ANALYSIS OF THE FACTORS INFLUENCING TECHNICAL EFFICIENCY IN INTEGRATED CROP-LIVESTOCK FARMING SYSTEM IN KADUNA STATE, NIGERIA

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

Abstract

The study was conducted to determine the best efficient integrated crop-livestock farming system in Kaduna state, Nigeria. Primary data were obtained through structured questionnaire and interview schedule. A multi-stage sampling procedure was employed to select 7 LGAs (Ikara, Kubau, Kudan, Lere, Soba, Sabon-Gari and Zaria) purposively in stage I for prevalence of integrated crop-livestock farming, 28 villages were selected purposively also for the same reason in stage II while at last stage 400 crop-livestock farmers were randomly selected. Descriptive statistics, Data Envelopment Analysis (DEA) and Tobit regression model were used to achieve the objective of this study. Results of the socio-economic characteristics revealed that about 92% of the integrated crop-livestock farmers were found to be male with mean age of 44 years and household size of 7 persons per farmer. Results from the DEA showed that the mean total efficiency, pure efficiency and scale efficiency were found to be 0.74, 0.89 and 0.83, respectively. The DEA results further revealed that farmers can reduce the quantity of farm size, labour, seed, fertilizer, manure and agrochemical inputs by 0.18%, 10.97%, 14.43%, 5.28%, 26.93% and 18.48%, respectively. Furthermore, the findings revealed that 19.9, 30.19 and 65.11% 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 (0.20), household size (0.0204), education level (0.206), farming experience (0.321), extension contact (0.311) and cooperative membership (0.1801) 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

INTRODUCTION

Agriculture has remained an integral sector in Nigerian economy providing both cash and food crops for man and industrial consumptions. It is made up of four subsectors: crop production, livestock, forestry and fishing (Sulaimon, 2014). The sector creates employment opportunities for more than 70 percent of the country’s active labour force which improved their livelihood and accounts for about 75% of non-oil exports in recent times (World Bank, 2017). It contributed up to about 50% to Nigeria’s GDP between 1960 and 1969, 25% between 1970 and 1979, 31% between 1980 and 1989, 34% between 1990 and 1999, 41% between
2000 and 2012 (Akarue and Eyovwunu, 2017), 24.11%, 24.44%, 21.09%, 23.38%,
24.23%, 24.17% and 21.09% in the third
quarter of 2016, 2017, 2018, 2019, 2020,
2021 and 2022, respectively (National
Bureau of Statics, 2022).
Integrated crop-livestock represents a model
of sustainable farming according to
principles of nutrient recycling and efficient
use of land and resources (Moraine, Duru,
Nicholas, Letterme and Therond, 2014). It
plays a supporting role in other beneficial
cropping practices as some techniques, such
as growing green manures, cover crops and
annual and perennial forages, become more
financially attractive when livestock products
can be gained from the system (Chen, Neill,
Burgess and Bekkerman, 2012). Integrated
crop-livestock farming system offers
promising solutions to deficiency on soil
fertility and reduction in crops productivity
among Nigerian farmers. 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
(Ezeaku, Mbah, Baiyeri and Okechukwu,
2015).
According to FAO (2017) 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. The
forecast was based on the fact that, rise in
human population, urbanisation and consumer purchasing power in the country
induced the demand for livestock-based
foods which is now increasing rapidly above
domestic livestock production. According to
FAO (2018) about 60% of the ruminant
livestock is found in the Nigeria’s semi-arid
zone (Sokoto, Potiskum, Maiduguri) and
managed by mostly Fulani-herders.
Domestically, production and supply of
livestock and livestock products is far below
the national demand which is leading to
importation. Thus, About 30 percent of live
animals slaughtered in Nigeria are imported
from neighbouring countries (FAO, 2018).
This goes in line with World Bank (2017)
which states that, the livestock sub-sector in
Nigeria does not produce to meet up with the
current country’s demand and by projection,
the gap between domestic demand and supply
will continue to widen in future.
In Kaduna, northern savannah zone of
Nigeria, as it happened in other African
countries in the tropics, most soils are faced
with problems of deficiency in nutrients due
to inadequacy in rainfall, high rate of
weathering and long leaching (Loks,
Manggoel, Daar, Mamzing and Seltim,
2014). This goes in line with Osundare
(2008) who stressed that, crop production in
the tropics is characterized by low fertility
status of most of the soils, caused by low
activity clay, 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 about the fact that chemical
fertilizers are expensive for them to buy and
their supply is not sustainable (Abdulaleem,
From the foregone paragraphs, the following
could be deduced: demand for livestock and
livestock products by far exceeds its supply
in the country; livestock production could be
an alternative source of farm nutrients
(manure) and may help in reducing costs of
crops production and solve some of the soil
problems caused by application of chemical fertilizers; livestock production if integrated with crop production could augment the means of livelihoods of farmers and thereby enhances their wellbeing. Therefore, there is a huge potential in livestock production which needs to be efficiently utilized and upon that background this study is designed to embark. The study hypothesized that, integrated crop-livestock farmers in the study area are not technically efficient in production.

CONCEPTUAL FRAMEWORK

Integrated farming system

According to Chan (2006), integrated farming system also known as integrated agriculture. It refers to agricultural systems that integrate livestock and crop production or integrate fish and livestock and may sometimes be known as Integrated Bio-systems. In this system, an inter-related set of enterprises are used so that the “waste” from one component becomes an input for another part of the system, which reduces cost and improves production and income. Integrated farming systems in the words of Vinod, Pradeep and Risam (2012), hold special position as in this system nothing is wasted, the by-product of one system becomes the input for other.

According to Ansar and Fathurrahman (2018), integrated farming system as an agricultural system which combines the activities of crops and horticulture, animal husbandry, fishery, forestry and other sciences related to agriculture within an area simultaneously at a time. According to Khan and Parashari (2018), integrated-crop livestock farming is a system in which crop farming and livestock rearing are practiced at the same time.

Figure 1: Conceptual framework of integrated crop-livestock farming system
Crop production
This involves the cultivation of different food and cash crops. Food crops are mainly for consumption and they include maize, rice, sorghum, soybean, cowpeas, millets, yam, cocoyam, cassava, tomato, pepper etc. The cash crops are only meant for sale either domestically or externally through export for foreign exchange. They include groundnut, cotton, cocoa, rubber, palm oil, palm kernel (Bell, Eckard and Pryce 2012).

Livestock Production
This involves rearing of domestic animals for consumption and means of livelihoods. These animals include large ruminants such as cattle, camels, horses, donkeys; small ruminants such as goats, sheep and poultry such as chickens, ducks, turkeys. Livestock production is the keeping of domesticated terrestrial animals for the provision of food, fibre and labour. Livestock occupy almost one-third of the ice-free terrestrial land surface of the globe and are an important agricultural sub-sector, that provides several benefits to human apart from the normal supply of food and fibre (Bell, Eckard and Pryce 2012).

A System
This is a set of inter-related, interacting and interdependent elements acting together for a common purpose and capable of reacting as a
whole to external stimuli (Elemo and Thomas, 2011).

Farming System
This is a unique and reasonably stable arrangement of farming enterprises that a household manages according to well defined practices in response to the physical, biological and socio-economic environment and in accordance with the household goals preferences and resources. Farming is defined as the way in which the farm resources are allocated to the needs and priorities of the farmers in his local circumstances which include: agro-climatic condition, soil type and topography and economic and institutional circumstances (Rana, 2015). A Farming system is defined as a population of individual farm systems that have broadly similar resource basis, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate (FAO, 2001).

MATERIALS AND METHODS
The Study Area: The study was conducted in Kaduna state of Nigeria which lies between latitudes 9°10’ East and 11°30’ North and longitudes 6° East and 9°10’ North, respectively. It shares borders with Kastina and Kano states to the north, Plateau state to the north-east, Nasarawa state to the south and Niger and Zanzfara states to the west. To the south-west, the state shares border with the Federal Capital Territory (FCT). The state has a total land area of about 4.5 million hectares, with an estimated total arable land of about 2.02 million hectares comprising 1.94 million hectares upland and 0.8 million hectares lowland. The state’s population is approximately 6,113,503 with an annual growth rate of 3.2% making it the third most populous state in Nigeria. The state’s population is projected to be 10,119,645 by 2022 (NPC, 2023). The main economic crops that are cultivated in the state include maize, rice, millet, beans, wheat and cotton. The focal animal husbandry of the state includes cattle, sheep and goats rearing, poultry and piggery. Hence, agricultural activities are the main sources of livelihood in the study area.

Data Collection and Sampling Procedure:
Primary source of data collection was used for this study after the researchers must have taken an ethical permission from the district heads of the study area. The data were obtained through the use of Key Informant Interviews (KII) method and with structured questionnaires which were administered to the farmers who can read and understand the context of it in the study area. The KII method was applied to the farmers who cannot read and or who prefer it to questionnaires. Few of the questions asked during the KII or stated in the questionnaire demand responses in a quantitative manner, otherwise known as close-ended in which there is a limited number of possible responses, for example ‘yes’ or ‘no’. Other questions demand responses in qualitative in which the respondent writes a descriptive piece of text or a verbal descriptive response, otherwise known as open-ended. Some measures were taken during the survey to avoid bias responses from the farmers which includes: asking few leading questions, avoiding assumptive, double-barreled questions, using of jargons, poor answer scale options, among others. The information collected from the farmers include socio-economic, institutional and production data, such as: age, sex, marital status, farming experience, educational background,
household size, farm size, types of livestock, number of livestock reared per farmer, inputs availability, farming technique, output and its price. Other information include: other livelihood means and strategies used by integrated crop-livestock farmers, factors influencing the livelihood strategies and constraints faced in integrated crop-livestock production in the study area.

A multi-stage sampling procedure was used for this study. In the first stage, out of the seven states in the North-West zone, Kaduna was purposively selected for the fact that, there is prevalence in practicing of integrated crop-livestock farming system therein. In the second stage, 7 out of 23 Local Government Areas (LGAs) in the state were randomly selected which comprised of Kubau, Kudan, Lere, Makarfi, Soba, Sabon-Gari and Zaria. In the third stage, 28 villages were randomly selected due to the prevalence in integrated crop-livestock farming system (four from each of the selected LGA). In the last stage 401 out of the total 540 integrated crop-livestock farmers were randomly selected, 74% in each of the 28 villages using Slovin’s formula for determination of sample size as expressed in Table 1. The formula is expressed as:

\[ n = \frac{N}{1 + Ne^2} \]  

(1)

Where:

- \( n \) = Sample size,
- \( N \) = Population size and
- \( e \) = Level of precision (5%)

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

\[ n = \frac{N}{1 + Ne^2} = \frac{540}{1 + 540 \times 0.05^2} = 399.26 \]

\[ n = 400 \]

The sample size was derived from each of the categories of the integration as follows: 72, 47, 60, 51, 55, 49 and 66 from \( M\text{-Sg}\text{-C\text{-L}} \), \( M\text{-Sg}\text{-L} \), \( M\text{-C\text{-L}} \), \( Sb\text{-M\text{-L}} \), \( Sb\text{-Sg\text{-L}} \), \( R\text{-M\text{-L}} \) and \( R\text{-Sg\text{-L}} \), respectively. The components of the integrated crop-livestock farming system in the study area stand for: \( M \) = Maize, \( Sg \) = Sorghum, \( Sb \) = Soybeans, \( C \) = Cowpea, \( R \) = Rice and \( L \) = Livestock.

Table 1: Crop-livestock farmers' sampling frame and sample size
Analytical Techniques

Descriptive statistics, Data Envelopment Analysis and Tobit regression model were used to achieve the objective of the study. According to Abruev, Theocharopoulos and Aggelopoulos (2012) Data Envelopment Analysis (DEA) is a non-parametric approach which is mathematically expressed as follows:

Objective function:

\[ \text{Max } \text{subject to:} \]

\[ \begin{align*}
\text{Subject to:} & \\
& j = 1, 2, \ldots, n \\
& r = 1, 2, \ldots, s \\
& i = 1, 2, \ldots, m \\
& \geq 0, \\
& \geq 0, \\
& \geq 0,
\end{align*} \]

Where:

- \( n \) is number of districts
- \( j \) is the district whose relative efficiency is being measured
- \( m \) =

...
number of inputs, \( s = \) number of outputs, \( = \) quantity of input \( i \) in each district \( j \), \( = \) quantity of output \( r \) from each district \( j \), \( = \) weight for output \( r \), \( = \) weight for input \( i \), \( \theta_j = \) relative efficiency of district \( j \).

The variables used in the data envelopment analysis (DEA) model were as follows:
\( Y_{ij} = \) 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: \( L_1 = LR-SR-P; L_2 = LR-SR; L_3 = LR-P; L_4 = SR-P; L_5 = LR; L_6 = P; L_7 = SR \). \( X_{ij} = \) 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 Tobin (1958), Tobit model is defined as follows:
\[ Y^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + e \]  
(5)

Where: \( Y^* = \) the estimated farm level output to the highest total output. For the purpose of this study, the model was explicitly expressed as follows:
\[ Y^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + e \]  
(5)

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; \( \beta_0 = \) Intercept to be estimated; \( \beta_1 - \beta_9 = \) Coefficients to be estimated.

**Results and Discussion**

The socio-economic characteristics of the farmers: Table 2 identifies the socio-economic characteristics of integrated crop-livestock farmers in the study area. Results of the socio-economic characteristics revealed that about 92% of the integrated crop-livestock farmers were found to be male with mean age of 44 years and 96.2% were married with mean household size of 7 persons per farmer. 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 about 65% of the farmers fell within the age brackets of 20 and 50 years, implying that integrated crop-livestock farming system in the study area is labour intensive and thus carried out by energetic young men and women within the active age group. It is revealed from result in
the Table that, 60.25% of farmers in the study area had only informal educational background while the rest had primary, secondary or tertiary education. This implies that, the farmers were literate but minority of them had formal education. Therefore, most of them could not take advantages of modern farming techniques, innovations, information and communications technology, ICT among others to enhance efficiency in resource (farm inputs) utilization in the study area. This is in line with studies of Hussaini, Oladimeji, Sanni and Abdulrahman (2019), Osuafor and Nwankwo (2017) and Hudu, Yaro, Baba, Yusuf, Saleh, and Suleiman (2015)

The results in the Table also show the mean, maximum, minimum and coefficient of variation of farming experience as 16.60, 36, 6 and 27.24% respectively. In addition, majority of the farmers (53.75%) had 11 to 20 years of integrated crop-livestock farming system experience with the minority (4.25%) who had more than 30 years’ experience. This implies that, integrated crop-livestock farming system has been a long known practice in the study area. The results in Table 1 also established that about 64% of the farmers had no contact with the extension agents while the rest that had have the average of two extension contacts per season. This implies that, there was an inadequate contact with the extension agents in the study area. Hence, most of the farmers produced crops and livestock with the previous knowledge they had whether wrong or right without a proper guide from professionals. This agreed with the results of Abdullahi, Sambo, Jamilu and Atiku (2017) and Abah, Mbanasor and Agwu (2018).

The result further revealed that, most of the farmers (72.2%) did not belong to any agricultural corporative society or association. Belonging to agricultural corporative societies or association; has many advantages which include: information on improved crop seed, breed of livestock, better animal feeds and where to get them at cheaper prices, new farming techniques, updates on markets situations among others. This improves efficiency and thereby optimizes productivity. Therefore, it was found in this study that, most of the integrated crop-livestock farmers in the study area might have not enjoyed the benefits derived from belonging to agricultural corporative societies or association. Lastly, the Table show the estimated mean of the loan obtained as ₦74,312.18k. The result also shows that, about 15% of the farmers only had access to loan and from informal sources in the study area. This implies that, access to loan was very poor and difficult. This could be due to low educational level of most of the farmers which hindered them from accessing the loan through a formal source and belonging to no any agricultural corporative society or association where they could be properly oriented on that. This is contrary to the findings of Abah, Mbanasor and Agwu (2018) in a study conducted to examine the socioeconomic analysis of ginger value chain in Kaduna state where majority (85% and above) of the farmers belonged to an agricultural corporative society or association. Also, This is consistent with the findings of Girei, Saingbe, Ohen and Umar (2018) in a study conducted to examine the economics of small-scale maize production in Toto LGA of Nasarawa state where 56% of the farmers had no access to loan in the study area.
out of the 21 DMUs namely, M-Sg-C-L₃, M-Sg-L₆, M-C-L₆, Sb-M-L₂, Sb-M-L₃, R-M-L₂, R-M-L₅ and R-M-L₆ were estimated to be CRS efficient. This implies that on average, integrated crop-livestock farmers were 26% efficient in the study area following CRS model assumption. Hence, the farmers can minimize on average 26% of their used inputs coupled with the existing technology and still achieve the same level of output. The result is consistent with the findings of Iginovia and Ogbeide (2018) in measuring the efficiency of selected quoted agricultural farms in Nigeria. The result of their findings shows that the farmers were 3.0% efficient under CRS (0.88) with a range of 0.15. All of the 21 DMUs were estimated to be VRS efficient with the exception of 5 DMUs namely, M-Sg-L₆, Sb-M-L₂, M-C-L₆, R-M-L₂ and R-M-L₅. This implies that 85% of the farmers were 11% inefficient in the study area following VRS model assumption. Hence, the farmers can minimize on average 11% of their used inputs coupled with the existing technology and still achieve the same level of output. Mukhtar, Mohamed, Shamsuddin, Sharifuddin and Iliyasu (2018), in application of data envelopment analysis for technical efficiency of smallholder pearl millet farmers in Kano state used VRS input-oriented...
The result of their findings indicates that, the farmers were inefficient with an average value of $TE$ under VRS as 0.81. According to Coelli et al. (2005) calculation of efficiency under VRS model is assumed to be appropriate only when all firms not operate at an optimal scale level. This is due to factors such as, imperfect competition, government controls and financial constraints.

Jean-Marc (2012) stressed that, the gap observed between the CRS and the VRS frontiers is due to a problem of scale. Hence, comparison between the two models reveals the source of inefficiency and it is carried out by estimating what is referred to as “scale efficiency” $SE$. This ($SE$) is calculated through the division of technical efficiency under CRS by technical efficiency under VRS: $SE_{DMU} = \frac{TE_{DMU, CRS}}{TE_{DMU, VRS}}$

The result also revealed the estimated scale efficiency ($SE$) of the farmers ranging from 57% to 100% with an average of 83% and standard deviation of 0.22 across the 21 DMUs integrated crop-livestock farmers in the study area. Also, only 8 out of the 21 DMUs namely, M-Sg-C-L5, M-Sg-L6, M-C-L6, Sb-M-L2, Sb-M-L5, R-M-L2, R-M-L3 and R-M-L6 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 8 DMUs appeared as the only DMUs which were estimated to be CRS, VRS and Scale efficient in the study area. This further implies that on average, integrated crop-livestock farmers were 17% scale inefficient in the study area. Hence, the farmers can minimize on average 17% of their used inputs coupled with the existing technology and still achieve the same level of output. This agreed with the findings of Benjamin, Simon and Wuraola (2011) who reported that the farmers were on average 70% scale efficient in application of data envelopment analysis to evaluate farm resource management of Benue state farmers.

These efficient DMUs had in totality 52 farmers, represented only 13% of the total number of integrated crop-livestock farmers (400) as shown in Table 2. This implies that, majority of the farmers (87%) 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. This result supported the study of applied data envelopment analysis by Boussofiane, Dyson and Thanassoulis (1992).

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 the result in Table 2 that on average, integrated crop-livestock farmers in the study area were 11% (100-89) inefficient and therefore can minimize on average 11% of their used inputs to achieve the same level of output with the existing technology.

Table 3: Distribution of farm level technical efficiency across DMUs

<table>
<thead>
<tr>
<th>S/No.</th>
<th>DMU</th>
<th>No. of Farmers</th>
<th>Percentage</th>
<th>$TE_{CRS}$</th>
<th>$TE_{VRS}$</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M-Sg-C-L1</td>
<td>97</td>
<td>24.25</td>
<td>0.94</td>
<td>1</td>
<td>0.94</td>
</tr>
<tr>
<td>2</td>
<td>M-Sg-C-L2</td>
<td>20</td>
<td>5.00</td>
<td>0.96</td>
<td>1</td>
<td>0.96</td>
</tr>
</tbody>
</table>
Excess used inputs (Slacks)

A slack refers to an additional improvement a firm required to become efficient through utilizing the leftover (excess) of an input used in production processes. Table 4 reveals the mean slacks of the respective explanatory variables in DEA model as well as the proportions of the excess inputs used in the study area. From the result, an input with the highest slack (26.93%) was farm yard manure (FYM), followed by agrochemicals (18.48%), seed (14.43%), labour (10.97%), fertilizer (5.28%) and farm size (0.18%). This implies that integrated crop-livestock farmers in the study area can reduce the quantity of these inputs: agrochemicals, seed, labour, fertilizer, and farm size by 18.48%, 14.43%, 10.97%, 5.28% and 0.18%, respectively as well as its proportionate cost while achieving the same level of output since all output slacks were zeros.

<table>
<thead>
<tr>
<th></th>
<th>M-Sg-C-L₃</th>
<th>19</th>
<th>4.75</th>
<th>0.97</th>
<th>1</th>
<th>0.97</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>M-Sg-C-L₄</td>
<td>63</td>
<td>15.75</td>
<td>0.62</td>
<td>0.78</td>
<td>0.79</td>
</tr>
<tr>
<td>4</td>
<td>M-Sg-C-L₅</td>
<td>5</td>
<td>1.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>M-Sg-C-L₆</td>
<td>27</td>
<td>6.75</td>
<td>0.95</td>
<td>1</td>
<td>0.95</td>
</tr>
<tr>
<td>6</td>
<td>M-Sg-L₆</td>
<td>8</td>
<td>2.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>M-C-L₆</td>
<td>9</td>
<td>2.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>8</td>
<td>Sb-M-L₂</td>
<td>7</td>
<td>1.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Sb-M-L₃</td>
<td>11</td>
<td>2.75</td>
<td>0.32</td>
<td>0.51</td>
<td>0.63</td>
</tr>
<tr>
<td>10</td>
<td>Sb-M-L₆</td>
<td>11</td>
<td>2.75</td>
<td>0.44</td>
<td>0.58</td>
<td>0.76</td>
</tr>
<tr>
<td>11</td>
<td>Sb-M-L₄</td>
<td>17</td>
<td>4.25</td>
<td>0.61</td>
<td>1</td>
<td>0.61</td>
</tr>
<tr>
<td>12</td>
<td>Sb-M-L₅</td>
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<td>1</td>
</tr>
<tr>
<td>13</td>
<td>Sb-M-L₆</td>
<td>11</td>
<td>2.75</td>
<td>0.44</td>
<td>0.58</td>
<td>0.76</td>
</tr>
<tr>
<td>14</td>
<td>R-M-L₁</td>
<td>11</td>
<td>2.75</td>
<td>0.63</td>
<td>0.77</td>
<td>0.82</td>
</tr>
<tr>
<td>15</td>
<td>R-M-L₂</td>
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<td>1.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>16</td>
<td>R-M-L₃</td>
<td>25</td>
<td>6.25</td>
<td>0.55</td>
<td>1</td>
<td>0.55</td>
</tr>
<tr>
<td>17</td>
<td>R-M-L₄</td>
<td>26</td>
<td>6.50</td>
<td>0.75</td>
<td>1</td>
<td>0.75</td>
</tr>
<tr>
<td>18</td>
<td>R-M-L₅</td>
<td>5</td>
<td>1.25</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>19</td>
<td>R-M-L₆</td>
<td>7</td>
<td>1.75</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>R-M-L₇</td>
<td>11</td>
<td>2.75</td>
<td>0.65</td>
<td>0.83</td>
<td>0.78</td>
</tr>
<tr>
<td>21</td>
<td>R-Sg-L₄</td>
<td>10</td>
<td>2.50</td>
<td>0.84</td>
<td>1</td>
<td>0.84</td>
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</table>

<table>
<thead>
<tr>
<th>Total</th>
<th>400</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>26.27</td>
<td>4.76</td>
</tr>
<tr>
<td>Maximum</td>
<td>99</td>
<td>23.13</td>
</tr>
<tr>
<td>Minimum</td>
<td>5</td>
<td>1.17</td>
</tr>
<tr>
<td>CV</td>
<td>110.60</td>
<td>110.71</td>
</tr>
</tbody>
</table>

Source: Field Survey, 2022


LR=Large Ruminant, SR=Small Ruminant P=Poultry and CV= coefficient of variation
The farmers in the study area were characterized to mostly having large household size, less formal education, operated on small scale, used local variety seeds and integrated crop farming with livestock. 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 excessively 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.

According to Mukhtar *et al.* (2018) 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 paragraphs it can be seen that a relatively high scale efficiency of 83% was obtained in the study area. This implies that inefficiencies were majorly caused by improper utilization of resource inputs in the study area.

**Returns to scale of the farming system**

According to Organisation for Economic Cooperation and Development (OECD) (2001), returns to scale refer to the rate by which output changes if all inputs are changed by the same factor. Constant returns to scale occur when a proportional increase in all inputs results in the same proportional increase in output. Increasing returns to scale occur when a proportional increase in all inputs results in more than proportional increase in output. Whereas decreasing returns to scale occur when a proportional increase in all inputs results in less than proportional increase in output.

Table 4: Inputs slacks estimates of DMUs from DEA model

<table>
<thead>
<tr>
<th>Input</th>
<th>Mean Slack</th>
<th>Max Slack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm Size (ha)</td>
<td>0.09</td>
<td>0.99</td>
</tr>
<tr>
<td>Labour (man-day)</td>
<td>514.165</td>
<td>5,744.64</td>
</tr>
<tr>
<td>Seed (kg)</td>
<td>559.814</td>
<td>3,688.93</td>
</tr>
<tr>
<td>Fertilizer (kg)</td>
<td>488.08</td>
<td>5,289.36</td>
</tr>
<tr>
<td>FYM (kg)</td>
<td>42,053.3</td>
<td>567,772.95</td>
</tr>
<tr>
<td>Agrochemicals (lit)</td>
<td>74.41</td>
<td>771.68</td>
</tr>
</tbody>
</table>

**Source:** Field Survey, 2022

**NB:** FYM = Farm Yard Manure; CV = Coefficient of Variation

Result presented in Table 5 reveals the distribution of integrated crop-livestock farmers in the study area according to operating at optimal (CRS), sub-optimal (IRS), and super-optimal (DRS) scales. Out of 400 integrated crop-livestock farmers in the study area, 81 (20.25%) operated at optimal (CRS) scale. 108 (27%) operated at sub-optimal (IRS) scale while 211 (52.75%) operated at super-optimal (DRS) scale, respectively. This implies that if the scale of 108 farms would be increased by 73% and that of 211 farms decreased by 47.25%, the efficiency of integrated crop-livestock farmers in the study area would be increased.

The result also shows that integrated crop-livestock farmers who operated at an optimal scale, produced crops on an average basis of 16,945.83 kg on 2.8 hectares of land with a yield of 6,052.08 kg per hectare in the study area. Farmers who were found to have operated at a sub-optimal (IRS) scale, averagely produced 7,126.36 kg of crops on 1.7 hectares and with 4,191.98 kg as yield per
hectare. For the farmers who operated at a super-optimal (DRS) scale, cultivated on average 2.3 hectares of farm land, produced 12,356.92kg of crops and with 5,372.57kg as yield per hectare. This implies that integrated crop-livestock farmers who operated at optimal (CRS) scale had the highest crops output per hectare in the study area, followed by those operated at super-optimal (DRS) and then sub-optimal (IRS) scales. This concurred the findings of Mukhtar et al. (2018) 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 5: Distribution of integrated crop-livestock farmers according to returns to scale

<table>
<thead>
<tr>
<th>Returns to scale</th>
<th>No. of farmers</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimal (CRS)</td>
<td>81</td>
<td>20.25</td>
</tr>
<tr>
<td>Sub-optimal (IRS)</td>
<td>108</td>
<td>27</td>
</tr>
<tr>
<td>Super-optimal (DRS)</td>
<td>211</td>
<td>52.75</td>
</tr>
<tr>
<td>Total</td>
<td>400</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: Field Survey (2023)
NB: CRS: Constant Returns to Scale, IRS: Increasing Returns to Scale, DRS: Decreasing Returns to Scale

Test of research hypothesis
The hypothesis of the study which states that integrated crop-livestock farmers are not technically efficient in production was tested. With reference to the study’s results found and presented in Tables 3, 4 and 5, the null hypothesis (H_0) is accepted while the alternative (H_1) rejected. That is to say, integrated crop-livestock farmers were not technically efficient in the study area.

Factors affecting farm level technical efficiency
Tobit regression model was used to determine how socio-economic characteristics of integrated crop-livestock farmers affected variable returns to scale technical efficiency (TE_VRS) in the study area. The selected farmers’ socio-economic characteristics included age, gender, household size, educational level, farming experience, extension contacts, belonging to a cooperative and loan obtained.

Table 6 shows results of the robustness test of the model having a strong explanatory power, revealing about 73% (Pseudo R^2 = 0.7306) of the variations in the study were collectively explained by the independent variables used in the model. The Table further reveals Log-likelihood (387.285) and LR Chi^2 (119.947) which were statistically significant at 1% probability level (P<0.0000). The data were normally distributed as Jarque-Bera test statistic indicates 0.428 (p>0.05).

The model revealed a coefficient of the integrated crop-livestock farmers was positive (0.201) as expected and statistically significant (t=3.7017) at 1% probability level. This implies that age increases technical efficiency in the study area. This could be because, the older the farmer becomes in farming the more experienced and efficient he/she turns to be. This agreed with the findings of Mukhtar et al. (2018) in application of data envelopment analysis for technical efficiency of smallholder pearl millet farmers in Kano state, where age was found positive (0.001) and significant (t=2.299) at 1% probability level.

Household size was found positive (0.0204) and significant (t=1.7895) at 10% probability level. Meaning that the more household size increases the more level of farm efficiency increases in the study area. This could be due to the fact that family members when cultivating their own land exhibit more dedication, good quality work done and the head ensures optimal utilization of resources.
which ultimately increases efficiency. This result is also in conformity with the findings of Yakubu et al. (2019) where household size was found positive (0.004) and statistically significant (t=2.1) in a study of technical efficiency of maize farmers in Kano state. The results in the study show that household size was among the factors affecting efficiency.

The result shows coefficient of educational level being positive (0.206) and significant statistically (t=2.1020) at 5% probability level. This implies that an increase in the farmers’ years of education increases integrated crop-livestock farming efficiency in the study area. This is probably because, educated farmers are 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. This agreed with the findings of Oladimeji and Ajao (2014) in structure and determinants of profit efficiency among small scale rice farmers in Kwara state, where educational level of the respondents was among the significant factors affecting rice production in the study area. Coefficient of farming experience was positive (0.1412) and significant (t=1.7302) at 10% probability level.

The result further reveals coefficient of extension contacts as positive (0.311) and statistically significant (t=2.8796) at 1% probability level. This indicates that an increase in the number of extension contacts to integrated crop-livestock farmers, increases farming efficiency in the study area. The possible reason for this is because, extension services are rendered by well trained professionals in farming activities. Therefore, it is assumed that farmers who had access to extension services would be more efficient in farming than those who had less or none at all in the study area, all things being equal. This went contrarily with the findings of Mukhtar et al. (2018) who found number of extension contacts to be insignificant (t=0.207) among the factors affecting technical efficiency in application of data envelopment analysis for technical efficiency of smallholder pearl millet farmers in Kano state.

Belonging to farming cooperative societies was found positively (0.1801) related to efficiency and significant (t=1.9923) at 10% probability level as revealed by the study. This implies that the farmers become more efficient in farming when they belong to agricultural cooperative societies or associations. This is probably true, because some of these cooperative societies or associations provide improved seeds, supply and sell fertilizers at cheaper prices, render free or cheaper extension services among others to their members. These helped in improving the yield as well as increasing the efficiency of integrated crop-livestock farmers in the study area. This agreed with the findings of Idumah et al. (2016) in measuring the production efficiency of food crop farmers in Rivers state where cooperative membership was found negative (-0.068) and statistically significant (t=-3.68) and thereby regarded as a factor affecting efficiency.

Table 6: Result of Tobit regression for factors influencing technical efficiency

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Probability</th>
</tr>
</thead>
</table>

Vol. 3(1) July 2023
Conclusion and Recommendations
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. 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. The study puts the following recommendations:

i) 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.

ii) More female should be encouraged by extension agents to adopt integrated crop-livestock farming system which is highly dominated by male.

iii) Both government and private sectors should provide accessible credit and loan schemes to support the integrated crop-livestock farmers.

iv) 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.

Contribution of the Study to Knowledge
i. The study shows that majority of the farmers (87%) were technically inefficient in production.

ii. Operating at optimal (CRS) scale helps farmers to produce highest crops output per hectare in the study area.

iii. Crop chaff/straw and farm yard manure in integrated crop-livestock farming system reduce cost of production which would have been incurred.
iv. Factors such as gender, loan obtained have no significant influence on technical efficiency in integrated crop-livestock farming system.

REFERENCES


