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Profit Efficiency of Integrated Crop-Livestock Production Systems in the Transitional belt of Ghana

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ABSTRACT

This paper is to evaluate the profitability of the integrated crop-livestock production system with the sole crop and sole livestock systems to guide investment decisions of smallholder integrated crop-livestock farmers in Ghana. Using data from 200 integrated crop-livestock farmers, 100 sole crop farmers and 100 sole livestock farmers in Ejura-Sekyedumase and Atebubu-Amantin districts; descriptive statistics, gross margin analysis and the translog stochastic profit frontier model with inefficiency effects were used to examine the profit efficiency of the three production systems. The empirical results reveal that even though farmers under the three systems are generally profit efficient, those under the integrated crop-livestock system are more profit efficient. Whereas farmer's age has a significant negative effect on profit efficiency, non-farm income improves profit efficiency significantly. The integrated crop-livestock production system is therefore recommended for young farmers in the transitional zone of Ghana to improve their competitiveness in agricultural production for increased income and livelihoods.

Keywords: Gross margin; integrated crop-livestock production system; profit efficiency analyses; stochastic profit function

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Introduction

Integrated crop-livestock system involves the production of various crops and livestock breeds in a diversified system (FAO, 2010). Agriculture in the past 60 years has seen substantial specialization bringing about separating crops and livestock productions (Ray & Schaffer, 2005). However, farmers engaged in sole crop enterprises face several constraints including low yields and sometimes partial or total crop failure which may result from exposure to a number of production risks including climate variability (Kumar *et al*., 2014). Some challenges faced by the sole livestock farmers include animals being left on the field to destroy farms causing human conflicts and losses, especially in the extensive system of production (Herrero *et al*., 2013). There are issues of theft of livestock and loss of manure which could have been used to enrich soil fertility lost through the prevalent use of extensive system of livestock production. Crop residues which could have been fed to the livestock in the integrated system end up being underutilized (Singh & Patel, 2022). One of the ways of minimizing these challenges is through the adoption of integrated crop-livestock system which offers some synergy such as the use of organic manure for enhancing soil fertility as well as using crop residue for feeding livestock (Lemaire *et al*., 2014; Gupta *et al*., 2012; Martin *et al*., 2016).

Although crop and livestock production systems have existed side by side since the beginning of agriculture, the way they have interacted has varied with location, culture and time. In this study, crop-livestock integration is defined as a system where farmers produce both crops and livestock not necessarily on the same piece of land, but use resources from those two enterprises to supplement one another. These farmers use crop residues from their farms to feed their livestock and use manure from their livestock to fertilize their croplands (Powell *et al*., 2004). From a sociocultural perspective, the aim of the integrated system is to promote diversification among farmers in order to enhance their wellbeing while ensuring equitable social dynamics especially among women, youth and elders, and also to increase food security and nutritional safety as well as meeting consumer demand and choice (FAO, 2010).

In spite of the benefits from the integrated system, most farmers still practice the sole crop or livestock system much more than the integrated system (Kumar *et al*., 2014). Even in the transitional zone of Ghana where the agro-ecology is more conducive for integrated crop-livestock production system, very little of that is seen happening in farming communities (Garrity *et al*., 2012). This is because most farmers do not have full knowledge of the relative profitability of each of the production systems to make informed production decisions (Allen *et al*., 2007). In addition, some of the major factors which affected adoption of crop-livestock integration were, availability of feed, land, labor, organic and inorganic fertilizer, educational level and age of the farmers. This paper evaluates the competitiveness of the integrated crop-livestock system with sole crop and sole livestock production enterprises in the transitional agroecological zone of Ghana. The study employs the stochastic profit efficiency technique as a proxy for competitiveness to better appreciate the fundamental factors influencing profit efficiency and make specific/targeted policy recommendations. The study estimates profit efficiency separately for the three production systems.

Competitiveness in agricultural can be described as the capacity of enterprises to profitably address consumers' need in terms of quantity, quality and price to ensure sustainability over time (Berti & Mulligan, 2016). Various approaches have been applied in evaluating competitiveness in agriculture (Latruffe, 2010) however, the fundamental principle underlying each of these approaches is comparison based on profitability of the enterprise. For instance, the 'diamond model' proposed by (Porter, 1990) examined competitiveness based on the farm or firm's structure and strategy using indicators such as profitability, productivity and efficiency. Profitability of production enterprises is often expressed in terms of the relationship between revenues and costs usually defined with regards to gross margin (*GM*) as a ratio/variation between revenues and costs. A profitable firm is usually competitive through its ability to keep its market share, which serves as a barrier of entry to new firms that could potentially reduce their profits (Martinelli *et al*., 2023; Tossou *et al*., 2023).

Gross margin analysis has been applied to evaluate profitability in agriculture. Nkadimeng *et al*. (2021) found individual managed farms to have higher gross margin (R15 281) than group managed farms with gross margin of (R6 031) suggesting the implications of the complexity in group production decision making hence, impeding profitability enhancing decisions among Nguni cattle farmers in Limpopo Province South

Africa. Aya & Akpan (2010) also revealed positive gross margins for all sellers of rice, beans and gari in the southern zone of Cross River State, Nigeria. Adeola *et al*. (2011) estimated the productivity and profitability of cowpea in Nigeria and found the gross margin per hectare to be N46, 090 while the return per Naira (N) invested was 45kobo.

Previous studies have used the stochastic production frontiers in evaluating profitability of different cropping systems. Rahman (2003) analyzed the efficiency of Bangladesh modern rice farmers by adopting the stochastic profit frontier and found an average profit efficiency of 0.77 for sole rice farming enterprise which implies the capacity to increase profits through technical and allocative efficiencies. Delgado *et al.* (2003) studied the efficiency and profitability of dairy farms in India by employing a stochastic profit model and found profit efficiency to vary through farm sizes. The major factors influencing profit efficiency were milk yield and concentrate feed prices. A translog stochastic profit frontier was employed by (Oguniyi *et al*., 2008) in examining the profit efficiency of cocoyam in Nigeria and obtained an average profit efficiency of only 12%. Profit efficiency was influenced by the soil type, farm size, credit, family size and experience in farming. Abu & Kirsten (2009) estimated profit efficiency of small and medium scale maize milling enterprises in South Africa using the translog stochastic frontier too and found a mean profit efficiency of 87.4% for medium-scale mills and 80.6% for the small-scale mills.

Furthermore, a stochastic profit frontier model was used by (Nganga *et al*., 2010) to analyze milk producing farmers' efficiency in Central Kenya where profit inefficiency was found to range from 26% to 73% with a mean of 60%. Farmers who had larger farm sizes, higher levels of education and more experience were found to be more profit-efficient.

Materials and Methods

Study area

The study was carried out in the Ejura-Sekyedumase and Atebubu-Amantin municipalities, found in the transitional zone of Ghana (Figure 1). Though the two districts are contiguous, Ejura-Sekyedumasi is located in the Ashanti Region whereas Atebubu-Amantin municipality is found in the Bono-East Region of Ghana. Atebubu-Amantin municipal has predominantly subsistence farmers, who mainly engage in the production of food crops such as rice, yam, cassava, millet, groundnut and cowpea. Some 63% of the active labor force is engaged in farming, while 19% are involved in commerce. The municipality produces 2130 Mt of groundnut and 637Mt of cowpea. The major animals kept in the municipality are cattle, sheep and goats. The population of goats and sheep reared in the district are 36,187 and 20,146 respectively (GSS, 2014).

Fig. 1: A map showing the study area

Ejura-Sekyedumase municipality is located between the transitional and guinea savannah zones of Ghana (Figure 1). Therefore, the vegetation comprises tall grasses interposed with short fire-resistant tree species. The municipality has a population of about 88,753 with majority being rural and farming as the main occupation. The strategic location of the municipal promotes the cultivation of crops that are adaptable to both forest and savanna environments such as maize, yams, cassava, cowpea, guinea corn, groundnuts, rice and plantain. The municipal produces an estimated 33,034 tons of yams, 934 tons of rice, 28,861 tons of maize, 751 tons of groundnut, 5,318 tons of plantain, 2,716 tons of cowpea and 17,046 tons of cassava (Yeboah, 2013). Livestock production in the municipality particularly, sheep, goats, cattle and poultry, has been significant partly as a result of the livestock development project (LDP) which was implemented in this municipality from 2022-2010. Subsistence goat and sheep farming are prominent and the number of goats and sheep reared in the municipality are 20,301 and 16,863 animals, respectively (GSS, 2014).

Sampling technique and data collection

Ejura-Sekyedumase and Atebubu-Amantin municipalities were selected for the study due to their high livestock density, market access, nearness to good livestock husbandry practice centers and their potential for crop-livestock integration. A substantial number of crops and livestock are produced in this municipality (MoFA, 2010). A total of four hundred (400) respondents were selected for the study, comprising 100 sole crop producers, 100 sole livestock producers and 200 crop-livestock producers. A multi-stage sampling technique was used in selecting farmers. In the first stage, the municipalities were purposively selected. The second stage involved a purposive sampling of five communities in each municipality based on the predominance of crop and livestock production activities. At the third stage, in each selected community, simple random sampling of 10 sole crop and 10 sole livestock farmers were selected. In addition, 20 integrated crops-livestock farmers were selected using snowball sampling from each community since there was no list of farmers practicing the intensive integrated system.

Analytical technique

Following (Battese & Coelli, 1995; Rahman, 2003; Nganga *et al.,* 2010), a stochastic profit production frontier is specified. Subsequently, a profit efficiency which is expressed as increase in profit as a result of operating on the profit frontier which depended on account of farm-specific factors and prices was specified. With regards to a farm operating under a perfectly competitive input and output markets and maximizes profit subject to inputs and outputs, with a given output technology which was semi-concave in the (*n x 1*) vector of variable factors, and the (*m x 1*) vector of fixed factors *Z*, a normalized profit function could be derived. Furthermore, a farm profit from each system using the gross margin (*M*) obtained as the variance between the total revenue (*R*) and total variable cost (*TVC*) and is specified as:

$$GM(\pi) = \sum (TR - TVC) = \sum (PQ - WX_i) \qquad (1)$$

The normalized profit function is thus obtained by dividing the gross margin (π) by the prevailing price of each output, *P*, expressed as:

$$\frac{\pi}{p}(P,Z) = \frac{\sum (PQ - WX_i)}{P} = Q - \frac{WX_i}{P} = f(X_i, Z) - \sum (P_i X_i) \qquad (2)$$

where *TR* denotes the total revenue from crop-livestock production, *TVC* represents the total variable costs (which include feed, crop residue, seed, fodder, hired labor, water, transport, medicines and vaccines, etc.), of acquiring revenue per farm *i*; *Q* is crop-livestock output; *X* denote the (maximum) amount of input used; *Z* denotes fixed inputs, $P_i = \frac{W}{P}$ is the normalized price of input X_i while $f(X_i, Z)$ is a representation of the production function.

Thus, profit efficiency of the three farming systems (*i.e. integrated crop-livestock producers, crop only producers and livestock only producers*) can be empirically specified by and estimated jointly with the profit inefficiency effects in a modified translog profit frontier model specified as:

$$\ln \pi = \beta_0 + \sum_{j=1}^{6} \beta_j \ln P_{ji} + 0.5 \sum_{j=1}^{6} \sum_{k=1}^{6} \beta_{jk} \ln P_{ji} \ln P_{ki} + v_i - u_i \qquad (3)$$

where, *ln* represents natural logarithm; *i* represents the i^{th} farm, π_i normalized gross profit per crop/livestock for i^{th} farm also referred to as gross revenue per crop/livestock excluding variable cost per crop/livestock and dividing with farm-specific mean crop/livestock price (P_y) and also with sample average of the normalized gross profit of crop/livestock. P_i 's denotes the variable input prices which has been normalized as the ration of the variable input prices to the farm-specific mean crop/livestock price (P_y) and also by sample average normalized input prices; (P_k) denote the k^{th} input price used by the i^{th} producer (where $i = j$ =1, 2, 3, 4, 5 and 6); P_6 is the fixed input. β_o, β_i, β_{ik}, β_{im}, and β_z are coefficients to be estimated. Table 1 presents the description of variables included in the model in equation (3).

TABLE 1
Description of Variables in the Frontier Profit Function

Variable	Descriptions	Expected sign
π	Normalized profit of the j^{th} farmer defined as gross revenue less variable cost divided by farm specific price (the dependent variable).	
Variable factors		
P_1	Price of output (crops or livestock) normalized by price of output (average price of crops or livestock)	+
P_2	Price of feed (that feed intake by the livestock in a production year) normalized by output price	-
P_3	Wage rate of labor* (the cost of hired labor and family labor normalized by output price)	-
P_4	Drug and Medication price normalized by the price of output	-
P_5	Cost of manure/crop residue normalized by price of output	-
Fixed inputs		
P_8	Capital input (land) used in farming	-

To understand variability in the profit efficiencies, key factors hypothesized to determine these variations are included to account for profit inefficiencies. The profit inefficiency[1] in model, following (Battese & Coelli,1995), is μ_i^k for the *k-th* production system is thus specified as:

$$\mu_i^k = \delta_0^k + \sum_{d=1}^{6} \delta_d^k Z_{di} \quad (4)$$

[1]Technical inefficiency measures the deviation between the individual producers' profit and the overall profit frontier

where μ denote the profit inefficiency effects relative to the profit frontier, which is the nonnegative error component, Z_{id} are vectors of variables explaining profit inefficiency, δ^k_j(= 0, 1, ..., 6) are unknown parameter to be estimated, and $\delta^k\ o$= = constant term in the equation. Table 2 presents the description of the inefficiency variables (Z variables). The variance of the random errors, σ^2_v and that of the profit inefficiency effect σ^2_u, and the overall variance of the model σ^2 are related as follows: $\sigma^2 = \sigma^2_v + \sigma^2_u$, which measures the total variation in the deviation of profit from the frontier (Battese & Corra, 1977).

TABLE 2

Description of Variables in the Inefficiency Model

Variable	Descriptions	Measurement	Expected sign
μ_i	Inefficiency effects		
δ_o	Intercept term		
Z_1	Gender of farmer	Dummy (Male=1, Female=0)	-/+
Z_2	Age	Years	-/+
Z_3	Years of schooling	Years	-
Z_4	Extension contact/visit	Dummy (*Yes=1, No=0*)	+
Z_5	Access to credit	Dummy (*Yes=1, No=0*)	-/+
Z_6	non-farm income of household	Amount (GHS)	-/+

The Likelihood Ratio of the errors in the inefficiency equation provides the log likelihood function (Battese & Coelli 1995) and it is estimated as:

$$\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2) \quad (5)$$

where γ (gamma) denotes the proportion of inefficiency in the overall residual variance. The γ (gamma) takes on values in the 0, 1 interval, with the value of 1 suggesting that the frontier is deterministic thus, signifying the importance of inefficiency effects in explaining variabilities in the profit function. On the other hand, value of 0 shows the existence of no profit inefficiency. The parameters of the profit and inefficiency frontiers as were jointly estimated using the maximum likelihood procedure.

Hypothesis Testing

The various tests of hypotheses, given specifications of the stochastic profit frontier with inefficiency effects following (Battese & Coelli, 1995) are presented in Table 3.

TABLE 3

Hypotheses testing

Hypotheses	*ln[L(H₀)]*	*ln[L(H₁)]*	**Test statistic**	$\chi^2_{0.90}(df)$	**Decision**
$H_0: \delta_j^k s = 0, \gamma = 0$					
Crops	92.88	127.87	69.99	23.10† (14)	Reject H_0
Livestock	22.08	45.68	47.20	23.10 (14)	Reject H_0
Integrated	13.00	50.76	75.52	23.10 (14)	Reject H_0
All systems[2]	42.99	118.51	151.04	23.10 (14)	Reject H_0
$H_0: \beta_j^k = 0$					
Crops	98.09	127.87	59.57	17.67 (10)	Reject H_0
Livestock	27.77	45.68	35.83	17.67 (10)	Reject H_0

[2] This statistic is obtained by estimating the frontier model with the data for all three production systems pooled together.

Integrated $H_0: \delta_j^k = 0$	14.39	50.76	72.74	17.67 (10)	Reject H_0
Crops	104.01	127.87	47.71	21.74 (13)	Reject H_0
Livestock	25.10	45.68	41.17	21.74 (13)	Reject H_0
Integrated	25.60	50.76	50.33	21.74 (13)	Reject H_0

†*The critical value for testing γ = 0 is obtained from Table 1 of (Kodde & Palm, 1986)*

First, the hypothesis that the Cobb-Douglas functional form is appropriate given the specification of the translog profit frontiers was tested and this was strongly rejected for the three production systems, which implies that translog profit frontier adequately presented the data.

Secondly, the hypothesis that inefficiency in the model is not random, hence coefficients of the explanatory variables in the profit inefficiency models are zero was tested. This hypothesis is also strongly rejected for all production systems. This implies that the traditional production function does not represent the data adequately, given the assumptions of the stochastic frontier models.

Lastly, the hypothesis that profit inefficiency is not influenced by any of the explanatory variables in the profit inefficiency model was also tested. This null hypothesis is also rejected for all farming systems which implies that at least one or more of the explanatory variables in the inefficiency models explains variations in profit inefficiency.

Results and Discussion

Descriptive analysis

The demographic characteristics of the farmers are presented in Table 4. The results show that male household heads dominate (70%) in all three systems and even much more in the integrated system. This could be attributed to the customs and norms of society where household productive assets are largely controlled by men especially in sub-Saharan Africa (Wahaga, 2018). The decision makers in most Ghanaian communities are men (Turkson & Naandam, 2006) with women usually in charge of marketing of farm produce and making food consumption decisions. However, some women also take part in primary agricultural production activities. For example, 34% of crop farmers, 28% of livestock farmers, and 29% of integrated crop-livestock farmers were women.

TABLE 4

Demographic characteristics of farmers across farming systems

Variables	Integrated	Crops	Livestock	All		
Age	43 (13)*	44 (14)	46 (16)	44(14)		
Household size	10(5)	9(6)	9 (5)	9(5)		
Years of schooling	5(2)		3(2)		4(3)	3(2)
Sex (Male=1)	0.71 (0.32)		0.66 (0.23)		0.72 (0.14)	0.70 (0.34)
Extension contact	0.53 (0.14)		0.57 (0.33)		0.59 (0.23)	0.52 (0.14)
Access to Credit	0.25(.03)		0.19(.11)		0.31(.02)	0.25(.01)

Figures in parenthesis are standard deviations

Education plays an important role in enhancing the adoption of improved technologies (Marinda *et al.*, 2006). However, more than half of the sampled farmers in all three systems had no formal education. Farmers who operated sole crop obtained the lowest number of years of formal education with an average of 3 years, followed by the livestock farmers with 4 years, then the integrated system with 5 years which is equivalent to lower primary school level of education. This result is consistent with the findings of (Bahta & Baker, 2015) where the average years of schooling for farmers was 4.95. The current result implies that the levels of education for farmers under the three systems do not differ, which means that generally farmers across these faming systems are homogeneous in terms of education.

Relevant institutions such as the extension services, directorate of the Ministry of Food and Agriculture are very important for Ghana to realize substantial growth in their agricultural productivity. However, in the study areas, slightly above half (52.25%) of the sample had access to extension services. This is slightly lower compared to the findings of (Asante *et al.*, 2018) where, an average of 48% of the farmers had access to extension service. This is an issue because with the high level of illiteracy, the farmers require the intervention of the extension officers for training on the use of new technologies as well as innovative ways of farming. If this is limiting, farmers get stuck to their old ways of production, which negatively affect their productivity. In addition, across all three systems, access to credit or financial services was limited. The results show that, a little over 25% have access to formal credit, with only 19% of crop farmers, 31% of the livestock farmers and 25% of the integrated farmers having access to credit.

This is relatively lower than the results obtained by (Kosgei, 2013) which indicated that 29% of the integrated farmers had access to credit. This result is in line with assertions made by (Moll, 2003) that formal financial institutions are inaccessible or absent in the rural parts of Africa; therefore, smallholder farmers tend to use livestock as an alternative form of insurance and investment (financing) to cope with the challenges of life. The average age of crop farmers is 44 years, livestock farmers is 45 and integrated crop-livestock farmers is 42 years. These ages fall within the economically active age range. The average household sizes are 8.77, 8.55 and 9.65 for the crop, livestock and integrated farmers respectively. This figure is higher than the reported national average of 4.5 (GSS, 2014). This infers that family labor might be available for all three systems particularly in the integrated system.

Profitability of production under different farming systems

Details of the production costs and returns associated with the sole crop, sole livestock and integrated crop-livestock production systems are presented in Table 5. The cost of veterinary service per animal for integrated crop-livestock production system was GH₵0.84 whereas that of the sole livestock system was GH₵1.84. Farmers incurred a cost of GH₵10.82 and GH₵7.80 on feed and crop residues respectively for every animal raised in the integrated system. Under the sole livestock system, however, a cost of GH₵16.28 and GH₵1.47 were spent on feed and crop residues respectively. On the average farmers employed 3.88 acres of land in the integrated system whereas 3.02 acres of land was employed in the sole livestock production system. The agrochemicals used on average came at a cost of GH₵90.32 in the integrated system whilst in the sole crop system it was GH₵150.3. The integrated system of production spent the most on labor followed by the sole crop production system, then the sole livestock system. The average labor cost for an acre of land in the integrated crop livestock production system was GH₵792.81 followed by the sole crop production (GH₵588.8) and GH₵574.71in the sole livestock system.

TABLE 5

Cost and returns associated with the three systems of production

Variable	Int. crop-livestock	Crops only	Livestock only
Veterinary services per unit animal (GH₵*)	0.84 (3.09)	-	1.84 (1.8)
Agrochemicals per acre (GH₵)	90.31 (20.4)	150.3(25.2)	-
Land size(acres)	3.9 (3.2)	3.02 (2.1)	-
Manure per acre (GH₵)	15.7(7.4)	0.55(1.5)	-
Crop residue per unit animal (GH₵)	7.80(7.71)	-	1.47 (1.3)
Feed per unit animal (GH₵)	10.8(12.6)	-	16.28 (15.3)
Labor (GH₵)	792.8(31.3)	588.8 (41.4)	574.71 (23.5)

GH₵1: US$.22316 (www.oanda.com), 01/03/2018

Presented in Table 6 are the total average costs, revenues, profits and also the gross margin analysis results as well as the returns on investments for all the systems under study. For the average cost incurred for the entire production year, the integrated system spent the most on production. This is only because it is a combination of its crop and livestock component here, followed by the sole livestock system, then the sole crop system. The result further shows that, the crop production system obtained a little over 100% return on their initial capital outlay for production, whereas the sole livestock system earned slightly more than half their investment back into the system. The integrated system was also leading with over three times returns on their initial investment.

TABLE 6

Average costs, revenues and profits of the various crop systems in per acre and livestock systems per herd size as well as their returns on investments

System	TVC (GH₵)	TFC (GH₵)	TC (GH₵)	TR (GH₵)	Profit(GH₵)	ROI(%)
Crops	117.71	64.14	181.85	16478.75	16296.9	113.78
Livestock	196.64	81.37	278.01	2516	2237.99	52.96
Integrated	219.86	149	368.86	36020.53	35651.67	316.96

**TVC is the total variable costs, TFC represents the total fixed costs, TC denote the total cost, TR is the total revenue and ROI is the return on investment. *GH₵1: US$.22316 (www.oanda.com), 01/03/2018*

Stochastic Profit Frontier Analysis

The determinants of profit efficiency for the three production systems are provided in Table 7. The value of gamma (γ) indicates profit inefficiency and it is detected by the generalised log likelihood ratio test. The estimated value of γ as shown in Table 7 is significantly different from zero in all three systems and this suggests that, depending on the magnitude of γ, variations in the profit occur as a result of exogeneous and inefficiency factors which are both beyond the control of farmers. This implies that the variation in actual profit from maximum profit (profit frontier) between farms which is 92.3% for the integrated system, 92.1% for the sole crop system and 83.3% for sole livestock system, arises mainly from the different farm practices rather than from random occurrence.

TABLE 7

Maximum likelihood estimates for parameters of the stochastic profit frontier

Variable	Int. crop-livestock		Crops only		Livestock only	
	Coefficient	S.E	Coeff.	S.E	Coeff.	S.E
Constant	0.321**	0.629	-0.9462	0.387	0.2179	0.822
Agrochemicals	0.936**	0.159	0.2493	0.762		
Land	0.000	2.274	-0.3545	1.216		
Feed	-0.437**	0.061			0.1362	0.649
Veterinary services	0.418**	0.385			0.1801	0.606
Manure	-0.744	0.836				
Crop residue	-0.504	0.537				
Labor			-0.1744*	0.132	-0.1197	0.564
Agrochemicals^2	-0.173	0.182	-0.0983	0.121		
Land^2	0.1381	0.907	0.1303	0.327		
Feed^2	0.0158	0.186			0.0057	0.937
Vet. services^2	-0.0683	0.116			0.016	0.075
Manure^2	0.7149**	1.88				
Crop residue^2	-0.1403	0.139				
Labor^2			-0.1744	0.132	0.0576	0.069
Agrochemicals × Land	0.232	0.753	0.1661	0.145		
Agrochemicals × Feed	-0.154	0.095				
Agrochemicals × Vet services	0.112	0.081				
Agrochemicals × Manure	-0.126	0.691				
Agrochemicals × Crop residue	0.0455	0.13				
Agrochemicals × Labor			-0.1038	0.088		
Land × Feed	-0.1546*	0.646				
Land × Vet services	0.4706*	0.884				
Land × Manure	-0.4671	0.444				
Land × Crop residue	-0.9309	0.87				
Land× Labor			0.0371	0.159		
Feed× Vet services	0.0301	0.113			0.0081	0.07
Feed× Manure	0.6362	0.643				
Feed× Crop residue	0.219	0.121				
Feed× Labor					-0.0275	0.069
Vet services× Manure	-0.8523**	0.853				
Vet services× Crop residue	-0.0731	0.083				
Vet services× Labor					-0.0001	0.069
Manure× Crop residue	0.9299	0.859				
Sigma squared	0.7769***	0.187	0.5350***	0.257	0.1538***	0.257
Gamma	0.9232		0.9219		0.8338	
Log likelihood	-59.96		-182.25		-309.47	

****, **, * denote statistical significance at the 1%, 5% and 10% level respectively*

The generalized Log Likelihood Ratio test, defined by a mixed Chi-square x^2 distribution set at 5% level of significance and 11 degrees of freedom, was significantly different from zero in all models for the different systems. The null hypothesis was thus rejected indicating that the stochastic frontier production function fits the data adequately (Kodde & Palm, 1986). The

σ^2 value is significant as well, which implies that the profit efficiency equation can explain the differences between each farm's profit and the profit on the frontier function which is for the best performing farm. The elasticity parameters of variables estimated with respect to profit of integrated crop-livestock, sole livestock and sole crop producers indicate that, out of all the independent variables, three are significant (Table 8). This gives an indication of the relative relevance of these variables to profit. These profit elasticities are directly acquired from the estimated coefficients of the profit frontier function because the explanatory variables involved in estimating the profit frontier were mean corrected by their respective arithmetic means. This suggests that the first order coefficient are the elasticities of each of these inputs with respect to profit at mean input values (Kramol *et al*., 2015)

TABLE 8

Elasticity of profit with respect to input price

Variables	Integrated	Crop only	Livestock only
Agrochemicals	0.435	0.249	
Land	0.792	-0.355	
Feed	-0.109*		0.136
veterinary services	0.0083**		0.180
Manure	-0.549		
Crop residue	-0.487		
Labor		-0.174*	-0.118

***, * denote statistical significance at 5% and 10% level respectively*

With respect to veterinary service, a positive and significant relationship exist between the cost and profit associated with integrated crop-livestock production. The profit elasticity of cost of manure and crop residue had a negative sign. A negative and significant relationship is found to exist between cost of labor and gross profit in the sole crop production system. This means that a 1% increase in the cost of labor may lead to 0.17% reduction in the profit level of the sole crop producers. The cost of animal feed however, is the most important variable in the sense that it had a negative and significant relationship with gross profit. It implies that a 1% increase in the cost of feed may lead to a 2.1% reduction in the profit level of the integrated crop-livestock farms. This result is consistent with that of (Effiong & Onyenweaku, 2006; Al-Masad, 2010) who also observed a negative relationship between the prices of feed and profit. The profit elasticity of the cost of agrochemicals and size of land, although positive, was statistically not significant.

Distribution of Profit Efficiency

It is revealed from the study that profit efficiency widely varies among the farmers and ranges from a minimum of 5.60% to a maximum of 88.3% (Table 9). The wide variation in profit efficiency estimates can be attributed to differences in farm management skills with respect to allocation and use of farm inputs among farmers. The mean profit efficiency of 63.65% means that the integrated crop-livestock farmers have the potential to raise their profits by 36.35% by employing the most efficient production techniques available without increasing current input levels. These average efficiency scores implied that farmers were not using production resources efficiently in order to achieve higher profits. Among the three production systems, the integrated system had the highest profit efficiency of 63.65%, which is similar to the 60% mean profit efficiency obtained by farmers across the by (Nganga *et al*., 2010).

TABLE 9

Distribution of Profit Efficiency (PE) scores of producers under the three production systems

PE Score (%)	Integrated Crop-livestock	Crops only	Livestock only
	%	%	%
>31-40	3	1	39
41-50	11	29	17
51-60	21.5	62	11
61-70	29	7	20
71-80	26	1	11
81-90	9.5		2
Total	100	100	100
Min	5.6	40.63	1.5
Max	88.3	72.65	76.62
Mean	63.65	52.63	45.47

From Table 9, the distribution of profit efficiency scores posits that, most (21%) of the integrated crop-livestock farmers' profit efficiency ranged from 61-70%, followed by 26.0% of the integrated farmers who had their profit efficiency ranging from71-80%. Out of the sampled integrated crop-livestock farmers, 21.5% obtained profit efficiencies ranging from 51-60%. Also, about 11% of the farmers had a profit efficiency score ranging from 61-70%, followed by 9.1% of them having a score range of 81-90%, and lastly 3% of the farmers with the profit efficiency scores lying within a range of 0-40%.

In the sole crop production system however, it can be observed that, most (62%) of the farmers' profit efficiency ranged from 51-60%. This was followed by (29%) of the farmers with PE scores ranging from 41-50, and (7%) scoring within the 61-70% range. In the sole livestock system 39% of the farmers had their profit efficiency scores lying within the 31-40% range, followed by 20% with PE scores within the range of 61-70%. About 11% of the sole livestock farmers had profit efficiency scores ranging from 51-60% and 2% of them attained profit efficiency scores within the 81-90% range.

These results are consistent with other studies across which has shown a significant potential for increasing profitability in agriculture. Profit efficiency scores of 53% was obtained by rice farmers in Myanmar, thus, such farmers could enhance their profitability by 57% through adaptations to reduce input costs (Linn & Maenhout, 2019). Conversely, low profit efficiencies scores were obtained for agricultural cooperatives in South Africa, thus, highlighting the need to address factors affecting profitability specifically (Xaba *et al*., 2018).

Profit inefficiencies in integrated crop-livestock farming

The determinants of the profit inefficiency among producers are presented in Table 10 below. A positive sign indicates the variable has the effect of increasing profit inefficiency whereas a negative sign has the effect of reducing profit inefficiency.

TABLE 10

Maximum Likelihood Estimates of the Profit Inefficiency Model

Variable	Int. crop-livestock		Crops only		Livestock only	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Constant	-2.848***	0.662	1.193*	0.6305	0.5512	0.5687
Age	0.039**	0.018	0.0037	0.0101	0.0029	0.0087
Gender (Male)	0.609	0.736	-0.8064**	0.3769	-0.0583	0.2810
Education (years)	-0.095	0.095	-0.0423	0.0593	-0.0182	0.05771
Credit	-0.346	0.566	-0.7068*	0.3717	0.1200	0.2765
Non-farm activity	-0.135**	0.066	-0.0329	0.0355	-0.0118	0.0296
Extension contact	-0.909	0.159	-0.0682	0.6305	-0.1420	0.2489

****, **, * denote statistical significance at the 1%, 5% and 10% level respectively. SE denote standard error*

The results reveal that farmers' age and non-farm income are statistically significant in the inefficiency model for integrated crop-livestock production system. However, in the sole crop production system, gender and access to credit are statistically significant. It further shows that, the age variable is positive and significant at 5% profitability level. This implies that older farmers under the integrated system are profit inefficient compared to their younger counterparts who are more likely to accept change and willing to adopt new systems of production. Consistent with this finding are findings by (Abdulai & Huffman,1998; Onumah & Aquah, 2010; Onumah & Acquah 2011; Nganga *et al*., 2010) as well as (Oyebanjo & Otunaiya, 2011).

The coefficient of the male gender is negative and statistically significant in the sole crop production system, implying that males are more profit-efficient than their female counterparts. This may be due to the fact that male farmers are more effective in their production activities. It is also consistent with the findings of (Kibaara, 2005; Adesiyan *et al*., 2011; Onumah & Aquah, 2010; Onumah & Acquah, 2011) that male farmers are more profit efficient. This finding however, is inconsistent with that of (Onyenweaku & Effiong, 2005). Non-farm income in the integrated system is negative and statistically significant at 5%. This means that integrated farmers with non-farm income tend to be more profit-efficient than those without any non-farm businesses. Incomes from non-farm sources are used to augment farm income to invest in purchased inputs on timely basis to ensure efficient production and higher profit. This result is consistent with the findings of (Abdulai & Huffman, 2000; Rahman, 2003).

A negative association exists between access to credit and profit inefficiency in the sole crop production system and it is statistically significant at 10% level. This implies that farmers who have access to credit are likely to be more profit efficient than the others who do not. This is in line with the findings of (Kolawole, 2006; Hyuha *et al*., 2007; Dwi *et al*., 2014; Yasin *et al*., 2014). The significance of credit access to the efficiency of smallholder farmers has been reported (Louw, 2013; Sinyolo *et al*., 2016). Access to credit by farmers helps them to acquire inputs on time which enhances their productivity, increases their revenue and profit levels.

Conclusion and Recommendation

This study evaluates the profitability of the integrated crop-livestock production systems with the sole crop and sole livestock systems to guide investment decisions of farmers in the transitional agroecological zone of Ghana using stochastic profit frontiers. The results show that the integrated crop-livestock, sole crop and sole livestock production systems in the transitional zone of Ghana are all profitable. Consistent with *a priori* expectations, a significant negative relationship was found between cost of inputs (labor and feed) and profit generated from the three production systems. However, a significant positive relationship was found to exist between cost of veterinary service and profit obtained from the integrated crop-livestock production system. The cost of feed was found to be the most important variable in determining the profit obtained by producers under the integrated farming system.

Generally, profit efficiency levels are quite low in the transitional belt of Ghana regardless of the type of production system adopted by farmers. However, the integrated crop-livestock production system is found to be more profit-efficient than the sole crop and sole livestock production systems. Furthermore, age and non-farm income activities are the most critical variables that influence the profit-efficiency level of farmers under the integrated crop-livestock production system. However, gender and credit access are the most important factors that influence the profit efficiency level of producers under the sole crop system. Improved access to credit, promotion of non-farm activities as alternative livelihood options among farmers and continuous education and awareness creation about the integrated crop-livestock production technique among farmers, especially the youth and male-headed households, are expected to improve resource use efficiency in the transitional agro-ecological zone of Ghana.

It is further recommended that in order to enhance the profit efficiency of especially livestock and integrated crop livestock farming, farmers will require effective targeting at interventions that will reduce the cost of feed as well as the cost of veterinary services. Regarding veterinary services, interventions from government and NGOs in the livestock industry could leverage on village based veterinary agents in improving the services and hence reducing the cost which will ultimately increase profit efficiency. Furthermore, governments, NGOs and other stakeholders in the livestock industry should explore and identify alternative improvised indigenous feed ingredients and feeds that will reduce the cost of production and eventually improve profit efficiency of integrated farming systems.

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