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Analysis of optimum combination of integrated crop-livestock enterprise in North-West, Nigeria

Sulaiman[1], M., *Oladimeji[2], Y. U., Egwuma[3], H. and Yusuf[4], H. O.

[1]*Department of Economics, Federal College of Education, Zaria-Nigeria*
[2 & 3]*Department of Agricultural Economics / Institute for Agricultural Research, Ahmadu Bello University, Zaria-Nigeria*
[4]*Department of Agricultural Extension and Rural Development / Institute for Agricultural Research, Ahmadu Bello University, Zaria-Nigeria*

****Corresponding Author:** yusuf.dimeji@yahoo.com; **Phone Number:** +2348032220000*

***Target Audience:** Livestock and crop farmers, extension agents, policy makers*

Abstract

The study was conducted to determine the optimum combination of integrated crop-livestock enterprises in north-west, Nigeria. Primary data were obtained through structured questionnaire and interview schedule. A multi-stage sampling procedure was employed to select 3 states, 3 zones, 21 LGAs, 84 villages, and 428 crop-livestock farmers made up of 178, 128 and 122 farmers in Kaduna, Kano and Katsina states respectively. Descriptive statistics and Data Envelopment Analysis (DEA) was used to achieve the objective of the study. The results of socio-economic characteristics showed that about 89% of the pooled farmers were male with mean age of 48 years and household size of 10 persons per farmer. The findings from DEA revealed the mean total efficiency, pure efficiency and scale efficiency of 0.79, 0.91 and 0.86 respectively. DEA results further indicated that farmers can reduce the quantity of farm size, labour, seed, fertilizer, manure and agrochemical inputs by 0.2, 12.9, 17.6, 6.6, 35.9 and 26.4 %, respectively. Results further specified that 17.3, 26.25 and 56.5 % of farmers operated at optimal, sub-optimal and super-optimal scale, respectively. Tobit regression model used to determine factors influencing technical efficiency established that coefficients of age (0.0210), marital status (0.0016), household size (0.0616), education level (-0.1247), farming experience (0.1412), extension contact (-0.2548) and cooperative membership (-0.1102) were statistically significant variables at different level of probability. There should be synergy between crop and animal scientists; extension agents and agricultural economists to bring into bearing the needs for farmers to imbibe integrated crop-livestock farming to achieve optimum level of efficiency.

***Keywords:** Crop-livestock, integration, efficiency, data envelope analysis (DEA), Nigeria*

Description of Problem

Agriculture has remained an integral sector in Nigerian economy providing animal products, cash and food crops for man and industrial consumptions. It is made up of four sub-sectors: crop production, livestock, forestry and fishing. The sector creates employment opportunities for more than 70% of the country's active labour force which improved their livelihood and accounts for about 75% of non-oil exports in recent times (1, 2). For decades, Nigeria has been experiencing increase in population which results in increase in food and animal consumption with increase in area cultivated (3). Therefore, food production has to be increased from 70% to 100% by the year 2050 based on the global population and consumption growth trend (4).

Crop-livestock integration represents a model of sustainable farming according to principles of nutrient recycling and efficient use of land and resources (5). It also plays a supporting role in other beneficial cropping practices such as growing green manures, annual and perennial forages, become more financially attractive when livestock products can be gained from the system (6). Livestock feeds are majorly produced using crop residues in mixed crop-livestock systems and, hence, improving the use and nutritional quality of crop residues is an integral requisite to improving farm productivity and profitability (7). According to (8), integrated crop-livestock farming system is very sustainable farming system in which crop by-products like crop residue, feed grains are used for feeding animals and animal by-products like manures used for enriching the soils.

In addition, there is a global rise in demand for crops and animal products, and a further demand increase of 59–98% is expected by 2050 (9). The cereal and legume crops, and more importantly, livestock production is one of the major sources of households' livelihoods in Nigeria. The total livestock resources consist of 201, 928, 991 chicken, 16,722, 190 cattle, 57, 937, 176 goats, 36, 372, 233 sheep and 7, 770, 599 pigs (10, 11). Livestock production leads to supply of products and services of different kinds, such as meat, milk, eggs, fibre, hides and skins, natural fertilizers, fuel, transport and drought power. According to (13) statistical prediction, Nigeria livestock sub-sector in the next 30 to 40 years if proper measures are not put in place, will face a pressure and thus a setback that has never happened before as about 30% of live animals slaughtered in Nigeria are imported from neighbouring countries (14).

In northern savannah zone of Nigeria, most soils are faced with problems of deficiency in nutrients due to inadequacy in rainfall, high rate of weathering and long leaching (15). This goes in line with (16) who stressed that, crop production in the tropics is characterized by low fertility status of most of the soils, caused by low level of organic matter, nitrogen, phosphorus, potassium among others. Crops need nutrients to grow healthier and yield more output and most of these nutrients are supplied by the farmers from application of chemical fertilizers during planting season. These crop growers are mostly smallholder farmers and usually complained that chemical fertilizers are expensive for them to buy and their supply is not sustainable (17).

Furthermore, many studies revealed that the use of chemical fertilizers leads to high crops yield and increase in income which affect positively the wellbeing of the farmers while the impact of the bio-organic input on the other hand has been neglected (18). Chemical fertilizers when applied unmanageably may lead to soil compaction which later results to land degradation and soil penetration resistance (19). This in the long run affects negatively the crop yield, income as well as wellbeing of the farmers.

Livestock production could be an alternative source of farm nutrients (manure) and may help in reducing costs of crops production and solve soil problems caused by application of fertilizers. Thus, the study is an attempt to answer this research question: what is the optimum combination of integrated crop-livestock enterprise in north-west of Nigeria?

Methodology

The Study Area

Nigeria is located in the tropical zone of West Africa between Latitudes 4°N and 14°N and Longitudes 2°2'E and 14°30'E and has a total area of 923,770 km^2 (20). The study was conducted in the north-west (NW) of Nigeria. The zone consists of seven states namely: Jigawa, Kaduna, Kano, Katsina, Kebbi, Sokoto and Zamfara (20). The zone accounts for about 25% of the Nigerian population with over 48,942,307 million people (21). The zone has an average annual rainfall of 657.3 mm and prolonged dry season of 6 to 9 months. The states in NW are ecologically more of sudan savannah with exception of Kaduna state which is more of north guinea savannah. The main economic crops that are cultivated in the zone include maize, rice, millet, beans, wheat and cotton. The focal animal husbandry includes cattle, sheep and goats rearing, poultry, piggery. Hence, agricultural activities are the main sources of livelihood in the zone.

Data Collection and Sampling Procedure

Primary source of data collection was used for this study. The data were obtained through the use of an interview method with structured questionnaire which were administered to the crop-livestock farmers in the study area. A multi-stage sampling procedure was used for this study. Firstly, three states namely Kaduna, Kano and Katsina were purposefully selected out of the seven states. These states share boundaries, having similar ecosystem, produce common crops and livestock. In the second stage, Kaduna north, Kano south and Katsina south zones were also purposively selected, respectively for the same reasons. In the third stage, seven Local Government Areas (LGAs) each from the selected zones were randomly selected which comprises of Ikara, Kubau, Kudan, Lere, Sabon-Gari, Soba and Zaria LGAs (Kaduna state); Bebeji, Doguwa, Garko, Kibiya, Kiru, Rogo and Tudun-Wada (Kano); Bakori, Dandume, Danja, Funtua, Kafur, Malumfashi and Sabuwa (Katsina). In the fourth stage, 84 villages, four from each of the selected LGAs, were randomly selected due to the prevalent integrated crop-livestock farming system. In the last stage, only 33% of the total numbers of integrated crop-livestock farmers in each of the 84 villages were randomly selected for this study. This represents a total sample size of 428 crop-livestock farmers using (22) sample size formula. The formula is expressed as:

$$n = \frac{N}{1+N\,(e)^2} \quad \ldots\ldots\ldots \quad (1)$$

Where: n = sample size, N = population size and e = level of precision (5%)

The minimum sample size (n) was determined as follows:

$$n = \frac{1296}{1+1296\,(0.05)^2} = \frac{1296}{1297\,(0.0025)} = \frac{1296}{3.2425} = 399.69 \therefore n = 400$$

This translates to 178, 128 and 122 crop-livestock farmers in Kaduna, Kano and Katsina states respectively. It is pertinent to note that the composition of crop-livestock integration includes: M = Maize, Sg = Sorghum, Sb = Soybeans, C = Cowpea, R = Rice and L = Livestock.

Analytical Techniques

Descriptive statistics and Data Envelopment Analysis (DEA) were used to achieve the objective of the study: to determine the optimum combination of integrated crop-livestock enterprises in north-west, Nigeria. According to (23), DEA is a non-parametric approach which is mathematically expressed as follows:

Objective function:

$$\text{Max } \theta_j = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \qquad \text{Subject to:}$$

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \qquad (j = 1, 2, \ldots, n) \qquad \textbf{(2)}$$

$u_r \geq 0, \quad (r = 1, 2, \ldots, s); \quad v_i \geq 0, \quad (i = 1, 2, \ldots, m)$

Where: n = number of farms, j = the farm whose relative efficiency is being measured, m = number of inputs, s = number of outputs, x_{ij} = quantity of input i in each farm j, y_{rj} = quantity of output r from each farm j, u_r = weight for output r, v_i = weight for input i, θ_j = relative efficiency of farm j.

With fractional programming, we proceed with the maximization of efficiency of j

(equation 2). Two restrictions are imposed in order to solve the problem: the weights cannot be negative and relative efficiency is less than or equal to one, $\theta_j \leq 1$ (23). The fractional programming can be transformed into a linear programming problem as

Objective function:

Max = $\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_I x_{ij}$ Subject to: $\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_I x_{ij} \leq 0,$ **(3)**

(j = 1, 2,…, n) and

$\sum_{i=1}^{m} v_i x_{ij} = 1$ Obj. function: Max $\theta_j = \sum_{r=1}^{s} u_r y_{rj}$ Subject to: $\sum_{r=1}^{s} u_r y_{rj} \leq 1$

The relative efficiency of farm *j* is θ_j & $\theta_j \leq 1$ is the imposed restriction. Farm *j* is efficient when:

$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} = 0 \rightarrow \sum_{r=1}^{s} u_r y_{rj} = \sum_{i=1}^{m} v_i x_{ij} \rightarrow \sum_{r=1}^{s} u_r y_{rj} = 1 \rightarrow \theta_j = 1$ **(5)**

On the contrary, when $\theta_j < 1$, farm *j* is inefficient. The overall efficiency (OE) is measured by equation 5 and refers to constant returns to scale, CRS (24). OE can be distinguished into technical efficiency (TE) and scale efficiency (SE). TE refers to variable returns to scale, VRS and can be measured if the restriction:

$$\sum_{j=1}^{n} \lambda_j = 1 \; \{\lambda_j \geq 0 \; (j = 1, 2, ..., n)\}$$

This function is added in the linear model where λ is the (n x 1) vector of parameters to be calculated. This restriction ensures that each inefficient farm is being compared with farms of similar size. Scale efficiency for each district is measured by the ratio OE / TE. SE=1 indicates an optimal scale, whereas SE<1 denotes a sub-optimal size and there is a problem of either over-producing or either under-producing compared to its size. To determine whether scale inefficiency can be attributed to increasing or decreasing returns to scale, the non-increasing returns to scale model (NIRS) can be applied if restriction (5) in the variable returns to scale model is substituted with the following one:

$$\sum_{j=1}^{n} \lambda_j \leq 1 \quad \textbf{(7)}$$

If $\theta_{CRS} = \theta_{NIRS} < \theta_{VRS}$, there are increasing returns to scale and if $\theta_{CRS} < \theta_{NIRS} = \theta_{VRS}$, decreasing returns to scale. Relative efficiency measured on the basis of the constant returns to scale model is θ_{CRS}, θ_{NIRS} is for the non-increasing returns to scale model and θ_{VRS} for the variable returns to scale model, respectively.

Variables measured in the DEA model

The variables used in the data envelopment analysis (DEA) model were as follows: **(4)**

Y_{rj} = Quantity of crop output (Kg). This crop output was derived from the following integrated crop-livestock farming systems:

(i) M-Sg-C-L; (ii) M-Sg-L; (iii) M-C-L; (iv) Sb-M-L; (v) Sb-Sg-L; (vi) R-M-L and (vi) R-Sg-L. Where: M = maize; C = cowpea; R = rice; Sb = soybean; Sg = sorghum and L = livestock

Livestock is of three categories, namely: LR = large ruminants such as cattle, donkeys; SR = small ruminants, such as goats, sheep and P = poultry, such as chickens, ducks, and turkeys. The livestock combinations are spelt out below:

L_1 = LR-SR-P; L_2 = LR-SR; L_3 = LR-P; L_4 = SR-P; L_5 = LR; L_6 = P; L_7 = SR **(6)**

X_{ij} = is a vector of factor inputs used by integrated crop-livestock farmers and these included: X_1= farm size (ha); X_2 =labour (man-days), X_3 = seed (kg); X_4 = fertilizer (kg), X_5 = farm yard manure (kg) and X_6 = agrochemical (litre).

Tobit regression model was used to estimate the determinants of economic efficiency of crop-livestock production system. Following (25), Tobit model is defined as follows:

$$Y_i^* = \beta X_i + e_i \qquad i = 1, 2, ..., n \qquad (8)$$

$$Y_i = Y_i^* = \begin{cases} Y_i = Y_i^* \text{ if } Y_i^* > 0 \\ Y_i = 0 \text{ if } Y_i^* \leq 0 \end{cases} \qquad (9)$$

Where: Y_i^* represents the latent variable (dependent variable) and is generated through ratio of farmer's crop-livestock output to the highest total output. The grain-livestock equivalent weight (GEW) developed by Nigerian Institute for Social and Economic research (NISER) was adopted to obtain each farmer's output and then technical efficiency. X_i is the independent variable, $i = 1, 2\ldots, n$; β^t is a vector of estimable parameters, and $\beta^t X_i$ denotes the scalar product of two vectors. e_i is the normally and independently distributed error term with zero mean and constant variance σ^2 ($\varepsilon_i \mid X_i \sim N(0, \sigma^2)$).

For the purpose of this study, the model was explicitly expressed as follows:

$$Y^* = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + e \quad (10)$$

Where: Y^* = the estimated farm level technical efficiency. This takes values from 0.0 to 1.0; X_1 = age of household head (years); X_2 = gender of household head (this is a binary variable where male =1, female = 0); X_3 = marital status (single = 0, married = 1, divorced = 2, widow = 3); X_4 = household size (number of persons per farmer); X_5 = level of education (years); X_6 = farming experience (years); X_7 = extension contacts (numbers); X_8 = cooperative association (years); X_9 = loan obtained (₦); e = error term; β_0 = Intercept to be estimated; $\beta_1 - \beta_9$ = Coefficients to be estimated.

Results and Discussion

Table 1 identifies the socio-economic characteristics of integrated crop-livestock farmers in the study area. The results showed that about 89% of the pooled integrated crop-livestock farmers were male. This may be due to cultural and religious background which favoured household heads, the access to farming activities as women are mostly in purdah and do not take active part in enterprises outside the household chores. The results further revealed that the mean age of the farmers was 48 years, 93.7% were married with mean household size of 10 persons per farmer which implies they are energetic with active labour force. Results also established that the mean extension contact was twice per season, average farming experience was 15 years and only 26.2% of farmers had at least secondary education. Inadequate extension and low literacy level may deprive the farmers of not taking advantages of technology, innovations, information and communications technology, among others to enhance efficiency in resource (farm inputs) utilization in the study area.

The result further revealed that, most of the farmers (72.2%) did not belong to any agricultural cooperative society or association and 83.9% could not access loan from either formal or informal credit institutions. This may impede information on an improved crops seed, breed of livestock, better animal feeds and where to get them at cheaper prices, new farming techniques, updates on markets situations, credits and loans schemes by governments among others. The results are comparable to findings of (12) of socio-economic characteristics integrated fish-vegetable farmers in Kwara state Nigeria.

Optimum Combination of Integrated Crop-livestock Enterprises

The results from input-oriented DEA analysis were obtained using a computer program called DEA Solver 8.0 developed by (26). Table 2 revealed the constant returns to scale technical efficiency (TE_{CRS}) or total efficiency ranges from 0.35-1.00 that is, 35% to 100% with an average of 0.79 (79%) and standard deviation of 0.21 (21%) across the 21 DMUs integrated crop-livestock farmers in the study area.

Table 1: Description of socio-economic characteristics used in the DEA and Tobit model

Variable	Range	F	%	Mean	Max	Min	CV
Gender	Male	379	88.6				
	Female	49	11.4				
Age	20-30	13	3.0	47.62	71	25	21.00
	31-40	94	22.0				
	41-50	164	38.3				
	51-60	101	23.6				
	> 60	56	13.1				
Marital status	Single	0	0.0				
	Married	401	93.7				
	Others	27	6.3				
Household size	Less than 4	16	3.7	9.55	20	2	36.00
	4-7	116	27.1				
	8-11	170	39.7				
	12 & above	126	29.5				
Education	Informal	259	60.5				
	Primary	57	13.3				
	Secondary	44	10.3				
	Tertiary	68	15.9				
Farming experience	Less than 11	123	28.7	15.2	46	3	48.00
	11-20	223	52.1				
	21-30	66	15.4				
	Above 30	16	3.7				
Extension	contact	166	38.8	2.17	4	1	25.80
	no contact	262	61.2	-	-	-	-
Cooperative	Nil	309	72.20	5.2	11	2	35.00
	1 – 5	85	19.86				
	6 – 10	26	6.07				
	Above 10	8	1.87				
Credit access	Loan	69	16.1	87,594.20	48,000	150,000	4.71
	No Loan	359	83.9				

Source: Field Survey, 2019

Only 5 out of the 21 DMUs namely, M-Sg-L_6, M-C-L_6, Sb-M-L_2, Sb-M-L_5 and R-M-L_5 were estimated to be CRS efficient. Hence, the farmers can minimize on average 0.21(21%) of their used inputs coupled with the existing technology and still achieve the same level of output. According to (27) calculation of efficiency under CRS model is assumed to be appropriate only when all firms operate at an optimal scale level. This is an assumption of a perfectly competitive environment which rarely occurs.

The result in Table 2 also presented the estimated variable returns to scale technical efficiency (TE_{VRS}) or "pure efficiency" ranging from 0.51(51%) to 1.00(100%) with an average of 0.91(91%) and standard deviation of 0.16(16%). All of the 21 DMUs were estimated to be VRS efficient with the exception of 6 of DMUs namely, M-Sg-C-L_5, Sb-M-L_3, R-M-L_6, R-M-L_1, R-M-L_2 and R-M-L_7. This implies that on average, integrated crop-livestock farmers were 9% inefficient in the study area following VRS model assumption.

The result further displayed the estimated scale efficiency (SE) of the farmers ranging from 0.53(53%) to 1.00(100%) with an average of 0.86(86%) and standard deviation of 0.15(15%) across the 21 DMUs integrated crop-livestock farmers. This implies that on average, integrated crop-livestock farmers were 0.14(14%) scale inefficient in the study area. Also only 5 out of the 21 DMUs namely, M-Sg-L_6, M-C-L_6, Sb-M-L_2, Sb-M-L_5 and R-M-L_5 were estimated to be scale efficient. This exactly corresponds to the efficient DMUs under CRS model and some efficient DMUs under VRS model. That is, these 5 DMUs (M-Sg-L_6, M-C-L_6, Sb-M-L_2, Sb-M-L_5 and R-M-L_5) appeared to be only the DMUs which were estimated to be CRS, VRS and Scale efficient. Hence, the farmers can minimize on average 0.14(14%) of their used inputs coupled with the existing technology and still achieve the same level of output. This agreed with the findings of (28) who reported that the respondents were on average 70% scale efficient in application of data envelopment analysis to evaluate farm resource management of Benue state farmers.

Table 2: Distribution of DEA technical efficiency scores across DMUs

S/No.	DMU	No. of Farmers	Percentage	TE_{CRS}	TE_{VRS}	SE
1	M-Sg-C-L_1	99	23.13	0.92	1	0.92
2	M-Sg-C-L_2	22	5.14	0.98	1	0.98
3	M-Sg-C-L_3	21	4.91	0.94	1	0.94
4	M-Sg-C-L_4	65	15.19	0.98	1	0.98
5	M-Sg-C-L_5	5	1.17	0.87	0.88	0.99
6	M-Sg-C-L_6	30	7.01	0.93	1	0.93
7	M-Sg-L_6	8	1.87	1	1	1
8	M-C-L_6	8	1.87	1	1	1
9	Sb-M-L_2	9	2.10	1	1	1
10	Sb-M-L_3	12	2.80	0.35	0.51	0.68
11	Sb-M-L_4	20	4.67	0.58	1	0.58
12	Sb-M-L_5	7	1.64	1	1	1
13	Sb-M-L_6	12	2.80	0.42	0.58	0.723
14	R-M-L_1	12	2.80	0.60	0.77	0.77
15	R-M-L_2	6	1.40	0.58	0.59	0.98
16	R-M-L_3	28	6.54	0.53	1	0.53
17	R-M-L_4	27	6.31	0.70	1	0.70
18	R-M-L_5	6	1.40	1	1	1
19	R-M-L_6	8	1.87	0.80	1	0.80
20	R-M-L_7	12	2.81	0.63	0.83	0.76
21	R-Sg-L_4	11	2.57	0.86	1	0.86
	Total	428	100			
	Mean	20.38	4.76	0.79	0.91	0.86
	Maximum	99	23.13	1	1	1
	Minimum	5	1.17	0.35	0.51	0.53
	CV	110.60	110.71	26.58	17.58	17.44

Source: *Field Survey (2019); Note: M = Maize, Sg = Sorghum, C = Cowpea, Sb = Soybean, R = Rice and L1-7 = Livestock L1 = LR-SR-P, L2 = LR-SR, L3 = LR-P, L4 = SR-P, L5 = LR, L6 = P and L7 = SR LR=Large Ruminant, SR=Small Ruminant P=Poultry and CV= coefficient of variation*

These efficient DMUs had in totality 38 farmers, representing only 9% of the total number of integrated crop-livestock farmers (428) as shown from the result in Table 2. This implies that, majority of the farmers (91%) were CRS and scale inefficient in the study area. Therefore, inputs of DMUs operating at decreasing return to scale (DRS) needed to be transferred to those DMUs operating at increasing return to scale (IRS) so as to increase average productivity at both sets of DMUs, as supported in the study of applied data envelopment analysis by (29).

Lastly, since the use of CCR (Charnes, Cooper and Rhodes) (CRS) model assumed perfect competitive environment which is not realistic in real world, BCC (Banker, Charnes and Cooper) (VRS) model which takes into account the existence of imperfect competition could therefore be regarded as more realistic and relevant to this study. Hence, it can be concluded from Table 2 that on average, integrated crop-livestock farmers were 9% inefficient and therefore can minimize on average 9% of their used inputs to achieve the same level of output with the existing technology.

Excess used inputs (slacks) of integrated crop-livestock farmers

A slack refers to an additional improvement a firm requires to become efficient through utilizing the leftover (excess) of an input used in production processes. Table 3 revealed the mean slacks of the respective explanatory variables in DEA model as well as the proportions of the excess inputs used. From the result, integrated crop-livestock farmers in the study area can reduce the quantity of these inputs: farm size, labour, seed, fertilizer, farm yard manure and agrochemical by 0.2%, 12.9%, 17.6%, 6.6%, 35.9% and 26.4%, respectively and its proportionate cost while achieving the same level of output since all output slacks were zeros.

The farmers were characterized to mostly having large household size, less formal education, less extension contact and integrated crop farming with livestock as reported in Table 1. Hence, farm size, seed, labour, farm yard manure were made cheaper and available during crop cultivation and this could be the possible cause for their excessive usage in the study area. Fertilizers and agrochemicals on the other hand were also used excessively, probably due to the fact that, most of the farmers did not have formal education. Thus, they could not read and understand the instructions given for a proper application of these inputs which ultimately led to their excess usage on the farms**.**

Table 3: Inputs slacks estimates of DMUs from DEA model

Input	Mean Slack	Max Slack	Min Slack	CV	Mean Input	Input Slack (%)
Farm Size (ha)	0.1	1.1	0	300.00	47.5	0.2
Labour (man-day)	604.9	6,758.40	0	261.75	4,683.7	12.9
Seed (kg)	682.7	4,498.70	0	202.50	3,885.1	17.6
Fertilizer (kg)	610.1	6,611.70	0	255.48	9,264.5	6.6
FYM (kg)	56,071.10	757,030.60	0	300.03	156,398.0	35.9
Agrochemicals (lit)	106.3	1,102.40	0	244.59	402.5	26.4

Source: *Field Survey (2019);* ***NB:*** *FYM = Farm Yard Manure; CV = Coefficient of Variation*

According to (30) inefficiency could be caused by either misallocation of resources or inappropriate scale. Misallocation of resources refers to inefficient input combinations while inappropriate scale on the other hand refers to failure of a farm to take advantage of economies of scale. From the previous results it can be seen that, a relatively high scale efficiency of 86% was obtained in the study area. This implied that, inefficiencies were majorly caused by improper utilization of inputs.

Returns to scale of integrated crop-livestock farmers

According to (31), returns to scale refer to the rate by which output changes if all inputs are changed by the same factor. Constant returns to scale (CRS) occur when a proportional increase in all inputs results in the same proportional increase in output. Increasing returns to scale (IRS) occur when a proportional increase in all inputs results in more than proportional increase in output. Whereas decreasing returns to scale (DRS), occur when a proportional increase in all inputs results in less than proportional increase in output.

Table 4 revealed the distribution of integrated crop-livestock farmers in the study area according to operating at an optimal (CRS), sub-optimal (IRS), and super-optimal (DRS) scales. Out of 428 integrated crop-livestock farmers, 74 (17.3%) operated at optimal (CRS) scale, 112 (26.2%) at sub-optimal (IRS) scale while 242 (56.5%) at super-optimal (DRS) scale, respectively. This implies that, if the scale of 112 farms would be increased by 73.8% and that of 242 farms decreased by 43.5%, the efficiency of integrated crop-livestock farmers in the study area can be increased.

The result also showed that integrated crop-livestock farmers operated at an optimal scale, produced crops on an average basis of 13,592.9 kg on 2.1 ha of land with a yield of 6,570.0 kg per ha. This implies that, integrated crop-livestock farmers who operated at optimal (CRS) scale had the highest crops output per ha, followed by those operated at super-optimal (DRS) and then sub-optimal (IRS) scales. This corroborates the findings of (30) who reported that the mean output of farmers who operated at optimal (CRS) scale was larger than that at the super-optimal (DRS), followed by that of sub-optimal (IRS) scale.

Table 4: Distribution of farmers according to returns to scale

Returns to scale	No. of farmers	Percentage	Mean farm size (ha)	Mean output (kg)	Yield (kg/ha)
Optimal (CRS)	74	17.3	2.1	13,592.9	6,570.0
Sub-optimal (IRS)	112	26.2	1.6	5,360.7	3,328.2
Super-optimal (DRS)	242	56.5	3.6	16,649.2	4,684.5
Total	**428**	**100**			

Source: Field Survey (2019)

Factors affecting farm level technical efficiency of integrated crop-livestock farmers

Tobit regression model was used to determine how socio-economic and institutional variables of integrated crop-livestock farmers affected farm level technical efficiency (TE_{VRS}) in the study area. Table 5 displayed results of the robustness test of the model having a strong explanatory power with R^2 of 0.71, log-likelihood of 128.572 and LR Chi^2 128.572 which was statistically significant at 1% probability level. The data were normally distributed as Jarque-Bera test-statistic (normality test) indicated 0.453 with $p>0.05$.

The result revealed that coefficients of age (0.0210), marital status (0.0016), household size (0.0616), education level (-0.1247), farming experience (0.1412), extension contact (-0.2548) and cooperative membership (-0.1102) were statistically significant at different levels of probability affecting farm level technical efficiency of integrated crop-livestock farmers. It is pertinent to note that age, marital status, household size and farming experience were significant and positive. This implies that a unit increase in any of these variables will lead to corresponding increase in technical efficiency of integrated crop-livestock farmers. This is largely due to preponderance of active age farmers married with active and large household size which increase opportunities for active participation, dedication to their farming activities in order to meet up with their families' basic needs and ensure optimal utilization of resources which ultimately increases efficiency.

Table 5: Result of Tobit regression for factors affecting technical efficiency

Variable	Coefficient	Std. Error	t-Statistic	P >/Z/
Constant	0.0903	0.0085	10.62	0.000
Age	0.0210*	0.0119	1.76	0.059
Gender	-0.0103	0.0087	-1.18	0.168
Marital status	0.0016***	0.0005	3.20	0.001
Household size	0.0616***	0.0138	4.46	0.000
Educational level	-0.1247**	0.0532	-2.34	0.017
Farming experience	0.1412*	0.0816	1.73	0.056
Extension contacts	-0.2548**	0.1267	-2.01	0.028
Cooperative membership	-0.1102***	0.0435	-2.53	0.004
Loan obtained	0.0032	0.0172	0.19	0.931
Diagnostic Statistics:				
Number of observations	428			
Log-likelihood	379.676			
Prob> Chi^2	0.000			
Normality test	0.453			
LR Chi^2 (9)	128.572			
Pseudo R^2	0.7103			

Source: *Field Survey (2019);* ***Note:*** ****, ** and * denote significant at 1%, 5% and 10%, respectively*

However, the negative coefficients of variables such as education, extension contact and cooperative membership might impede the integrated crop-livestock farmers to achieve frontier or optimal efficiency. This implies that an increase in the farmers' years of education and exposure to extension education and cooperative associations were likely to have more knowledge of and access to modern farming techniques, improved seeds, extension contacts and credits/loan among others. These could improve yield and minimize quantity of inputs usage and cost, thereby increases efficiency. The study is comparable to the findings of (32) that examine technical and scale efficiency in the agricultural sector in Nigeria using DEA.

Conclusion and Applications

1. This study concluded that majority of the pooled integrated crop-livestock farmers were male, fell within the active age brackets, married and had informal educational background.
2. Results also established that crop-livestock farmers did not attain frontier under variable return to scale, constant return to scale and scale efficiency. Variables such as age, marital status, household size, education, farming experience, extension contact and

cooperative were statistically significant factors affecting technical efficiency.

3. Synergy is needed between crop and animal scientists as well as between extension agents and agricultural economists to bring into bearing the needs for farmers to imbibe integrated crop-livestock farming to achieve optimum level of efficiency.
4. More female should be encouraged by extension agents to adopt integrated crop-livestock farming system which is highly dominated by male.
5. Both government and private sectors should provide accessible credit and loan schemes to support the integrated crop-livestock farmers.
6. Farmers should form a formal and strong association that would help them have updates about integrated crop-livestock farming, market situations and access to financial supports.

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