GUSAU JOURNAL OF ECONOMICS AND DEVELOPMENT STUDIES (GUJEDS)
ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 **Vol. 3(1) July 2023**

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 (*0.201*), 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

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023

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, Leterme 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, Oluwatusin and Kolawole, 2017).

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

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023

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

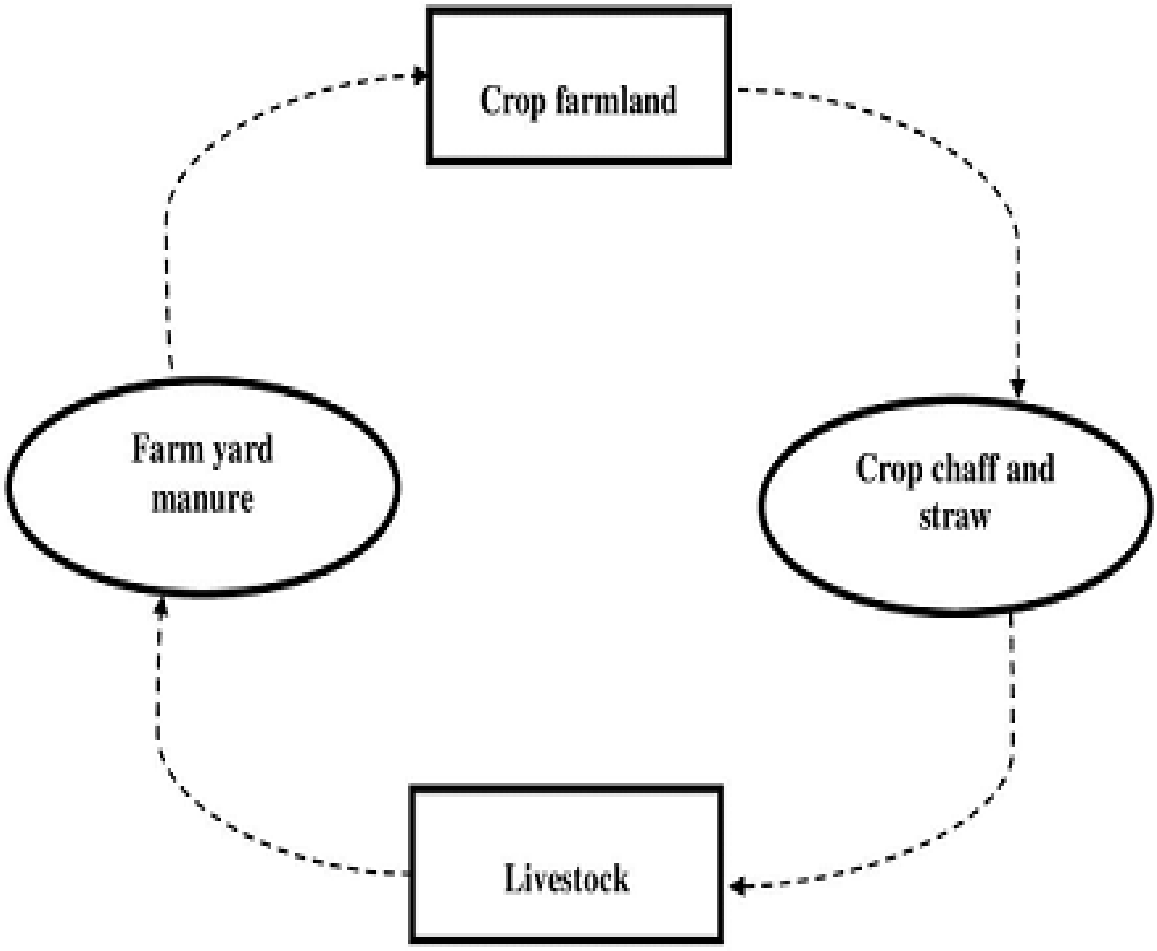
Integrated farming system

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

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023



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

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023

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 9º10' East and 11º30' North and longitudes 6º East and 9º10' 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 Zanfara 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,

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023

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:

$$n = \qquad (1)$$

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

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

n = = = = 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–Sg–C–L , M–Sg–L, M–C–L, Sb–M–L, Sb–Sg–L, R–M–L and R–Sg–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

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ISSN: 2786-9695
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		Integrated Crop-livestock								Integrated Crop-livestock							
LGAs	**Village**	**M – Sg – C – L**	**M – Sg – L**	**M – C – L**	**Sb – M – L**	**Sb – Sg – L**	**R – M – L**	**R – Sg – L**	**Sampling Frame**	**M – Sg – C – L**	**M – Sg – L**	**M – C – L**	**Sb – M – L**	**Sb – Sg – L**	**R – M – L**	**R – Sg – L**	**Sample Size (74%)**
Kubau:	Damau	4	3	3	2	0	4	1	17	3	2	2	2	0	2	1	12
	Haskiya	3	2	3	0	2	2	2	14	2	2	2	0	1	1	2	10
	Kargi	6	3	4	4	2	2	2	23	4	3	2	3	2	2	2	18
	Magami	5	3	2	4	3	3	0	20	4	2	2	3	2	2	0	15
	Sub-total:	**18**	**11**	**12**	**10**	**7**	**11**	**5**	**74**	**13**	**9**	**8**	**8**	**5**	**7**	**5**	**55**
Kudan:	Rimin-Biso	4	2	4	2	1	3	0	16	3	2	2	2	1	2	0	12
	Doka	6	2	4	3	3	3	2	23	4	2	3	2	2	2	2	17
	Hawan-Maimashi	3	2	4	2	3	3	1	18	2	2	2	2	2	2	1	13
	Danbami	5	2	4	2	0	2	0	15	3	1	3	2	0	2	0	11
	Sub-total:	**18**	**8**	**16**	**9**	**7**	**11**	**3**	**72**	**12**	**7**	**10**	**8**	**5**	**8**	**3**	**53**
Lere:	Dan-Alhaji	4	3	3	2	2	4	0	18	3	2	2	2	2	2	0	13
	Saminaka	6	3	5	2	3	4	1	24	4	2	3	2	3	3	1	18
	Goron-Dutse	4	0	3	3	2	4	0	16	3	0	2	2	3	3	0	13
	Bisallah-Hausa	3	3	3	3	3	3	2	20	2	2	2	2	2	2	2	14
	Sub-total:	**17**	**9**	**14**	**10**	**10**	**15**	**3**	**78**	**12**	**6**	**9**	**8**	**10**	**10**	**3**	**58**
Makarfi:	Dandamisa	6	4	3	3	4	3	3	26	3	2	2	3	2	2	2	16
	Gangara	5	2	4	3	1	1	1	17	3	3	2	2	2	1	1	14
	Gimi	7	2	4	3	2	2	1	21	4	3	2	2	2	2	1	16
	Marke	4	2	3	2	2	2	2	17	3	1	2	2	2	2	2	14
	Sub-total:	**22**	**10**	**14**	**11**	**9**	**8**	**7**	**81**	**13**	**9**	**8**	**9**	**8**	**7**	**6**	**60**
Soba:	Fagachi	7	3	4	3	2	6	3	28	5	2	3	2	2	4	2	20
	Marwa	5	4	4	5	3	0	0	21	4	3	3	3	2	0	0	15
	Alhazawa	7	0	6	3	0	5	0	21	5	0	4	2	0	4	0	15
	Gamagira	6	5	3	5	1	3	1	24	5	3	4	3	1	3	1	20
	Sub-total:	**25**	**12**	**17**	**16**	**6**	**14**	**4**	**94**	**19**	**8**	**14**	**10**	**5**	**11**	**3**	**70**
S/Gari:	Bomo	6	1	3	5	0	5	0	20	4	1	2	4	0	4	0	15
	Sakadadi	3	1	3	3	2	3	0	15	2	1	2	2	2	2	0	11
	Gwanda	3	0	3	2	2	1	3	14	2	0	2	2	2	1	2	11
	Katanga	6	1	5	3	1	2	0	18	4	1	3	2	1	2	0	13
	Sub-total:	**18**	**3**	**14**	**13**	**5**	**11**	**3**	**67**	**12**	**3**	**9**	**10**	**5**	**9**	**2**	**50**
Zaria:	Bizara	3	0	5	0	0	5	1	14	2	0	4	0	0	4	1	11
	Bogari	4	1	5	3	0	5	0	18	3	1	4	2	0	4	0	14
	Dambo	2	3	3	4	0	4	0	16	2	2	2	2	0	3	0	11
	Gabari	3	2	6	6	1	7	1	26	2	2	4	4	1	5	1	19
	Grand-total:	**12**	**6**	**19**	**13**	**1**	**21**	**2**	**74**	**9**	**5**	**14**	**8**	**1**	**16**	**2**	**55**
Total:		**130**	**59**	**106**	**82**	**45**	**91**	**27**	**540**	**90**	**47**	**72**	**61**	**39**	**68**	**24**	**401**

Source: Field Survey, 2022

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:

Max = (2)

Subject to:

(j = 1, 2,…, n)

≥ 0, (r = 1, 2,…, s)

≥ 0, (i = 1, 2,…,m)

Where:

n = number of districts, j = the district whose relative efficiency is being measured, *m* =

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023

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*, θ_j = relative efficiency of district *j*.

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

$$Y* = X + \quad = 1, 2, \ldots, \quad (3)$$

$$Y = Y^* \quad (4)$$

Where: $Y*$ represents the latent variable (dependent variable) and is generated through ratio of farmer's crop-livestock output to the highest total output. For the purpose of this study, the model was explicitly expressed as follows:

$$Y^* = \beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 + \beta_7X_7 + \beta_8X_8 + \beta_9X_9 + e \quad (5)$$

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; β_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 reveled from result in

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023

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.

ISSN: 2786-9695
https://doi.org/10.57233/gujeds.v3i1.24 Vol. 3(1) July 2023

Table 2: Description of socio-economic characteristics of the farmers

Variable	Range	F	%	Mean	Max	Min	CV
Gender	Male	368	92				
	Female	32	8				
Age	20-30	9	2.25	44.43	68	28	18.00
	31-40	89	22.25				
	41-50	161	40.25				
	51-60	98	24.50				
	> 60	43	10.75				
Marital status	Single	0	0.0				
	Married	385	96.2				
	Others	15	3.8				
Household size	Less than 4	13	3.25	10.24	16	3	36.00
	4-7	104	26.0				
	8-11	161	40.25				
	12 & above	122	30.50				
Education	Informal	241	60.25				
	Primary	51	12.75				
	Secondary	42	10.50				
	Tertiary	66	16.50				
Farming experience	Less than 11	114	28.50	16.60	36	6	27.24
	11-20	215	53.75				
	21-30	54	13.50				
	Above 30	17	4.25				
Extension	Contact	146	36.50	1.63	3	1	29.21
	no contact	254	63.50				
Cooperative	Member	91	22.75				
	Non-member	309	77.25				
Credit access	Access	59	14.75	141,312.18	200,000	25,000	8.48
	No access	341	85.25				

Source: Field Survey, 2022

Farm level technical efficiency across integrated crop-livestock enterprises

Table 3 revealed the constant returns to scale technical efficiency (TE_{CRS}) also known as total efficiency. This ranges from 38% to 100% with an average of 74% and standard deviation of 0.24 across the 21 decision making units (DMUs) integrated crop-livestock farmers in the study area. Only 8 out of the 21 DMUs namely, M-Sg-C-L_5, M-Sg-L_6, M-C-L_6, Sb-M-L_2, Sb-M-L_5, R-M-L_2, R-M-L_5 and R-M-L_6 were estimated to be CRS efficient. This implies that on average, integrated crop-livestock farmers were 26% inefficient 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 Igbinovia and Ogbeide (2018) in measuring the efficiency of selected quoted agricultural firms in Nigeria. The result of their findings shows that the farmers were technically inefficient under CRS (0.88) with a range of 0.51% to 100%. According to Coelli, Rao, O'Donnell and Battese (2005) 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 perfectly competitive environment which rarely occurs.

The result in the Table further shows the estimated variable returns to scale technical efficiency (TE_{VRS}) also known as "pure efficiency" ranging from 54% to 100% with an average of 89% and standard deviation of 0.75. All of the 21 DMUs were estimated to be VRS efficient with the exception of 5 DMUs namely, M-Sg-C-L_4, Sb-M-L_3, Sb-M-L_4, R-M-L_3 and R-M-L_4. This implies that on average, integrated crop-livestock 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

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model. 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: $SE_{DMU} = TE_{DMU, CRS} / TE_{DMU, VRS}$

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-L_5, M-Sg-L_6, M-C-L_6, Sb-M-L_2, Sb-M-L_5, R-M-L_2, R-M-L_5 and R-M-L_6 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

S/No.	DMU	No. of Farmers	Percentage	TE_{CRS}	TE_{VRS}	SE
1	M-Sg-C-L_1	97	24.25	0.94	1	0.94
2	M-Sg-C-L_2	20	5.00	0.96	1	0.96

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3	M-Sg-C-L_3	19	4.75	0.97	1	0.97
4	M-Sg-C-L_4	63	15.75	0.62	0.78	0.79
5	M-Sg-C-L_5	5	1.25	1	1	1
6	M-Sg-C-L_6	27	6.75	0.95	1	0.95
7	M-Sg-L_6	8	2.00	1	1	1
8	M-C-L_6	9	2.25	1	1	1
9	Sb-M-L_2	7	1.75	1	1	1
10	Sb-M-L_3	11	2.75	0.32	0.51	0.63
11	Sb-M-L_4	17	4.25	0.61	1	0.61
12	Sb-M-L_5	6	1.50	1	1	1
13	Sb-M-L_6	11	2.75	0.44	0.58	0.76
14	R-M-L_1	11	2.75	0.63	0.77	0.82
15	R-M-L_2	5	1.25	1	1	1
16	R-M-L_3	25	6.25	0.55	1	0.55
17	R-M-L_4	26	6.50	0.75	1	0.75
18	R-M-L_5	5	1.25	1	1	1
19	R-M-L_6	7	1.75	1	1	1
20	R-M-L_7	11	2.75	0.65	0.83	0.78
21	R-Sg-L_4	10	2.50	0.84	1	0.84
	Total	**400**	**100**			
	Mean	26.27	4.76	0.74	0.89	0.83
	Maximum	99	23.13	1	1	1
	Minimum	5	1.17	0.38	0.54	0.57
	CV	110.60	110.71	23.82	15.18	21.63

Source: Field Survey, 2022

Where: **M** = Maize, **Sg** = Sorghum, **C** = Cowpea, **Sb** = Soybean, **R** = Rice and **L_{1-7}** = Livestock. **L_1** = LR-SR-P, **L_2** = LR-SR, **L_3** = LR-P, **L_4** = SR-P, **L_5** = LR, **L_6** = P and **L_7** = SR

LR=Large Ruminant, **SR**=Small Ruminant **P**=Poultry and CV= coefficient of variation

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.

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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.

Table 4: Inputs slacks estimates of DMUs from DEA model

Input	Mean Slack	Max Slack	Min Slack	Mean Input	CV	Input Slack (%)
Farm Size (ha)	0.09	0.99	0	270.00	42.75	0.18
Labour (man-day)	514.165	5,744.64	0	222.49	3,981.15	10.97
Seed (kg)	559.814	3,688.93	0	166.05	3,185.78	14.43
Fertilizer (kg)	488.08	5,289.36	0	264.38	7,411.60	5.28
FYM (kg)	42,053.3	567,772.95	0	225.02	117,298.30	26.93
Agrochemicals (lit)	74.41	771.68	0	171.21	281.75	18.48

Source: Field Survey, 2022
NB: FYM = Farm Yard Manure; CV = Coefficient of Variation

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.

Result presented in Table 5 reveals 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 400 integrated crop-livestock farmers in the study area, 81 (20.25%) operated at optimal (CRS) scale, 108 (27%) at sub-optimal (IRS) scale while 211 (52.75%) 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 16,945.83kg on 2.8 hectares of land with a yield of 6,052.08kg per hectare in the study area. Farmers who were found to have operated at a sub-optimal (IRS) scale, averagely produced 7,126.36kg of crops on 1.7 hectares and with 4,191.98kg as yield per

GUSAU JOURNAL OF ECONOMICS AND DEVELOPMENT STUDIES (GUJEDS)
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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

Returns to scale	No. of farmers	Percentage	Mean farm size (ha)	Mean output (kg)	Yield (kg/ha)
Optimal (CRS)	81	20.25	2.8	16,945.83	6,052.08
Sub-optimal (IRS)	108	27	1.7	7,126.36	4,191.98
Super-optimal (DRS)	211	52.75	2.3	12,356.92	5,372.57
Total	**400**	**100**			

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 result reveals that coefficient of age 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

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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 responds 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

Variable	Coefficient	Std. Error	t-Statistic	Probability

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Constant	0.0201	0.0036	5.5833	0.000
Age	0.201	0.0543	3.7017***	0.004
Gender	-0.024	0.0191	-1.2565^{NS}	0.149
Household Size	0.0204	0.0114	1.7895*	0.010
Educational Level	0.206	0.098	2.1020**	0.021
Farming Experience	0.321	0.1407	2.2814**	0.032
Extension Contacts	0.311	0.108	2.8796***	0.008
Cooperative	0.1801	0.0904	1.9923*	0.019
Loan Obtained	0.0128	0.0087	1.4713^{NS}	0.812
Diagnostic Statistics:				
Number of observation	400		Log-likelihood	387.285
LR Chi^2 (8)	119.947		Prob> Chi^2	0.000
Pseudo R^2	0.7306		Normality test	0.428

Source: Field Survey, 2022

Note: ***, ** and * denote that the concerned coefficient is significant at 1%, 5% and 10%, respectively. NS denotes not significant

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.

ISSN: 2786-9695
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iv. Factors such as gender, loan obtained have no significant influence on technical efficiency in integrated crop-livestock farming system.

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