



# Profit Efficiency of Smallholder Vegetable Farms in Nepal: Implications for Improving Household Income

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### Specialty section:

This article was submitted to  
Land, Livelihoods and Food Security,  
a section of the journal  
Frontiers in Sustainable Food Systems

Received: 06 April 2021

Accepted: 06 December 2021

Published: 24 January 2022

### Citation:

Shrestha RB, Bhandari H and  
Pandey S (2022) Profit Efficiency of  
Smallholder Vegetable Farms in  
Nepal: Implications for Improving  
Household Income.  
Front. Sustain. Food Syst. 5:691350.  
doi: 10.3389/fsufs.2021.691350

Enhancing profit efficiency in vegetable farming is important to increase income, livelihoods, and nutrition security, and to reduce poverty of smallholder farmers, particularly in developing countries. This study examined the profit efficiency and its determinants in smallholder vegetable farms in Nepal using the stochastic translog profit function with cross-section data collected in 2013. The results revealed a high level of inefficiency in vegetable farms because of the combined effects of technical, allocative, and scale inefficiencies. The profitability differential in vegetable farms is significantly explained by input variables, namely, labor, land, seeds, fertilizer, pesticides, and capital. The determinants of profit inefficiency in vegetable farming were the types of crop varieties, access to information and extension services, access to agricultural credit, distance of farms to markets, and sex of farm manager. The profit efficiency in vegetable farming can be enhanced by adopting improved seed varieties, improving effective information and extension programs, increasing accessibility of credit facilities to the farmers, developing market infrastructure, and empowering women farmers in vegetable farming that leads to improve household income and nutrition security.

**Keywords:** profit efficiency, vegetable farms, stochastic function, household income, Nepal

## INTRODUCTION

Vegetable farming is an important sub-sector to increase income, reduce poverty, and improve nutrition, particularly in the developing countries. This sector provides greater opportunities for self-employment to different actors of the food value chain such as input suppliers, farmers, traders, transporters, processors, and other supportive line agencies. Nepalese economy has long been relying on agriculture, which shares more than 25% of the gross domestic product (GDP) where vegetable is one of the major components in contributing to the Agriculture Gross Domestic Product (AGDP). The Ministry of Agriculture and Livestock Development (MOALD, 2020) reported that in 2019, more than 3.2 million farmers were involved in vegetable farming and produced 3.96 million tons of vegetables under 0.69 million acres of land with average yield of 5.74 tons/acre. Despite the huge contribution to the AGDP, the growth rate of this sector has decreased from 5.98% (2007–2009) to 3.07% (2010–2019), and the productivity remains low (MOALD, 2020), which is lowest in Asian countries (Rai et al., 2019). Thus, enhancing productivity is crucial to narrow down the productivity gap (productivity potential 7 tons/acre) and eventually improve the technical, allocative, and economic efficiencies in vegetable production.

The major agricultural policies of Nepal, as it does not have a separate vegetable policy, are Agriculture Perspective Plan (APP; NPC, 1995), Agriculture Development Strategy (ADS; MOAD, 2014), and Fourteenth Development Plan 2019–2024 (NPC, 2017). The main objectives of these policies are to alleviate poverty and ensure food and nutrition security through transforming subsistence agriculture into commercial and competitive agriculture. In spite of these greater efforts, the agriculture sector has not been successful in improving income, livelihoods, food security, and nutrition, particularly of the vulnerable groups such as the landless, smallholders, women, and children (MOAD, 2014; Rai et al., 2019). In order to address these issues and improve the agriculture sector, appropriate empirically tested evidence-based policies and programs need to be formulated.

Nepalese vegetable farms are characterized by <1 ha farm size with the average agricultural landholding of 0.7 ha (CBS, 2019) and integrated cropping systems where different vegetable crops are grown in a single farm (Shrestha et al., 2016a). Most farmers grow vegetables in their own land, adopt both improved and local varieties, use manual and animal power in plowing their land, and use different fertilizers and chemicals including compost, green manure, chemical fertilizers, and pesticides (Timsina and Shivakoti, 2018). The common constraints encountered by smallholder vegetable farmers are subsistence-oriented farming, lack of improved technologies, inadequate extension services, poor road networks and infrastructure, and poor market facilities that led agriculture sector less productive and inefficient (Pokhrel, 2010; Timsina and Shivakoti, 2018). Although Nepal's vegetable farming is dominated by smallholders, it is gradually changing from subsistence to commercial type (Pokhrel, 2010; Shrestha et al., 2016b; MOALD, 2020). Improving productivity and profitability in agriculture is central to make this sector economically sustainable (Abu et al., 2012; Akamin et al., 2017). This requires understanding of technical, allocative and economic efficiencies, and factors determining them. Past research studies on vegetable farming in Nepal were mainly focused on cost-benefit analysis, value chain analysis, and marketing issues (Pokhrel, 2010; USAID, 2011; Rai et al., 2019; Sharma, 2019). To our knowledge, literature analyzing the profit efficiency of smallholder vegetable farmers of Nepal is limited. This study aims to bridge this knowledge gap.

The paper examines two main research questions. First, what is the level of profit efficiency in vegetable farming in Nepal? Second, what factors determine the profit efficiency in vegetable farming in Nepal? The main objective of this study is to measure the profit efficiency, determine factors affecting inefficiency, and derive policies to increase profitability and income of smallholder vegetable farms. The paper will contribute to the body of knowledge on methodology for agriculture production efficiency analysis, understanding efficiency in vegetable farming, and identifying factors contributing to inefficiency in vegetable farming in Nepal. The relationship of the profit efficiency with different variables such as production inputs, socioeconomic factors, and technology would be useful in formulating policies and programs to improve input use efficiency, address socioeconomic constraints, and to make the vegetable sector economically more competitive and efficient. As the study areas

and sample units were considered from diverse agro-ecological settings, the finding can be inferred to the whole country and to similar agro-ecologies in other countries.

## Literature Review on Profit Efficiency of Vegetable Farms

Globally, several studies have done on the profit efficiency of cereal crops (Rahman, 2003; Ogunniyi, 2011; Abu et al., 2012; Nmadu and Garba, 2013; Nwauwa et al., 2013). In Nepal, a few studies have been conducted on efficiency analysis in agriculture (Dhungana et al., 2004; Bhatta et al., 2006; Adhikari and Bjørndal, 2009; Kafle, 2011), while these studies failed to consider the vegetable farms. Shrestha et al. (2016a) evaluated the economic efficiency of winter season vegetable farms using Data Envelopment Analysis (DEA) and Shrestha et al. (2016b) determined technical efficiency of summer season vegetable farms using stochastic translog production function. There is dearth of studies carried out on the profit efficiency of vegetable farming at a household level because farmers in developing countries including Nepal produce multiple vegetable crops in the same land in a year (Nwauwa et al., 2013; Shrestha et al., 2016a). Past studies on efficiency analysis on vegetable farming in Nepal were based on plot level and season level data instead of household level data (Shrestha et al., 2016b; Rai et al., 2019). Also, past studies in Nepal focused on technical efficiency analysis and literature on profit efficiency is very limited (Shrestha et al., 2016a; Dahal et al., 2019; Sapkota and Joshi, 2021). This study contributes to the body of literature on the economics of vegetable farming and methodological aspect from three perspectives. First, we used samples from different agro-ecologies (high-hill, mid-hill, and plain areas) of Nepal thus it is representative of different agro-ecologies of Nepal. Second, we collected and analyzed the data at a household level instead of farm level. This captures the effect of socio-economic variables on profit efficiency of vegetable farms. Third, most stochastic profit functions used either technical or allocative efficiency analysis. But, our stochastic profit function model integrates technical, allocative, and economic efficiency into a system of equations so that we can capture both technical and economic aspects. The parameters of the profit function and the inefficiency components were estimated jointly through a system of equations (Ali and Flinn, 1989; Coelli et al., 2005; Islam et al., 2011; Budi Setiawan and Ari Bowo, 2016). Four, instead of seasonal crops, we incorporated all vegetable crops grown by sampled households throughout the year considering as a single entity that give actual efficiency level because the inputs used and outputs produced from different crops are interlinked and interdependent in the farm. The remainder of the paper is organized in three sections. First, we discuss methodology describing sampling design, study area, and methods of analysis. Then, we discuss results and discussion. The final section concludes the paper.

## METHODOLOGY

### Sampling Design and Study Area

A multi-stage random sampling approach was adopted in this study. First, we purposively selected the central region of Nepal because this has the highest contribution in total

vegetable production among the five regions (eastern, central, western, mid-western, and far-western; MOALD, 2020). Second, four districts: Dolakha, Lalitpur, Dhading, and Dhanusha, were purposively selected in three agro-ecological regions: mountain, hills, and *terai* (tropical plain) on the basis of contribution in vegetable production; thus, this study represents three agro-ecological regions. Dolakha District represents the mountain agro-ecology, Lalitpur and Dhading Districts represent the hill agro-ecology and Dhanusha District represents the *terai* agro-ecology. Two districts—Dhading and Lalitpur—were selected from the hilly region to represent relatively larger number of vegetable farmers growing vegetables in the hill areas. The vegetable production was highest in Dhading District (59,347 tons) followed by Lalitpur District (41,262 tons), Dhanusha District (38,666 tons), and Dolakha District (19,480 tons) in 2015 (MOALD, 2016).

Third, we randomly selected 12 villages (three villages from each district) among the major areas producing vegetables on the basis of profile provided by the respective District Agriculture Development Office (DADO). The sample villages in Dolakha district—Boach, Bhimeshowar, and Kavre—are characterized by higher altitudes (2,000 m to 2,600 m), cold weather, steep land, lack of basic infrastructures (irrigation, agriculture roads, and market facilities, for example), and weak access to public services including agriculture extension services to the farmers (DADO, 2016b). The sample villages under Lalitpur District—Luvu, Jharuwarasi, and Devichor—and under Dhading District—Jeevanpur, Benighat, and Dhusa—are characterized by moderately cool weather with moderate altitude (1,000 m to 1,900 m), upland and valley with terraced land, and relatively better access to roads, market infrastructure, extension services, irrigation facilities, and education facilities (DDC, 2013; DADO, 2016a). Similarly, the sample villages under Dhanusha District—Dhalkebar, Bengadabar, and Digambarpur—are characterized by lower altitudes (250 m to 500 m), hot climate, mostly lowland, and with better access to roads, agriculture markets, irrigation facilities, and extension services than rest of the districts in our study (DDC, 2008).

Fourth, a random sampling design was adopted to select 325 households consisting of 86 in Dolakha District, 75 in Lalitpur District, 84 in Dhading District, and 80 in Dhanusha District, who produce vegetables not only for household consumption but also for sale in the markets throughout the year. The sample size per district was determined to proportionally represent the total number of farm households in the district. The sample size represents about 10% of the total farm households in the study areas. The primary cross-section data were collected from the sample households using a pre-tested semi-structured questionnaire during July–September 2013. In this study, we considered common vegetables namely tomato, cauliflower, cabbage, potato, gourds, okra, cucumber, bean, and eggplant grown by the sample farmers. In Nepal, farmers grow different vegetable crops within and between seasons in a year. The input and output structure vary by crops but the production technology, marketing system, production knowledge of farm households, and other factors affecting the production efficiency are more or less similar for the main vegetable crops. Given

that a single farmer grows different vegetable crops in a year, it becomes complicated to compute profit efficiency for each crop. As our main objective is to find out the overall profit efficiency of vegetable farmers, we combine different vegetable crops cultivated by each farmer into an overall vegetable production by the farmer. We used a weighted average method to combine the inputs and outputs of different vegetable crops into an overall vegetable production of each farmer.

## Environmental Condition of the Study Area

The study was conducted in four districts, namely, Dhanusha, Dhading, Lalitpur, and Dolakha, in the Central Development Region representing three agro-ecologies where major vegetable production occurs. Dhanusha District (150–400 masl) represent the *terai* (plain) agro-ecological region, Dhading District (800–1,500 masl) and Lalitpur District (1,000–1,800 masl) represent the mid-hill agro-ecological region, and Dolakha District (2,000–2,600 masl) represent the high-hill agro-ecological region where cool temperate climate is dominant (MOALD, 2020). The *terai* region is characterized by subtropical hot climate, monsoon rainfall, flat terrain, and majority of farms are irrigated. The mid-hill region is characterized by warm temperate climate, monsoon rain, sloppy hill terrain, and the major source of irrigation remains local streams, ponds, and rain. The high-hill region is characterized by cool temperature climate, low monsoon rainfall, sloppy hill terrain, and the major source of irrigation remains on streams, ponds, and rain (Paudel et al., 2021). The variation in the environmental conditions affects the types of vegetable crops and varieties grown across study agro-ecologies. The variation in socio-economic characteristics (e.g., extension services, market linkage, and infrastructure) is described in the sampling design and study area section. The study area covers different geographies and agro-ecologies to capture in the production systems and to represent a large part of the country.

## Theoretical Framework: Stochastic Frontier Translog Profit Function

Efficiency is measured as a ratio of inputs to outputs and it is essentially related to production and cost (Battese and Coelli, 1995; Coelli et al., 2005). Production efficiency refers to the ability to produce goods and services through an optimal combination of inputs in order to produce maximum output at minimum cost. Profit efficiency is a combination of three components: technical, allocative, and scale efficiencies (Rahman, 2003; Coelli et al., 2005; Islam et al., 2011; Budi Setiawan and Ari Bowo, 2016). The technical efficiency refers to the capacity of a farm to produce the optimum level of outputs in the given level of inputs, while inefficiency is the level of output below the frontier line (Rahman, 2003). A farm is allocative efficient when the combination of inputs is in the optimal proportion with the minimum cost that produce a given quantity of outputs (Coelli et al., 2005). In a profit-maximizing framework, scale efficiency exists if farm produces output level by equating the product price with marginal cost (Kumbhakar et al., 1989). Recent empirical development combined all these measures into a single system that enables more efficient estimates, which can be obtained by

simultaneous equation system using a profit function framework (Kumbhakar et al., 1989; Ali and Byerlee, 1991; Ali et al., 1996). Thus, profit efficiency is the ability of a farm to achieve the optimum possible level of profit given the prices and levels of fixed factors of production (Ali and Flinn, 1989; Ali et al., 1994; Mehedi Adnan et al., 2021). Profit efficiency is the ratio of the actual to the maximum possible profit (Sheriff, 2005), while inefficiency is the loss of profit because of not operating the farms at the highest possible frontier level (Ali and Flinn, 1989).

The stochastic profit frontier is the most suitable approach to estimate the profit efficiency because it assumes that any errors in the production decision are translated into lower profit for the farmers (Ali et al., 1994). The profit frontier approach is theoretically consistent with the production technology to estimate production, revenue, and cost efficiency with cross-section data (Battese and Coelli, 1992; Khumbhakar and Lovell, 2000) that led us to adopt this approach in our study. We applied a two-stage procedure; first stage, estimated the profit inefficiency of individual farms, and second stage, regressed inefficiency score by socioeconomic and technology related variables with regard to vegetable production. The inefficiency effect can be expressed as a linear function of explanatory variables in stochastic production frontier model (Battese and Coelli, 1995). In this study the stochastic profit function was defined as a function of variable input prices, fixed factors, and error terms (Equations 1 and 2).

$$\pi_i = f(P_i, Z_i) \cdot \exp(\xi_i) \quad (1)$$

$$\xi_i = v_i - u_i \quad (2)$$

Where  $\pi_i$  represents normalized restricted profit of  $i$ th farm;  $P_i$  represents vector of variable input price of  $i$ th farm;  $Z_i$  represents vector of fixed factor of  $i$ th farm; and  $\xi_i$  is error term of  $i$ th farm. A two-sided random variable ( $v_i$ ) is assumed to be independently and identically distributed  $N(0, \delta_v^2)$ , and a non-negative random variable ( $u_i$ ) accounts for profit inefficiency in production process assumed to be independently distributed with mean,  $\mu_i = \delta_0 + \sum_d \delta_d S_{di}$ , and variance,  $N(\mu_i, \sigma_u^2)$ . The  $S_{di}$  represents  $d$ th socioeconomic variable that explains inefficiencies of  $i$ th farm,  $\delta_0$  is intercept, and  $\delta_d$  is coefficient for unknown parameters to be estimated. The profit efficiency (PE) of  $i$ th farm is presented in Equation 3.

$$PE_i = E[\exp(-u_i) \mid \xi_i] = E\left[\exp\left(-\delta_0 - \sum_{d=1}^D \delta_d S_{di}\right) \mid \xi_i\right] \quad (3)$$

The expected operator ( $E$ ) can be achieved by obtaining the conditional expectation of  $u_i$  with the observed value of error term,  $\xi_i$ . The maximum likelihood estimate (MLE) of STPF was applied to measure the unknown parameters using Frontier 4.1 (Coelli, 1996). The variance parameters, sigma-squared, ( $\sigma^2$ ) =  $\sigma_v^2 + \sigma_u^2$ , and gamma, ( $\gamma$ ) =  $\sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ , were estimated (Battese and Coelli, 1995). The gamma ( $\gamma$ ) value ranges from 0 to 1, where  $\gamma = 0$  indicates that the farms were efficient, while  $\gamma > 0$  indicates that the farms were inefficient because of technical, allocative, and scale inefficiency. The likelihood-ratio (LR) test (Equation 4) was adopted to hypothesize that the farms

were profit efficient. The LR test statistics have 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).

$$LR = -2[\ln\{\text{likelihood}(H_0)\} - \ln\{\text{likelihood}(H_1)\}] \quad (4)$$

In addition, the heteroskedasticity problem was tested using the White's test in the data set (Hill et al., 2011). The calculated value was found to be less than the critical value [ $25.03 < \chi_{(0.99,35)}^2 = 57.342$ ], and this confirmed that the heteroskedasticity problem did not exist.

## Empirical Model

The stochastic translog profit function was used to estimate profit efficiency dropping  $i$ th subscript in vegetable farms (Equation 5) and inefficiency effect model (Equation 6).

$$\begin{aligned} \ln \pi' = & \alpha_0 + \sum_{j=1}^5 \alpha_j \ln P'_j + \frac{1}{2} \sum_{j=1}^5 \sum_{k=1}^5 \beta_{jk} \ln P'_j \ln P'_k \\ & + \sum_{j=1}^5 \sum_{l=1}^2 \varphi_{jl} \ln P'_j \ln Z_l + \sum_{l=1}^2 \tau_l \ln Z_l \\ & + \frac{1}{2} \sum_{l=1}^2 \sum_{t=1}^2 \varphi_{lt} \ln Z_l \ln Z_t + v - u \end{aligned} \quad (5)$$

$$u = \delta_0 + \sum_{d=1}^7 \delta_d S_d + \omega \quad (6)$$

where  $\pi'$  represents the restricted profit, estimated with total revenue less total cost of variable inputs normalized by dividing with the price of vegetable outputs;  $P'_j$  represents the price of  $j$ th input normalized by output price, where  $j$  stands for inputs namely labor, animal power, seed, fertilizer and pesticide;  $Z_l$  represents the quantity of fixed inputs, where  $l$  stands for area under vegetable cultivation and farm capital, and  $\ln$  is a natural logarithm. An output price index was computed from a vector of output prices to normalize profit and input prices.  $S_d$  represents for socioeconomic variables to explain profit inefficiency of vegetable farms, where  $d$  stands for seed type, information index, contact of farmer with extension agent, credit access, experience, distance of farm to market, and gender of farm manager;  $\omega$  represents the truncated random variable;  $\alpha_0, \alpha_j, \beta_{jk}, \varphi_{jl}, \tau_l, \varphi_{lt}, \delta_0$ , and  $\delta_d$  are unknown parameters to be estimated.

## Data and Variables

The primary cross-section data were collected from the principal decision maker of the farm households through face-to-face interview using pre-tested semi-structured questionnaire. The major input and output variables include area under vegetable cultivation, output value at farm gate price, labor cost (hired and family), animal power cost, seeds cost, fertilizers cost, pesticides cost, and farm capital used in the vegetable farms. Other variables include seed types, information index, extension contact, access to credit, experience in vegetable farming, distance to market,

and sex of farm manager. The type of seeds used, defined as a dummy variable for improved or local varieties, hypothesized that improved seed varieties were more yielding, have good disease resistance, and increased production efficiency than the local one. Seed type was assumed to be 1 if producer used improved varieties and 0 otherwise. Nepalese vegetable farmers are constrained with information services that adversely affect output. To analyze the access to information, this study introduced a new variable called information index, comprising of five information components: input marketing, improved farming technology, output marketing, demand and supply situation of vegetables in the markets, and price movement of products in the markets. The cost of access approach was adopted where each of these components indexed (1 to 5 in each farm); thus, the total index of the farm ranges from 5 (minimum) to 25 (maximum). It was hypothesized that the higher the index, the better the information accessed to the farmers, and leading to higher level of profit efficiency. An extension service is a powerful tool in disseminating improved farming technology to the farmers that has positive impact on efficiency. Number of contacts of farmer with extension agents of government extension system, non-governmental organization (NGO), and private agro-vet enterprises during a cropping period was used to analyze its effect on profit efficiency. Access to finance is a major constrained to farmers because of inadequate number of formal financial institutions working in rural areas. This study used credit access as a dummy variable to capture the effects of financial resource access on profit efficiency, considering 1 if the farmer availed credit and 0 otherwise. The experience of farmer was adopted as the number of years working in vegetable farming. In addition, market access is one of the key concerns for vegetable farmers, which plays a vital role in profitability of the farmers and vegetable sector development. Thus, distance of farm to the market (in mile) was used to measure the effect of market access on profit efficiency, assuming that the longer the distance, the higher the profit inefficiency. Gender inequality is an important issue in agriculture development, which might have an effect on productive efficiency. Therefore, as a dummy variable, sex of farm manager was considered 1 if the farm was handled by male and 0 otherwise.

## RESULTS

### Descriptive Statistics of Variables

**Table 1** presents the descriptive statistics of the parameters used in this study. The results showed that an average vegetable farm size was quite small (0.96 acres), and about 65% of the farms were smaller than the average size. The mean information index was found to be 15.75 out of 25, which indicated that vegetable farmers utilized more than 50% information, particularly on input marketing and farming technology. The information index was fairly lower in output marketing activities, i.e., price movement of the product in the market, demand-supply situation, and market availability of the products.

The mean of farmers' contact with extension agents was found to be 1.88 times during a cropping period, while 30% of them had no contact. Furthermore, majority of farmers (75%)

**TABLE 1** | Descriptive statistics of variables used in profit efficiency analysis.

Variable	Mean	Std. Dev.
Input, output, and profit		
Land cultivated (acre)	0.96	0.76
Vegetables output value (USD/farm)	1,169.76	939.89
Profit (USD/farm)	421.59	403.06
Fertilizer cost (USD/farm)	123.89	105.64
Labor cost (USD/farm)	297.86	253.86
Animal power cost (USD/farm)	125.73	124.09
Seed cost (USD/farm)	95.88	86.01
Pesticide cost (USD/farm)	104.80	90.15
Farm capital (USD/farm)	112.95	85.03
Socio-economic variable		
Seed types (dummy)	0.75	0.43
Information index (number)	15.75	4.6
Extension contact (number)	1.88	1.90
Credit access (dummy)	0.29	0.45
Experience of farmers (year)	12.31	8.79
Distance of farm to market (mile)	15.64	38.35
Sex of farm manager (dummy)	0.77	0.42
Number of observation	325	

*Authors' calculation from the field survey data (2013).*

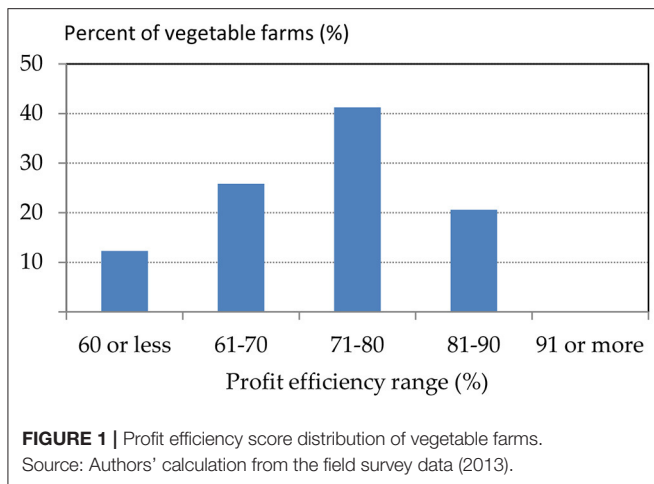
used improved seed varieties, limited numbers of farmers (29%) availed credit, average years of experience of farmers in vegetable farming was 12.31, average distance of farm to market was 15.64 mile, and the majority of vegetable farms (77%) were handled by male farmers in the study areas.

### Profit Efficiency of Vegetable Farms

**Figure 1** presents the distribution of the profit efficiency of the sample vegetable farms. The mean profit efficiency was found to be 0.72, ranging from 0.12 to 0.90. This implies that on average, 28% of the farms that are inefficient could be increased within the existing technology by overcoming the constraints. The majority of the farms (61.8%) exhibited more than the average score of profit efficiency, limited farms (12.3%) showed  $\leq 0.60$  score, whereas none of the farms performed higher than 0.90 score. The average profit efficiency level varied slightly across districts. The profit efficiency was highest (0.75) in Dhanusa District followed by Lalitpur (0.72), Dolakha (0.71), and Dhading (0.70).

### Stochastic Translog Profit Function

The results of the maximum likelihood estimates (MLE) of stochastic translog profit function are presented in **Table 2**. The coefficients of variable inputs namely labor wage (W), seed cost (S), fertilizer cost (F), and pesticide cost (P) were significantly different from zero. An appropriate use of input resources increases production efficiency, while inefficiency exist because of not using inputs in the right combinations necessary to reduce production cost and increase profit (Parikh et al., 1995; Ali et al., 1996; Watkins et al., 2014). The negative 2.43 coefficient of labor indicated that 1% increase in labor wage will decrease profit by 2.43%, and the negative 3.73 coefficient of seed price



**FIGURE 1 |** Profit efficiency score distribution of vegetable farms. Source: Authors' calculation from the field survey data (2013).

implied that 1% increase in seed price will decrease profit by 3.73%. The coefficients of fertilizer and pesticide showed positive relationship with profit, which indicated that further increases the use of these inputs will increase the profit to the farmers with the given level of price. The fixed factors, land and capital, were statistically significant at 1% level implied that the profit level would sharply increase with the increase in land size in vegetable farming. Profit elasticity with respect to land was estimated at 7.7, which indicated that 1% increase in area under vegetable cultivation will increase profit by 7.7%. In contrary, the statistically significant negative coefficient of capital showed that 1% increase in farm capital will decrease profit by 3.94% initially, but in the long-run, the profit will increase with increase in capital.

The null hypothesis of profit efficiency ( $\gamma = 0$ ) was tested using a likelihood ratio (LR) test (Table 3). The null hypothesis was strongly rejected at 1% level [LR statistics  $8.36 > X^2_{(1,0.99)} = 6.63$ ] and revealed that profit inefficiency existed in vegetable farms. The variance parameter, gamma ( $\gamma$ ), was found to be 0.63, which was statistically significant at 1% level. This indicated that 63% of the inefficiency in vegetable farms was because of the technical, allocative, and scale inefficiency and the rest, 37%, of the inefficiency was due to random errors caused by climate or other external factors not included in the model. Indeed, climate change extremes (for example, floods, drought, landslides, hailstones, etc.) have severe effects on agriculture in the world, and more pronounced in developing countries including Nepal. As the risk in agriculture is an intrinsic aspect, farmers adopt climate adaptation and mitigation strategies to reduce the adverse effects, which depends on farm and farm household characteristics, farmers' risk perceptions, and their risk attitudes (Ullah and Shivakoti, 2014).

### Determinants of Profit Inefficiency

The results of factors explaining profit inefficiency in vegetable farms are presented in Table 4. All the socio-economic variables included in the model were statistically significant. The statistically significant negative coefficient of seed type (defined in

**TABLE 2 |** Maximum likelihood estimates of stochastic translog profit function.

Variable	Parameter	Coefficient	t-value
<b>Profit function</b>			
Constant	$\alpha_0$	30.265 (9.941)	3.045***
$\ln P'_W$	$\alpha_W$	-2.426 (1.578)	-1.538*
$\ln P'_A$	$\alpha_A$	1.286 (1.348)	0.954
$\ln P'_S$	$\alpha_S$	-3.726 (1.320)	-2.823***
$\ln P'_F$	$\alpha_F$	2.027 (0.736)	2.754***
$\ln P'_P$	$\alpha_P$	1.619 (0.845)	1.915**
$\frac{1}{2}(\ln P'_W \times \ln P'_W)$	$\beta_{WW}$	-0.127 (0.193)	-0.660
$\frac{1}{2}(\ln P'_A \times \ln P'_A)$	$\beta_{AA}$	-0.216 (0.123)	-1.760**
$\frac{1}{2}(\ln P'_S \times \ln P'_S)$	$\beta_{SS}$	0.031 (0.107)	0.294
$\frac{1}{2}(\ln P'_F \times \ln P'_F)$	$\beta_{FF}$	0.065 (0.024)	2.734***
$\frac{1}{2}(\ln P'_P \times \ln P'_P)$	$\beta_{PP}$	0.076 (0.031)	2.467***
$\ln P'_W \times \ln P'_A$	$\beta_{WA}$	0.307 (0.134)	2.294***
$\ln P'_W \times \ln P'_S$	$\beta_{WS}$	0.012 (0.135)	0.087
$\ln P'_W \times \ln P'_F$	$\beta_{WF}$	-0.098 (0.086)	-1.139
$\ln P'_W \times \ln P'_P$	$\beta_{WP}$	-0.093 (0.082)	-1.138
$\ln P'_A \times \ln P'_S$	$\beta_{AS}$	0.095 (0.133)	0.718
$\ln P'_A \times \ln P'_F$	$\beta_{AF}$	-0.066 (0.077)	-0.863
$\ln P'_A \times \ln P'_P$	$\beta_{AP}$	-0.152 (0.115)	-1.318*
$\ln P'_S \times \ln P'_F$	$\beta_{SF}$	0.065 (0.053)	1.241
$\ln P'_S \times \ln P'_P$	$\beta_{SP}$	0.065 (0.052)	1.259
$\ln P'_F \times \ln P'_P$	$\beta_{FP}$	-0.097 (0.060)	-1.626*
$\ln P'_W \times \ln P'_L$	$\emptyset_{WL}$	-0.588 (0.206)	-2.854***
$\ln P'_W \times \ln P'_C$	$\emptyset_{WC}$	0.227 (0.128)	1.767**
$\ln P'_A \times \ln P'_L$	$\emptyset_{AL}$	0.153 (0.193)	0.793
$\ln P'_A \times \ln P'_C$	$\emptyset_{AC}$	-0.136 (0.119)	-1.149
$\ln P'_S \times \ln P'_L$	$\emptyset_{SL}$	-0.357 (0.180)	-1.979**
$\ln P'_S \times \ln P'_C$	$\emptyset_{SC}$	0.197 (0.078)	2.535***
$\ln P'_F \times \ln P'_L$	$\emptyset_{FL}$	0.226 (0.098)	2.297***
$\ln P'_F \times \ln P'_C$	$\emptyset_{FC}$	-0.078 (0.043)	-1.829**
$\ln P'_P \times \ln P'_L$	$\emptyset_{PL}$	0.255 (0.141)	1.806**
$\ln P'_P \times \ln P'_C$	$\emptyset_{PC}$	0.016 (0.042)	0.390
$\ln Z_L$	$\tau_L$	7.701 (2.246)	3.428***
$\ln Z_C$	$\tau_C$	-3.943 (1.185)	-3.328***
$\frac{1}{2}(\ln Z_L \times \ln Z_L)$	$\emptyset_{LL}$	1.039 (0.276)	3.770***
$\frac{1}{2}(\ln Z_C \times \ln Z_C)$	$\emptyset_{CC}$	0.264 (0.107)	2.475***
$\ln Z_L \times \ln Z_C$	$\emptyset_{LC}$	-0.461 (0.143)	-3.221***

Source: Authors calculation from the field survey data (2013).  
*W*-Labor wage, *A*-animal power cost, *S*-seed cost, *F*-fertilizer cost, *P*-pesticide cost, *L*-cultivated land, and *C*-capital cost.  
 \*\*\*, \*\*, \* indicate the level of significance at 1%, 5% and 10%, respectively, and values in parenthesis are standard errors.

terms of dummy variable with value of 1 if a farmer use improved seed varieties, 0 otherwise) revealed that the use of improved seed varieties reduce the profit inefficiency.

The statistically significant negative coefficient of information index showed negative effect of access to information on the inefficiency. This indicated that farmers' access to information on farming technology, inputs marketing, and outputs marketing could help them earn higher profit in vegetable farming. An average information index was higher in input

**TABLE 3** | Variance parameters of stochastic translog profit function.

Variable	Parameter	Coefficient	t-value
<b>Variance parameters</b>			
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	$\sigma^2$	0.338 (0.051)	6.613***
$\gamma = \sigma_u^2 / (\delta_u^2 + \delta_v^2)$	$\gamma$	0.634 (0.110)	5.759***
Log likelihood		-198.361	
Log likelihood ratio	LR	8.363***	

Source: Authors' calculation from the field survey data (2013).

\*\*\* indicates the level of significance at 1% and values in parenthesis are standard errors.

**TABLE 4** | Determinants of profit inefficiency.

Variable	Parameter	Coefficient	t-value
<b>Inefficiency effect model</b>			
Constant	$\delta_0$	0.3542(0.0237)	14.95***
Seeds type	$\delta_1$	-0.0762 (0.013)	-5.94***
Information index	$\delta_2$	-0.0018 (0.0013)	-1.41*
Extension contact	$\delta_3$	-0.0045 (0.0029)	-1.52*
Credit access	$\delta_4$	0.0228 (0.0118)	1.93**
Experience of farmers	$\delta_5$	-0.0009 (0.0006)	-1.38*
Distance of farm to market	$\delta_6$	0.0004 (0.0002)	2.63***
Sex of farm manager	$\delta_7$	0.0198 (0.0128)	1.55*

Source: Authors' calculation from the field survey data (2013).

\*\*\*, \*\*, \* indicates the level of significance at 1%, 5% and 10%, respectively, and values in parenthesis are standard errors.

marketing, followed by farming technologies, output marketing, demand-supply situation of vegetables, and price movement of products in the markets. This index indicated that the farmers utilized information mainly on input marketing and farming technology rather than output marketing. Indeed, the farmers cannot improve profit efficiency and earn higher profit from vegetable farming unless they access output marketing information appropriately.

The statistically significant negative coefficient of extension contact indicated that increasing the number of contacts of farmer with extension agents can decrease the profit inefficiency. This is because extension workers provide information on better management of resources and increasing productivity to farmers. The coefficient of credit was positively related with inefficiency, revealed that farmers, who availed credit, reduced their profit efficiency because of high cost of credit. In smallholder farming, investment capital is a major constraint and access to credit is central to buy inputs and use improved technologies. The coefficient of experience of farmers was significantly different from zero and consistent with the expected sign. This means longer experience in farming help to reduce inefficiency in farming. The result is as expected because experienced farmers can better manage production inputs and resources to maximize outputs.

The distance from farm to market was statistically significant at 1% level, and consistent with the expected sign. This means that farms with better access to market were more efficient than

those with poor access to markets. Gender perspective analysis in profit efficiency is a useful discipline in formulating policies for vegetable farming. The coefficient of sex of farm manager was significant and positively related with the profit inefficiency, which implied that female farmer had better profit performance than that of male counterpart.

## Profit, Profit-Loss, and Profit Efficiency

The profit-loss is the amount that have been lost due to inefficiency in production given prices and fixed factor endowments (Rahman, 2003). The average profit and profit efficiency were significantly higher in the vegetable farms where the farmer used improved seed varieties than those that are of local varieties (Table 5).

The farms that adopted better information performed significantly higher level of actual profit, higher level of the profit efficiency, and lower profit-loss. Farmers' contact with extension agents equal to or more than 1.88 times in a cropping period, considered as more extension contact, earned a significantly higher level of actual profit, operated the farm at a higher level of efficiency, and lower profit-loss as compared with less extension contacts. Those farmers, who did not receive credit in vegetable farming, had higher level of actual profit than that of credit availed. Similarly, the farmers, who had more than 12.3 years of experiences in vegetable farming, performed higher actual profit and profit efficiency. Those vegetable farms, located near the market (< 15.64 mile), earned a higher level of actual profit, lowered profit-loss, and operated the farm at higher efficiency level.

## DISCUSSION

The paper examined two main objectives. First, the profit efficiency level of vegetable farms. Second, the determinants of profit efficiency of vegetable farms. The results of these two objectives are discussed in the following two sub-headings.

### Profit Efficiency Level of Vegetable Farms

The average profit efficiency level of the vegetable farms was found to be 72%, which means 28% of the profit in vegetable production is lost due to a combination of both technical and allocative inefficiency. The likelihood ratio test of the stochastic translog profit function revealed that profit inefficiency existed in vegetable farms. The results showed that 63% of the profit inefficiency in vegetable farms was because of the technical, allocative and scale inefficiency. This indicates that 63% inefficiency can be minimized and farmers' vegetable output and profit can be increased by improving the technical, allocative, and economic efficiencies with better management of existing resources and technology. On other hand, the rest, 37%, of the inefficiency in vegetable farms was because of the random error accounted for climate or other factors not included in the model. Minimizing this 37% inefficiency requires climate-smart agricultural technologies and adaptation practices (Pal et al., 2019; Shrestha and Bokhtiar, 2019). The profit efficiency

**TABLE 5 |** Average profit, profit-loss, and profit efficiency by socio-economic variables.

Socio-economic characteristics	Sample size	Actual profit (USD/acre)	Profit-loss <sup>a</sup> (USD/acre)	Profit efficiency
Profit-loss by seeds type				
Local seed	81	2,184.01	12.11	0.65
Improved seed	244	3,395.45	12.40	0.74
<i>t</i> -ratio (local vs. improved)		-3.212***	-0.185	-6.950***
Profit-loss by information index <sup>b</sup>				
Less information (< 15.75 index)	156	2,699.90	11.55	0.71
Better information (≥ 15.75 index)	169	3,456.87	13.04	0.73
<i>t</i> -ratio (less vs. better information)		-2.3006**	-1.102	-3.251***
Profit-loss by extension contact				
Less extension contacts (< 1.88 times)	159	2,516.30	10.95	0.70
More extension contacts (≥ 1.88 times)	166	3,646.41	13.64	0.74
<i>t</i> -ratio (less vs. more contacts)		-3.472***	-2.009**	-3.929***
Profit-loss by credit availed				
Credit not availed	231	3,118.43	12.14	0.72
Credit availed	94	3,032.318	12.77	0.71
<i>t</i> -ratio (Credit not availed vs. availed)		0.236	-0.4221	0.524
Profit-loss by experience <sup>c</sup>				
Less experiences (< 12.314 years)	180	2,553.78	11.85	0.69
More experiences (≥ 12.314 years)	145	3,763.55	12.92	0.75
<i>t</i> -ratio (less vs. more experiences)		-3.705***	-0.794	-4.868***
Profit-loss by distance of farm to market <sup>d</sup>				
Farms near market (< 15.64 mile)	245	3,367.62	12.99	0.73
Farms far-market (≥ 15.64 mile)	80	2,254.10	10.30	0.68
<i>t</i> -ratio (near vs. far-farms)		2.933***	1.726**	3.71***
Profit-loss by gender of manager				
Female manager	75	3,444.24	13.47	0.73
Male manager	250	2,988.31	11.98	0.72
<i>t</i> -ratio (female vs. male manager)		1.162*	0.929	0.74
All farms	325	3,093.52	12.33	0.72

<sup>a</sup>Estimate of profit-loss by multiplying maximum profit with profit inefficiency score. Maximum profit was calculated by dividing the actual profit per acre of individual farm by its efficiency score.

<sup>b</sup>Better information refers to the index equal or above the mean index (15.75). <sup>c</sup>More experience refers to the years of farmers cultivating vegetables for more than average (12.31 years).

<sup>d</sup>Far-farm was considered if the farm was located equal or more than the mean distance (15.64 miles).

\*\*\*, \*\*, \* indicate the level of significance at 1%, 5%, and 10%, respectively.

varied slightly across four districts. The efficiency was highest in Dhanusa (75%) and lowest in Dhading (70%).

The major determinants of having such different levels of efficiency could be the access of infrastructure related to agriculture development and socio-economic factors associated with the vegetable production (Rahman, 2003; Nwauwa et al., 2013; Rai et al., 2019). More specifically, the higher efficiency in Dhanusa can be attributed to greater access to agriculture extension, road infrastructure, and marketing networks than those of the rest of the study areas. Whereas, the farmers in Dhading were relatively in a remote area, which is relatively inaccessible to agriculture extension services, marketing networking, and road networks that could have contributed to the lower level of profit efficiency. The finding of this study is consistent with other studies (Rajendran, 2014; Dahal et al., 2019; Lamichhane et al., 2019; Mehedi Adnan et al., 2021) revealed. For example, Lamichhane et al. (2019) reported 21% technical inefficiency in potato production in the western terai

region of Nepal and Dahal et al. (2019) estimated 36% technical inefficiency in cauliflower production in the mid-hill region of Nepal. Similarly, Rajendran (2014) reported 40% technical inefficiency in fruits and vegetable production farms in Tamil Nadu, India. Literature shows that the production inefficiency and its determinants are similar in Asia and Africa. For example, Akamin et al. (2017) reported 33% technical inefficiency in vegetable farming in Cameroon, and Mulaudzi et al. (2019) found 21% technical inefficiency in indigenous vegetable production in South Africa. The variables that significantly affected technical inefficiency in South Africa's indigenous vegetable production were years of schooling, extension services, gender, and access to irrigation system (Mulaudzi et al., 2019).

## The Determinants of Profit Efficiency in Vegetable Farms

To analyze the second objective, stochastic Translog Profit Function was run. The statistically significant factors that



affected the profit inefficiency were improved varieties, access to information, access to extension services, access to credit, number of years of experience in farming, access to market, and sex of the farm household decision maker. The factors affecting the production efficiency and profit efficiency in vegetable production were almost similar between Asia and Africa. For example, Mulaudzi et al. (2019) reported that the years of schooling, extension services, gender, and access to irrigation system are the main variables affecting efficiency in South African indigenous vegetable production. The adoption of improved varieties increased profit efficiency. Improved varieties are used as a risk aversion strategy for weather risk tolerance, disease-pest tolerance, and reduce yield gap adopting high yielding crop varieties (Tavva et al., 2017) that contribute to enhance efficiency and provide more profit to the farmers. The use of advanced technology increases the productive efficiency and productivity in agriculture, while it needs huge investments and qualified human resources (Dahal et al., 2019). Cummins and Xie (2013) argued that investment in advanced technologies and human resource development improves the farm efficiency and productivity. The government support is crucial to formulate policies in developing human resources, allocate sufficient budget, and conduct researches for varietal development to improve seed varieties resilience to adverse weather (Bozoglu and Ceyhan, 2007). Farmers should also be encouraged and incentivized to adopt improved varieties of seeds that reduce cost per unit and eventually increase the profit efficiency.

In this study, we developed an index to analyze farmers' access to information. The access to information was defined as the index of three types of information: farming technology, input marketing, and output marketing. The access to information increased profit efficiency. Better information access to the farmers on output marketing helps them in decision making to select crop varieties and appropriate season to be cultivated, purchase inputs from markets, sell outputs in markets, and leading to be higher profit. Effective market information service also helps farmers to minimize market losses during storage, transportation, packaging and handling of products. Information services could be effective by encouraging private sector to be involved in information dissemination using media, publications, extension materials, and training and visit programs. The finding is consistent to other studies (Bhusal et al., 2021).

The effect of access to extension services on profit efficiency was found positive. The finding is consistent with other studies. For example, Dinar (1996) argued that extension system play important role to increase farm efficiency and it needs to be more diversified, and efforts are needed to provide different packages of extension services to different targeted group of farmers. Similarly, Karafillis and Papanagiotou (2009) and Nmadu and Garba (2013) argued that education and extension system increase the efficiency and profitability. In the same line, Tavva et al. (2017) reported that technology transfer through training and extension services could enhance yield potentials. Binici et al. (2006) emphasized that extension education program should focus on the appropriate use of variable inputs such as chemical, urea, tractor, and labor. Extension service can be effective with the pluralistic extension mechanism that incorporates farmers'

group, private sector, and NGO, particularly in the areas where public extension service is inadequate (Dinar, 1996; Bhatta et al., 2006; Tavva et al., 2017). The non-governmental organizations could play positive and significant role in providing agricultural extension services to the farmers that enhance the productivity and efficiency in agriculture (Bhatta et al., 2006).

The effect of access to credit on profit efficiency was found positive. The result is consistent with other studies. For example, Kumar et al. (2013) reported credit constraint reduces the use of inputs and limits outputs, and Jensen (2000) argued that farmers' friendly credit programs improve productive efficiency. Ferrari et al. (2007) reported that 72% households borrowed credit from informal sector (money lender, relatives and friends) despite its higher interest rates up to 42% in Nepal, while banks charged 8% to 10% per year because of inaccessibility of credit service in rural areas. As a result, farmers compelled to avail required credit from informal sources at a higher interest rate that affected vegetable farms to be profit inefficient. Indeed, access of farmers to formal credit could improve the farm efficiency (Parikh et al., 1995; Yegbemey et al., 2017) and contribute for fostering the economic sustainability. Therefore, policies should encourage formal financial institutions, micro-credit programs, and cooperative credit programs to provide financial resources to farmers with subsidized rate in vegetable farming.

The effect of numbers of experiences in farming on profit efficiency was found positive. Experiences help farmers allocate resources appropriately, better farm management, explore and utilize alternative markets for inputs and outputs, and consequently improve efficiency performance. Our finding is consistent with the studies (Rahman, 2003; Abu et al., 2012; Sanusi and Ajao, 2012; Nmadu and Garba, 2013). These studies reported that a longer experience in farming increases the productivity and efficiency in agriculture because they can optimize the use of technologies, services, and inputs.

The effect of market access on profit efficiency was found positive. A shorter distance to markets gives better access to input and output markets, increases availability of information, and reduces transportation cost of products. Farms that are closer to input markets can buy agro-inputs on time and at lower price (Dastagiri et al., 2012). Farms that are closer to output markets could have greater opportunities to sell their products in competitive price and help farmers to earn higher level of profit. Nepalese vegetable farmers are suffered on the government rules and regulations, Agriculture Produce Market Regulation Directives-1996, which limit farmers for getting entry in agricultural markets to sell their products (Shrestha et al., 2016a). Additionally, market infrastructure development (collection centers, cooperative markets, wholesale or retail markets) nearby vegetable production areas and rural road networks that link the production areas to the markets need to be established. The infrastructure development requires strong government supports to allocate resources and set-up the rules that ensure that farmers have good access to market facilities. Fostering triangular cooperation could be useful to address the farmers' market development. Farmers also need to be encouraged for vegetable farming in the areas across the road-corridor or nearby markets. Farmers groups or cooperative

marketing could be an appropriate strategy for smallholder vegetable farmers that improve profit efficiency. Improving the marketing efficiency contribute for food security and economic growth (Lenné and Ward, 2010), while it is handicapped by a wider range of marketing margin and a higher level of price spread for fruits and vegetables (Rajendran, 2014). Promoting the private corporate sectors in the agriculture marketing at the village level could enhance the marketing efficiency (Basu, 2010).

Female-headed households were found more efficient than male headed households. Female farmers account for a substantial total labor use and contribute significantly to productivity as well as technical efficiency (Rahman, 2009; Shrestha et al., 2016a; Mirjana et al., 2020) and female farmers are more efficient technically than men farmers (Oladeebo and Fajuyigbe, 2007). Although, women have relatively less access to resources and opportunities in extension services, they are more sincere in resource allocation and economic planning that led them more efficient in vegetable farming (Bozoglu and Ceyhan, 2007; Shrestha et al., 2016a; Joshi and Kalauni, 2018). Farmers' contact with extension agencies, affiliation of farmers with organization, and access to credit significantly contribute to the sustainability dimension in agriculture (Yegbeme et al., 2017). Therefore, policymakers should give more attention to encourage women in vegetable farming with incentive packages integrating extension services, training programs and credit facilities.

## CONCLUSIONS

Enhancing productivity, profitability and the profit efficiency in vegetable farming improve income, livelihood, and nutrition of smallholder farmers. This study measured the profit efficiency of smallholder vegetable farms and identified factors affecting profit inefficiency using the stochastic frontier function. The mean of the profit efficiency was found to be 0.72, which indicated that 28% inefficiency could be removed by implementing appropriate managerial, technological, institutional, and policy interventions. The input variables, labor, seed, fertilizer, pesticide, land, and capital, were proved to be significant factors to determine profit

in vegetable farming. The policymakers should focus on policy formulation to educate farmers in allocating resources at the optimum proportion to achieve the frontier level of profit. The socio-economic variables, improved seed varieties, better information, higher number of contacts with extension workers, long years of experience in vegetable farming, farms near to the markets, and female farmers, demonstrated better performance in profit efficiency. Therefore, policy interventions should be tailored to promote improved seed varieties in vegetable farming, provide effective information services to the farmers, deliver effective extension services, provide financial access to the farmers, develop markets linking with production areas, and encourage women in vegetable farming with adequate incentive packages to enhance profit efficiency.

## DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## ETHICS STATEMENT

Ethical review and approval was not required for this study with human participants, in accordance with the local legislation and institutional requirements. The participants provided their informed consent to participate in this study.

## AUTHOR CONTRIBUTIONS

RS was primarily responsible for problem identification and data collection. All authors were involved in research design, data analysis, and writing of the manuscript.

## SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2021.691350/full#supplementary-material>

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