Technical Efficiency of Catfish Farms in Davao City: An Application of Data Envelopment Analysis

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ABSTRACT

The technical efficiency of catfish production in Davao City has been studied utilizing data envelopment analysis. With the aim of doing so, a total of 51 catfish farms located in Davao City were considered as the decision-making units (DMUs) to be assessed in this study. The catfish farms' input and output profiles were determined. The econometric analysis was implemented using multi-stage DEA in DEAP 2.1 software. The results reveal that four (4) farms are fully efficient having 1.00 technical efficiency scores in both constant returns-to-scale and variable returns-to-scale assumptions. Out of the four, Farm 5 is can be benchmarked by 29 other farms based on peer count summary. Moreover, in analyzing the total efficiency, it is relevant to discern the input slacks, which can advise aspects that require attention in order for the farmers to be efficient.

Keywords: *technical efficiency, data envelopment analysis, decision-making units, catfish farms, Philippines*

INTRODUCTION

The government agricultural sectors in the Philippines are increasingly concerned with enhancing the efficiency of fish production. However, the production of fisheries has consistently decreased as significant subsectors experienced a decline in output (National Economic Development Authority, 2013). In 2018, the most recent data from the Philippine Statistics Authority indicated that the sector experienced a contraction of 0.04 percent in output, with a production volume of 972,910 metric tons. The current level of production is inadequate to meet both domestic demand and the requirements for export (Alexandratos & Bruinsma, 2012). Furthermore, the scarcity of supply in the market will ultimately drive up the price of fish and other associated products. Large corporations are obligated to augment their production to a satisfactory level (Food and Agriculture Organization, 2016).

Fish farming is making a substantial contribution to the economy by creating job opportunities in both urban and rural areas. It is also providing a sustainable source of nutrients and improving the country's food security (Southeast Asian Fisheries Development Center, 2017). Therefore, catfish farming is regarded as a lucrative enterprise. However, the increasing costs of production necessitate that catfish farms be operated efficiently, taking advantage of available technology to enhance production (Bureau of Fisheries and Aquatic Resources, 2015). Therefore, it is imperative to enhance domestic production in order to address the shortage of demand and supply. However, the present obstacles in production necessitate prioritizing technically proficient production systems. In order to achieve this, firms must strive to maximize their output based on the amount of inputs used (Alawode & Jinad, 2014). Similarly, catfish farms aim to maximize their output (measured in quantity of harvested fish per kilogram) by carefully managing inputs such as stocking densities, feed consumption, pond area/size, labor, and other resources (Boonchuwong, Boonchuwong, & Noorit, 2007).

Catfish farming is a subsector of aquaculture that involves the nurturing of catfish below controlled conditions for social and economic advantage (Adah, Grace, & Unekwu, 2017). In the Philippines, three species of the *genus Clarias* exist which are the native *hito (Clarias microcephalus)*, the African Hito, *(Clarias gariepinus)*, and Thai catfish *(Clarias batrachus)*. Out of the three species, only *C. microcephalus* is native within the Philippines while the remaining are introduced species. Moreover, *C. gariepinus* can be traced its way from Africa whereas *C. batrachus* was from Thailand. The Native Hito remains to be the most liked species because of its tenderness and delicate taste (Philaquaculture, 2010). However, concerning the growth patterns, the native *hito* appears to grow the slowest, while African catfish grows the fastest (Buendia & Surtida, 2000).

Total volume of catfish production during the third quarter of year 2018 posted at 3.08 thousand metric tons (Philippine Statistics Authority, 2018). Davao City's catfish industry is gaining attention as evident by the growing concern in the fish species and the consistent surge on demand and production. Catfish pond operators in the community has grown to 100 with a combined area of 160 hectares. Some 80 to 90 percent of catfish sold in the city's market come from the catfish farms in Los Amigos as such a catfish or "*hito*" industry projected to expand in the coming years. The demand has been increasing and there is a need to meet it with more production (Carillo, 2014).

There is currently no local research being conducted to evaluate the technical efficiency of catfish farms in Davao City. Despite the rapid advancement of technology, farmers continue to depend on traditional methods and techniques for production. Los Amigos is noted for its flourishing catfish industry, with daily production of 2.5 to 3 tons daily, and businesses could still expand with the entry of more investors. The catfish industry is an alternative source of income since rice production has become insufficient, as a main source of income; there is an increasing interest and demand in this fish species (Bureau of Fisheries and Aquatic Resources, 2015).

The study aims to assess the technical efficiency of farming production by employing data envelopment analysis, which takes into account various inputs and outputs. Data envelopment analysis (DEA) is a tool used to assess efficiency. It is a non-parametric approach that can handle multiple inputs and outputs (Cook, Tone & Zhu, 2014). With the results, farmers can utilize this information to optimize their production process. Furthermore, policymakers can utilize this information to identify and focus on public interventions aimed at improving farm productivity and financial profitability.

Statement of the Problem

The study aims to determine the technical efficiency of catfish farms in Davao City. Specifically, the study seeks to address the following objectives:

1. What is the profile of the catfish farms in terms of:
    - 1.1 farming inputs such as:
        - 1.1.1 stocking density (number of fingerlings);
        - 1.1.2 feed consumed (kg);

1.1.3 labor (manhours); and

1.1.4 pond size (m^2)?

1.2 farming output measured as:

1.2.1 quantity of catfish harvested?

2. What are the technical efficiency scores of catfish farms in Davao City?
3. Which of the catfish farms lie in the efficiency frontier?

Conceptual Framework

The study is anchored on technical efficiency (Tung, 2013) which reflects the capacity of an enterprise to attain maximum output depending on the inputs provided and in contrary, based on the minimum amount of utilized inputs to generate relevant amount of output. This also signifies that farmers' technical efficiency may be acquired depending on its capability to generate the ideal amount of catfish produced per harvest season grounded on the set of inputs, e.g. feed cost, farm size number of fingerlings and number of helpers (Cobb & Douglas, 1928).

The theory of production involves some of the most fundamental principles of economics (Dorfman, 2016). Thus, production function expresses the relationship between the quantity of good produced (output) and factors of production (inputs). Hence, the study deemed to determine the factors of production in catfish farming in Davao City. The theory of production explains input-output relationship in a firm so as to minimize cost of production output (Harle, 1966).

Figure 1 illustrates the conceptual framework in assessing technical efficiency. In measuring production according to Farrell (1957) and Tung (2013), the input variables included pond size which refers to farm area per hectare; feeds consumed refers to the food consumption of fish per kilo; stocking density refers to number of fingerlings; labor refers to the number of workers deployed in farm and utilities produce ratio with an output quantity of harvest (kg). Catfish production efficiency is measured comparing the ratio of observed input to produce the given output.

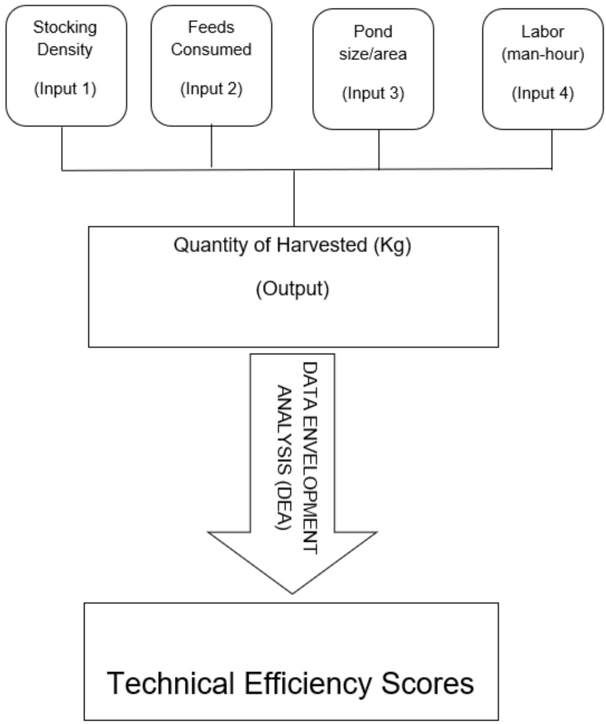

Figure 1. Conceptual Framework of the Study

METHOD

The study utilized econometric approach particularly data envelopment analysis (DEA). DEA measures the comparative efficiency manifested by single input-output and multiple inputs and outputs factors of firms or decision-making units (DMUs). When the weights are restricted, efficiency of DMUs could be defined as the ratio of the weighted sum of outputs over the weighted sum of inputs (Talluri, 2000). Two general approaches are considered in measuring efficiency - mathematical programming approach and econometric approach. The DEA, which will be utilized in this study, signifies the former group and is a common approach.

This study will employ DEA to improve relative measures in terms of technical inefficiency of the catfish farms in Davao City. The mathematical foundations of DEA held the study of Farrell (1957) and DeBreau (1951), the proponents of the idea that linear programming could be employed to empirically apprehend economic components of the production circumstance. This technique of measuring efficiency was based on the recognized body of input-output trajectories of the production potentials. The measure employs the information provided by the members of a group of enterprises and hence, is a relative measure of efficiency (Coelli, 1996).

This study utilized secondary data. The data for this input-output specification for technical performance efficiency were taken from the respective reports from the fishery technicians of Bureau of Fisheries and Aquatic Resources for the year 2018 as approved for release by the Chief of Fisheries Production Support and Services Division. The latest data are required to identify the technical efficiency scores and to determine the farms that lie in the efficiency frontier. Data were personally sought through writing to the Chief of BFAR-Fisheries Production Support and Services Division. In addition, the study focuses on three years or more of operation.

The inputs and outputs chosen are based on the existing review of literature and studies that have chosen the above inputs and outputs in their respective specifications at different applications and methods used. To this effect, the DEA model in this study considered the following inputs and outputs for the two models studied:

Table 1. *Inputs and outputs to be used in the estimation*

Inputs	Output
• stocking density/number of fingerlings • pond size • feeds consumed • labor (man/per hour)	• quantity of harvested (per kg)

The model specification in DEA must have its positivity and isotonicity property. The first term refers to the positive values of inputs and outputs or values greater than zero, while the latter term refers to the mathematical property, which means that an increase of inputs should, in some ways, result to increasing outputs (Bowlin, 1998).

In the analysis of the data, descriptive summaries of both inputs and the output were determined in Microsfot Excel. Data envelopment analysis that is used in measuring the efficiency of the DMUs was performed in Coelli's DEAP 2.1 software, a Fortran-based executable software. Input and output slacks were also determined for catfish farms, while the efficient farms which served as benchmarks for other farms are derived using the peer count.

RESULTS AND DISCUSSIONS

Farming inputs were examined through identifying the threshold value of inputs in catfish farming which comprises stocking density (number of fingerlings), feed consumed (kg), labor (man-hour), pond size (m^2). The inquiry was conferred with the minimum, average and maximum values which data were taken from 51 catfish farms.

Shown in Table 1 are the indicators used to evaluate the performance of the different catfish farms. It is noted that, in terms of pond size, fish farmers acquire at least 200 sqm and a maximum of 50, 000 sqm utilized for catfish farming with the average size of 4,114.12 sqm (*SD*=9,878.814). In terms of number of fingerlings, farmers stocked at least 1,000 to 1,000,000 pcs at most with an average of 76,471.37 fingerlings (*SD* =217,938.19) stocking density. Farmers minimum feed usage is 200 kg to maximum of 500,000 kgs with an average usage of 26,947.43 kg (*SD*=97,673.34). Finally, in terms of labor, farmers use at least 312 hours to assist in cropping and at most 49,920 hours. Overall, the catfish farms employ an average 3,369.25 hours (*SD*=8,555.241).

Table 1. *Production variable in catfish farming*

Input Variables	Min	Max	Mean	SD
Production (kg)	145	300000	19069.31	55701.98
Stocking Density (pc)	1000	1000000	76471.37	217938.19
Feed Consumed (kg)	200	500000	26947.43	97673.34
Labor (man-hour)	312	49920	3369.25	8555.241
Pond Size (m2)	200	50000	4114.12	9878.814

The descriptive summary reveals that the catfish farms have minimum yield of 145 kg and maximum of 300,000 kg. Moreover, it shows that catfish farms have a normal produce of 19, 069.31 kg (*SD*=55, 701.98). This implies that catfish farms can yield an optimum number of kilos of catfish based on the expended inputs.

Variety of DEA models was developed to measure the efficiency and capability in several approaches. These can generally be categorized into either input-oriented or output-oriented models. Based on the estimations done under input-oriented DEA, the average score for constant returns-to-scale (CRTS) technical efficiency was 35 percent, and for variable returns-to-scale (VRTS) technical efficiency was 67.5 percent. Table 2 presents input-oriented efficiency records of 51 catfish farms in Davao City by utilizing DEA assumptions: the constant returns-to-scale (CRS) and the variable returns-to-scale (VRS). It appears that the maximum efficient is rated with 1.0 while inefficient firms are rated with 0.0 scores (Perelman & Serebrisky, 2012).

Relevant with CRS assumption, four catfish farms established a full technical efficiency while under the VRS assumption, 14 were found to have full TE scores. Note that in terms of the farmer's capability to be marked as technically efficient in CRS and VRS assumptions, it found out that there are four farmers that are fully efficient exhibiting 1.00 TE scores. These farms are Farm 5, Farm 14, Farm 15 and Farm 36. This implies that they could gain a specified level of productivity at the minimum inputs' requirement of the production (Keskin & Degirmen, 2013).

The linear programming model was designed to distinguish the cost of the input the firm could utilize if the firm will use it in an efficient method to attain a constant output level. The only component used to measure the production was

Table 2. *Input-Oriented CRS and VRS Technical Efficiency DEA*

Farm	Input-Oriented		Output-Oriented	
	CRS	*VRS*	*CRS*	*VRS*
1	0.22	0.62	0.219	0.314
2	0.22	0.52	0.217	0.295
3	0.17	0.31	0.165	0.182
4	0.71	0.81	0.714	0.757
5	1.00	1.00	1.00	1.00
6	0.23	0.41	0.234	0.236
7	0.2	0.52	0.203	0.256
8	0.97	1.00	0.969	0.999
9	0.17	1.00	0.169	1.00
10	0.65	0.65	0.645	0.645
11	0.17	0.32	0.174	0.191
12	0.12	1.00	0.117	1.00
13	0.23	1.00	0.232	1.00
14	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00
16	0.41	0.48	0.414	0.435
17	0.58	0.63	0.579	0.597
18	0.63	0.68	0.626	0.658
19	0.57	0.61	0.567	0.589
20	0.46	0.52	0.455	0.479
21	0.77	1.00	0.774	1.00
22	0.31	0.8	0.31	0.56
23	0.23	0.28	0.232	0.33
24	0.22	1.00	0.217	1.00
25	0.22	0.39	0.217	0.221
26	0.04	0.32	0.038	0.038

Table 2. *Input-Oriented CRS and VRS Technical Efficiency DEA*

Farm	Input-Oriented		Output-Oriented	
	CRS	*VRS*	*CRS*	*VRS*
27	0.22	1.00	0.219	1.00
28	0.85	0.91	0.854	0.898
29	0.58	0.81	0.581	0.863
30	0.35	0.41	0.35	0.366
31	0.11	0.26	0.108	0.11
32	0.22	0.54	0.216	0.295
33	0.2	0.56	0.203	0.276
34	0.44	0.72	0.435	0.591
35	0.11	1.00	0.106	0.895
36	1.00	1.00	1.00	1.00
37	0.17	0.48	0.171	0.236
38	0.13	1.00	0.125	0.745
39	0.21	0.73	0.214	0.43
40	0.16	0.47	0.157	0.217
41	0.11	0.5	0.11	0.138
42	0.22	0.74	0.219	0.44
43	0.22	0.4	0.219	0.239
44	0.11	0.45	0.11	0.137
45	0.1	0.51	0.097	0.131
46	0.11	0.34	0.109	0.119
47	0.21	0.37	0.214	0.223
48	0.12	0.69	0.119	0.23
49	0.22	1.00	0.216	1.00
50	0.11	0.68	0.108	0.211
51	0.11	1.00	0.109	0.938
Mean	**0.35**	**0.675**	**0.35**	**0.539**

based on the analysis of the actual features of production. Given that the variables cannot be condensed, input-oriented DEA model then appears to become less important in the assessment of capacity utilization. Moreover, modifications could be done to transform traditional input-oriented DEA approach provided that it is feasible to classify the decline in a given set of variables on a fixed approach and plead output level.

In output-oriented DEA, however, the linear programming approach was remodeled to establish the firm's output if the production was efficiently managed utilizing their best practice frontier. The approach was more comparable with the SF which estimates the feasible output based on a given inputs and measures the ability of utilizing the ratio of the actual to potential output. Such models were noted as "very much in the spirit of neo-classical production functions, defined as the maximum achievable output given input quantities" (Färe et al., 1994, p. 253). This estimate establishes the components of the degree given that each feature was assigned with a value either zero or one, with one suggesting full technical efficiency (Coelli, 1996).

In output-oriented DEA the average score for constant returns-to-scale (CRTS) technical efficiency was 35 percent, and for variable returns-to-scale (VRTS) technical efficiency was 53.9 percent. Table 2 also shows the output-oriented relative efficiency score of 51 catfish farms through validating with two DEA assumptions: the CRS and the VRS. Four fish farms weighted 1.0 in their CRS technical efficiency scores, which signifies that it achieves maximum technical efficiency. Additionally, when it comes to the VRS assumptions, 11 fish farms acquired full technical efficiency with 1.0 score. Also, note that when it come to the farmers' capability to be efficient in both assumptions, only four farmers were found to be fully efficient exhibiting TE score of 1.00 in CRS and VRS assumptions. These farms are Farms 5, 14, 15 and 36. This implies that they could achieve the optimal output from the inputs provided in the production.

Based on TE summary, there are only four DMUs that are efficient while 47 DMUs are considered inefficient. Studying the slack analysis helps the inefficient farmers to obtain the given level of output. This value presents the difference in the modification of the sets of input and output variables (Eckermann & Coelli, 2008). It also corresponds to the quantity of value for enhancement of both input and output.

Shown in Tables 3 and 4 is the slack summary both in input- and output-oriented DEA. Slacks only present the variable discrepancy among output and input. Under the input-oriented DEA, the inefficient catfish farms need to increase their inputs by an average of 568 fingerlings, 3,080.457 kg of feeds, 142.925 sqm more of pond size, and 363.188 man-hours to increase their efficiency. Accounting all DMUS, 19% have issues regarding the necessity to increase fingerlings to cope up with the optimal output, 47% have issues that concerns increasing the feeds, 29% have issues with regards to the need for pond size expansion, while 45% have labor (man-hours) concerns.

Under the output-oriented DEA, the inefficient catfish farms need to increase their inputs by an average of 2,778 fingerlings, 4408.265 kg of feeds, 318.138 sqm more of pond size, and 674.77 man-hours to increase their efficiency. Accounting all DMUS, 12% have issues regarding the necessity to increase fingerlings to cope up with the optimal output, 53% have issues that concerns increasing the feeds, 43% have issues with regards to the need for pond size expansion, while 47% have labor (man-hours) concerns.

In addition, shown in Figure 3 is the peer count summary of fully efficient farms that can be benchmarked or

Table 3. *Slack analysis of needed inputs per farm (based on input-oriented DEA)*

Farm	*Number of fingerlings*	*Feeds consumed (in kg)*	*Pond size (sqm)*	*Labor (man-hours)*
1	-	-	162.657	-
2	-	32.09	80.096	33.92
3	794	-	-	52.248
4	-	2,825.97	-	-
6	425	-	-	-
7	-	40.587	-	-
8	8,163	-	-	970.319
10	-	15,617.61	3,429.51	-
11	-	55.481	21.178	67.839
16	-	830.021	-	760.025
17	-	-	-	1,443.75
18	-	3,040.87	-	1,038.05
19	-	6,852.71	-	2,473.82
20	-	4,720.76	-	814.637
22	-	-	58.108	-
23	4,408	-	-	758.435
25	3,986	-	-	342.688
26	8,111	-	87.327	661.221
28	-	12,301.33	-	1,335.93
29	-	92,833.18	-	6,131.08
30	-	5,132.04	-	1,340.64
31	-	151.584	-	-
32	-	-	-	31.268
33	-	-	-	26.098
34	-	82.01	357.226	90.452

35	1,000	8	624	-
37	-	199.42	306.145	22.613
38	706	676.471	844.235	-
39	-	212.587	326.533	11.307
40	-	188.589	289.518	18.844
41	431	-	287.154	-
42	-	114.042	136.697	12.06
43	-	-	-	85.434
44	-	-	278.804	-
45	189	-	-	-
46	-	95.569	-	-
47	-	10,864.54	-	-
50	-	89.717	-	-
51	737	138.158	-	-
Mean	568	3080.457	142.925	363.188

can serve as reference to the inefficient farms to improve their operations. Farm 5 can be a benchmark of 29 other farms, Farm 14 can be a benchmark of one farm, Farm 15 can be a benchmark of 24 other farms, and Farm 36 can serve as a benchmark of 12 other farms.

The four technically efficient fish farmers presented with the number of peer farmers are readily available to benchmark their efficient farming approaches and utilization of inputs in fish production processes. Based on peer count, the most technically efficient DMU is Farm 5, with the highest number of peers. The peer suggests several firms that are inefficient in their practice, hence, inefficient to follow (Coelli, 2008). For input-oriented DEA, shows in Figure 3, inefficient firms like Farm 1 may follow other farmers practice for efficient

Table 4. *Slack analysis of needed inputs per farm (based on output-oriented DEA)*

Farm	*Number of fingerlings*	*Feeds consumed (in kg)*	*Pond size (sqm)*	*Labor (man-hours)*
1	-	-	468.844	-
2	-	216.432	540.214	168.750
3	4,135	-	87.516	413.494
4	-	3,588.067	-	-
6	-	-	-	65.998
7	-	339.086	-	-
8	8,425	-	-	977.231
10	-	22,859.249	5,561.319	-
11	-	603.500	492.000	450.000
16	-	1,021.686	-	1,463.250
17	-	-	-	2,348.134
18	-	4,146.686	-	1,038.05
19	-	10,745.703	-	3,951.928
20	-	8,521.686	-	1,463.250
22	-	-	142.404	-
23	33,540	-	686.064	3,353.976
25	8,896	-	-	1,010.227
26	21,000	-	48.000	2100.000
28	-	13,521.686	-	1,463.250
29	65,657	111,616.162	-	9,191.919
30	-	11,671.030	-	3,122.369
31	-	1,539.890	1,214.242	-
32	-	304.687	145.500	168.750
33	-	104.687	153.5000	168.750
34	-	170.313	708.000	168.750

35	-	-	927.680	-
37	-	619.390	950.876	168.750
38	-	500.000	624.000	-
39	-	358.314	550.370	56.250
40	-	619.390	950.876	168.750
41	-	-	444.393	-
42	-	226.563	256.500	56.250
43	-	201.777	402.909	450.000
44	-	-	574.296	-
46	-	910.714	212.571	-
47	-	30,085.460	-	-
48	-	14.683	-	-
50	-	139.683	-	-
51	-	175.000	-	-
Mean	2778	4408.265	318.138	674.770

fish farming similar with Farms 12, 15, 5 and 24. However, the efficient farms like Farm 5 do not have to follow any practice. In contrary, the interpretation from output-oriented DEA showed in Figure 4, suggests that Farm 1 should consider the input-output variables of Farms 5, 9, 15 and 24. To become efficient given the values of the output variable. Again, peer weights of firms show that the Farm 1 can either follow 28.3 percent of Farm 5 values or follow 63.5 percent of Farm 9 values and it can follow 8.2 percent of Farm 24's value.

Lastly, Farm 5, Farm 9, Farm 12, Farm 14, Farm 15, Farm 21, Farm 24, Farm 27 and Farm 36 are good recommendation to become the benchmark farm whose output-input scale can be followed in order to be efficient. Farm 5 has been benchmarked 30 times, 10 times, 3 times, twice, 20 times, once, 10 times, 3 times and 16 times, respectively.

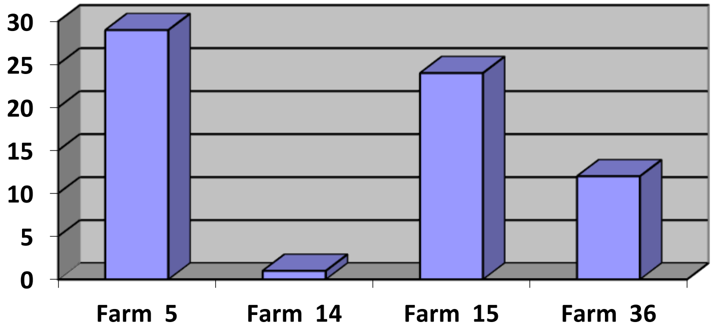

Figure 3. Peer Count Summary of Technically Efficient Farms (Based on Input-Oriented DEA)

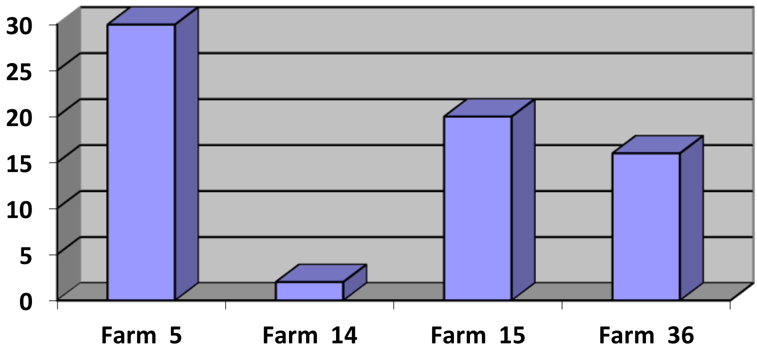

Figure 4. Peer Count Summary of Technically Efficient Farms (Based on Output-Oriented DEA)

The summary of slacks refers to a value that demonstrates the inconsistency in the constant or relative change among the input and the output variable (Coelli, 2008). The measure ought to display the result that would either increase or decrease (Cooper, Seiford, & Zhu, 2011). The findings from the summary of slacks based on variable scale assumptions, input and output orientation has different results. Where in input-oriented DEA there is 37 catfish farms were inefficient that shows input shortage or surplus. While, output oriented DEA has 40 catfish farms and has input discrepancy. Furthermore, in both orientations, the feed consumption has the highest rated input slack and the lowest is the labor or number of hours attended by farm helpers. It is the same with the study of Alawode and Jinad (2014) that shows feeds is the major input in fish production processes of different culture systems and species contain slacks, which need to reduce or increase accordingly. In addition, in the study of Tsue et al. (2013) and Kareem et al. (2008), quantity of feed increased production while labor use is less significant. These slacks may guide each farmer to be technically efficient. This data can give an advice aspect that needs attention so that each catfish farm can be efficient.

Input and output-oriented DEA both CRS and VRS assumes that there are four technically efficient farms, these four farms have a TE scores of 1.0 or 100 percent, which they have different farm profile depends on their current farming practices. As the result of efficiency score shows, their inputs and output relationship are deemed proportion. The peers set indicates an inefficient firm to follow or as reference (Coelli, 2008). However, the efficient farms like Farm 5 do not have to follow any farm. While, peer weight has several variables that can be followed for respective reference firm (Cooper et al., 2011). As a result, the four fully efficient farms do not have to follow any firm, instead they can be benchmarked or compared to the inefficient farms.

The central advantage of DEA lies on its ability to effectively integrate several inputs and outputs to measure technological performance by means of characterizing peers for firms that are not considered to be efficient; offers feasible role models that a firm should look, for example, as means of enhancing its operations (Fried, Lovell, & Schmidt, 1994). Implementing DEA provides a set of peers to the firms that are beyond the production frontier. Peer firms are organizations with analogous characteristics when it comes to the utilization and distribution of the resources.

However, DEA is vulnerable to a biased efficiency estimate (Gajewski et al., 2009) grounded on the number of facilitating assumptions that requires to be accredited during the interpretation of the DEA-related studies outcome. This study limits to the DEA scores that are found to be complex to input and output condition, and to the scope of the sample. If only then that the sample size could be increased, the result will tend to decrease the scores of average efficiencies since involving more farms provide greater scope for DEA. Regardless of this limitation the data envelopment analysis is a useful tool to estimate the technical efficiency of catfish farms that could be helpful in producing more yield.

This study is important for some firms because it will serve as a model that will guide farmers to efficient fish farming especially for firms that demonstrates lesser efficiency. In addition, it can be concluded that these fish farmers can be considered to be the most technically-efficient provided that they can produce optimum amount of output regardless of their farm size, having only one helper to fully maximize the catfish production, as noted in the study of Betonio, Cugat, Indanan, Entero, and Murcia (2016) a small farm is easy to manage and maintain, which contribute to his full technical efficiency. Moreover, there are many factors affecting technical efficiency of farms, but as the fixed input involves this study revealed how much inputs to increase/decrease to maximize their outputs/productions. Nonetheless, both models of measuring efficiency can be used to provide a better understanding and determination of which firms were efficient and inefficient, and to which firms a firm should be patented or modelled upon to achieve full technical efficiency. A non-parametric envelopment frontier over the data points so that all discerned points lie on or below the production frontier (Coelli, 1996). Hence, points that lie on CRS or VRS efficient while the point or points that lie on both CRS and VRS are fully cost efficient. However, those who are below in the line are inefficient.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Input-output relationship in catfish production and the variations within the catfish output was conjointly accounted for by the variable of inputs of production such as pond size, labor, fingerlings, and feed quantity. It anchors on the production theory of Cobb and Douglas (1928) which explains an input and output relationship. In this production process, the manager is concerned with efficiency in the use of the inputs.

The average technical efficiency scores based on CRS is only 0.35, this indicates that on average they could increase their inputs by about 0.65 to maximize their outputs. As such, by the help of slack analysis farmers have a basis what input they need to increase/decrease to achieve an efficiency score of 1.00. Moreover, the range of measures is an important tool to determine the efficiency of the firms in yielding maximum output (Perelman & Serebrisky, 2012).

In this study, out of 51 catfish farmers only four are technically efficient having an efficiency scores of 1.00 both orientations and based on CRS and VRS assumptions. These mean that they can gain the optimal outputs depending on the provided set of inputs. All discerned points lie on or below the production frontier (Coelli, 1996). Hence, points that lie on both CRS and VRS efficient while the points that lie on both CRS and VRS are fully technical efficient. However, those that are below the line are inefficient. However, among these four fully technical farms, the best practice is Farm 5 having the higher peer counts; hence, they may become capable of benchmarking their best practices in the utilization of inputs for optimal production.

Recommendations

The purpose of this study is not to provide uncritical information on the existing decision-making processes; however, it will assist in illustrating the potential value of efficiency projected by fish farmers. Low average TE scores are noted, with this the government or more specifically the Bureau of Fisheries and Aquatic Resources (BFAR) with the coordination of the president of the catfish association in Davao City, may improve their practices in fish farming. BFAR can use these data to present to catfish farmers that there are many chances of improvement in their farming practices. In addition, give them some insights about the importance of technical efficiency.

In addition, catfish farmers must have this knowledge how to measure their technical efficiency to improve their production. Some catfish farmers in Davao City are somewhat hesitant for new learnings because for them, they are in a decade in farming but still they can survive in their production cost so they stick to their usual practices. This study pursues to have an analysis of their current farming practices. But due to the limitation of the study, if the number of DMU's are to be expanded, the technical efficiency farms might no longer be the same, because of the weakness of DEA method.

To the future researches, they can use this study as a basis for helping the inefficient farmers and they can proceed with an allied study to know the causes of technical efficiency in catfish farms in Davao City.

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