ECONOMICS OF SOLE FISH AND INTEGRATED FISH-VEGETABLE PRODUCTION AND ITS OPTIMUM INPUTS COMBINATION IN KADUNA STATE, NIGERIA

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ABSTRACT

The objective of this study was to examine economics of sole fish (SF) and integrated fish-vegetable (IF-V) production and its optimum inputs combination in Kaduna State, Nigeria. A multistage sampling procedure was used to select 136 farmers that comprised of 95 SF and 41 IF-V farmers. Primary data was obtained using structured questionnaire. Descriptive and inferential statistics were used to achieve the objectives of the study. The average total revenue per production cycle for SF farming was ₦600,000 with net farm income (NFI) of ₦360,646. The NFI obtained from IF-V system was ₦661,679. A total of ₦169,188.4 was generated as additional earning for fish farmers who practiced integration. The Logit and Tobit regression results indicated that factors that influence farmer's decision in the choice of IF-V production shows variation from those influencing its intensity where it does, not by the same magnitude and direction. The dominant enter5:39 PMprise combinations of integrating fish with vegetable are tomatoes, pepper, onion and lettuce (34%), tomatoes, onion and pepper (32%) and fish-pepper (24%). Only three-enterprise combination entered into the optimal farm-plan solution: fish-tomato (67.3%), fish-pepper (25.2%) and fish-lettuce (7.5%). The slack variables indicate that land and feed were used optimally. The parametric model shows that the output was found to increase by 66% when 27.7, 49 and 25 %, respectively increased stocking density, labour and medication. Fish farmers should liaise with extension agents, resource personnel, relevant ministries and agencies to organize seminars, workshops and training on farm plan and inputs sources and enterprise combinations.

Keywords: Sole fish, Integrated fish-vegetable, Optimum inputs, Logit and Tobit regression

INTRODUCTION

Agriculture in Nigeria has considerable potential in terms of resource endowment as well as prevailing ecological conditions. It is generally believed that the available land in the country is more than adequate for the attainment of self-sufficiency in both livestock (including fishery) and crop production. The country is endowed with a coastline of about 800 km, a continental shelf of about 256,000 km^2, and an exclusive economic zone area of 210,900 km^2 (Oladimeji, 1999). The drainage systems of rivers Niger and Benue as well as their main tributaries straddle the topography of the coastal area, in addition to the available land area, estimated at 92.4 million hectares, of which 77% is considered potentially cultivable but only about 40% is currently under crop cultivation (Food and Agricultural Organization, FAO 2018).

Fish farming contributes significantly to the economy, creating employment opportunities in rural and urban areas, serving as a viable source of protein nutrients in Nigerian households, and improving national food security (Oladimeji *et al.*, 2019). In 2018, fish account for about 17% of animal protein consumed by the global population and overall provide about 3.2 billion people globally with about 20% of their average per capita intake of animal protein (FAO, 2018). Increasing demand for fish products has resulted in the growth of fish farms to meet a substantial part of the world's food requirements (Olasunkanmi, 2012). Currently, Nigeria produces just over 1 million metric tons of fish, leaving a deficit of over 800,000 metric tons, which is imported annually (FAO, 2018). Over the past 35 years, aquaculture production in Nigeria has grown by 12% annually compared to the world average of 8%, from a little over 6,000 metric tons in 1980 to nearly 307,000 metric tons in 2016 (World Fish Centre, 2018).

Similarly, vegetables are nutritionally important to humans as they provide much-needed vitamins, minerals, and fibre. It is an important protective food and highly beneficial for the maintenance of health and the prevention of diseases. Vegetables are nourishing foods because they contain a little of all the substances man needs: protein, mineral salts, sugars, vitamins, aromatics, colouring agencies, iron, and essential oils that increase man's resistance to disease (Ebojei, 2016). However, about 5.9 million tonnes are produced in Nigeria annually (FAO, 2016).

However, a low level of animal protein consumption in Nigeria as reported by the FAO revealed that the diet of an average Nigerian contains 20% less than the recommended FAO minimum of 53.8g (Adekunmi *et al.,* 2017). Yet, the consumption of vegetables in Nigeria is generally lower than the FAO recommendation of 75 kg per year, which is 206 g per day per capita (Badmus and Yekinni, 2011). Thus, there is a need for a suitable agricultural system to meet this increasing demand for both fish, and crops (including vegetables), and maximize the utilization of the available limited resources without much wastage.

Therefore, integrated fish-vegetable farming is multiple land-use approach in food production, which combines fish culture with vegetable crops. Moreover, based on the principle of enhancing natural biological processes above and below the ground, the integrated system is the combination that helps in the efficient use of water, reduces pests and diseases, intensifies land use, improves profits, and can therefore help reduce malnutrition and strengthen environmental sustainability (Walia and Navdeep, 2013). According to Oladimeji *et al.* (2019) in land-based fish culture, water quality is controlled by a high rate of both water exchange, which is costly, or water treatment and subsequent recirculation, which comes at a price. This makes integration a source of hope for cost reduction in that direction. Its significance is in making various types of food available all year round as well as making farmers self-reliant and occupied the most time of the year (Gabriel *et al.*, 2007). In view of this, sustainable development in agriculture must include an integrated farming system with efficient soil, water, crop, and pest management practices, which are environmental-friendly, and cost-effective (Walia and Navdeep 2013) in line with sustainable development goals (SDGs) mandate of conservation and management of resources for development.

In Nigeria, integrated fish farming has been reported in many states of the federation in which few fish farmers integrate poultry, piggery or livestock with fish production. Integrated fish cum crop production is on the rise also in several states in Nigeria including Kaduna State (Aquaculture and Inland Fisheries project, AIFP, 2005, Gabriel *et al.*, 2007; Zira *et al.*, 2015, Oladimeji and Isah, 2019). Despite this, there has been little information on the economics of fish and integrated fish-vegetable production in Kaduna State, Nigeria. It is on this basis that the following research questions were addressed by this study:

i. What are the costs and benefits of fish and integrated fish–vegetable production?
ii. What are the factors influencing farmers' decisions in the choice of integrated fish–vegetable production?
iii. What are the optimum combinations of enterprise under the integrated fish-vegetable production system?

RESEARCH METHODOLOGY

Description of the Study Area and Data Collection

The study was conducted in Kaduna State which has four (4) agricultural zones and 23 Local Government Areas (LGAs). The agricultural zones include Maigana, Lere, Samaru, and Brini Gwari (Kaduna Agricultural Development Agency, KADA, 2018). The State lies between Latitudes 9° 00' N and 11^0 30' N and Longitudes 6° 00' E and 9° 10' E of the prime meridian (KADA, 2018). Based on the National Population Commission, NPC (2006), estimate and an annual growth rate of 3.2% for the State, Kaduna State has a projected population of 8,702,476 in 2019 and a land mass of about 48,000 square kilometres. The state has River Kaduna and its tributaries, which run across the State through Niger and Kwara States and empties itself as a major tributary to River Niger in Kogi State. The vast lands, the presence of freshwater bodies, and favourable climatic conditions, with rainfall between 1837 mm - 3236 mm and temperature ranging from 18 to 39 ^{0}C (KADA, 2018), affords the residents of the State the opportunity to practice fish farming in addition to crop and livestock agriculture. The main crops are maize, sorghum, rice, millet, yam, potatoes, ginger, groundnuts, chillies, shea nuts, beni-seed, and soybeans. The predominant livestock is cattle, sheep, goats, poultry, and fisheries.

Sampling Procedure and Sample Size

A pilot survey of existing fish farms and integrated fish vegetable farmers was conducted in Kaduna State in 2019/2020 and this formed the basis for the sample frame employed in the study. A multistage sampling procedure involved a purposeful selection of the Maigana agricultural zone based on the predominance of vegetable and fish production. The second stage involved the random selection of three Local Government Areas (LGAs) in the agricultural zone: Giwa, Kudan, and Sabon-gari LGAs. Thereafter, four villages each were selected randomly from Giwa and Sabon-gari LGAs and five villages from Kudan LGA among villages that are predominant in fish and vegetable production. The farmers were identified mostly through the Agricultural Extension Units of the LGAs and the sole fish marketers. All the farmers identified during the pilot survey constituted the sample size (136) which comprises 95 sole fish farmers and 41 integrated fish-vegetable farmers.

Primary data was obtained with a structured questionnaire, which was used for this study. Data that were obtained from these farmers include farmers' socio-economic characteristics, fish and vegetable production information, and type of pond. Others include the scale of operation, type and quantities of inputs used, prices and technique of production, the output of production type of vegetable, the scale of operation, type and quantities of inputs used, prices and technique of production, and output of production and integrated farming information.

Analytical Techniques

Descriptive statistics such as frequency, percentage, mean, standard deviation and, net farm income analysis, as well as inferential statistics including Logit and Tobit regression models, and data envelopment analysis (DEA) were used to achieve the objectives of the study. The Net Farm Income (NFI) was used to determine the costs and benefits (profitability) of fish and fish–vegetable integration in the study area. Thus:

$$NFI = TR - TC \quad (1)$$

Where: NFI = net farm income (₦); TR = total revenue (₦); TC = total cost of production (₦). Total cost is the sum total of total variable cost and total fixed cost.

The fixed inputs and pieces of machinery are not used up in a production process. Hence, the fixed items were depreciated using the straight-line depreciation method given by equation 2:

$$D = \frac{P-S}{N} \quad (2)$$

Where: D = depreciation (₦), P = purchase value (₦), and S = salvage value (₦) and N = life span of asset (years).

The Logit regression model assumes that the probability of the integrated fish vegetable decision in the choice of integrated or sole fish (Pi) is expressed as:

$$P_i = \frac{1}{1 + e^{-Zi}} \quad (3)$$

Pi ranges between zero and one and it are non-linearly related to Zi,

$$Zi = \beta_0 + \beta_1 X_1 + \cdots + \beta_{11} X_{11} + u \quad (4)$$

Zi is the stimulus index that ranges from minus infinity to plus infinity while Pi ranges between zero and 1. For ease of interpretation of the coefficients, a logistic model could be written in terms of the odds and log of odds. The odds ratio is the ratio of the probability that a farmer would integrate fish with vegetable production (Pi) to the probability of a farmer engaging only in sole fish farming (1-Pi). It is expressed as:

$$Zi = \frac{\text{Pi}}{1 - \text{Pi}} \quad (5)$$

By taking the natural logarithm of the odd of sole fish farming, the Logit of engaging in sole fish farming is expressed explicitly as:

$$Ln\left[\frac{P_i}{1-P_i}\right] = \beta_0 + \beta_1 X_1 + \ldots + \beta_{11} X_{11} + \text{u Ui} \quad (6)$$

(Equation 1 through 3 was adopted and modified from the works of Idi *et al.* (2019) and Akpan *et al.* (2020), Where: Y = integrated (= 1) and sole fish farming (= 0). β_0 = constant term, β_i – β_8 = coefficients, u_i = error term. The independent variables fitted in the model were operationalized as followed:

X_1 = age of the farmers (years); X_2 = gender (male = 1, female= 0); X_3 = marital status (Single =0, married=1; X_4 = experience (years); X_5 = level of education of the farmers (years); X_6 = household size (number); X_7 = membership of cooperatives (Years); X_8 = extension contact (number); X_9 = access to credit (Naira) and X_{10} = output (Kg); and X_{11} = income (Naira).

Similarly, factors influencing farmers' intensity or the extent to which they engaged in integrated fish farming were achieved using the Tobit regression model. Thus:

$$Y_i = \beta_0 + \beta_1 X_1 + \ldots + \beta_{11} X_{11} + \text{u Ui} \quad (7)$$

Where: Y_i is the index of the amount earned by integrated fish-vegetable farmers from fish farming to the sum total of earnings realized from fish-vegetable production; β_0 = constant term, β_1 to β_{11} are coefficients to be estimated, Ui = error term with zero mean and constant variance. The independent variables fitted in the model were operationalized in the Logit model stated in equation 6 and subsequent results. The two models were estimated using the maximum likelihood estimation procedure (MLE). The Logit and Tobit regression was analysed with STATA 15.0 software.

Data Envelopment Analysis (DEA), an application of linear programming methodology was used to determine the optimum combinations of enterprise under the fish-vegetable integrated system. It is used for assessing the relative performance of a set of farm firms, usually called decision-making units (DMUs), which use a variety of identical inputs to produce a variety of identical outputs such as using fingerlings, seedlings, labour, and manure to produce fish and vegetables. The principal advantage of the DEA framework is that it requires neither profit maximization nor cost minimization but only the quantity of data and the efficiency is measured relative to the highest observed performance rather than some average (Oladimeji and Abdulsalam, 2017).

Given the constant return to scale (CRTS) assumption, the best way to introduce DEA is via the *ratio* form. For each decision-making unit (DMU), one would like to obtain a measure of the ratio of all outputs such as fish and vegetable products over all inputs, such as fingerlings, seedlings, manure, labour, and agrochemicals. This is expressed as:

$$\text{Max } u, v \left({u' y_i}/{v' x_i} \right),$$

$$\text{st} \quad {u' y_j}/{v' x_j} \leq 1, \text{j} = 1, 2, \ldots, \text{n},$$

$u, v \geq 0$ (8)

These values of u and v, imply the efficiency measure of i-th DMU is maximized, subject to the constraint that all efficiency measures must be less than or equal to one. One problem with this particular ratio formulation is that it has an infinite number of solutions. To avoid this, one can impose the constraint, $v'x_i = 1$, which provides:

$Max_{\grave{\imath}}, v(\grave{\imath}'y_i),$

st $v'x_j = 1,$

$u'y_j - v'x_j \leq 0, \quad j = 1,2, \ldots, n$

$\mu, v \geq 0,$ (9)

Where: the change in sign from u and v to µ' and v' reflects the transformation. This is the multiplier form of the linear programming problem. An equivalent *envelopment* form of this problem can be derived in linear programming using duality linear programming problem:

$Min_{\theta,\lambda}\, \theta,$

$st\ -y_i + Y\lambda \geq 0,$

$\theta x_i - X\lambda \geq 0$

$\lambda \geq 0,$ (10)

Where: θ is a scalar and λ is a $N\, x1$ vector of constants. According to this envelopment form, it involves fewer constraints than the multiplier form $(K + M < N + 1)$, and hence is generally the preferred form to solve. The value of θ obtained will be the efficiency score of the i-th DMU. It will satisfy $\theta \leq 1$, with a value of n_1 indicating a point on the frontier and hence a technically efficient DMU, according to Farrell (1957), definition. It is necessary that the linear programming problem must be solved N times, once for each DMU in the sample. A value of é is then obtained for each DMU as adopted by Oladimeji and Abdulsalam, (2017).

The linear programming problem in terms of constant return to scale (CRS) can be easily modified by adding the convexity constraint to account for variable return to scale (VRS): $N_1'\lambda = 1$ to provide:

$Min\theta, \ddot{e}^{\theta},$

$st\ -y_i + Y\lambda \geq 0,$

$\theta x_i - X\lambda \geq 0$

$N_1'\lambda = 1$

$\lambda \geq 0,$ (11)

Where: θ is a scalar and λ is $N\, x1$, θ obtained will represent the efficiency score of the i-th Decision Making Unit.

$\theta \leq 1$, with a value of 1 represent technically efficient DMU and a point on the frontier.

Cost minimization Data Envelopment Analysis is operationalized as:

$Min_{\lambda,xi^*}\, w_{i2}X_i^*$

$st\ -y_i + Y\lambda \geq 0,$

$x_i^* - X\ddot{e} \geq 0,$

$N_1'\lambda = 1$

$\lambda \geq 0,$ (12)

Where: w_i is the input prices for the i-th DMU and $x_i{}^*$ is the cost-minimizing of input quantities such as fingerlings, seedling, labour, manure, medication, and transport for the i-th DMU, given the input prices w_i (such as price of fingerlings, seedling, labour, manure, medication and transport, and the output levels y_i for fish and vegetables. The DEA was analysed with FRONTIER DEAP 2.1 version software by Coelli *et al.* (2005).

RESULTS AND DISCUSSION

Costs and Returns of Sole Fish and Integrated Fish-Vegetable Farming

The result presented in Table 1 showed the average costs and returns of sole fish and fish-vegetable production in the study area per production cycle with average of 5 and 3 months, respectively. In the cost component of fish production, the total variable cost (TVC) accounted for the large proportion of total cost (TC) in both sole fish (99.12%) and integrated fish- vegetable (98.4%) farming while total fixed cost (TFC) was 0.88 and 1.6 % respectively. However, cost of feed constituted the largest proportion of the TC component accounting for 61.75 and 48.68% of sole fish and integrated fish-vegetable production, respectively. This is in line with the study of Oladimeji and Isah (2019) on economic and potential benefits of using fish pond water for vegetable production among fish farmers in Kwara State, Nigeria.

The results also reveal that the quantities of fingerlings were 993 and 1023 per pond and these constitutes 17.43 and 13.9 % respectively of the TC of production for sole fish and integrated fish-vegetable production. Furthermore, wages accounted for 12.53% in sole fish and 17.49% in integrated fish-vegetable farming while average labour cost per production cycle took a paltry of 4.59 and 5.04 % respectively. Other variable inputs such as medication, lime, transportation and, depreciated fixed cost items, though play a vital role in the sole fish production system but accounted for 3.70%. This result is comparable to the study of Oladimeji and Isah (2019), on economic and potential benefits of using fish pond water for vegetable production among fish farmers in Kwara State, Nigeria.

Table 1 also revealed the returns to fish farming in the study area. It is pertinent to note that majority of fish farmers operate concrete pond but adjustments per standard pond size and number of fingerlings using equivalent conversion factor to estimate costs and returns were made. Economic theory states that an entrepreneur will continue in production in the short run if it can cover the variable cost; over the long run, production continues only if total cost is covered. Analysis revealed that total revenue is positive and substantial per average pond size. The average total revenue per production cycle for sole fish farming was positive ₦600,000 and covered both total variable cost and total fixed cost with net farm income of ₦360,646.

Table 1: Costs and returns (profitability) of sole fish and integrated fish-vegetable farmers

	Sole fish production			Fish-vegetable production		
Variable	**Qty**	**Price**	**Value (%)**	**Qty**	**Price**	**Value (%)**
Fingerlings	993	42	41,706 (17.43)	1023	42	42,966 (13.92)
Feed	885	167	147,795 (61.75)	900	167	150,300 (48.68)
Labour	24.4	450	10,980 (4.59)	28.3	550	15,565 (5.04)
Medication /lime	5.24	1000	2,620 (1.10)	4.64	1000	2,320 (0.76)
Transportation			4,112.5 (1.72)			6,590.4 (2.13)
Wages (salary)	1	15,000	30,000 (12.53)	1	18000	54,000 (17.49)
Pond / farm size	-	-	-	0.62	8000	4,960 (1.61)
Manure	-	-	-	186.6	110	20,526 (6.65)
Seed	-	-	-	0.89	1000	890 (0.29)
Herbicides	-	-	-	2.66	1600	4,256 (1.38)
Pesticides				1.71	1600	2,736 (0.89)
TVC			237,214 (99.12)			305,109.4 (98.4)
TFC			2,140 (0.88)			3613.89 (1.16)
TC			239,353.5 (100)			308,723.3 (100)
Fish output	750	800	600,000	997	800	797,600
Tomato	-	-	-			102,887.9
Pepper	-	-	-			19,500.5
Onion	-	-	-			46,800
TR			600,000			966,788.4
NFI			360,646.5			661,679
ROI			2.51			3.13

Field Survey, 2020

In the integrated farming system, the estimated total revenue (TR) was ₦797,600, ₦102,887.9, ₦19,500.5 and ₦46,800 for fish, vegetable 1, vegetable 2, and vegetable 3 respectively. The net farm income (profit) obtained from integrated fish-vegetable system was ₦661,679. A total of ₦169,188.4 was generated as additional earning for fish farmers who integrated fish and vegetable production. Therefore, integrated-fish vegetable farming system is a promising technology to generate more income for the farmer on a small plot of land having access to sediment and used fish pond water. This corroborates the submission of Inusah *et al.* (2013), Daba *et al.* (2017), Lemma *et al.* (2017), and Oladimeji and Isah (2019) that integrated fish farming is more profitable than sole fish farming.

The return to investment in sole fish farming was 2.51 and 3.13 for fish-vegetable farmers implies that for every ₦1 invested in sole fish production, a profit of ₦1.51 kobo was made while for a fish-vegetable production, a profit of ₦2.13 was made. The fish pond supplied not only nutrients to the vegetable, but also fully utilizes the wastewater at no cost, which would have become detrimental to the environment in line with the study of

Oladimeji and Isah (2019). This also corroborates Muendo *et al.* (2014), who opined that the drained water from the fish pond can improve the condition of agricultural soils as the content of drained water and sediment can play a major role in soil formation and hence improve soil physical and chemical conditions which in turn facilitate crop production.

Factors Influencing Farmers' Decision and Intensity in the Choice of Integrated Fish-Vegetable Production in Kaduna State, Nigeria

The Logit regression model showed the estimated factors that influence farmers' decisions in the choice of integrated fish-vegetable production in Kaduna State, Nigeria. The estimated coefficients of the Logit model, Z-values, and marginal effect are presented in Table 2. The likelihood ratio test was -60.716 with 7 degrees of freedom statistically significant at a 1% level of probability. This implies that all the variables included in the model are jointly statistically significant in influencing farmers' decisions in the choice of integrated fish-vegetable production. The results in Table 2 also revealed that age, sex, household and farm size were statistically significant variables determining fish farmers' decision in the choice of integrated fish-vegetable production. However, the parameter estimates of the Logit model provide only the direction of the effect of the independent variables on the dependent (response) variable. The estimates did not represent the actual magnitude of change or probabilities. Thus, the marginal effects from the model, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are also reported in Table 2.

The result shows that the coefficient of age was positive and significant in influencing farmer's decision in the choice of integrated fish-vegetable production at 5% level of probability. The implication of positive coefficient of age is that as the age of the farmer increases, the probability of involving in fish-vegetable integration increases by 0.009 units. Furthermore, the marginal effect of 0.0026 shows that a unit increases in farmers' age increases the probability of integrated fish-vegetable production by 0.0026 units. The result is expected as majority of integrated fish farmers were young and energetic, with mean age of 38 years, to withstand the rigorous nature of fish farming activities cum vegetable production which are labour-intensive. This finding is in line with Awotide (2012), who opined that young fish farmers with better education might be exposed to new ideas and more likely to participate in any developmental programmes and bear more risk than older farmers.

Coefficient of sex (-0.2715) was negative and statistically significant in influencing farmers' decision to engage in integrated fish-vegetable farming at 1% level of probability. If male farmers have more access to opportunities than female farmers do, the probability of integrating fish-vegetable is expected to be positive for the former. The negative coefficient signifies that the result is skewed towards female folk who play dominant roles in fish and vegetable production and related business in the study area. Furthermore, the marginal effect of -0.077 shows that female farmer is 0.077 units more likely to involve in integrated fish-vegetable production than male farmers are. This result is in contrast to study of Oladimeji *et al.* (2017), which found male dominating fisheries activities in Kwara State, Nigeria.

Table 2: Factor Influencing Farmers' Decision and Extent in the Choice of Integrated Fish-Vegetable Production

	Decision			Intensity		
Variable	**β**	**Z**	ME	**β**	**Z**	ME
Age	0.009 **	2.02	0.003	0.103 *	1.98	0.218
Sex	-0.272 ***	-3.55	-0.077	-0.492	-0.76	$-0.3e^{-4}$
Income	$4.4e^{-08}$	0.39	$1.25\ e^{-08}$	0.228 ***	3.21	$0.7e^{-5}$
Education	-0.085	-1.42	-0.024	$0.9e\text{-}^{06}$ *	1.84	$0.6e\text{-}^{3}$
Household size	0.033 ***	2.52	0.009	-0.004 **	-2.19	-0.432
Farming experience	0.008	0.98	0.002	-0.165	-0.54	-0.009
Farm size	0.055 **	2.20	0.016	0.008 ***	3.05	0.321
Extension contact	-0.051	-0.83	-0.015	0.395 **	2.04	0.165
Constant	0.045 **	2.05	0.007	0.007	2.06	0.087
Log likelihood	-60.72			-102.05		
Wald chi^2 (8)	46.52			63.01		
Prob>chi2	0.000			0.003		
McFadden R^2	0.694			0.721		
No. of observation	136			41		

Field Survey, 2020; ***; **; * denote statistically significant at 1, 5, & 10 %, respectively

Coefficient of household size (0.033) was positive and statistically significant at 1% of probability level. The positive coefficient suggests that individuals with large household size *ceteris paribus*, were likely to integrate fish-vegetable production. This is because they appeared to have more labour to partake in the venture, and more family burden to cater for, in terms of social and economic services, and therefore need support to meet their family daily needs compared to their counterpart with less household size. The marginal effect of 0.0092 showed that a unit increase in farmers' household increases the probability of integrated fish-vegetable production by 0.0092 units.

Farm size also has positive coefficient (0.055) and statistically significant at 5% level of probability. This result affirms that those individual with large size of farm land were more likely to involve in integrated fish-vegetable production. The marginal effect of 0.016 indicates that one extra unit of farm size increases the probability of involving in integrated fish-vegetable production by 0.016 units. Oladimeji *et al.* (2017) opined that the amount of space available for fish farming will determine to a large extent the integration of other agricultural activities.

It is pertinent to note that the factors that influence the intensity of participating in integrated fish-vegetable production include income accrued to farmers, level of education, household size, farm size and extension contact.

Description of Farmers by Enterprise Combination

The result in Figure 1 presents the distribution of enterprise combinations of integrated fish-vegetable farming. The major vegetables integrated were tomatoes, pepper, onion and lettuce. The proportion of combinations majorly includes fish tomatoes enterprise (34%), fish tomatoes, onion and pepper (32%) and fish pepper (24%) in the study area.

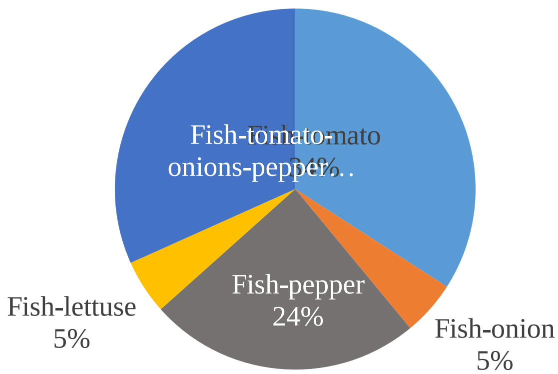

Fig. 1: Enterprise combinations of integrated fish-vegetable farming

It is expected that the farmers practicing sole fishing system, may be willing to practice fish-vegetable integration if expose to requisite training from extension personnel and has access to land. among other factors. This may inform the reason, why majority (69.9%) of the farmers in the area choose the sole fish production system. On the other hand, those who may have the objective of integrating fish with other vegetables production may consider their food security status and will consider the fish-vegetable integration as a better choice. A plausible explanation to this is that the major feature of this system includes utilization of waste such that the waste of one system becomes the input of the other system. Thus, integrated fish farming promotes efficient utilization of farm space for multiple productions (Eyo *et al.*, 2006).

Optimal Farm Plan Solution for Different Enterprises

Table 3 depicts the optimal farm plan solution for different enterprises. It is pertinent to mention that the farmers who practice fish-vegetable integration in the study area planted different combinations of vegetable crops in order to meet up with their food and possibly financial needs. Therefore, such farmers require an optimal farm plan of enterprises combination that brings the best output and in the cheapest way possible. There are many fish-vegetable crop combination activities in the study area but five prominent ones were used in this study.

From the entire integrated farms cultivated, an output of about 3155 kg was realized per hectare. However, only three of the combination entered into the optimal farm plan solution. Furthermore, fish-tomato has the largest proportion of 67.3% of the crop production. Fish-pepper and fish-lettuce have 25.2% and 7.5% respectively to be devoted to it in the optimal farm solution. It is noted that the fish-tomatoes, fish-pepper and fish-lettuce were mainly the one that entered the optimal farm solution in the area. This implies that the three enterprises are better-off in the area than fish-onion and fish-tomato-onion-pepper enterprises in utilization of resources as demonstrated in Table 3.

Table 3: Optimal farm plan solution for different enterprises

Enterprise	Original value	%	Radial movement	Slack / Existing level	Optimum level
Objective function	3155.3		-	-	5480.1
Fish-Tomato	0.54	67.3	3297.3	410.9	2886.4
Fish onion	0.00	0.00	0.000	-	-
Fish-pepper	0.21	7.5	366.01	-679.49	1045.5
Fish-lettuce	0.25	25.2	1233.7	-314.5	1548.2
Fish-tomato-onion-pepper	0.00	0.00	0.000	-	

Field Survey, 2020

Measurement of Slack / Surplus Variables in the Optimal Farm Plan

Table 4 indicates slack or surplus variables in the optimal farm plan. To get the optimal farm solution, the farmers are expected to expand and reduce some of their resource in fish-vegetable production. The result in Table 4 shows that land was used optimally. Although, land is the most important asset for the farmers, farming families' livelihood depends mainly on land, the model suggested that more land should be added for optimal performance. This finding is in line with Abdulrahman and Yusuf, (2018), on sensitivity analysis and efficiency of cocoyam producers in Kaduna State who revealed land is the most limiting factor when compared to other resource available.

In contrast, stocking density is not a limiting resource and for the optimal farm plan, about 120 fingerlings need to be reduced from the system. However, the feed is at optimal, suggesting that increasing the fish feed will not increase the value of output. Furthermore, labour and medication are not limiting resource and for the optimal farm plan. About 17.5% each of man-days and drugs need to be reducing from the system. The abundant availability of human labour in line with *a priori* expectation is relative to the area, given that an average farmer in the area cultivates small farm size per planting season due to nature of the crop and pond size. There was an overutilization of these resources of 140 man-days and 7gm of medication in the model out of the average of 60 man-days and 3gm of medication available for fish-vegetable production.

Table 4: Slack / Surplus variables in the optimal farm plan

Enterprise	Original value	Radial movement	Slack movement (%)	Projected value
Pond / Land size	1.00	0.00	0.00(0)	1.000
Stocking density	900.00	-720.00	-120(16.7)	60.00
Feed	1.00	-0.80	0.00(0)	0.20
Labour	1000.00	-800.00	-140(17.5)	60.00
Medication	50.00	-40.00	-7(17.5)	3.00

Field Survey, 2020

Sensitivity Analysis of Inputs Combination

The initial farm plan was subjected to three parametric models as shown in Table 5. The selection of stocking density, labour and medication were based on the fact that those resources were not completely used up in the initial optimal plan. The first model subjected the initial model into using up the entire surplus in both resources and the output was found to increase by 66% when 27.7, 49 and 25%, respectively increased stocking density, labour and medication. This indicated that the percentage increase in the resource level is lower than that of the output level but not fully optimized. Furthermore, in the second model, the initial quantity of stocking density, labour and medication were increased to have 73.6, 80, over 100 % increase in stocking density, labour, and medication usage levels, respectively and this time, there was about 173% increase in the output level.

Table 5: Sensitivity analysis

Models	**Changes in inputs variables in integrated fish-vegetable enterprises**			
Changes	**Stocking density (% increase)**	**Labour (% increase)**	**Medication (% increase)**	**Output (% increase)**
Initial	900 (0.0)	1000 (0.0)	50 (0.0)	3155.3 (0.0)
1st	1150 (27.7)	1490 (49.0)	75 (25.0)	5246.21 (66.2)
2nd	1562 (73.6)	1800 (80.0)	100(50.0)	8642.87 (173.0)

Field Survey, 2020

CONCLUSION AND RECOMMENDATIONS

It can be concluded that integrating fish with vegetable production is more profitable compared to sole fish farming. The factors that influence farmer's decision in the choice of IF-V production shows variation from those influencing its intensity where it does, not by the same magnitude and direction. Fish-tomato has the largest proportion of the crop production. From the findings of this study, the following recommendations were made:

- Farmers are employed to increase the pond and farm size by forming a functioning and formidable cooperative society to liaise with non-governmental organization and government to enjoy economic of scale in the provision of inputs and trainings to embrace fish-vegetable integration to earn more profit.

- Fish farmers should liaise with extension agents, resource personnel, relevant ministries and agencies to organize seminars, workshops and training on farm plans and inputs sources and enterprise combinations.
- In view of the fact that integrated fish-vegetable production is more profitable with a higher rate of return on investment when compared with sole fish farming, it is recommended that farmers must channel resources towards integrated fish-vegetable production for higher yield, profit, income and efficiency.
- This will invariably enhance food security and improved nutrition, promote sustainable agriculture, ensure availability and sustainable management of water, protect terrestrial ecosystems, and halt biodiversity loss engendered in SDGs goals.

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