compared to small-size farms. Bielik and Rajčániová (2004) argued that the small farms are more efficient than the larger one. Very small-size farms are usually operated by the family labour, and both risks and benefits are shared by the family members which leads to a greater efficiency than in the small-size farms. Vegetable farms, which used the improved seed varieties, showed a higher level of the economic efficiency and lower levels of the potential cost reduction.

Economic efficiencies were not affected by the number of trainings (less versus large numbers) received by the farm manager. Those farmers, who accessed credit in the vegetable farming, showed higher levels of efficiency than the farmers who did not, which indicated that credit programs can have a

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positive impact on the vegetable farming. Vegetable farmers with a better access to markets performed at a significantly higher level of efficiency and a lower level of the potential cost reduction. Vegetable farms, which used less external support, showed a higher level of efficiency than those that used more supports.

Vegetable farms managed by female managers performed at a significantly higher level of the economic

Table 9. Economic efficiency, actual cost, minimum cost, and potential cost reduction in vegetable farms

Variables	N[1]	Mean EE	Actual cost levels (Rs)[2]	Minimum cost levels (Rs)	Potential cost reduction (Rs)	Potential cost reduction (%)
Cost minimization by farm size						
Very small-size (< 0.128 ha)[3]	311	0.35	25 944	8 610	17 335	66.81
Small-size (≥ 0.128 ha)	191	0.21	54 117	9 766	44 352	81.95
t-value (very small vs. small)		13.538[a]	–19.428[a]	–4.898[a]	–19.214[a]	
Cost minimization by seed types						
Local variety	387	0.29	37 359	9 038	28 321	75.81
Improved variety	115	0.32	34 324	9 087	25 236	73.52
t-value (local vs. improved)		–1.645[b]	1.370[c]	–0.177	1.443[c]	
Cost minimization by number of trainings						
Less number of trainings (< 1.213)[4]	352	0.30	34 877	8 872	26 006	74.56
Large number of trainings (≥ 1.213)	150	0.30	40 855	9 467	31 389	76.83
t-value (less vs. large number)		0.350	–2.960[a]	–2.334[a]	–2.758[a]	
Cost minimization by credit access						
Credit not availed	335	0.29	35 590	8 832	26 758	75.18
Credit availed	167	0.31	38 816	9 485	29 331	75.56
t-value (credit not availed vs. availed)		–1.045	–1.634[c]	–2.641[a]	–1.349[c]	
Cost minimization by market access						
Market not access	388	0.29	38 195	9 113	29 082	76.14
Market access	114	0.32	31 450	8 832	22 619	71.92
t-value (market not access vs. access)		–1.714[b]	3.058[a]	1.008	3.036[a]	
Cost minimization by external support						
Less external support (< 5.277 index)[5]	257	0.31	33 344	8 823	24,520	73.54
More external support (≥ 5.277 index)	245	0.29	40 146	9 286	30,859	76.87
t-value (less vs. more supports)		1.616[c]	–3.695[a]	–1.981[b]	–3.565[a]	
Cost minimization by gender of farm manager						
Female manager	91	0.34	29 652	8 671	20 981	70.76
Male manager	411	0.29	38 215.78	9 133	29 083	76.10
t-value (female vs. male manager)		3.173[a]	–3.582[a]	–1.520[c]	–3.510[a]	
Cost minimization by women participation index						
Less women participation (< 15.72 index)[6]	277	0.29	38 706	9 105	29 601	76.48
More women participation (≥ 15.72 index)	225	0.31	34 149	8 981	25 168	73.70
t-value (less vs. more participation)		–2.191[b]	2.445[a]	0.529	2.464[a]	
Average potential cost reduction						74.73%

[1]N = Number of sample farms; [2]Nepali currency (Rupees) Rs 86.96 = 1USD as of February 2013; [3]Mean of vegetable farms size is 0.128 ha; smaller than mean is regarded as very small-size, and equal or larger than mean is small-size; [4]Mean of number of training is 1.213; less than mean is regarded as less number of training and equal or more than mean is large number of training; [5]Mean of external support index is 5.277; less than mean is regarded as less external support and equal or more than mean is more external support; [6]Mean of women participation index is 15.72; less than mean is regarded as less women participation and equal or more than mean is more women participation

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efficiency and a lower level of the potential cost reduction as compared with the farms managed by the male managers. This result was consistent with a previous study by Oladeebo and Fajuyigbe (2007), but contradicted the findings of Nisrane et al. (2011). We found that those farms with higher levels of the women participation, showed significantly higher levels of the economic efficiency and lower levels of the potential cost reduction suggesting that the efficiency of vegetable farming could be increased by policies designed to empower women farmers. Women can be empowered by providing higher levels of education and with the capacity building programs (Yousefy and Baratali 2011; Guinée 2014) and by increasing their access to assets, resources and opportunities (Wiig 2013).

CONCLUSIONS AND POLICY IMPLICATIONS

This study analyses the efficiency of the winter vegetable production in Nepal. We utilised an input oriented data envelopment analysis (DEA) model to estimate the alternative measures of farm efficiency using the cross-sectional data collected from 502 randomly selected farm households. Our measure of the farm output is the volume of vegetable produced at the farm level. We considered seven different inputs in our DEA model to estimate the efficiency of the small-scale vegetable farms. The efficiency values were then regressed on a set of explanatory variables (including technology, socio-economic and agriculture support service related variables) to identity the policy and programmatic interventions that would do most to boost the farm level efficiency.

The DEA results showed that a majority of the farms are operating very inefficiently relative to the most efficient farms. The average technical and allocative efficiency were estimated as 0.62 and 0.50, respectively, suggesting that there is a potential to increase both the technical as well as allocative efficiency for majority of the farms when compared with best practice farms. The average potential for the cost reduction is 75% (67% and 82%, respectively, for very small and small farms) and such cost reduction comes by adopting the best technology practices of the efficient farms through the optimal resource allocation.

Our results from the Tobit model suggest that the technical efficiency and the allocative efficiency of vegetable farms are affected by a number of explanatory variables related to types of external support index (combination of seven different input related services like seed, fertilizer, pesticide, irrigation etc.), gender of farm manager, women participation index, access to credit, access to market, and type of seed. The external support and gender related factors (the participation of women in vegetable production activities and gender of the farm manager) are positive and significant for the TE but not the AE. This suggests that these variables are important to augment the output. The credit access, market access and the improved seed, on the other hand, are statistically significant for the AE but not for the TE. This suggests that the policies that create a better access to credit, market and the improved seed lead to the cost efficiency of the farm households.

The improved seed with a better germination and a greater tolerance against the weather (heat or cold), disease and pest susceptibility would increase the efficiency and yield for any given level of inputs. The increased yield augments the income for farmers subsequently reducing poverty. The policymakers should therefore consider promoting the agricultural research and varietal trails for the development of the improved vegetable seeds. Given the fact that the women's role in the vegetable production is very important, the policies that promote women capabilities (like training, support to women farmer's groups, targeted programs for households headed by women) are suggested. Credit programs are also shown to be important for small farmers and we suggest that the policymakers develop programs that make the production credit more accessible to small farmers, particularly through cooperatives, micro-finance institutions or other means that are more cost effective for administering small loans.

Our findings reinforce some of the current agriculture sector policies and priorities (see the MOAD 2014) but we also suggest these policies to be streamlined with the sectors like the rural infrastructure, banking and social programs (such as the gender equality and the women empowerment). In this paper, we provide an analysis and assessment of the vegetable farm performance (efficiency), and identify the factors that can positively impact the farm efficiency. Finally, we make some policy recommendations for the improved farm efficiency and the increased farm household income which, when sustained over time, can contribute to the national poverty reduction goal. Given the fact that our sample constitutes

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farm households randomly selected from all three agro-ecological regions of the country, our findings and policy prescriptions can be generalized to the national level.

We suggest a future research to determine the characteristics of farms (technology employed, level of support services availed, and women's contribution, for example) for efficient versus inefficient farms, based on the specific vegetables grown and the specific agro-ecological regions of the country. Such research would not only supplement the contribution of this study but also determine if there is a need for the crop and region-specific priorities for the increased efficiency. An on-going research of this type will lead to the policies that would enhance the income of small scale vegetable farmers allowing them to better contribute to the national goal of the poverty reduction.

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