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Irrigation Energy Sources and Profit Efficiency of Vegetable Farming in the Keta Municipality, Volta Region

Mawuli Antwi DOTSE[1], Franklin N. MABE[2*], Joseph A. AWUNI[3]

[1]Department of Agriculture and Food Economics
[2]Department of Agricultural Management and Policy
[3]Department of Economics
University for Development Studies
P. O. Box TL 1350
Tamale, Ghana

**Correspondence: mfnantui@uds.edu.gh*

ABSTRACT

This study estimated and compared profit and profit efficiency levels of energy sources for irrigation in the Keta Municipality of Ghana. The data was analysed using profit and Stochastic Frontier Analyses. The multi-stage sampling technique was used to sample 250 respondents. A semi-structured questionnaire was used via face-to-face interview to collect data from the respondents. The most profitable energy source for irrigated vegetable production is solar energy while the least profitable is petrol energy. On average, farmers had a profit efficiency of 59%. The study concluded that energy sources have significant effects on the profit levels of vegetable production as well as the profit efficiency level of the farmer. Solar-powered irrigation facilities should be promoted in the study area and Ghana as a whole.

***Keywords**: Profit, profit efficiency, irrigation energy sources, vegetables, stochastic frontier analysis.*

INTRODUCTION

In Ghana, small-scale irrigation started in Keta area around the 1980s and was done between lagoons and sandbars (Kyei-Baffour & Ofori, 2006). Currently, Ghana has a potential irrigable land size of 1,900,000 hectares, but as of 2015, only 221,000 hectares representing 11.63% was put under irrigation (Ministry of Food and Agriculture [MoFA], 2016). At the regional level, irrigation agriculture has been part of the Comprehensive Africa Agriculture Development Program (CAADP) (Hamududu and Ngom, 2019). Generally, irrigation is mostly done in vegetable production than roots and tubers, cereals and perennial crops.

The agriculture sector remains the major user of water globally (Hamududu and Ngom, 2019). Therefore, with the increasing global climate change, not only there is a growing need for water for agricultural production and domestic uses among others but also, water resource management has become a major concern to all stakeholders and central to agricultural discussions. In agriculture, water scarcity remains a major issue due to the increasing demand for quality water for domestic and industrial use. Meier *et al*. (2018) opined that low irrigation efficiency techniques such as sprinkler, unsustainable use of groundwater and changing river regimes underline the need for efficient and sustainable water management. Energy inputs for modern and sustainable agricultural production and processing systems is a key factor in moving beyond subsistence farming towards food security and expansion into new agricultural markets (Brussaard, 2010). It is important to note that different sources of energy are available for the agricultural production process, for example, by fuelling irrigation pumps or post-harvest cooling or drying systems or processing such as milling and pressing etc.

Lifting water remains one of the topmost activities in irrigation farming. Therefore, the level of profit or profit efficiency is functional on the type of irrigation scheme or the sources of energy for lifting irrigation water. Alves *et al*. (2014) argued that although there are different sources of energy for driving irrigation pumps, the most common are diesel and electric methods. The authors, however, noted that diesel pump energy is mostly used in places where electricity is unavailable. According to Alves *et al*. (2014), the economic analysis of water pumping mechanisms is essential since the capital requirement is high.

In irrigation, energy is required to lift water by pumping from surface sources, such as ponds, streams, or canals; or from below-ground sources using open wells or boreholes. This water is typically pumped to surface canals, reservoirs, or elevated tanks. In pumping irrigation water, the farmer needs to source energy from the national grid (electricity) or hydroelectric power, petrol, diesel, solar or manpower. Empirically, evidence suggests that the profitability or economic potentials of these energy sources differs. For instance, Hossain *et al*. (2014) concluded from their study that not only are solar pumps economically profitable for vegetable production but also, they are environmentally friendly while diesel pumps are both economically unprofitable and environmentally unfriendly. Specifically, Alves *et al.* (2014) argued that although solar-powered pumping of irrigation water has a high initial investment cost, it has a lower total cost and it is economically viable than diesel energy pumps. Shouman *et al*. (2016) showed that although diesel energy pumps have low capital cost, they have high operational and maintenance cost that affects their economic viability, thereby concluded that photovoltaic like solar are better in terms of profitability.

Diaba *et al.* (2015) examined the energy sources (wind and electric pumps) for lifting irrigation water by farmers in the Keta District of Ghana. This study concluded that although the level of wind pumps is low than electric and manual pumps, wind energy could increase the incomes from vegetable production and also reduce the pressure on farmers. Therefore, understanding the role of irrigation energy sources in improving the profit and profit efficiency of vegetable farmers is crucial and necessary. Specifically, the results of this study are expected to provide vegetable farmers in Keta Municipality and other parts of Ghana with information on which sources of energy can increase their profit level and efficiency.

Profit can be defined as the net surplus of a large number of policies and decisions. It is largely defined as the difference between the gross or net returns and the gross or net total costs of production (Wognaa *et al.*, 2019). Also, profit efficiency involves attaining the highest possible profit from a production activity, given the price levels and the fixed cost of production (Ali & Flinn, 1989). Sadiq & Singh (2015) therefore defined profit inefficiency as the distance between the observed profit of a firm and the profit frontier of firms in such industry. Profit efficiency is broader than cost efficiency since this accommodates the choices in both inputs prices and output prices.

MATERIALS AND METHODS

Sampling Technique, Sample Size and Instrumentation

The target population for this study is defined as all households involved in irrigated vegetable farming in the Keta Municipality. The study used a two-stage sampling technique. In the first stage, a list of irrigation farming communities was obtained from the Ministry of Food and Agriculture (MoFA) at the Municipal Assembly. Six communities were then sampled from the list of communities through simple random sampling. The selected communities were Anloga, Denu, Silanfo, Hedranawo, Tegbui and Viefa. In the second stage, the researcher visited the selected communities and obtains an approximate number of irrigation vegetable farmers from the community irrigation farmers' leader. The irrigated vegetable farmers in Anloga, Denu, Hedzranawo, Silanfo, Tegbui and Viefa were 49, 39, 76, 43, 32 and 43 respectively. The irrigation vegetable farmers were selected using simple random sampling procedure. With the help of Yamane's (1967) sampling selection formula, 44, 36, 64, 39, 30 and 39 irrigation vegetable farmers were selected from Anloga, Denu, Hedzranawo, Silanfo, Tegbui and Viefa respectively. For instance, the sample size (n) for Anloga was calculated as shown below:

$$n = \frac{N}{1+N(e^2)} \qquad (1)$$

Where n denotes sample size, N denotes population (N=49 at Anloga), e denotes margin of error (e=0.05).

$$n = \frac{49}{1 + 49(0.05^2)} = 44$$

A semi-structured questionnaire was used for collecting primary data from irrigated vegetable producers for the study. The data was collected through a face-to-face interview.

Stochastic frontier model for analysing profit efficiency

Estimation of profit

To estimate the profit efficiency, it is first important to determine the profit levels of each of the farmers:

$$\pi = TR - (TVC + TFC) \qquad (2)$$

where TFC is total fixed cost, TR is total revue, TVC is the total variable cost and π is profit.

Analytical and empirical framework for profit efficiency

There are many efficiency estimation methods for assessing firm performances. The prominently used one is production efficiency which is usually analysed by its two components: technical and allocative efficiencies (Farrel, 1957). Profit efficiency is the product of input and output efficiencies (Battese & Coelli, 1995). Profit efficiency measures the ability of a firm to achieve the highest possible profit given output, input prices and levels of fixed factors. Following Rahman *et al.* (2015), stochastic profit frontier which defines profit as a function of factor prices, the quantity of output, output price and fixed inputs is given as:

$$\pi_i = h(q_i, z_i, p_i, w)\exp(v_i - u_i) \qquad (3)$$

where: π_i= profit of vegetable farmers; q = quantity of output; z = vector of fixed input(s); p = output price; w=factor price; exp (v-u) =composite error term (ε) and i =ith vegetable farmer.

The composite error term is two-sided, *u* and *v*. The *v* constitutes the random factors beyond the control of the farmer such as climatic conditions, measurement errors, omitted explanatory variables and statistical noise. The other error component (*u*) is a non-negative error term. This non-negative error term, *u* measures the profit loss due to farmers' inefficiencies. Both *v* and *u* are assumed to be independently and normally distributed with zero mean and constant variance.

The profit efficiency of an individual vegetable farmer is defined as a ratio of the observed profit (π_i) to the corresponding maximum achievable profit (π_i*) for the best vegetable farm given the price of variable inputs and the level of fixed factor(s) of production (O'Donnell *et al.*, 2008). Mathematically, the profit efficiency is expressed as:

$$PE = \frac{\pi_i}{\pi_i^*} = \frac{h(q_i, z_i, p_i, w)\exp(v_i - u_i)}{h(q_i, z_i, p_i, w)\exp(v_i)} = \exp(-u_i) \quad (4)$$

Following Ansah *et al.* (2014), the empirical stochastic translog profit model is given as:

$$\begin{aligned}\ln \prod_i = {} & \beta_0 + \beta_1 \ln EC_i + \beta_2 \ln P_{R_i} + \beta_3 \ln Fs_i + \beta_4 \ln P_{S_i} + \beta_5 \ln P_{F_i} + \beta_6 \ln P_{P_i} + \beta_7 \ln P_{L_i} \\ & + 0.5\beta_{11} \ln Y_i \ln Y_i + 0.5\beta_{22} \ln P_{R_i} \ln P_{R_i} + 0.5\beta_{33} \ln Fs_i \ln Fs_i + 0.5\beta_{44} \ln P_{S_i} \ln P_{S_i} + \\ & 0.5\beta_{55} \ln P_{F_i} \ln P_{F_i} + 0.5\beta_{66} \ln P_{P_i} \ln P_{P_i} + 0.5\beta_{77} \ln P_{L_i} \ln P_{L_i} + \beta_{12} \ln Y_i \ln P_{R_i} + \\ & \beta_{13} \ln Y_i \ln Fs_i + \beta_{14} \ln Y_i \ln P_{S_i} + \beta_{15} \ln Y_i \ln P_{F_i} + \beta_{16} \ln Y_i \ln P_{P_i} + \beta_{17} \ln Y_i \ln P_{L_i} + \\ & \beta_{23} \ln P_{R_i} \ln Fs_i + \beta_{24} \ln P_{R_i} \ln P_{S_i} + \beta_{25} \ln P_{R_i} \ln P_{F_i} + \beta_{26} \ln P_{R_i} \ln P_{P_i} + \\ & \beta_{27} \ln P_{R_i} \ln P_{L_i} + \beta_{34} \ln Fs_i \ln P_{S_i} + \beta_{35} \ln Fs_i \ln P_{F_i} + \beta_{36} \ln Fs_i \ln P_{P_i} + \\ & \beta_{37} \ln Fs_i \ln P_{L_i} + \beta_{45} \ln P_{S_i} \ln P_{F_i} + \beta_{46} \ln P_{S_i} \ln P_{P_i} + \beta_{47} \ln P_{S_i} \ln P_{L_i} + \\ & \beta_{56} \ln P_{P_i} \ln P_{P_i} + \beta_{57} \ln P_{P_i} \ln P_{L_i} + \beta_{67} \ln P_{P_i} \ln P_{L_i} + (V_i - U_i)\end{aligned} \quad (5)$$

where βs represents the parameters to be estimated.

As noted earlier, U_i measures profit inefficiency which is empirically stated as:

$$U_i = \delta Z_i + +\delta W_i + e_i \quad (6)$$

Where e_i denotes the error term in the profit inefficiency model and Z_i is a vector of socioeconomic and institutional variables and W_i is a vector of energy sources for lifting irrigation water. These variables are specifically listed and their measurement as well as a priori expectations provided in the appendix.

RESULTS AND DISCUSSIONS

Profit by Irrigation Energy Sources

Table 1 shows that the total cost of vegetable production for an acre of land is GH₵2,852. The total cost of production is highest for farmers who used a petrol pump as their source of energy for lifting irrigation water. The least cost of vegetable production (GH₵1,128.67) was obtained by farmers who used solar energy for lifting irrigation water. The energy source with the second least total cost was diesel. These findings are consistent with the findings of Alves *et al*., (2014) who estimated that the total cost of solar pumped irrigation is lower than diesel pumped energy. Similarly, Shouman *et al*. (2016) showed that although diesel energy pumps have low capital cost, they have high operational and maintenance cost that increases their total cost over solar pumped energy systems. On electricity, IRENA (2016) explained that its low cost or provisioning at zero price can prevent cost recovery. The profit from an acre of an irrigated vegetable farm is averagely GH₵4,408.42. The highest profit of GH₵7,671.33 was obtained under solar energy irrigation farming while the least profit of GH₵1,582.83 was obtained under petrol pump irrigation farming. Since the unit price for output does not necessarily differ between energy systems, the high profit from solar energy irrigation farms is due to high output from the system.

TABLE 1. **Cost, Revenue and profit of vegetable production by energy source**

	Source of irrigation energy (GH₵)					
Item	Manual/Treadle	Electric	Petrol	Diesel	Solar	**Total**
Revenue	7,806.55	7,143.44	5,421.67	8,728.57	8,800	7,260.49
Total Cost	2,560.90	2,950.42	3,838.83	1,706.00	1,128.67	2,852.07
Net margin (GH₵/acre)	5,245.65	4,193.02	1,582.83	7,022.57	7,671.33	4,408.42

Source: Author's analysis from field data (2018).

Stochastic Frontier Profit Estimates

Test of model specification

A likelihood ratio (LR) test was conducted to determine the appropriate functional form of the data. The test indicated that the translog was appropriate (Table 2). This is based on the results of the LR statistic of 24.46 which is statistically significant at 5%. This implies that the null hypothesis that the Cobb-Douglas functional form is a better specification of the data is rejected. Also, the hypothesis of no inefficiency effect is rejected, implying that the use of the stochastic frontier framework is ideal.

TABLE 2. **LR Test of Hypothesis Result**

Test Type	**Null Hypothesis**	**Statistic**	**Decision Rule**
Functional form	$H_0 : \beta_{ij} = 0$	24.46 (0.0403)	Reject H_0: Translog is appropriate
Frontier test	$H_0 : \delta_1 = \delta_2 ... \delta_{14} = 0$	32.84 (0.0019)	Reject H_0: MLE is appropriate, inefficiency effects exists

Note: MLE stands for maximum likelihood

Source: Author's analysis from field data (2018).

Determinants of vegetable profit

Table 3 shows the maximum likelihood estimates of the stochastic translog model. The stochastic frontier model was used to assess the impact of conventional inputs (fertilizer, pesticides, labour, seed, farm size and capital) on the profit of irrigated vegetable farmers. The input variables were normalised by dividing the respective input and output variables by their means. This was necessary so that the coefficients can be interpreted as partial production elasticities.

The monotonicity condition was checked and the observation was that all the models were monotonic since the respective sums of the estimated first-order coefficients of all the logarithmic inputs were positive. Also, the convexity and no free lunch assumptions of the production functions were binding since the use of translog is valid and no vegetable farmer indicated that he/she harvested vegetable from the uncultivated field.

The factors that significantly determine the profit in irrigated vegetable farming are prices of energy, pesticide, labour and cost of capital. While labour and energy prices have positive significant influence on profit, cost of capital and price of pesticides have negative influence. This suggests that prices of energy and labour increase profit from vegetable farming whilst capital and price of pesticides decrease farm profit, holding other factors constant. Consistently, Shettima *et al.* (2016) found that labour wage has a positive effect on the production of onion, tomato and pepper. This is also consistent with the result of Anim *et al*. (2015). Weldegiorgis *et al*. (2018) estimated that both labour and cost of labour affect the production of vegetables.

The profit elasticities of prices of energy, pesticide and labour as well as cost of capital are statistically different from zero. Price of energy has the highest positive impact on profit with labour having the lowest. The elasticities of profit with respect to prices of energy and labour are 0.91 and 0.43 respectively. This implies that a 100% increase in price of energy and production associated price will increase mean profit by 91.1%, *ceteris paribus*. This finding is consistent with the result of Shettima *et al.* (2016). Also, Nmadu and Garba (2013) estimated a positive but insignificant effect of the price of irrigation water on profit levels from vegetable production. On the other hand, Anim *et al*. (2015) estimated a negative effect of irrigation price on vegetable production. Similarly, if labour price increases by 100%, mean profit will increase by 43%, holding other factors constant. However, cost of capital and price of pesticides were found to have negative impacts on profit. The elasticities of profit with respect to cost of capital and price of pesticides are 0.27 and 0.57 respectively. This implies that a 100% increase in cost of capital will result in a reduction of mean profit by 29.7%, *ceteris paribus*. This is contrary to the findings of Shettima *et al*. (2016) and Mbanasor & Kalu (2008). Similarly, if pesticides price increases by 100%, mean profit will reduce by 50.7%. Empirically, Nmadu and Garba (2013) found that the cost of agrochemicals and depreciated price of tools leads to a decline in profit from vegetable production. Relatedly, Shettima *et al*. (2016) and Mbanasor & Kalu (2008) estimated that the cost of agrochemicals has a positive effect on profit levels from vegetable production. Statistically, farm size, prices of seed and fertilizer do not influence profit of irrigated vegetable farmers in the study area. The positive insignificance of price of seed on profit efficiency is consistent with the result of Anim *et al*. (2015). On the contrary, Weldegiorgis *et al*. (2018) estimated a positive significant effect of cost of land on vegetable production while Shettima *et al*. (2016) found a significant effect of fertiliser price on irrigated vegetable production. Asravor *et al*. (2016) also estimated a significant effect of farm size on chilli pepper production and cost of production in Ghana.

TABLE 3. **Maximum Likelihood Estimates of Stochastic Translog Model**

Variable	Coefficient	Standard Error
ln(Price of energy)	0.9189**	0.4352
ln(Price of labour)	0.4330**	0.1967
ln(Price of fertilizer)	0.2693	0.2605
ln(Price of pesticides)	-0.5078**	0.2666
ln(Price of seed)	0.1157	0.1378
ln(Cost of capital)	-0.2979***	0.0928
ln(Farm size)	-0.3608	0.3646
ln(Price of energy squared)	-0.9183***	0.2757
ln(Price of labour squared)	-0.0393	0.1160
ln(Price fertiliser squared)	0.0147	0.0492
ln(Price pesticide squared)	-0.0773	0.1186
ln(Price seed squared)	0.0322	0.0400
ln(Cost of capital squared)	-0.0915***	0.0278
ln(Farm size squared)	0.7641***	0.2546
*ln(Price of energy)*ln(Price of labour)*	-0.7085***	0.2479
*ln(Price of energy)*ln(Price of fertiliser)*	-0.3347	0.2869
*ln(Price of energy)*ln(Price of pesticide)*	0.3233	0.3345
*ln(Price of energy)*ln(Price of seed)*	-0.1956	0.2037
*ln(Price of energy)*ln(Cost of capital)*	0.0398	0.1100
*ln(Price of energy)*ln(Farm size)*	1.4740***	0.4167
*ln(Price labour)*ln(Price of fertiliser)*	-0.1284*	0.0724
*ln(Price labour)*ln(Price of pesticide)*	-0.0102	0.1063
*ln(Price of labour)*ln(Price of seed)*	-0.2411***	0.0695
*ln(Price of labour)*ln(Cost of capital)*	-0.1142	0.1566
*ln(Price of labour)*ln(Farm size)*	0.3261*	0.1778
*ln(Price of fertilizer)*ln(Price of pesticide)*	-0.1157	0.1211
*ln(Price of fertilizer)*ln(Price of seed)*	0.0898	0.0882
*ln(Price of fertilizer)*ln(Cost of capital)*	0.0170	0.0704
*ln(Price of fertilizer)*ln(Farm size)*	0.2335*	0.1330
*ln(Price of pesticide)*ln(Price of seed)*	-0.1219	0.1271
*ln(Price of pesticide)*ln(Cost of capital)*	-0.1226**	0.0592
*ln(Price of pesticide)*ln(Farm size)*	0.3254**	0.1704
*ln(Price of seed)*ln(Cost of capital)*	-0.0631	0.0445
*ln(Price of seed)*In(Farm size)*	-0.0551	0.1494
*ln(Cost of capital)*ln(Farm size)*	0.0129	0.0874
Constant	0.2119	0.2209
σ_v^2	-3.179	
σ_u^2	0.203	

Note: *, ** and *** significant at 10%, 5% and 1% respectively.

Source: Author's analysis from field data (2018).

From the translog model (Table 3), significant input complementary effects were observed between farm size and pesticide. Also, the same observation was made for farm size and prices of fertilizer, energy and labour as well as farm size. These are contrary to the results of Mbanasor & Kalu (2008). The implication is that if the prices of the input pairs are increased, profits will also increase. Additionally, the result revealed statistical significant input substitution effects on profit level. Prices of seed and labour; prices of fertilizer and labour; prices of energy and labour; prices of pesticides and cost of capital were found to be substitutes.

The substitution effect of seed and labour is plausible because farmers do not have enough money to purchase certified seeds and high labour at the same time. Therefore, to reduce the investment burden, they sometimes trade avoid hiring labour but rather use family labour when they spend so much on certified seed. Also, the vegetables under cultivation in the study area (such as onions, pepper, carrots among others) require the use of certified seeds. Hence farmers have no option than to purchase them. As a result of the cost, vegetable farmers cannot afford the services of hired labour but depend on family and friends for labour. This is contrary to the result of Asravor *et al*. (2016).

Similarly, fertilizer and labour have substitution effect on profit because vegetable farmers would prefer to purchase fertilizer (organic and inorganic) which would boost production and depend on family labour rather than employing high cost of labour. Due to the infertile nature of soils in the study area, the use of fertilizer is inevitable in the cultivation of vegetables. In their study, Mbanasor & Kalu (2008) found that there is a positive effect of the interaction of labour wage and fertiliser on the profit level from vegetable production.

Again, farmers will substitute labour for energy cost. Energy cost is necessary, that is frequent flow of irrigated water in vegetable growth juxtapose individual and household labour. Capital cost and pesticides also had a substitute effect on profit. Pesticides and capital are cost-intensive but capital cost is a long term investment. Hence, vegetable farmers prefer using fewer pesticides to investing in irrigation equipment for irrigating vegetable production to make profit.

Determinants of Profit Inefficiency of Irrigated Vegetable Farmers

Table 4 shows that age, sex, marital status, farming experience; vegetable farming experience, household size, FBO membership, ownership of vegetable production technology, livestock ownership, soil fertility perception, pest infestation perception, energy from fuel and energy from national grid statistically determine profit inefficiency in the study area. From the results, sex, marital status, farming experience, vegetable farming experience, household size, FBO membership, ownership of vegetable production technology, livestock ownership, soil fertility perception, energy from fuel and energy from national grid are statistically significant at 1% each. Age and pest infestation perception on the other hand are statistically significant at 10% and 5% respectively.

From the results in Table 4, younger vegetable farmers were more profit efficient than older ones. This is evident in the coefficient (0.0281) of age which was significant at 10%. This means that when the age of a vegetable farmer increases, the profit efficiency of vegetable will decrease. This is expected and plausible as older farmers are expected to be less adventurous and participate less in the market compared to their younger counterparts. Weldegiorgis *et al*., (2018) also estimated a negative relationship between economic inefficiency of vegetable production and age, and this is consistent with the result of this present study. On the contrary, however, is the finding of Nmadu & Garba (2013).

Results in Table 4 reveal that female vegetable farmers were more profit efficient compared to their male counterparts. The sex coefficient value of 2.7303 is negative and statistically significant at 1%. This means that female vegetable farmers were more efficient at maximising profits from their vegetable venture compared to their male counterparts. Also, in most cases, women produce vegetables on small scale for household consumption while men produce on large scale for sale. This is consistent with the result of Mbanasor & Kalu (2008) but contrary to Kyomugisha *et al*. (2017). Marital status is statistically significant with negative sign. This means that vegetable farmers who are married were more profit efficient compared to those who were single. This is plausible because the husband and wife could assist each other in vegetable farming. This assistance could be in the form of assistance in carrying out cultural activities on the vegetable farm and/or the marketing of vegetables. This is consistent with the finding of Konja *et al*. (2019).

TABLE 4. **Determinants of Profit Inefficiency among Vegetable Farmers**

Variable	Coefficient	Standard Error
Farmer Characteristics		
Age	0.0281*	0.0152
Sex	2.7303***	0.7650
Marital status	-1.5452***	0.4485
Farming experience	0.1725***	0.0413
Vegetable farming experience	-0.2638***	0.0491
Household head	0.0418	0.0913
Household size	3.2644***	0.7057
Land ownership	0.5795	0.4540
Ownership of Livestock	-0.9127***	0.3734
Ownership of production technology	2.4059***	0.5708
Secondary occupation	-0.1775	0.5164
No formal education	-0.1433	0.6000
Institutional and Policy Variables		
FBO membership	-3.4012***	0.7954
Access to credit	-0.1034	0.6969
Environmental Factors		
Perception on soil fertility	2.2784***	0.6507
Perception of the amount of rainfall	0.3114	0.3968
Perception on the infestation by pests	-2.1555**	0.7607
Pumping Technology (Energy)		
Energy from manual source	0.3171	0.5415
Energy from the national grid	5.1367***	1.0654
Energy from fuel	-5.8701***	1.8791
Constant	-8.5964***	1.9123

*, ** and *** significant at 10%, 5% and 1% respectively.

Source: Author's analysis from field data (2018)

The number of years in vegetable farming was found to determine the profit efficiency of farmers. This implies that when the number of years in vegetable farming increases, farmers' profit efficiency decreases. That is to say that less experienced vegetable farmers are more profit efficient compared to the relatively experienced ones. This confirms the findings of Nwauwa *et al.* (2013) who found farm experience to have a positive relationship with inefficiency but contradicts the findings of Hyuha *et al*. (2007) and Shettima *et al*. (2016) who found experience to be negatively related to the profit inefficiency of farmers.

Household size was another significant determinant of profit efficiency of vegetable farmers. This variable is positive with a coefficient of 3.26 and significant at 1%. This means that profit efficiency decreases with an increase in household size. Again, results from Table 4 indicate that vegetable farmers who own livestock are more profit efficient than those who do not. This is not surprising because livestock could generate manure for fertilizing vegetable farms which are catalysts for improving output per acre and subsequently profit efficiency. Also, livestock could be used on the vegetable farm for traction. Vegetable farmers who belong to FBOs were found to be more profit efficient than those who belong to no FBOs. Farmers learn modern and innovative ways of improving their production activities from FBOs. With FBOs, farmers can get connected to bigger markets both in terms of input and outputs. It is therefore not surprising that the association variable was statistically significant at 1%. Although this supports the findings of Shettima *et al*. (2016), it contradicts to work of Ume *et al*. (2016).

Perception of farmers on soil fertility was positive and statistically significant at 1%. This suggests that vegetable farmers who perceived that the soil was fertile were found to be more efficient compared to those who perceived that the soil was infertile. Vegetable farmers who used petrol and diesel were found to be more profit efficient compared to those who used solar energy for pumping irrigation water. This variable was significant at 1% and negative with a coefficient value of 5.14. This could be attributed to the high installation cost of solar panels relative to the use of petrol and diesel for pumping irrigation water for vegetable production. Finally, the use of energy from the national grid (electricity) was positive and statistically significant at 1%. This implies that vegetable farmers using energy from the national grid for irrigation were less profit efficient compared to farmers using energy from solar. This is expected considering how expensive electricity tariffs have become in recent times and the erratic nature of the supply which causes damages that farmers are unprepared for. Thus, for a vegetable farmer to be profit efficient in the study area, he/she should not rely solely on energy from the national grid as it contributes to profit inefficiency, *ceteris paribus*.

Distribution of Profit Efficiency Scores

Table 5 shows the efficiency levels of the farmers based on the various irrigation energy sources. This shows that overall; the average farmer had a profit efficiency of 58.86%; minimum and maximum of 1.3% and 97.23% respectively. The implication is that the farmers generally have an inefficiency level of 41.14%. This is a reasonably high inefficiency level by the farmers. The estimated mean efficiency is lower than the 61% economic efficiency estimated by Mbanasor and Kalu (2008); 67.36% by Weldegiorgis *et al*., (2018) and 65.76% by Asravor *et al*. (2016). Specifically, the highest mean profit efficiency was recorded by diesel energy users and this was followed by solar energy users. The implication is that although the use of these energy sources is low, the farmers who used these energies have high-profit efficiency. The least mean profit efficiency was obtained by electricity energy users. Recalling from section 4.3 where solar energy and diesel users had the highest and third-highest profit margin and juxtaposing with the high efficiency of these farmers, it can be established that these energy sources are more economically viable for irrigation vegetable production in the Municipality.

TABLE 5**. Profit efficiency levels of farmers**

Efficiency level	Manual/Treadle		Electricity		Petrol		Diesel		Solar		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
0.1-10	8	18.2	8	5.6	2	16.7	0	0.0	0	0.0	18	8.6
10.1-20	0	0.0	3	2.1	1	8.3	0	0.0	0	0.0	4	1.9
20.1-30	1	2.3	15	10.4	0	0.0	0	0.0	0	0.0	16	7.6
30.1-40	0	0.0	17	11.8	0	0.0	0	0.0	0	0.0	17	8.1
40.1-50	0	0.0	16	11.1	1	8.3	0	0.0	0	0.0	17	8.1
50.1-60	5	11.4	9	6.3	1	8.3	0	0.0	0	0.0	15	7.1
60.1-70	9	20.5	15	10.4	2	16.7	0	0.0	2	66.7	28	13.3
70.1-80	12	27.3	30	20.8	0	0.0	0	0.0	1	33.3	43	20.5
80.1-90	3	6.8	26	18.1	3	25.0	3	42.9	0	0.0	35	16.7
90.1-100	6	13.6	5	3.5	2	16.7	4	57.1	0	0.0	17	8.1
Total	44	100.0	144	100.0	12	100.0	7	100.0	3	100.0	210	100.0
Mean	60.51%		56.57%		57.90%		92.66%		69.71%		58.86%	
Min	84.79%		1.30%		1.44%		6.51%		64.61%		1.30%	
Max	97.23%		92.98%		95.07%		91.11%		77.05%		97.23%	

Source: Author's computation from STATA

CONCLUSIONS AND RECOMMENDATIONS

This study estimated and compared the profit and profit efficiency levels of energy sources for irrigation in the Keta Municipal. It also identified the determinants of profit efficiency of vegetable farmers. The study employed the stochastic frontier analysis to determine the effect of irrigation energy on profit efficiency of irrigated vegetable farmers in the study area. The results show that solar energy usage is the most profitable source of energy for irrigation vegetable production. The least profitable energy source for irrigation vegetable production is petrol energy. The factors that significantly determine the profit of vegetable farming were prices of energy, pesticide, labour and cost of capital. While labour and energy prices had positive influence on the profit levels of vegetable production, cots of capital and price of pesticides had negative influence. Inputs such as seed and labour; fertilizer and labour; labour and energy; and capital and pesticides have substitution effects on profit of vegetable production. The profit efficiency of irrigated vegetable production ranged from 1.3% to 97.23% with a mean of about 59%. Energy from the national grid and energy from fuel sources were found to have an influence on profit efficiency of irrigated vegetable farmers.

While farmers are encouraged to use solar energy pumps for irrigated vegetable production, MoFA should collaborate with other related state and non-state institutions to make solar energy available to the farmers. Since installation cost is generally a major hindering factor to solar energy adoption, the provisioning of solar energy should be on subsidized prices and/or the payment for the cost of installation should be spread over time for the farmers. Female farmers should be encouraged to enter into irrigated vegetable production since they have high profit efficiency from its production. To improve the profit efficiency of irrigated vegetable production, farmers must endeavour to join a farmer-based organisation. MoFA should also take keen interest in forming and promoting farmer organisation among farmers.

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Appendix List of variables in profit and profit efficiency models

Variables	**Description/ Measurement**	**A priori Expectation**
E_C	Price of energy (Gh¢)	-
P_R	Cost of pesticides (Gh¢)	-
F_S	Farm size (acres)	+
PF	Cost of fertilizer (Gh¢)	-
P_L	Cost of labour (Gh¢)	-
P_S	Cost of seed (Gh¢)	-
Yi	Cost of depreciated capital (Gh¢)	-
Age	The total number of years from birth of a farmer	+
Sex	Dummy: 1 if a famer is male and 0 if female	-
Marital status	Dummy: 1 if a famer is married and 0 if single	-
Farming Experience	The total number of years a farmer had been into farming.	-
Vegetable farming experience	The total number of years a farmer had been into vegetable farming.	-
Household head	Dummy: 1 if a famer is household head and 0 if only a household member	-/+
Household size	Total number of persons living in the same house and sharing/pooling resources together	-
Land ownership	Dummy: 1 for vegetable farmers who rent farmland and 0 if otherwise	-/+
Livestock	Dummy: 1 if a famer is own livestock and 0 if not	-
Ownership of production technology	1 for vegetable farmers who own production technologies (sprinkler/water pumps) and 0 if otherwise.	-
Secondary occupation	Dummy: 1 for farmers who had a secondary occupation and 0 for those without any secondary occupation.	-/+
Formal education	Total number of years a farmer had in formal education.	-
FBO membership	Dummy: 1 if a farmer belonged to an FBO and 0 if a farmer does not.	-

Access to credit	Dummy: 1 if a farmer had access to credit in the production season and 0 if not	-
Soil fertility	Dummy: 1 for vegetable farmers who perceived that the soil was fertile and 0 for those who perceived that the soil was infertile	-
Rainfall	Dummy: 1 for a farmer perceived adequate rainfall and 0 if inadequate	-
Pests	Dummy: 1 for vegetable farmers who perceived that there was high pest infestation on their vegetable farms, and 0 if low	-
Manual	Dummy: 1 for farmers who use generator for lifting irrigation water and 0 if otherwise.	-
National grid	Dummy: 1 for farmers who use national grid electricity for lifting irrigation water and 0 if otherwise.	+
Fuel	Dummy: 1 for farmers who use fuel (petrol/diesel) for lifting irrigation water and 0 if otherwise.	-