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Productivity and constraints analysis of commercial tilapia farms in Ghana

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ABSTRACT

This study examined the factors affecting productivity and constraints of commercial tilapia farms in the Dangme West District of the Greater Accra Region of Ghana. Primary data was obtained from 41 tilapia farms using multistage sampling. The data was then analyzed using descriptive statistics and regression analysis, and the agreements within ranked constraints was assessed. The empirical results revealed that the tilapia farmers in the three towns from which the data were collected, namely Achavanya, Kajanya and Dormeliam, produced a mean output of 74 kg per cage (6 m × 6 m × 3 m) as a productivity measure. Productivity of the cage farms were found to be positively affected by quantity of seed, feed and education level of managers; and negatively affected by cage size, labour and year of experience. Furthermore, the major constraints identified were high cost of inputs, lack of access to feed and credits and in adequate extension services and stealing of fish. The study suggests the need for supporting policies on inputs such as fingerlings and feed, and also providing education i.e. training to tilapia farmers. Efforts should also be made by financial institutions and NGOs to make credit easily available and accessible to commercial fish farmers so that they could cope with high cost of inputs.

Introduction

Fishing is a major economic activity along the 245-mile (550 km) coastline of Ghana, around the lakes and rivers such as the Volta and Bosomtwe. The fisheries sector employs about 135,000 fishers in the marine subsector alone, and indirectly supports the livelihoods of 2.2 million people, about a tenth of Ghana's population (MoFA, 2011).

Large populations of some regions in Ghana, rely on fishing for their livelihood and sustenance but ecological changes have altered this (Agbenyo, 2009). The growth in the fishing sector declined especially from the 1970s through to the 1980s as economic conditions deteriorated (Bank of Ghana Research Department, 2008). This reduction in growth was mainly due to the damming of the Volta River and has driven many artisanal fishermen into aquaculture.

According to the Ghana Statistical Service (2011), the fisheries sector provides about 7.3% of Ghana's agricultural sector's contribution to GDP. The fishing sector also supplies over 20% of the total protein intake in Ghana (Jacquet & Alder, 2006).

Tilapia has always been one of the biggest contributors to total fish harvest in Ghana. Fish production reached 9,000 tons in 2009, mainly with tilapia production (MoFA, 2009). Tilapia is also a highly sought after delicacy in Ghana

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(Asmah, 2008) and supplements the protein requirement of Ghanaians. However, the high price of tilapia has put the commodity out of the reach of the average Ghanaian (MoFEP, 2011). The price-hikes in tilapia is mainly due to reduced tilapia stock in the Volta Lake as a result of damming (Agbenyo, 2009). The desire to harness water resources for energy production led to the construction of two hydroelectric plants on the Volta Lake. Damming of the Volta has ruined somewhat the ecology of the lake and reduced the availability of fish in large commercial quantities (AEDC, 2009). However, there might be other constraints contributing to the reduced production.

The estimated annual domestic fish production in Ghana reached 444,000 tons as at the end of 2011. This is broken down into 291,000 tons, 150,000 tons and 3000 tons from marine capture, inland capture and aquaculture farming respectively (MoFA, 2011). Marine and inland capture are the dominant sources of fish supply, however, supply from capture fisheries in general, has rather seen a declining trend from 450,000 MT in 1998 to about 410,000 MT in 2010 as noted by Onumah, Brummer, and Horstgen-Schwark (2010). In this regard, aquaculture is considered as the only way of salvaging the situation. However, the contribution of aquaculture to national fish supply is still inadequate. Fish production from aquaculture was only 38,547 MT in 2014, and increased by about 20%–46,250 MT in 2015.

Aquaculture in Ghana involves the rearing of fish in cage and earth ponds and has been especially useful in tilapia production. The use of cages in rearing fish on the Volta Lake increased general production levels of tilapia by a huge margin. This has potential to create economic opportunities for small-scale investors, fishers and entrepreneurs (WRI/CSIR, 2010).

Increasing aquaculture production will be a very important step towards achieving food security and reducing fish import.

Onumah et al. (2010) noted that Ghana's fish requirement has seen imports increase by 10–60% in 12 months as local fish producers continue struggling to meet demand, amidst declining fish stock. Data available to the Business and Financial Time indicates that as at the end of 2014, fish consumption had reached a million metric tonnes, which is an increment of over 10% from the 900,000 MT consumed in 2013, with only 400,000 MT supplied from the country's catches at sea and the rest through aquaculture production and direct imports at a cost of US$200 million.

There are some constraints to the productivity of tilapia farms, and fish farms in general; constraints that are central to efficient production and high productivity. Some of these constraints are likely to be, lack of tilapia fingerlings, lack of quality fish feed, and high cost of inputs.

In recent years, the contribution of aquaculture to global fisheries has increased (FAO, 2016). Aquaculture production increased from about 0.5 million MT in 1950 to 72 million MT of world production in 2014 (FAO, 2016). On the average, aquaculture, with an annual growth rate of 7–8%, outpaced the world population growth rate and is the highest growth rate among the food production sectors. Total world production of fish for food is about 140 MT, out of which aquaculture supplies nearly half (FAO, 2016).

The present study was carried out to assess the level of tilapia production by commercial tilapia farms, estimate the productivity, identify the factors influencing the productivity of commercial tilapia farms, and to identify and rank the constraints of commercial tilapia farming in the study area.

Materials and Methods

The Study Area

The study was undertaken in three towns: Achavanya, Kajanya and Dormeliam in the Dangme West District of the Greater Accra Region of Ghana. The study area occupies a land area of 1,442 square km, which makes it the largest in the Greater Accra Region. The maximum temperature in the area is 40 °C during the dry season (November–March). There is a characteristic low and erratic rainfall pattern in the district, with a mean annual rainfall of 762.5–1220 cm. The soils are predominantly black-clayey and support the cultivation of some major crops such as cassava, cocoyam, maize and mango. The Dangme West District shares boundaries with North Tongu District to the North East, Yilo and Manya Krobo Districts to the North West, Akwapim North District to the West, Tema Metropolitan to the South West, Dangme East District to the East and the Gulf of Guinea to the South (MoFEP, 2011). The District has a 37 km coastline and a 22 km stretch of the Lower Volta River running through and along the Northern to Eastern boundaries of Ghana, where a lot of tilapia farms exist (Figure 1).

Sampling

Structured questionnaires with open and closed-ended questions, and interview schedules were used to solicit primary data from 41 fish farms. A two-stage sampling technique was adopted in this study. The first stage involved the purposive selection of the tilapia producing areas in the Dangme West District. The second stage involved simple random sampling of 41 commercial tilapia farms from the three towns: 14 from Dormeliam, 12 from Achavanya and 15 from Kajanya. Prior to the data collection, a pilot test was carried out to validate the suitability and appropriateness of the questions and expected responses from the respondents. Revision of the questionnaire in light of errors detected during the pilot survey was subsequently carried out.

Methods of Analysis

Tilapia Production

Descriptive statistics, cross tabulations, summary statistics of means, frequencies and percentages were then used to show the production levels of the farms. The productivity of the 41 tilapia farms was calculated using equation (1):

$$Y_p = \frac{O_y}{C_a} \tag{1}$$

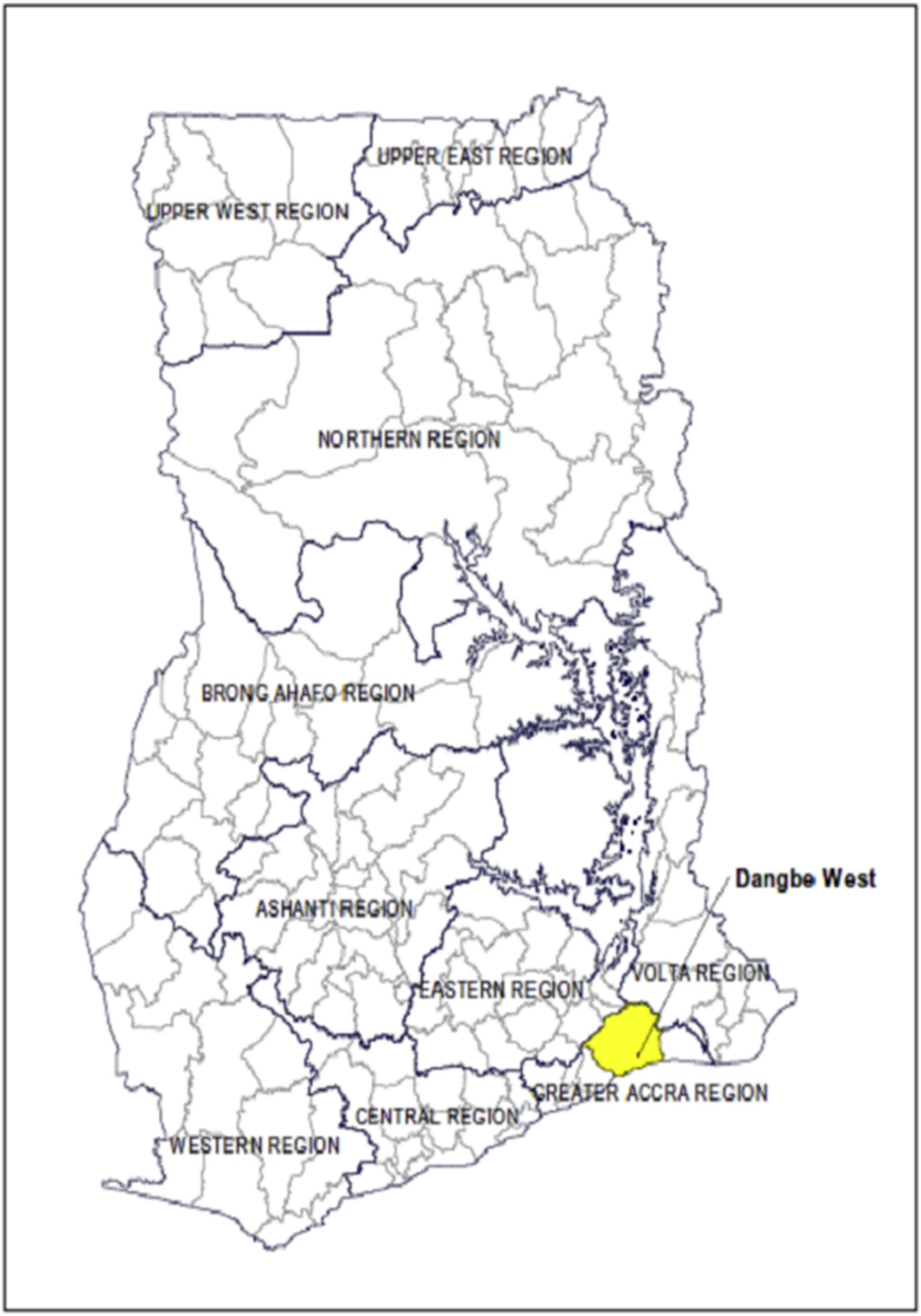

Figure 1 Map of Ghana showing Dangme West District

where Y_P denotes productivity, O_y denotes output in kg, and C_a denotes total cage volume in cubic meters. Cages visited on all the farms had equal depth of 3 m. Further, descriptive statistics were used to show means and standard deviations productivities of the tilapia farms categorized based on sizes.

Determining Factors of Productivity of the Tilapia Farms

The ordinary Least Squares regression model was used to analyze the factors that influence the productivity of tilapia farms in the study area. In this respect, a modified Cobb Douglas production model was employed as specified in equation (2):

$$In(Y_{pi}) = \beta_0 + \beta_1 InX_{1i} + \beta_2 InX_{2i} + \beta_3 InX_{3i} + \beta_4 \text{ In } X_{4i} + \beta_5 X_{5i} + \beta_6 X_{6i} + \beta_7 X_{7i} + \beta_8 X_{8i} + \beta_9 X_{9i} + \varepsilon_i \quad (2)$$

where, Y_{pi} denotes Productivity of the farm (output in kg/cage), X_1 – Fingerlings in kg, X_2 – Feed in kg, X_3 – Cage size (m^2) in cubic meters, X_4 – Labour in person-days, X_5 – Marital status (dummy variable: married = 1, 0 Otherwise), X_6 – Experience in years, X_7 – Age, X_8 – Extension in number of extension visits, X_9 – Education in years of formal education of the *i*th farm; β_1, β_2, ..., β_9 are parameters to be estimated,ε_i denotes the error term and *In* is natural logarithm operator.

Constraint Analysis

The main goal of the constraint analysis was to identify important challenges faced by tilapia farmers. Some production constraints were identified from existing literature and from pre-testing, and these were included in the questionnaire and presented to the farm managers to rank in order of importance. The productive constraints of the farmers were collected and the mean ranks were computed with the aid of SPSS. The constraint with the least mean rank is ranked as the most pressing whiles the one with the highest mean rank is ranked as the least pressing constraint, in that order. The Kendall's Coefficient of Concordance was then used to assess the agreement among the rankings to determine the extent to which the farmers' rankings agree with each other.

Kendall's Coefficient of Concordance (W) is given by:

$$W = \frac{12\left[\sum T^2 - (\sum T)^2 / n\right]}{nm^2(n^2-1)} \quad (3)$$

where T denotes sum of ranks for each constraint, m denotes number of fish farms sampled, and n denotes number of constraints being ranked. The value of the Coefficient of Concordance (W) was to be interpreted as follows; W = 0 means there is no agreement in the assessments and as such the variables presented do not collectively affect productivity. Hence, the following hypothesis was postulated:

H_o: W = 0, there is no agreement among the constraints ranked by the fish farmers.

H_a: W ≠ 0, there is agreement among the ranked constraints.

Results and Discussion

Socio-economic Characteristics of Respondents

Among the three towns in the Dangme West District considered for the study, the highest number of respondents interviewed was from Kajanya (15) making up 36.6% with the least number of respondents from Achavanya (12) making up 29.3% of the total number. The remaining 14 respondent farmers (34.1%) were from Dormeliam.

The field data showed that out of the 41 farms visited, all the farm managers were male (100%). This is the case because the requirements of the job are very demanding and burdening, which may not be suitable for women. Out of the 41 respondents interviewed, 32 were married representing 78.0% and 9 (22.0%) single.

The majority of farmers (i.e. 22 representing 53.7%) had attained middle school level, 12 attained primary education (29.3%), 3 Senior High school level (7.3%) and 4 of them had no formal education at all. No respondent had any form of tertiary education. The educational level among the respondents is quite low and this may have affected the adoption of best farm practices or new tilapia farming technologies.

The field data also revealed that there are at least four major ethnic groups in the study area. Of the 41 respondents interviewed, 25 were Ga-Adangme, 14 were Ewe, 1 was Akan, and another Ga, representing 61.0%, 34.1%, 2.4%, and 2.4% respectively. The majority of respondents were Ga-Adangme.

The farm managers had varying years of experience. The majority of them (27 or 65.8%) had 1–4 years of experience in the tilapia aquaculture business. Those with experience between 5 and 8 years were 13 (31.7%) while only one person had more than 8 years experience in the industry.

Age of farm manager, family size, and the number of adults and children that make up the family size were also solicited. The age ranged between 24 and 43 years with the average age of farm manager being 30 years. The average family size was 4 people. Tables 1 and 2 provide a summary of the socio-economic characteristics of the respondent tilapia farmers.

Farm Production

The production levels of the sampled farms in the three towns were used to determine the average production levels in the district. Achavanya produced 9,600 kg of tilapia per season, Kajanya 12,000 kg per season and Dormeliam, 11,200 kg of tilapia per season, giving a total of 32,800 kg of tilapia production by 41 farms spread across the three towns. This shows an average production of 800 kg per farm per season.

These production levels could have been higher if farmers had long-lasting solutions to some of the

Table 1
Socio-economic characteristics of respondents

Characteristics	Frequency	Percentage (%)
Location		
Kajanya	15	36.6
Dormeliam	14	34.1
Achavanya	12	29.3
Gender		
Male	41	100
Female	0	0
Marital status		
Married	32	78.0
Single	9	22.0
Education level		
No education	4	9.8
Primary	12	29.3
Middle school/JHS	22	53.7
Secondary/SHS	3	7.3
Religious background		
Christians	38	92.7
Muslims	3	7.3
Ethnic background		
Akan	1	2.4
Ewe	14	34.1
Ga	1	2.4
Ga-Adamgbe	25	61.0
Experience (years)		
1–4	27	65.8
5–8	13	31.7
>8	1	2.4

Source: present survey in 2014.

Table 2
Other socio-economic characteristics of respondents

Characteristics	Minimum	Maximum	Mean
Age	24	43	29.6
Family size	1	7	3.8
Number of adults	1	5	2.3
Number of children	1	4	2.3

Source: present survey in, 2014.

constraints. In carrying out the research it was observed that even though most of the farms had more than 10 cages, a number of the cages were lying dormant and had not been restocked for some time because the fish farmers were unable to secure funds to rehabilitate the cages. All of these factors might have affected the average output of these farms.

Farm Productivity

The ratio of the output to the cage area of each farm was computed as a measure of productivity of each farm. The average production was found to be 74 kg/cage. Research reveals that if the majority of cage farmers in Ghana could improve and increase their productivity to 1 ton per cage per cycle, which is common in Asia, then current number of cages operated in Ghana could yield fish quantities up to the level of current capture fisheries production of 90,000 MT per year (Ofori, Abban, Karikari, & Brummett, 2010). There was a significant correlation (0.53) between output and cage volume ($p < .01$), (Appendix 1). Therefore, we divided the farms into three groups using the cage volumes (i.e. small: 648 m^3–1,080 m^3, medium: 1,296 m^3–1,530 m^3, and large: 1,620 m^3–1,728 m^3), and computed the averages and standard deviations of the outputs (Table 3).[1] The average production levels for small size, medium size and large size farms were 731 kg, 835 kg, and 1,027 kg, respectively. This clearly shows that there is a big productivity gap and therefore room for improvement in production. This means that if these commercial tilapia farms are managed properly they could perform incredibly well to meet the demand in terms of volume and productivity.

Factors Influencing the Farm Productivity

The Ordinary Least Square (OLS) regression of the factors influencing the productivity of tilapia farms indicate that quantity of fingerlings, quantity of feed, cage size, experience and educational level were significant at 1% level while labour in person-days was significant at 5% level. The R^2 value indicates that about 45% of the variation in productivity is explained by these independent variables (Table 4). The following equation is the outcome of the regression:

$$
\begin{aligned}
In(Y_{pi}) = {} & 1.82 + 1.352\, InX_1 + \beta 0.777 InX_2 - 3.28\, InX_3 \\
& - 1.085\ \ \mathrm{In}\, X_4 - 0.337X_5 - 0.303X_6 + 0.099X_7 \\
& + 0.113X_8 + 0.458X_9 + \varepsilon_i
\end{aligned}
\tag{4}
$$

The quantity of fingerlings and feed, extension agent visits and education had a positive relationship with productivity of the fish farms. However, the variables cage size, labour and experience had negative relationship with productivity, contrary to our expectations.

The results showed that a percentage increase in the quantity of fingerlings and feed increased productivity by 1.35% and 0.77% respectively which is common in most cage culture systems. Interestingly a percentage increase in cage size (i.e. either length or breadth, but not depth) led to a 3.23% decrease in productivity. Increasing cage size can be counterproductive because inputs and the management may not increase at the same level. This is consistent with other findings that specified cage size in relation to other input factors is needed to enhance fish farm production (e.g. Onumah et al., 2010). The results also revealed that a percentage increase in labour increased productivity by 1.08%, whilst a year increase in farmers' experience decreased productivity by 0.3 units. This finding conforms to Esmaeili (2006) who revealed that young farmers in the Iranian fisheries are more productive than older and experienced ones. Coelli and Battese (1996) also argued older farmers are less likely to adopt new innovations to increase productivity because they are conservative. Similarly, more labour might be disturbance to the fish. Minimization of laborers and excessive fish handling is necessary. An increase in the educational level of the farmer or farm manager by a year resulted in a 0.46 unit increase in productivity. However,

[1] The depth of the cages was 3 m. Therefore, using the cage area would yield the same categorization.

Table 3
Fish output (kg) based on cage sizes

	Small size		Medium size		Large size	
	Cage volume (m^3)	Fish output (kg)	Cage volume (m^3)	Fish output (kg)	Cage volume (m^3)	Fish output (kg)
	648	500	1,296	650	1,620	800
	825	850	1,404	760	1,512	750
	900	1,050	1,296	760	1,512	450
	825	800	1,455	560	1,620	870
	1,032	710	1,422	600	1,788	940
	1,125	500	1,305	840	1,836	1,280
	1,065	780	1,296	840	1,836	1,250
	1,080	550	1,296	790	1,836	1,500
	1,080	500	1,404	860	1,728	1,350
	972	700	1,488	1,100	1,620	1,250
	1,074	830	1,398	850	1,728	860
	972	910	1,347	1,360		
	1,188	750	1,530	880		
	972	800				
	1,080	650				
	972	700				
	1,080	850				
Average		731 kg		835 kg		1,027 kg
Standard deviation		155 kg		210 kg		318 kg

Table 4
Ordinary Least Squares regression results of factors influencing productivity of tilapia farms

Variable	Coefficient	Standard error	*t*	*p*
Fingerlings/seed	1.352**	0.479	2.82	.009
Feed	0.777**	0.230	3.38	.002
Cage size (m^2)	−3.280**	0.983	−3.34	.002
Labour_person-days	−1.085*	0.491	−2.21	.035
Marital status	−0.337	0.112	−3.02	.115
Experience	−0.303**	0.107	−2.84	.008
Age	0.099	0.033	3.03	.265
Extension	0.113	0.079	1.43	.163
Education	0.458**	0.170	2.70	.011
_cons	1.820	1.986	0.92	.367

**, * indicate significance at 1% and 5% respectively
Source: survey data, 2014.

age, marital status and extension were not significant in the model.

We have carried out normality test of the error term. The Jarque-Bera statistic of 0.38 ($p = .82$) showed that the error terms are independently normally distributed, satisfying the distributional assumption of the error term (Figure 2). Furthermore, Figure 3 shows the actual, predicted, and residual productivity obtained from the ordinary least squares regression. The error terms are mean reverting and this implies that the residuals are independently normally distributed with zero mean and constant variance. We have also carried out correlation analysis of the variables. In general, majority of the explanatory variables are not significantly correlated, signifying the absence of multicollinearity in the regression model (Appendix 2).

Constraints of Tilapia Farming

The results of the constraints analysis are shown in Table 5. The farmers ranked high cost of input as the most pressing. The farmers perceived prices of input such as fingerlings and feed as exorbitant. To further exacerbate the situation, high transportation costs increase the prices of inputs. The high cost of input is a general problem and this affects productivity since these farmers try to avoid these costs by either settling for lower quality input or underfeeding the fish, resulting in lower productivity. The second most pressing constraint is the access to feed, and the third most pressing being access to credit. According to farmers, it is hard to come across people who are interested in investing in tilapia cage farming. Access to credit from formal financial institutions involves a very cumbersome process, making it very difficult and impossible most of the time. The farmers also said that the interest rates on loans are too high for the operation of the tilapia farms. Inadequate extension services, stealing, land tenure problems and inadequate storage follows in that order of ranking.

The Kendall's Coefficient of Concordance (Wa) value is 0.894 with a chi-square value of 220 which is asymptotically significant at 1%. There is therefore about 89.4% agreement within the ranked constraints of the farmers, indicating strong agreement among the rankings.

Other problems or constraints include poor management and handling, which have resulted in low yield and productivity. Aside these constraints, tilapia fingerlings also have limited sources or sales points and are also expensive. The price of a fingerling in Ghana is about 40% the price of the adult fish (AEDC, 2009). Due to the high cost of fingerlings, there is a resulting low profit margin and this discourages fish farmers from the business of rearing tilapia in cages or other forms of confinement. Measures have been put in place to solve this problem of low yield and high cost of fingerlings. Some of these include the Diversified Agricultural Program, where tilapia fingerlings are sold to farmers at relatively cheaper prices (BoGRD, 2008).

One important indicator to look at in analyzing the impact of aquaculture on world economy vis-à-vis tilapia production is to look at the prices of tilapia, and other cost

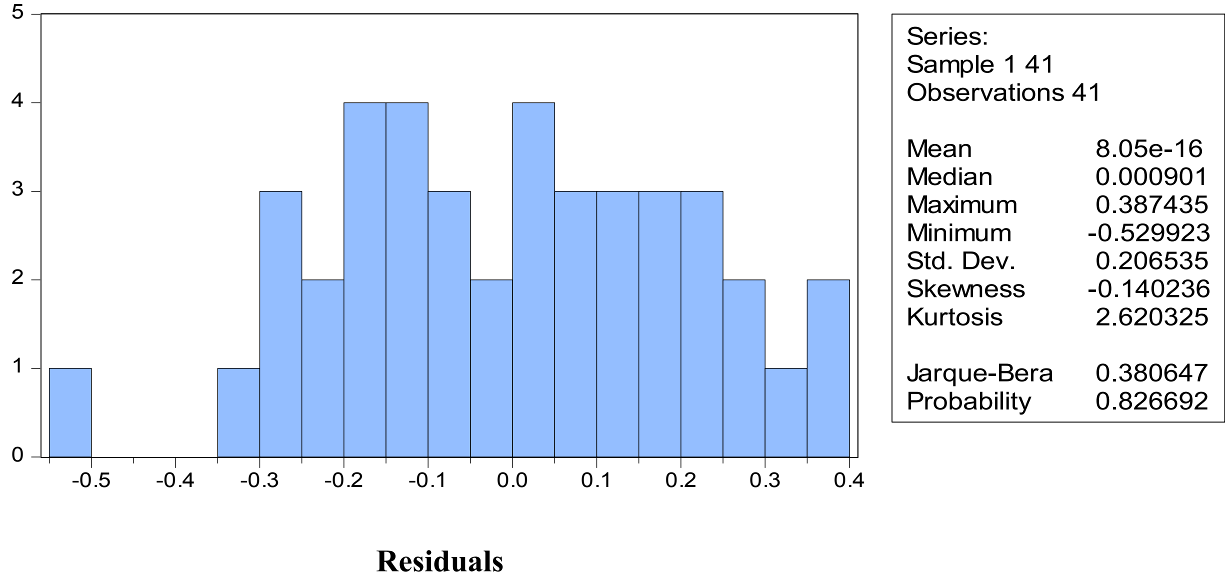

Figure 2 Normality test of the error term

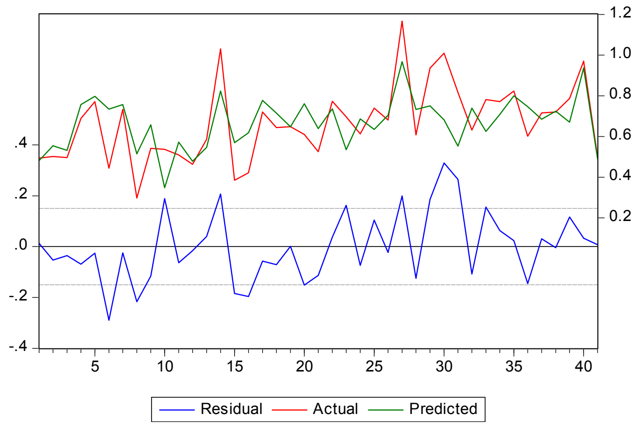

Figure 3 Actual, predicted, and residual productivity of the fish farms

items associated with its production, on the world market and how they compare to domestic prices. In Ghana, the price of feed per kg is about twice that in the Philippines and about four times that in China. It is worth noting that these countries have many feed-manufacturing mills.

Ghana imports all types of feed for aquaculture. The cost of importing fish feed, high interest rate on credit and poor production technology are some of the bottlenecks that have led to high cost of production which greatly reflects on fish prices. For instance, while a kilogram of fish feed costs US$ 0.3 in Egypt and US$ 0.53 in China, the average price in Ghana is US$ 1.96. Therefore, Tilapia from Egypt, China, etc., appears to have competitive advantage over that from Ghana, not only on the global market but also on the Ghanaian local market given the current price differences (Blow & Leonard, 2007; Hamenoo, 2011). Also, lack and high cost of fingerlings are also some of the constraints inimical to aquaculture (Anane-Taabeah, Frimpong, Amisah, & Agbo, 2012).

Table 5
Ranking of constraints associated with tilapia farming

Constraint	Mean score	Rank
1. High cost of inputs	1.54	1
2. Access to feed	2.05	2
3. Access to credit	2.46	3
4. Inadequate extension services	4.34	4
5. Stealing	4.93	5
6. Land acquisition problems	5.68	6
7. Inadequate storage facilities	7.00	7

Source: survey data, 2014.

Conclusions and Recommendations

The survey results showed that the average production levels for small, medium and large cage farms were 731 kg, 835 kg, and 1027 kg, respectively.

Increasing fingerlings for stocking, quantity of feed, and educational level of the farm managers increases productivity whereas cage size, labour and level of experience decreases productivity.

Among the seven constraints that were given to the farmers to rank in order of severity, high cost of inputs was their most pressing constraint; 25 of the 41 respondents pointed out that. Access to feed, access to credit and inadequate extension services were ranked as other most important constraints after the high cost of inputs. The other minor constraints were stealing, land acquisition problem and inadequate storage facilities for harvested tilapia. These are obvious since, according to the farmers; the high demand for tilapia requires no storage.

Policy makers should consider roles of these factors while making policies, extension agents should put their efforts accordingly and farmers should also understand which factors are important while managing their cage farms in order to maximize the limited space available for them.

Conflict of Interest

There is no conflict of interest regarding this manuscript.

Appendix 1 Correlation of output and cage volume

Correlation		
Probability	CAGE_VOLUME	OUTPUT_KG
CAGE_VOLUME	1.000000 –	
OUTPUT_KG	**0.526271** 0.0004	1.000000 –

Appendix 2 Correlation among the explanatory variables

Correlation Probability	AGE	EDUC	EXP01	EXT	LNCAGEAREA	LNFEED	LNFINGERLINS_CAGE	LNLABOUR_DAYS	LNP	MAR
AGE	1.000000 –									
EDUC	−0.296790 0.0595	1.000000 –								
EXP01	0.345151 0.0271	−0.533779 0.0003	1.000000 –							
EXT	−0.142757 0.3733	−0.120886 0.4515	−0.127557 0.4268	1.000000 –						
LNCAGEAREA	0.190393 0.2331	−0.103660 0.5190	0.211631 0.1841	−0.158056 0.3237	1.000000 –					
LNFEED	−0.426319 0.0054	−0.011648 0.9424	−0.109088 0.4972	−0.054343 0.7358	−0.518599 0.0005	1.000000 –				
LNFINGERLINS_CAGE	0.216794 0.1734	−0.522533 0.0005	0.589843 0.0000	0.120918 0.4514	0.072461 0.6526	−0.124532 0.4379	1.000000 –			
LNLABOUR_DAYS	0.337326 0.0310	−0.262730 0.0970	0.334193 0.0327	0.007763 0.9616	0.391552 0.0114	−0.310048 0.0485	0.245126 0.1224	1.000000 –		
LNP	0.054223 0.7363	0.013486 0.9333	−0.415546 0.0069	0.098251 0.5411	−0.369425 0.0174	0.289140 0.0667	−0.140916 0.3795	−0.125888 0.4329	1.000000 –	
MAR	0.084923 0.5976	0.017568 0.9132	−0.115174 0.4733	0.005792 0.9713	0.033351 0.8360	0.070715 0.6604	−0.154253 0.3356	0.157106 0.3266	−0.091765 0.5683	1.000000 –

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