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Achieving Food Security through Sustainable Aquaculture: An Evidence from Osun State, Nigeria.

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Abstract

Fish consumption accounts for over 40% of the protein sources consumed in Nigeria. This number is expected to increase with increasing population in the coming years as fish is a primary source of protein and essential nutrients. This increasing demand means that the current capacity of the aquaculture industry would be overstretched as catch from the wild is already dwindling as a result of stock depletion, overfishing and other global trends. Fish farmers, in their quest to meet up with this demand are shorthanded by increasing cost of production. This is likely to push-out fish farmers from business and would end up leaving consumers vulnerable as the production process might be compromised. The reason being that sustainable aquaculture practices would have been substituted for higher revenue. This research therefore sought to examine sustainability in ensuring food security. The study used the descriptive correlational survey design to ascertain the interplay between environmental, social, and economic sustainability on food security using fish farmers in Osun state, Nigeria as the respondents. The study used multistage sampling to generate a sample size of 150 fish farmers. The study made use of the SmartPLS 3.3.2 software to run the analysis. Results from the study showed that there is a positive significant effect between economic sustainability and food security ($\beta = 0.195$, $p \leq 0.1$), as well as social sustainability and food security ($\beta = -0.450$, $p < 0.01$). However, environmental sustainability showed no effect on food security ($\beta = -0.085$, $p > 0.1$). Also, it was revealed that there was no significant association between socioeconomic characteristics of fish farmers and food security. Again, it was revealed that the major constraint of fish farmers was the high cost of feed and poor pricing by customers. It was concluded that for fish farmers to achieve food security, there is the need for an improved economic and social sustainability practices. The research recommends that government of Nigeria should empower extension agents to educate farmers on the need to improve on social and economic sustainability to safeguard food security while farmers themselves are encouraged to seek current and improved knowledge to improve their productivity.

Keywords: Food Security, Sustainable, Aquaculture, Nigeria

Introduction

Fish is one of the oldest creatures that served as food for humans over the centuries (Christensen *et al.*, 2014) and provides 19% of animal protein intake to Africans. It plays a unique role in providing a range of micronutrients and essential fatty acids, especially long-chain polyunsaturated fatty acids, which cannot be easily substituted by other food commodities (Béné *et al.*, 2015, Kassebaum *et al.*, 2014, Kawarazuka and Béné,

2011, Tacon and Metian, 2013). It has provided man with up to 55 percent of total animal protein needs in Nigeria alone (FAO, 2005). Fish is a vital source of food for people. It is man's most important single source of high-quality protein, providing ~16% of the animal protein consumed by the world's population (FAO1997). Fish has significant potential to contribute to the goal of reducing food and nutrition insecurity in Africa.

As the world capture fish industry is falling by 0.5 million tonnes per year, aquaculture is replacing this with a 2.5 million tonnes per year (Salin *et al*., 2018). Aquaculture was introduced in Nigeria like other developing countries as a way of improving the livelihood of rural community in an attempt to escape poverty. According to Olaganathan *et al.* (2017), aquaculture is the fastest route for poor household to escape poverty and make a living while earning the country these household belong, a valuable foreign exchange. Fisheries is a major economic sector, estimated to employ over 8.6 million people directly and a further 19.6 million indirectly, 70 percent of whom are women. (WorldFish. 2018.)

The need to feed a growing global population, and to address a growing demand for fish, puts pressure on natural resources and challenges the sustainability of marine and inland fisheries and of aquaculture development. Also, the risks and environmental impacts of some aquaculture practices is enormous but the growth of aquaculture also presents countries with the opportunity to expand and improve fish farming so that it is sustainable and environmentally responsible.

According to World Bank 2014, the aquaculture sector has been recognized as an alternative to fish production due to its high reliability in returns and low capacity intensity relatively to capture fisheries. As the global population inches towards nine billion by 2050, there will be a need for more food and jobs which a growing aquaculture industry can help meet. But it needs to be practiced responsibly. Aquaculture is poised to be an essential part of the solution to global food security thus the industry is expected to improve its practices in line with expectations from the market for sustainable and responsibly produced seafood.

Despite the potential of aquaculture in Nigeria, the country face difficulties in meeting the desired demand of the citizenry. The challenges include poor planning and policies, inadequate quality fish seed, poor extension services, ineffective cooperative societies, poor infrastructure facilities, high cost of fish feed and poor funding among others (Omitoyin and Aderanti, 2020; Ugwumba and Nnabuife; 2008 Adeogun, *et al*., 2007; Ugwumba, 2005). However, aquaculture continues to be an integral part of Nigeria's agri-food system and has the potential to reducing food insecurity yet the current challenges has led to increasing concern for Nigeria's food industry.

Whereas efforts are being made to improve food security worldwide, the story is quite different in Sub-Saharan Africa where food insecurity goes noticeable (Sadiddin *et al*., 2019). It was reported that one out of four Sub-Saharan African country is undernourished (FAO, 2017). In Nigeria, the average protein intake per person is around 19.38g/output per day which falls below the FAO standard of 65g/output per day. This situation has been attributed to the country's growing population outweighing aquatic organisms output supply. A recent study by Bradley, *et al.*, 2020 estimated that Nigeria ranks third globally for the number of people dependent on coastal fisheries for food and nutrition security, and the demand for fish is growing, alongside growth in population and incomes. However, household fish consumption in Nigeria measured at 13.3 kg/capita/year is low compared with the world's average of 20.3 kg/capita/year (FAO 2018). This national average likely masks a much lower average among resource limited and vulnerable population groups as well as a notable supply-demand gap. Increased fish production and consumption may contribute to alleviating food and nutrition insecurity. The majority of households in Nigeria (58%) suffer from chronic or transitory food insecurity (Ogundari 2017). It is estimated that the current deficit in

fish production stands at an estimated 2.5 million tonnes. The resulting impact is the malnutrition and starvation of more than a million Nigerians mainly in rural communities (Timothy, 2018). The major issue for Nigeria in using aquaculture as a way out of food insecurity lies in the country's production level, distribution network and purchasing power parity thus for Nigeria to meet up with current demand deficit, accessibility, availability, utilisation and stability, there is the need to look at sustainability of the country's aquaculture sector.

Aquaculture sustainability has in current times assimilated new approaches to driving sustainable intensive aquaculture production system that encompasses historical, current and future perspectives (Boyd *et al*., 2020). Sustainability in aquaculture through economic and environmental sustainable management has led to the reduction of greenhouse emission, reduce freshwater and land use, improved feed management, domestication of species, increased knowledge of nutrient requirements and farming practices. According to Boyd *et al*., (2020), the sustainable aquaculture production combined with integrative efforts is increasing efficiency and increasing global demand for protein and food security needs of millions. However, in the case of Nigeria, the issue of sustainability has not gain grounds as the wide margin of child labour in aquaculture, abject poverty, modern slavery and social inequality in wealth has made the realisation of social sustainability an increasing mirage (Adewumi, 2015). This is not limited to social sustainability alone, as economic sustainability issues such as poor marketing, difficulty in obtaining credit, input and poor human resource are upfront to achieving sustainability. In environmental sustainability, selecting the best practices and procedure for fish farming has been a struggle for aquaculture policy makers. This issue stems from the desire of fish farmers to see fast result and increase income, poor adoption among farmers and the continuous absence of extension agents to assist farmers in adopting these new practices and procedures. This research therefore, examined how food security can be achieved through sustainable aquaculture. The following hypothesis were tested.

1. H_0: There is no association between socio economic characteristics of fish farmers and food security
2. H_0: There is no statistical significant relationship between sustainability and food security.
3. H_1: There is a statistical significant relationship between economic sustainability and food security.
4. H_2: There is a statistical significant relationship between environmental sustainability and food security.
5. H_3: There is a statistical significant relationship between social sustainability and food security.

Materials and Methods

The study used the descriptive correlational survey design to ascertain the interplay between environmental, social, and economic sustainability on food security. Fish farmers in Osun state of Nigeria were the respondents. Osun state is located in the south-west of Nigeria with its capital, Osogbo. The state is known for its major contribution to aquaculture fish stock of the country. This is attributed to the location of the state which sits at the rainforest belt of the Western uplands, making it one of the adequate rain receiving state in Nigeria. Geographically, the state lies between longitude 4^0 and 5^0 E and latitude 7^0 and 8^0 N. It covers an estimated land size of 14,875 km square. The area is one of the few states in Nigeria where the government has embarked on massive fish farming promotion as part of the federal government goal to using fish farming to reduce poverty, generate employment and ensuring improved nutrition among local residence. The state is one of Nigeria's major producer of agriculture output.

In selecting the sample size for the study, a multi stage sampling was conducted with the first stage being the stratification of the state into three strata based on existing Agriculture Extension zonation made by the Extension

department in the area. The zones were Iwo zone, Osogbo zone, and Ede zone. Stage two saw a simple random sampling used to select one community each from the zone due to the homogeneity of fish farmers in the zones. The last stage used simple random sampling to select 50 respondents from each community. This led to a total sample of 150 fish farmers used for the study.

The data collected for the study was mainly primary data through the use of questionnaires. The instrument had questions based on the farmer characteristics, sustainability practices adopted and used on their farms, food security questions and challenges faced in achieving food security. Sustainability was measured in terms of environmental, social and economic. Food security was measured using the household food insecurity access index. The total 150 questionnaires issued were all retrieved and thus a 100 percent retrieval rate. The data collected was coded, inputted and cleaned using Microsoft Excel. After data cleaning, the study made use of the SmartPLS 3.3.2 software in Structure Equation Modelling (SEM) to run the analysis for the measurement model and the structural model. According to Hair *et al*., (2015), the two-stage approach was needed to evaluate the model fit as well as the relationship between the exogenous and the endogenous variables in the PLS-SEM. Reflective models suggest that the measurement model be evaluated first. This takes into account the model's validity and reliability coefficients based on cronbach alpha, composite reliability, average variance extracted, discriminant validity and finally, Heterotrait-Monotrait. Also, the structural model examination is based on the relationship between the variables as hypothesised. Sustainability indicators (social, economic and environmental) and food security were analysed using correlation. The study based the model's significance on the p-values, t-values, R^2 effect size, f^2 effect size and Q^2 predictive relevance.

Model Specification

Kendall's coefficient of concordance, which is normally denoted by W, measures the level of agreement between observations (Gisev, Bell & Chen, 2013). It bears resemblances to the spearman's rank correlation coefficient and considers all observations of the study. The Kendall's equation is stated as;

W- $\frac{12s}{p^2(n^3-n)-pT}$ 1

S- Sum of squares from row sum of ranks R_i
n- Number of objects
p- The number of judges
T- Correction factor for tied ranks
Therefore, S- $\sum_{i-1}^{n} R_i^2 - SSR$ 2

T-$\sum_{k-1}^{m}(t_k^3 - t_k)$ 3
m- Number of groups
t_k – the number of tied ranks in each k of m groups

On challenges faced in achieving food security, the data was analysed using Kendell's coefficient of concordances.

Results and Discussion

Socio-economic characteristics of fish farmers

The Table 1 reveals that majority of fish farmers used for the study were males (83.3%). The low number of female respondent may be due to the laborious nature of fish farming. The findings of this study agrees with that of Ibok *et al*., (2017) and Omitoyin, *et al*., (2019) who also reported that fish farming in Nigeria was male dominated due to the nature of fish farming, high capital outlay and the activeness of men. On age of fish farmers, it was revealed that the majority of fish farmers were in the age bracket of 29-40 (50.4%). This shows that fish farmers in Osun state are relatively young. This is in line with the findings of Omitoyin and Adejoke-Adediran (2019). The results however disagrees with the study of Igoche *et al.,* (2019) and Olaoye *et al.,* (2013) who reported that majority of fish farmers in Nigeria are within the age bracket of 41- 50 years. Also, it was revealed in Table 1 that fish farmers were not having much visit from extension agents. Fish farmers reported that the number of visit

from extension agents was 0- 3 times a year (89.2%).This was the same observation of Omitoyin and Osakuade (2021) among fish farmers in Ekiti State who decried inadequate monitoring by extension workers. This indicates that fish farmers in Osun state rely mostly on their experience in fish farming and other sources to overcome challenges they face on their farms. Furthermore, on their years of formal education, it was revealed that fish farmers have 8- 14 years of formal education (48.8%). This shows that fish farmers in this study were not highly educated. The findings of this study disagree with Olaoye *et al*., (2013) and Omitoyin *et al*., (2020) who reported that fish farmers in Nigeria had formal education to be over 15 years. Lastly, on scale of operations, it was revealed that fish farming was done mostly on medium scale basis (54%). This is attributed to resource constraints of farmers. The findings of this study disagree with Omitoyin *et al*., (2019), Emaziye (2020) and Omitoyin and Osakuade (2021) who revealed that majority of fish farmers in Nigeria were into small-scale operations due to financial constraints and labour wages.

Table 1: Socio-economic characteristics of fish farmers

Socio-economic Variables	**Freq.**	**%**	**Mean ±SD**	**X^2**
Sex				.140
Male	120	83.3		
Female	24	16.7		
Age			2.439± .985	.147
17-28	15	12.2		
29-40	62	50.4		
41-52	29	23.6		
53-64	11	8.9		
65-76	6	4.9		
Number of extension Visit			1.108± .311	.031**
0-3	124	89.2		
4-7	15	10.8		
Years of formal Education			2.228± .758	.003**
1-7	20	15.7		
8-14	62	48.8		
15-21	42	33.1		
22-27	2	1.6		
28-34	1	.8		
Scale of operations				.081*
Small	52	37.4		
Medium	75	54.0		
Large	12	8.6		
Total	**149**	**100.0**		

***** Significant at 1% ** Significant at 5% * sigificant at 10%**

H_0: There is no association between socioeconomic characteristics of fish farmers and food security

The analysis of the hypothesis of association between food security and socio-economic characteristics of fish farmers revealed that number of extension visit (.031), years of formal education (.003) and scale of operation (.081) were significant. However, sex (.140) and age (.147) were not significant. This indicates that not all socio-economic characteristics of fish farmers have an association with their food security status. Hence the null hypothesis of "There is no association between socioeconomic

characteristics of fish farmers and food security" is accepted.

Sustainability and food security

The measurement (inner) model assessment is the first-stage approach to testing the model fit in a reflective model. The reliability, convergent validity and average variance extracted are tested and the Cronbach Alpha for SI Econs (0.715), SI Env (0.824), SI Soc (0.941) and HFIAS (0.963) revealed that the model is very much reliable. Likewise, the test for validity was conducted using face and content validity. Besides, an examination of a discriminant validity was done using the Heterotrait Monotrait (HTMT) values (Hair *et al*., 2017) and Fornell-Larcker (Fornell & Larcker, 1981 as cited in Wong, 2013). The values from the diagonals of HTMT are all recorded as 0 and that of the Fornell-Larcker Criterion were 0.796, 0.725, 0.808 and 0.841 more than the off-diagonals. This indicates that the discriminate validity of the model has been established.

Furthermore, the significant relevance of structure (outer) model is assessed at the second-stage of the analysis. According to Hair *et al*., (2017), the study verified its structural model path coefficients against the rule of thumb of 5000 samples of bootstrap with t-values and p-values so that the critical t-values were considered at 2.57 (1%), 1.96 (5%) and 1.65 (10%) significant levels. However, the p-values were considered significant at $p < 0.01$ (1%) and $p < 0.1$ (10%) respectively. Results from the structural model analysis as presented in Table 2 showed that Economic Sustainability has positive significant relationship with Food Security at 10% significance level ($\beta = 0.195$, $p \leq 0.1$). The study rejects the null hypothesis. This is because, economic sustainability offers employment opportunities, increases income and wealth accumulation in the long run when there is efficiency in the production of fish. Therefore, economic sustainability is a strong predictor of food security. This finding is in line with that of Naylor *et al.*, (2021), Boyd *et al.*, (2020) and Valenti, Kimpara, Preto and Moraes-Valenti (2018) who argue that economic sustainability are the possible ways to maintaining food security globally. The reason being that income generation alone is not sufficient to enhance food security but also, employment, labour, profit as well as economic growth in general (Farmery, White & Allison, 2021).

Moreover, the result on Environmental Sustainability showed a negative relationship with Food Security ($\beta = -0.085$, $p > 0.1$). Here, the p-value is greater than the 10% significance level and therefore the null hypothesis for this construct was accepted. This is because, even though there are no direct correlation between environmental sustainability and food security, however, the governance and stakeholder involvement is very crucial to achieving an environmentally sustainable aquaculture. No wonder Reverter *et al*., (2020) contended that if the environmental sustainability is not practice properly, it would result to changes in the environment that could be harmful to human existence. Likewise, Leung and Bates (2013) submits that there are some infectious diseases that could affect the fishes due to non-environmental sustainability practices from farmers and this may increase with climate change.

Nonetheless, the result on Social Sustainability revealed a positive significant relationship with Food Security at 1% significance level ($\beta = -0.450$, $p < 0.01$). The null hypothesis for this construct was rejected. This is because, a socially sustainable food security would mean, there is enough food with the require nutrient for the population. It also enhances once health and promote the education of the workforce. Finding agrees with the studies of Cavallo, Pérez Agúndez, Raux and Frangoudes (2021) so that social sustainability goes a long way to assist government in policy and decision making processes with practical methods and actions. In aquaculture, social acceptability increases when socio-economic benefits for instance employment opportunities are made available as well as the impacts on the environment are assessed and communities are kept informed about the management requirements that

business must comply with (Cavallo *et al*., 2021).

In addition, the R^2 effect size measures the proportion of variance shared by the exogenous and endogenous variables. As a result, the variables of Economic Sustainability, Environmental Sustainability and that of Social Sustainability explains 0.160 representing 16% variations in Food Security. Also, the f^2 effect size shows the main explanatory variables. From the study, it is seen that Economic Sustainability and Social Sustainability are the main explanatory variables since their f^2 values showed 0.021 and 0.063 respectively. Last but not least is the predictive relevance (Q^2). According to Hair *et al.*, (2017), the predictive sample reuse technique is the criteria for evaluating the model's predictive relevance based on the blindfolding process. As such, the study's result showed a Q^2 value of 0.093 as the extent to which the model is consistent with the cross-validation predicted data. Figure 1 showed the graphical representation of the structure model PLS-SEM.

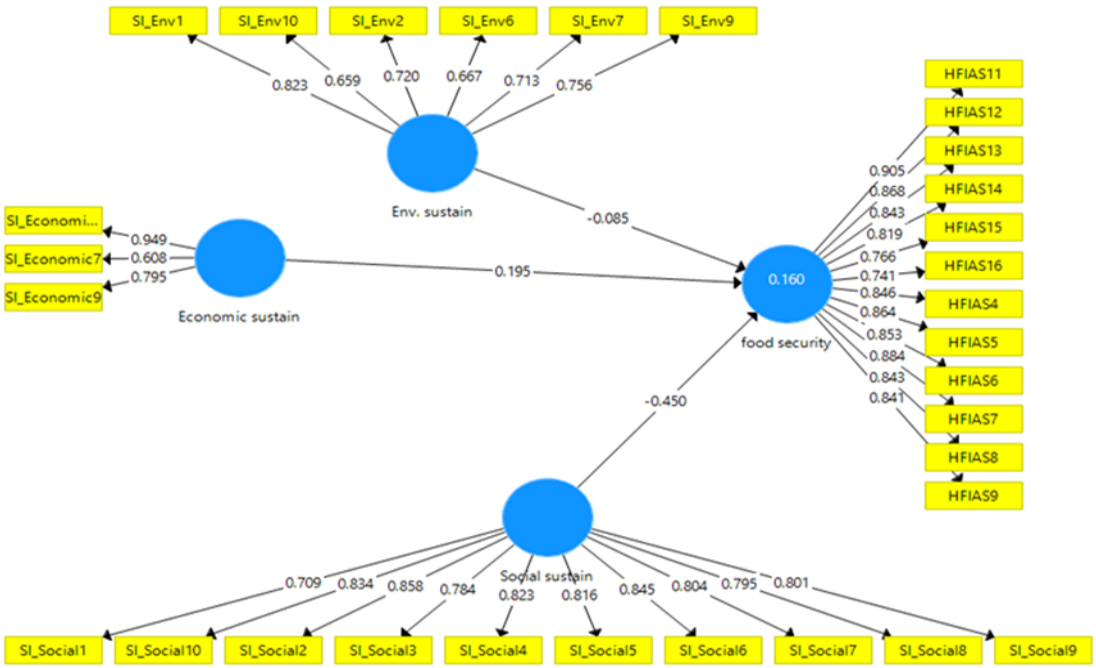

Figure 1: Algorithm results showing the relationship between the constructs with indicator loadings and path coefficients of the structural model.

Table 2: Summary of Results

	Original Sample (O)	Sample Mean (M)	STDEV (|O/STDEV|)	T-Stats	P Values	R^2	f^2	Q^2
SI Econs -> HFIAS	0.195	0.168	0.124	1.574	0.116*		0.160	0.021 0.093
SI Env -> HFIAS	-0.085	-0.120	0.127	0.673	0.502		0.160	0.003 0.093
SI Soc -> HFIAS	-0.450	-0.411	0.164	2.751	0.006*		0.160	0.063 0.093

Source: Field survey (2020) *sig value

Constraints faced by fish farmers

The ranking of the constraints faced by fish farmers was shown in Table 3. This shows that the constraints faced by fish farmers is moderate to high. Using the median score, the result revealed that high cost of feed (10.0) and poor pricing by customers (10.0) were the major constraints faced by fish farmers and the least faced challenge were disease outbreak, high cost of transportation,post-harvest losses and inadequate water supply (4.00). The results of the median and mean affirm the result of the mean rank. The model specification revealed that the model is significant in ranking the constraints of fish farmers with a chi-square value of 544.989. The Kendall's W report that there is a .322 level of agreement by fish farmers concerning constraints they faced. The results of the study agrees with Omitoyin and Adejoke,(2019), Igoche *et al*., (2019) and Olaoye *et al*., (2013) who also found that high cost of feed was the major constraint faced by fish farmers in Nigeria.

Table 3: Constraints faced by fish farmers

Variables	Mean	S.D	Mean rank	Median	Rank
High cost of feed	8.73	2.39	13.05	10.00	1st
Scarcity of quality fish seeds	7.30	3.06	11.19	8.00	3rd
Inadequate water supply	4.42	3.29	6.86	4.00	12th
Inadequate capital	7.08	3.38	10.56	9.00	4rd
Flooding	4.65	3.02	7.30	5.00	11th
Disease outbreak	4.02	2.69	6.33	4.00	15th
High cost of transportation	4.13	2.79	6.63	4.00	13th
Post-harvest losses	4.19	2.96	6.53	4.00	14th
Poor storage facilities	6.19	3.58	9.16	8.00	6th
Prompt marketing after harvest	5.27	3.50	7.91	5.00	9th
Lack of technical know-how	5.33	3.23	7.93	6.00	8th
High cost of labour	4.99	3.35	7.66	5.00	10th
Theft	5.60	3.38	8.79	6.00	7th
Limited land space	6.78	3.29	10.19	8.00	5th
Poor pricing by customers	8.43	2.88	12.80	10.00	2nd

n= 149 X^2= 544.989 Asymp. Sig = .000 Kendall's W= .322

Conclusion and Recommendation

In conclusion, the research which sought to examine how food security can be achieved through sustainable aquaculture has been able to expand the understanding on the relationship that exist between the variables of sustainability (economic, environmental, social) and food security within the aquaculture sector of the food industry in Osun state, Nigeria. The direct relationships found between economic and social sustainability showed that they are strong predictors or determinants of food security. It is therefore concluded that, for fish farmers to achieve food security, there is the need for an improved economic and social sustainability practices. Also, an innovative, socially and economically well balanced system that will optimize production efficiency. Further, the study found no association between socio-economic characteristics of fish farmers and food security and more so, the high cost of feed is a major constraint for fish farming in Osun state. The recommendation from the study is that the government of Nigeria should empower extension agents to educate farmers on the need to improve on social and economic sustainability to safeguard food security. Also, fish farmers are encouraged to do self-learning from other farmers on best practices to achieved sustainability and last but not least, the cost of feed should be subsided by the government to make it accessible to farmers.

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