COMPARATIVE ANALYSIS OF TECHNICAL EFFICIENCY IN INTEGRATED AND NON-INTEGRATED AQUACULTURE FARMS IN RIVERS STATE, NIGERIA

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Abstract: The study compared technical efficiency in integrated and non-integrated aquaculture farms in Rivers State, Nigeria. The integrated aquaculture farms produced feeds and fingerlings without processing the fish while the non-integrated aquaculture farms buy feeds and fingerlings from independent suppliers. Purposive sampling was used for the 37 integrated aquaculture farms while multi-stage technique was used to sample the 119 non-integrated aquaculture farms. Data were analyzed using descriptive statistics, annual depreciation and stochastic frontier model. The two production systems of integrated and non-integrated aquaculture production were efficient given the least efficiency of a farm as 0.50. The integrated aquaculture farms had 62% of the farms with indices of 0.96-1.00 as efficient, while the non-integrated aquaculture farms had 61% of the farms with indices of 0.93-1.00 as efficient; meaning that the integrated aquaculture production is a more efficient system of natural resource management in aquaculture production. However, for this rate of efficiency to be sustained; current technical and price information is needed by the integrated aquaculture farmers which can only be disseminated by qualified and adequate extension workers.

Keywords: Aquaculture production, stochastic frontier production model, technical efficiency

Introduction

Rivers State is a coastal state located in the Niger River Delta of Southern Nigeria and therefore has great potential for sustainable aquaculture development (Anyanwu *et al.*, 2007). The aquaculture farmers may allocate the resources correctly but obtain a sub-optimal output relative to the benchmark (Kelly, 1977). This inefficiency in the use of resources results in the continuous drop in the output of fish even when more quantity of the inputs has been combined. For instance, according to Olasunkanmi and Yusuf (2014) fingerlings and feeds were estimated to be underutilized (31.6%) and over utilized (1.1%) respectively, of the total inputs used in production even when the quantity of fingerlings used was more than that of the feeds. When the resources are inefficient, adjustment needs to be made in the use of factors of production in optimal direction. In case the resources are efficient, the only way of increasing production would be the use of modern inputs and improved technology of production (Singh, 1975). Efficient aquaculture firms are those operating on the production frontier, while the inefficient aquaculture firms are those operating below the frontier (Aigner *et al.*, 1977). It is possible for resources to be allocated optimally, yet the actual realized output may be below potentially expected output (Kelly, 1977). This problem may occur through the use of some inferior techniques or through technical inefficiency and may also occur as a result of the free hand given to the decision maker in selecting and implementing his course of action (Bamiro *et al.*, 2006). This results in low profit among the aquaculture farmers.

In Rivers State, according to Onoja and Achike (2011) the mean efficiency of the farms was 71% which is high given the least efficiency of a farm as 50% (Ebong, 2005). Yet significant inefficiency were recorded in farm area and water used. For the variables that were efficient such as fingerlings, labour, and feed, it was concluded that the productivity could be enhanced by purchasing high quality fingerlings, training existing staff or employing more skilled labour, and also the utilization of capital on high quality feeds respectively. In Nigeria, the output of aquaculture is inadequate and this may not be unconnected with the low efficiency of the aquaculture farms (Onoja and Achike, 2011). Between the periods (1990-2002), the domestic fish production from the artisanal sub-sector of fishery was 1,517,458 million tons against 619,705 tons from the aquaculture subsector (Akinrotimi *et al.*, 2011). Increasing aquaculture production requires the use of quality and efficient resources. According to Oladejo (2009) the resources used in aquaculture production are pond, fingerlings, fertilizer, land, water, feeds, and shovels. Others include fishing nets, veterinary services and drugs. To support this, Ugwumba (2010) emphasized that pond size, stock size, fingerlings, labour, lime, fertilizer, depreciation cost, feeds, and water are resources or inputs used in aquaculture production.

Resource use efficiency is critical to aquaculture production (Olasunkanmi and Yusuf, 2014). According to Olayide and Heady (2006) resource use efficiency is defined as the index of the ratio of the value of total farm output to the value of the total input used in the production. In aquaculture production, an efficient method of production is that which utilizes the least quantity of resources in order to produce a given quantity of output (Penda *et al.*, 2013). Efficiency is achieved by maximizing output from a given set of resources required for producing a given output (Ebong, 2007). Besides, efficiency is a measure of the producer performance, which is very often useful for policy purposes (Ajibefun and Daramola, 2000). Furthermore, in neoclassical economics, efficiency refers to making the optimum use of a given set of resources for a given set of prices and output markets (Bamiro *et al.*, 2006). Growth in aquaculture production can occur either by moving from a less efficient to a more efficient use of resources or by increasing productivity of resources so that more output can be obtained from a given level of resources.

Different types of efficiency exist namely: economic, technical, allocative, marketing and managerial efficiency (Battese and Coelli, 1995). For the purpose of agricultural production, Farrell (1957) used three types of efficiency namely: technical, allocative, and economic efficiency; to measure efficiency. Technical efficiency is the maximization of the ratio of output to input, given a range of alternative technologies available without taking into consideration the prices (Arene and Okpukpara, 2006). Allocative efficiency (price efficiency) refers to the adjustment of inputs and outputs to reflect relative prices (price efficiency) under a given technology (Ellis, 1988). It can also be defined as the willingness and ability of an economic unit to equate its specific Marginal Value Product (MVP) to its Marginal Cost (MC) (Kalirajan and Shand, 1999). Economic efficiency is a term applied to the concept of the overall efficiency with allocative and technical efficiency forming its component parts. This is defined as the ability of a firm to produce a specific maximum level of output at minimum cost in order to maximize profit under a given level of technology. It is important to note that resources combined; great or small must be used to produce the same amount of physical product (Arene and Okpukpara, 2006).

The measurement of any productive efficiency is grouped into non-parametric frontiers and parametric frontiers. Non-parametric frontiers do not impose a functional form on the production function and do not make assumptions about the error term. These have used linear programming approaches. The most popular non-parametric approach has been the Data Envelopment Analysis (DEA). The parametric frontier approaches impose a functional form on the production function and make assumptions about the data. The most common functional forms include the Cobb-Douglas, constant elasticity of substitution and translog production functions. Another distinction is between deterministic and stochastic frontiers. The deterministic frontiers assume that all the deviations from the frontier are as a result of the firms' inefficiency. The stochastic frontiers on the other hand assume that part of the deviation from the frontier is due to random events (reflecting measurement errors and statistical noise) and part is due to firm specific inefficiency (Forsund *et al.*, 1980; Battese, 1992; Coelli *et al.*, 1998).

According to Kalirajan (1981) variables such as level of education, age, farming experience, frequency of contact with extension agent, gender of the farmer and household size may affect efficiency. These factors have a negative relationship with technical inefficiency.

There are four main conceptual sources of technical and economic inefficiency namely: failure to minimize the physical input used, failing to use the least cost combination of inputs, operating at the wrong point on the short run average cost curve and long run average cost curve (Hensher, 2001).

Thus, when resources are sustainably managed in aquaculture production, the resources used (fingerlings and feeds) can be replenished easily and their long-term availability assured. This strategy lower costs and brings about higher profits (Bamiro *et al.*, 2006). The profits are realized because the resources used are allocated optimally. There is therefore the need for the understanding of the use of technical efficiency in integrated and non-integrated aquaculture farms in Rivers State, Nigeria; as it applies to fingerling and feed production as well as processing of fish using annual depreciation and stochastic frontier production.

Materials and Methods

The study was conducted in Rivers State which is located in the South-East; Geopolitical zone of Nigeria. Its geographical coordinates are 4º 47' 22" North and 6º 59' 55" East. The estimated total area is about 11,077 km^2 with a population of 5,185,400 (National Population Commission, 2006). There are 23 Local Government Areas in Rivers State. The major ethnic groupings in the State are Ikwerre, Ibani, Opobo, Okrika and Kalabari, Etche, Ogba, Ogoni and Engenni. While the major languages spoken are Igbo, Ikwerre, Kalabari and Khana. The geomorphology of the State shows that the soil types are formed from the Coastal Plain Sand (Ayolagha and Onuegbu, 2002). The genesis of the soils have resulted from cycles of soil formation which alternated with cycles of erosion in the mid tertiary to Holcene era in Nigeria and deposited by receding water during the Miocene to Pleistocene age (Ojanuga *et al.*, 1981). The study area lies in the zone of humid tropical climate which has two major seasons- the wet season and dry season. The wet season extends from March to October and dry season extends from November to February. The State falls in the transitional zone of climate in Koppen's climatic classification scheme. The monthly rainfall in the study area is almost predictable and follows a temporal sequence of increase toward July and August before decreasing in the dry season months of November to February. Rainfall in the State exhibits a double maxima regime, with peaks in July and September and a little dry season in the month of August. The mean annual rainfall is approximately 2,500 mm (Ayolagha and Onuegbu, 2002).

The prevailing winds from South-West and South-East direction during the rainy season while it comes from the North East during the dry season when the dusting wind bearing the desert sand (Harmattan) causes haze and cloud cover (Ayolagha and Onuegbu, 2002).

Average wind speed of 2.7 m/s in a predominantly South-West (SW) direction was recorded. The mean daily minimum and maximum temperatures are 20 – 23ºC and 28 – 33ºC, respectively (Ayolagha and Onuegbu, 2002). The relative humidity is high throughout the year. It generally decreases from morning to evening daily. This variation is greater during the dry season than in the wet season. The mean monthly relative humidity is 79-85% (Benson and Odinwa, 2010). The State is located in the high rain forest area. However, the primary forest in most of the area had been reduced to secondary forest, due to farming.

The study was based on the list collected from the Rivers State Agricultural Development Programme, Fishery Unit, Port Harcourt, which classified the aquaculture farms into integrated and non-integrated (Dobashi *et al.*, 1999).There were 37 integrated and 357 non-integrated aquaculture farms in the study area. In the study area, the integrated aquaculture farms majorly produced feeds and fingerlings without processing the fish (drying); the farms do not use the fish smoking kiln or fire wood for drying. The non-integrated aquaculture farms buy feeds and fingerlings from independent suppliers. The population of the study comprises all the 37 integrated and 357 non-integrated aquaculture farms in Rivers State. All the 37 integrated aquaculture farms in the State were used for the study due to the low number of the farms. The multi-stage sampling was adopted for the non-integrated aquaculture farms because of the high number of the farms. The first stage involved the purposive use of the three (3) Agricultural Development Programme Zones in Rivers State, namely; Nchia, Degema and Ahoada. The purposive sampling was adopted for the selection of the zones because of the low number involved in the study. In the second stage, a purposive sampling of 7 out of the 9 area offices of the Agricultural Development Programme in Rivers State, namely; Ahoada East, Bori, Degema, Eleme, Ikwerre, Okrika, and Rumuduomaya (Bonny and Port Harcourt did not possess list of fish culture farms). The purposive sampling method was also adopted for the area office because of the low number that exists in the State. In the third stage, a purposive selection of 10 functional blocks out of the 48 blocks that exist in Rivers State. The purposive sampling was adopted for the blocks because of the low number of the functional blocks that were in operation in the State. In the fourth stage, the purposive sampling of 27 functional cells out of 282 cells that exist in the State was carried out. The purposive sampling was also adopted because of the low number of functional cells that were in the State. Finally, the simple random sampling technique was employed; thus bringing the number to 119 non-integrated aquaculture farms. This resulted in a total sample size of 156 respondents (37 integrated and 119 non-integrated) aquaculture farms for the study.

Various analytical techniques were used for the analysis of the data obtained through the questionnaires. In comparing the technical efficiency of integrated and non-integrated aquaculture farms; annual depreciation and stochastic frontier production function were used for the analysis. Annual depreciation value of each farm asset was calculated using the straight-line method (Ebong, 2007). Thus:

AD= (OC–SV)/(UL) Eqn. 1

Where: AD=Annual depreciation; OC=Original cost at the time of purchase; SV=Salvage Value; UL=Useful life

The use of annual depreciation becomes necessary in order to account for that part of a farm asset that has been used up during the production cycle of the fish. Ordinarily, it involves the spreading of the cost of an asset over its useful life. Besides, expected replacement cost for the fixed farm assets was used to account for inflation. This is necessary because the cost of most working capital items such as equipment and machinery tend to increase both in monetary and real terms with time. It is considered appropriate from a management and planning point of view to use expected replacement cost (Bamiro *et al.*, 2009).

The model specification

For this study the production technology specified by the Cobb-Douglas production function as follows was used:

$LnQ = b_o + b_1Ln\times_1 + b_2Ln\times_2 + b_3LnX_3 + b_4Ln\times_4 + b_5Ln\times_5 + b_6Ln\times_{6+} b_7 Ln\times_7 + b_8Ln\times_8 + b_9Ln\times_9 + V_i - U_i$ Eqn. 2

Where: Q = the value of fish output in naira; $\times_1$ = the pond size measured in square metres; $\times_2$ = the stock size (total number of fingerlings stocked by the farmer); $\times_3$ = the cost of fingerlings measured in naira; $\times_4$ = is the quantity of labour used in aquaculture production in man days; $\times_5$ = the cost of fertilizer in naira; $\times_6$ = the cost of lime in naira; $\times_7$ = the depreciation cost on fixed inputs of the farm in naira; $\times_8$ = cost of feed in naira; $\times_9$ = quantity of water used in litres; V_i = random error; U_i = technical efficiency

The technical inefficiency model is also specified by the equation:

$TE = \partial_0+\partial_1 z_1 + \partial_2 z_2 + \partial_3 z_3 + \partial_4 z_4 +\partial_5 z_5 + \partial_6 z_6 + e_1$ Eqn. 3

Where: TE = technical efficiency of the farms; Z_1 = age of the farmers (years); Z_2 = experience in aquaculture farming in years; Z_3 = level of education of the farmers; Z_4 = frequency of contact with extension agent; Z_5 = gender of the farmers (Male = 1) (Female = 0); Z_6 = household size; e_1 = error term assumed to be randomly and normally distributed; ∂_0, ∂_1, ∂_2, ------ ∂_6 are the parameters to be estimated using the computer software frontier version 4.1c (Coelli and Battese, 1995).

Results and Discussion

Comparison of the technical efficiency between integrated aquaculture farms and non-integrated aquaculture farms

In order to compare the differences between the integrated and the non-integrated aquaculture farms, the results obtained from the related statistical tests and the estimated parameters were examined, the estimated determinants of efficiency compared, and the ways in which the technical efficiency of the integrated aquaculture farms and the non-integrated aquaculture farms were distributed was also considered. The analysis was done based on Equations (2) and (3) above, using the variables in Equation (2) for the estimated parameters and Equation (3) for the estimated determinants of efficiency. It was then subjected to the parameters of the stochastic frontier production were estimated using the maximum likelihood, using the computer programme FRONTIER version 4.1c.

The related statistical tests obtained from the analysis of the integrated aquaculture farms showed that the sigma-square (δ^2) has the value of 0.00173 which was highly significant at 1% level of probability. This means that the variation that occurs in the technical efficiency of the integrated aquaculture farms is caused by 0.173% of the error term (measurement error). The estimate of gamma (γ) is 0.99999 which was also significant at 1% level of probability. This means that 100% of the variation in output among the integrated aquaculture farms is due to differences in technical efficiency. This justifies the use of the stochastic frontier production function. Conversely, the related statistical tests obtained from the analysis of the non-integrated aquaculture farms revealed that sigma square (δ^2) has the value of 0.00052 which was highly significant at 1% level of probability. This indicates that the variation that occurs in the technical efficiency of the non-integrated aquaculture farms is caused by 0.052% of the error term (measurement error). The estimate of gamma (γ) was also highly significant at the 1% level of probability. This justifies the use of the stochastic frontier production function. In summary, the result of the integrated aquaculture farms and the non-integrated aquaculture farms revealed that the two farms differ greatly in terms of the related statistical tests in that the sigma-square (δ^2) value of the integrated aquaculture farms is higher than that of the non-integrated aquaculture farms. This may be attributed to the fact that the operators of the integrated aquaculture farms committed a lot of measurement errors which must have caused the difference.

The estimate of gamma (γ) for the integrated aquaculture farms and the non-integrated aquaculture farms is the same since the two production systems indicate that 100% in output is due to differences in technical efficiency. However, the highly significant level of probability of 1% for the two production systems in their sigma-square (δ^2) and gamma (γ) means that the variables used in the production of fish in the study area were very important.

In Table 1, the estimated parameters of the stochastic frontier production function namely; pond size, stock size, fingerlings, labour, fertilizer, lime, depreciation cost, feed and water for the integrated aquaculture farms were as analyzed. The estimates for pond size, stock size, feed, and depreciation cost have positive coefficients of 0.45936, 0.10726, 0.04134 and 0.01093, respectively. Pond size, feed, and depreciation cost were all significant at 1% while stock size was not significant. The fact that these variables (pond size, stock size, feed, and depreciation cost) have positive coefficients showed that they have direct relationship in the yield of fish among the integrated aquaculture farms in the study area. Pond size, feed and depreciation cost were highly significant at 1% level of probability. This revealed that they exerted significant influence in the production of fish, while stock size was not significant. Fertilizer, lime, water, labour, and fingerling have negative coefficients of -0.12236, -0.19756, -0.34723, -0.72177, respectively. Fertilizer, lime, labour and fingerling were all significant at 1% level of probability respectively while water was not significant. The estimated parameters of the stochastic frontier production function namely; pond size, stock size, fingerlings, labour, fertilizer, lime, depreciation cost, feed and water for the non-integrated aquaculture farms were also analyzed.

Table 1: Maximum likelihood estimates (MLE) for parameters of the stochastic frontier production function of integrated aquaculture farms

Variables	Parameters	Coefficient	T-ratio
Stochastic Frontier			
Constant	β_0	0.78733	7.72367***
Pond size ($X_{1)}$	β_1	0.45936	4.42757***
Stock size ((X_2)	β_2	0.10726	0.87995
Fingerlings(X_3)	β_3	-0.75412	-8.77290***
Labour (X_4)	β_4	-0.72177	-9.37246***
Fertilizer (X_5)	β_5	-0.12236	-1.17599
Lime (X_6)	β_6	-0.19756	-1.97338*
Depreciation cost(X_7)	β_7	0.01093	10.79695***
Feed (X_8)	β_8	0.04134	4.62654***
Water ((X_9)	β_9	-0.34723	-2.89311***
Diagnostic Statistics			
Sigma-square	δ^2	0.00173	3.84888***
Gamma	γ	0.99999	10.72575***
Log (likelihood)		0.79911	
LR test		0.99797	
Sample size		37	

Source: Field data (2017); *****Significant at 1%; ** at 5%; *10%

Table 2: Maximum likelihood estimates (MLE) for parameters of the stochastic frontier production function of non-integrated aquaculture farms

Variables	Parameters	Coefficients	T-ratios
Stochastic Frontier			
Constant	β_0	0.55096	0.72316
Pond size (X_1)	β_1	-0.02191	-0.89393
Stock size ((X_2)	β_2	0.10464	3.30042***
Fingerlings(X_3)	β_3	-0.01915	-0.88779
Labour (X_4)	β_4	0.01345	0.33289
Fertilizer (X_5)	β_5	0.01984	0.56529
Lime (X_6)	β_6	-0.00441	-0.08833
Depreciation cost(X_7)	β_7	-0.00727	-0.58200
Feed (X_8)	β_8	0.04140	1.05986
Water ((X_9)	β_9	0.01458	0.60267
Diagnostic Statistics			
Sigma-square	δ^2	0.00052	6.63927***
Gamma	γ	0.99998	9.13076***
Log (likelihood)		0.28379	
LR test		0.92537	
Sample size		119	

Source: Field data (2017); **Significant at 1%; **at 5%; * 10%**

In Table 2, the estimated parameters of the stochastic frontier production function namely; pond size, stock size, fingerlings, labour, fertilizer, lime, depreciation cost, feed and water for the non-integrated aquaculture farms were also analyzed. The estimates of stock size, feed, fertilizer, water, and labour have positive coefficients of 0.10464, 0.04140, 0.01984, 0.01458 and 0.010464 and only stock size was significant at 1%, while feed, fertilizer, water, and labour were not significant, respectively. The fact that these variables (stock size, feed, fertilizer, water and labour) have positive coefficients showed that they have direct relationship in the yield of fish among the non-integrated aquaculture farms in the study area. Stock size being significant at the probability level of 1%; it means that the variable is very important in fish production among the non-integrated aquaculture farms in the study area. The estimates of lime, depreciation cost, fingerling, and pond size have negative coefficients of -0.00441, -0.00727, -0.01915, and -0.02191 and not significant at any of the levels of probability, respectively. In summary, among the variables used for the production of fish by the integrated aquaculture farms pond size, stock size, feed, and depreciation cost have positive coefficients. Pond size, feed, and depreciation cost were all significant at 1% while stock size was not significant. Fertilizer, lime, water, labour, and fingerling have negative coefficients. Fertilizer, lime, labour and fingerling were all significant at 1% while water was not significant. For the non-integrated aquaculture farms stock size, feed, fertilizer, water, and labour have positive coefficients that were not significant except stock size that was highly significant at 1% level of probability. Pond size, fingerling, lime, and depreciation cost have negative coefficients which were not significant at any of the levels of probability. In all, among the integrated aquaculture farms and the non-integrated aquaculture farms, stock size and feed were the only variables that have positive coefficients. This means that these variables have direct relationship in the yield and output of fish. Among the two variables, stock size was the only variable that was highly significant at the 1% level of probability. This means that stock size was a very important variable among the integrated aquaculture farms and the non-integrated aquaculture farms in the study area for the production of fish.

In order to estimate the determinants of inefficiency factors (age, experience of the fish farmers in years, education level, extension contact, gender and household size) considered in this study which were related to the socio-economic characteristics of the farmers in the study area in Table 3. The inefficiency factors or sources of inefficiency were examined by using the estimated δ-coefficient associated with the explanatory variables in the model of the inefficiency effect. A negative sign means that the variable increases technical efficiency and decreases inefficiency while a positive sign means that it decreases technical efficiency and increases inefficiency. The estimated determinants of inefficiency of the integrated aquaculture farms in the study area were as follows: farming experience, education, and household size have negative coefficients and highly significant at the 1% level of probability.

This is an indication that farming experience, education and household size increases technical efficiency and decreases inefficiency. These factors have a direct relationship with the yield and output of fish production in the study area among the integrated aquaculture farms. These variables being highly significant at the 1% level of probability; it means that these factors are very important variables that determine the productivity and production of fish. An increase in any of the factors increases the output of fish. The other variables such as age, extension contact, and gender are highly significant at the 1% level of probability but have positive coefficients. The positive coefficients revealed that these variables decrease technical efficiency and increase inefficiency in the production of fish among the integrated aquaculture farms in the study area.

Table 3: Estimated determinants of efficiency in fish production in integrated aquaculture farms

Variables	Parameters	Coefficient	T-ratios
Constant	δ_0	-0.22237	-2.06987**
Age (Z_1)	δ_1	0.44887	2.89554***
Experience (Z_2)	δ_2	-0.11754	-67.57571***
Education (Z_3)	δ_3	-0.12204	-11.16537***
Extension contact (Z_4)	δ_4	0.18215	8.22050***
Gender (Z_5)	δ_5	0.01831	0.66527
Household size (Z_6)	δ_6	-0.06706	-9.21593***

Source: Field data (2017); ***** Significant at 1%; ** at 5%; * 10%**

Table 4: Estimated determinants of efficiency in fish production in non-integrated aquaculture farms

Variables	Parameters	Coefficients	T-ratios
Constant	δ_0	0.06991	2.31512**
Age (Z_1)	δ_1	-0.00259	-8.34868***
Experience (Z_2)	δ_2	-0.00020	-0.42878
Education (Z_3)	δ_3	-0.00417	-5.99881***
Extension contact (Z_4)	δ_4	0.00273	0.79563
Gender (Z_5)	δ_5	0.00426	0.51065
Household size (Z_6)	δ_6	-0.00197	-1.21732

Source: Field data (2017); *****Significant at 1%; ** at 5%; * at 10%**

In Table 4, the estimated determinants of inefficiency of the non-integrated aquaculture farms in the study area which have negative coefficients include farming experience, household size, age and education with -0.00020, -0.00197, -0.00259, and -0.00417, respectively.

This is an indication that these variables increase technical efficiency and decrease inefficiency. These factors have a direct relationship with the yield and output of fish production in the study area among the non-integrated aquaculture farms. Among these variables, age and education were highly significant at the 1% level of probability, meaning that they very important factors necessary in the production of fish in the study area. Farming experience and household size were not significant. The other variables such as extension contact and gender have positive coefficients with 0.00273 and 0.00426, respectively but not significant at any of the levels of probability. The positive coefficients revealed that these variables (extension contact and gender) decrease technical efficiency and increase inefficiency in the production of fish among the non-integrated aquaculture farms in the study area. In summary, farming experience, education, and household size have negative coefficients for the integrated aquaculture farms and the non-integrated aquaculture farms. With education as the only variable that was significant at the 1% level of probability. This is an indication that education is a very important variable in the production of fish. Education increases technical efficiency and decreases inefficiency among the integrated aquaculture farms and the non-integrated aquaculture farms in the study area.

In Table 5, the frequency distribution of technical efficiency of the integrated aquaculture farms in the study area shows that all the sampled farms were efficient in the use of their resources since a farmer is considered efficient from the index of 0.50 while 0.85 was the minimum efficiency.

Table 5: Distribution of technical efficiency of the integrated aquaculture farms

Technical Efficiency Range	Frequency	Percentage
0.85-0.90	1	2.70
0.91-0.95	13	35.14
0.96-1.00	23	62.16
Total	37	100.00
Mean Efficiency	0.96	
Minimum Efficiency	0.85	
Maximum Efficiency	0.99	

Source: Field data (2017); *****Significant at 1%; ** at 5%; * at 10%**

Table 6: Distribution of technical efficiency in fish production in non-integrated aquaculture farms

Technical Efficiency Range	Frequency	Percentage
0.85-0.88	1	0.84
0.89-0.92	45	37.82
0.93-0.96	62	52.10
0.97-1.00	11	9.24
Total	**119**	**100.00**
Mean Efficiency = 0.93		
Minimum Efficiency = 0.88		
Maximum Efficiency = 0.98		

The mean technical efficiency (0.96) for the farms is very high. This implied that on the average, some of the farms were able to obtain 96% potential output from a given mix of production inputs. In the short-run, there is hope that the remaining farms can increase output by 0.04% by adopting the techniques and technologies employed by the best farm. There exist a narrow gap between the "maximum" the most technically farm (0.99) and the "mean" farm (0.96).The farms had more than 62% indices of 0.96-1.00 (above the mean efficiency) and more than 37% indices of 0.85-0.95 (below the mean efficiency). The result revealed that more than 99% of the integrated aquaculture farms were efficient given the least efficiency of a farm as 0.50 (Ebong, 2005). In Table 6, the frequency distribution of technical efficiency of the non-integrated aquaculture farms in the study area revealed that all the sampled farms were efficient in the use of their resources since a farm is considered efficient from the indices of 0.50, while 0.88 was the minimum efficiency. The mean technical efficiency (0.93) for the farms is very high. This implied that on the average, the farms were able to obtain 93% potential output from a given mix of production inputs. In the short-run, there is hope that the farmers can increase output by 0.07% by adopting the techniques and technologies employed by the best farm. There exist a narrow gap between the "maximum" the most technically efficient farm (0.98) and the "mean" farm (0.93). The non-integrated aquaculture farms had more than 61% of the farms with indices of 0.93-1.00 (above the mean efficiency) and more than 38% of the aquaculture farms with indices of 0.88-0.92 (below the mean efficiency).

This result reveals that more than 99% of the non-integrated aquaculture farms were efficient given the least efficiency of a farm as 0.50 (Ebong, 2005). In summary, the two production systems of integrated and the non-integrated aquaculture farms differ in the minimum, mean and maximum efficiency which was in favour of the integrated aquaculture farms except the minimum efficiency (0.88) of the non-integrated aquaculture farms that was higher than that of the minimum efficiency (0.85) of the integrated culture farms. Besides, the integrated aquaculture farms had more than 62% of the farms with indices of 0.96-1.00 and more than 37% of the farms with the indices of 0.85-0.95. The non-integrated aquaculture farms had more than 61% of the farms with indices of 0.93-1.00 and more than 38% of the farms with indices of 0.88-0.92. However, the two production systems had more than 99% of their farms being efficient. This may not be far from the fact that the few extension workers available in the study area concentrated more on the non-integrated aquaculture farmers than the integrated aquaculture farmers since most of the operators of the integrated aquaculture farms were graduates of fishery who decided to combine their professional practice alongside their official jobs. Besides, they attended conferences, seminars and trainings which enhance their production and productivity of fish in the study area.

Conclusion and Recommendations

The two production systems of integrated and non-integrated aquaculture production were efficient. The integrated aquaculture farms had 62% of the farms with indices of 0.96-1.00 as efficient, while the non-integrated aquaculture farms had 61% of the farms with indices of 0.93-1.00 as efficient; meaning that the integrated aquaculture farms were more efficient than the non-integrated aquaculture farms in replenishing the fingerlings and feeds as resources used in aquaculture production. However, for this rate of efficiency to be sustained; current technical and price information is needed by the aquaculture farmers which can be disseminated by qualified and adequate extension workers. Besides, aquaculture farms that can produce feeds and fingerlings should be encouraged to do so.

Conflict of Interest

Authors have declared that there is no conflict of interest reported in this work.

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