What determines aquaculture fish production? empirical evidence from South Aceh Regency, Indonesia

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Abstract. This study empirically assesses the determinants of aquaculture fish production in South Aceh District using multiple linear regression analysis. The study documented that, except for the number of fish seeds, the factors of land area, the number of workers, and capital had a significant positive effect on aquaculture production. These empirical findings suggest that to improve aquaculture production, fish farmers should possess adequate capital, land area, and the number of workers. The government must assist in providing soft loans by coordinating with provincial government-owned banking institutions, providing sufficient land areas by initiating conversion programs for vacant land into fish ponds. Various free of charges of the training program should be undertaken by the government regularly and continuously to enhance the capacity of aquaculture farmers to produce professional fish farmers who enable to ensure an increase in aquaculture fish production throughout the years.

1. Introduction
Indonesia has a huge agribusiness potential in the fisheries sector in terms of the availability of resources and market opportunities, both domestically and globally. In addition, to address the fisheries export promotion program, the government has prepared various development programs for marine and coastal areas through the development of brackish and marine aquaculture and fisheries agribusiness for the cultivation of freshwater fish by the Marine Fisheries Agency through the Fish Seed Center and the People's Hatchery Unit [1]. As one of 34 provinces in Indonesia, Aceh province has a long coastline in the east, west, and south with an area of water covering of 295,370 km² [2] and bordering the sea coast. This geographical location drives the majority of the population in the province to work as fish farmers or fishers. The fisheries sector is one of the sectors that favor Aceh's economy with leading commodities in the form of sea capture fisheries and aquaculture.

Capture fisheries and aquaculture production in the province of Aceh showed an increasing trend over the period 2011 to 2018. The amount of capture fish production has increased from 143,680 tons in 2011 to 288,034 tons in 2018, showing an average increase of 9.60%. The increase in aquaculture production was higher than capture fisheries production with an average of 12.79% from 2011, with a total production of 37,225 tons to 104,246 tons in 2018 [2]. Of 104,245 tons aquaculture production in Aceh province in 2018, each of 23 regencies/cities in the region, on average, produced only 4.35% to the total fish production. Compared to other districts which have similar natural conditions and geographical location, the amount of aquaculture production in South Aceh Regency is relatively low, which was only 0.29% of the total provincial production. Whereas South Aceh Regency has a great
potential for fishery production whose geographical location is 16,173 km² along the coastline of the Indian Ocean with the majority of the population is fishermen [3]. The low amount of aquaculture production has caused various questions. Why does it happen in South Aceh District? Meanwhile, the natural conditions and geographical location of South Aceh District are very supportive and have great potential as one of the centers of aquaculture production in Aceh province.

Many previous studies have examined factors influencing fish production. For example, labor is found to have a positive effect on fisheries production [4]; finding supported the theory of factors of production. Working capital is also found to play a vital role in the production process [5], as it facilitates the production process. This is a major problem that is often faced by small-scale fish farmers who have limited capital for the costs of raising fish, providing land, and using fisheries handling technology. Limited land area, the use of non-superior seeds, unskilled workers, inadequate fish feed, and traditional fish farming technology was the result of lacking capital that causes the low production of small-scale fish farmers [6].

The development of aquaculture is also very much determined by the number of fish seedlings because aquaculture production begins with the presence of fish seeds. The availability of fish seeds that meet the requirements of quality, quantity, and continuity determines the output of aquatic fisheries [6] and [7]. The availability of seedlings has a positive effect on the production of soft-shelled crabs (Scylla sp) in the District of Sei Lepan, Langkat, North Sumatra [8]. Land area had a positive effect on aquaculture production [9]. The addition of land area can accommodate more fish seeds and avoid fish density [7] increased fish productivity. The optimal density of quality of seeds must be proportional to the capacity of the land so that the process of fish enlargement is not disrupted [10] and reduces fish productivity [11]. The improper density of the number of seedlings and the capacity of the land area certainly causes the risk of production in vannamei shrimp farming [12].

Comparing to previous related studies, this study, at least, has four distinctive features. First, in contrast to previous studies that were more focused on the determinants of marine capture fisheries production [4], this study focused on the determination of aquaculture fish production in South Aceh District. Second, previous research focused on a single fish pond [7], while this study focused on various types of community aquaculture ponds across sub-districts within the South Aceh Regency. Third, previous studies more dominantly discussed the influence of seasonal factors, experience, capital, labor, technology, and the amount of land area [8] and [9], and very rarely included the number of seed factors as one of the determinants of aquaculture production investigated in our study. Finally, previous research focused on the determination of aquaculture production in Langkat District of North Sumatra [8] and Rokan Hulu Regency, Riau Province [9], and there has not been any research on this topic was carried out in South Aceh District. This study fills the gaps of previous research by examining the determination of fish aquaculture production in South Aceh District. These are the main novelty of this research.

More specifically, this study aims to empirically examine and analyze the determinants of aquaculture production, consisting of land area, number of seedlings, labor, and capital in South Aceh District, Indonesia. The results of this study are expected to be beneficial for fish farmers, the government, and banking institutions in supporting the increase in aquaculture production, especially in South Aceh or other regions in Indonesia that have similarities characteristics in their aquatic fisheries activity.

2. Material and Methods
This study uses primary data collected by distributing questionnaires to 100 aquaculture fishers selected as respondents in this study using random sampling techniques. The number of respondents selected from 1,690 fish farmers spread across 18 sub-districts in South Aceh Regency [3] is believed to represent the entire population.

This study focuses on four determinants (independent variables), comprising the amount of capital, labor, land area, and fish seedlings that affect the aquaculture production (the dependent variable) in South Aceh District. In this study, the amount of capital is measured by the number of costs that are
routine expenditures to buy, maintain or improve fish culture facilities in units of Indonesian Rupiah (IDR) per harvest. Labour is calculated from the number of wages paid for workers who directly involved in aquaculture business activities, such as preparing cultivated land, sowing seeds, maintaining, and harvesting measured by the average number of workers multiplied by the number of wages per day per harvest. Furthermore, the land area is the size of the land area used for aquaculture business activities and is measured in hectares per harvest. The number of seedlings is the number of costs incurred to purchase seeds or broodstock used in the aquaculture production process and is calculated by the IDR per harvest. Finally, the aquaculture production is calculated as the total amount of fish produced in kilogram (kg) multiplied by the selling price of fish per kg that is measured in the IDR per harvest [12].

Prior to the data analysis, rigorous classical assumption tests of normality, multicollinearity, and heteroscedasticity were firstly performed, following the standardized procedures [13]. In general, the production function analyzed in this study refers to the Cobb-Douglas model [14], as the following equation:

$$Prod = \alpha . Land^{\beta_1} . Seeds^{\beta_2} . Labor^{\beta_3} . Capital^{\beta_4}$$

(1)

Furthermore, the study transforms the Cobb-Douglas production model in Equation (1) into the following mathematical equations:

$$\ln Prod = \ln \alpha + \beta_1 \ln Land + \beta_2 \ln Seeds + \beta_3 \ln Labor + \beta_4 \ln Capital + \epsilon$$

(2)

where $Prod$ is aquaculture fisheries production, the $land$ is the land area of aquaculture fisheries, $Seeds$ is the number of aquaculture fish seeds, $labor$ is the number of aquaculture fisheries workers, $capital$ is the amount of aquaculture capital, $\alpha$ is an intercept, $\beta$ is the estimated coefficients for each independent variable, and $\epsilon$ is the standard error.

3. Results and Discussion

3.1. A brief overview of aquaculture in South Aceh regency

South Aceh is one of the 23 regencies/cities in the Province of Aceh, Indonesia. Administratively, it has a capital city of Tapak Tuan and oversees 18 sub-districts with a population of 235,115 people in 2018 [2]. The regency is bordered by Aceh Singkil Regency and the Indian Ocean to the south, Southwest Aceh Regency and the Indian Ocean to the west, Southwest Aceh District, Gayo Lues, Southeast Aceh, and Subulussalam City to the north, and Gayo Lues Regency, Southeast Aceh, Aceh Singkil, and Subulussalam City to the east. Farmers and fishers have dominated the livelihoods of the people of South Aceh Regency.

Out of 235,115 inhabitants in South Aceh Regency, a total of 1,690 people were aquaculture farmers in 2018 [3]. 100 of them have been selected as respondents in this study with various socio-economic backgrounds. Most aquatic fish farmers are aged between 26-30 years (23%), graduated Senior High School graduates (51%), and earned an average monthly income of IDR3 million and above (62%). Most of them employed 1-2 workers (74%) and grew tilapia (82%), goldfish (13%), catfish (3%), and carp (2%). In general, they possess a land area of 501-2,000 hectare (29%), purchase fish seeds between IDR301-350 per unit (72%), spent a total capital of IDR 9-11 million (35%), produce fish between 401-600 kg per season (51%), and sell them for IDR36,000-40,000 per kg (34%). This shows that aquatic fish farmers in South Aceh Regency are still on a small-scale business, both in terms of the inputs used and their production.

3.2. Determinants of aquaculture production

Before the study measures and analyzes the determinants of aquaculture production, the study ensured the fulfillment of classical assumption. As observed in the last row of Table 1, the study found that all variables investigated in the study were normally distributed as shown by the Jarque-Bera’s p-values.
which are lower than 5% level of significance. The study also found no multicollinearity problems between independent variables, as demonstrated by the Variance Inflation Factor (VIF) values between 2.782-4.502 and Tolerance Values (TV) between 0.222-0.359. The VIF values are smaller than 10, and TV is lower than 0.1, indicating that the independent variables are free from the multicollinearity problem [13]. Finally, our data are also homoscedastic as noted in the BP p-value. Overall, these findings are indicated that the variables have fulfilled all classical assumptions; thus, they could be used in the model for further estimation.

Table 1 also reports the findings of the determinants of aquaculture production in the South Aceh Regency. As illustrated in the table, the estimated constant value is found to be insignificant, indicating that the aquaculture production process cannot be carried out without being supported by the availability of land area, the amount of labor, and the amount of capital. This empirical evidence is strengthened by the significance of the estimated coefficient of determination (Adjusted-$R^2$) of 0.779 at the level of 1%. This shows that the variation in aquaculture production is explained by 77.90% changes in land area, number of fish seedlings, workers, and capital used. Only 22.10% of their changes were caused by other determinants that were not examined in this study, such as seasonal changes, fish market competition, types of fish diseases, and so forth.

Table 1. The findings of determinants of production of aquaculture

| Variable  | Estimated Coefficient | t-statistics | P-value |
|-----------|-----------------------|--------------|---------|
| Constant  | 1.902                 | 1.520        | 0.132   |
| Land Area | 0.122***              | 2.167        | 0.033   |
| Seeds     | 0.015                 | 0.194        | 0.847   |
| Labor     | 0.211***              | 2.799        | 0.006   |
| Capital   | 0.666***              | 5.543        | 0.000   |

J-B (P-value) = 0.002 – 0.045; VIF = 2.782 – 4.502; TV = 0.222 – 0.359;
B-P (P-value) = 0.324; Adjusted-$R^2$ = 0.779; $R^2$ = 0.788;
F-Stats = 88.177; F-Stats (P-value) = 0.000

Note: ***, and * indicate significances at the 1% and 5% levels, respectively. J-B is the Jarque-Bera test for normality; VIF and TV are the Variance Inflation Factor and Tolerance Value for testing multicollinearity; and B-P is the Breusch-Pagan test for heteroscedasticity.

Table 1 also shows that the land area has a positive effect on aquaculture production at a significance level of 5% with the estimated coefficient of 0.122. This indicates that an increase in the one-hectare land area contributed to the rise in the aquaculture production by 0.122%, ceteris paribus. As it is well-known that a land is a place where production occurs, without having land, the production process cannot be carried out. In other words, land area is a prime determinant of aquaculture production which contributes significantly to the increase in aquaculture production. The amount of idle land or vacant land in South Aceh District needs government attention to be converted for aquatic fisheries. Because the available idle land, in general, is very suitable to be used for the development of aquaculture.

Our findings of the positive influence of land area on aquaculture production in South Aceh Regency are in line with the previous studies. For example, the land area had a significant positive effect on catfish production in Denpasar City, Bali, Indonesia [7], India [15], Oyo City, Nigeria [16], and the Caribbean lake region, Zambia [17].

Furthermore, Table 1 shows that the number of fish seedlings has insignificant influence on aquaculture production in South Aceh District. The result indicates that a large number of fish seedlings were not an essential factor in determining aquaculture production. This is due to the fact that although there were quite a lot of seedlings available, without the support sufficient of feed quantity, land area, and water quality, the addition of fish seedlings did not contribute to an increase in the aquaculture production. If the availability of feed is inadequate, the fish eats each other, causing most fish to die. Likewise, a larger quantity of fish seedlings put into a narrow pond area, creating the density of fish, making fish unhealthy and even death. Finally, low water quality, such as the
unsuitable Power of Hydrogen (Ph) water, dissolved oxygen conditions, dissolved carbon dioxide, and other organic loads deteriorates fish healthiness [18] and, ultimately, cause fish death [19].

These findings signify the importance of adjusting the amount of fish seed put into fish ponds proportionately to the area of land, supported by adequate feeding and meeting the nutritional needs of fish, and the quality of fish pond water following fish species. Without meeting these conditions, there is no point in putting more fish seeds into fish ponds. In this case, the role of the government through the marine and fisheries agency in the region becomes crucial in providing a fish growing and handling-related training.

Our empirical evidence of the insignificant influence of the number of fish seedlings on the increase in aquaculture production is in line with the results of a previous study conducted by [20] in the Tugu District of Semarang, Indonesia. The development of fish seedlings needs to be supported by the use of feed and appropriate medicines to keep the seeds healthy, so that avoid conditions that cause fish death. Fish seed health, breeding advantage, and water quality level affect the mortality rate of fish seedlings and, in turn, largely determine fisheries production [21] and [22]. Previous studies also found that the number of fish seedlings that are not supported by water quality is among the main determinants of the unhealthy and death levels of freshwater and brackish fish and, ultimately, reduce the level of fish production [23].

The next factor that was found to have a positive effect on increasing aquaculture production in South Aceh District was the number of workers with an estimated coefficient of 0.211 at a significance level of 1%. These results indicate that an additional workforce of 100% contributed to an increase in aquaculture production by 21.10%, ceteris paribus. The use of the right amount of labor, efficient, professional, and capable of performing aquaculture handling tasks such as providing fish bait, maintaining water conditions, cleaning fish ponds, and providing fish treatment is crucial to increasing aquaculture production [22]. The ability of workers to carry out fish handling tasks must always be updated by providing relevant training so that they are responsive to changes in natural conditions and the emergence of various types of new fish diseases. In this case, government support through the local marine and fisheries agency is very much needed in conducting socialization and providing training related to the handling of aquaculture in a professional manner following the latest conditions.

The significance of the number of workers towards the increase in aquaculture production in South Aceh Regency is in harmony with previous research that found the maximum fish production had been realized by using proportional and professional numbers of workers [24]. The previous study by [25] also found evidence that labor contributed to increasing catfish production in Tasikmalaya District, West Java, Indonesia. Increasing fish production, in turn, will increase fish farmers' income and profits so they can expand their business. The expansion of this aquaculture business certainly requires the recruitment of new workers. This will, of course, help the government in reducing unemployment in the local area. In addition, an increase in aquaculture production means an increase in farmers' income and the recruitment of new workers which, in turn, contributes to a poverty reduction [26].

Finally, as illustrated in Table 1, the amount of capital is found to have a positive effect on aquaculture production with an estimated coefficient of 0.666 at a significance level of 1%. This result indicates that each additional capital of 100% has led to an increase in the amount of aquaculture production by 66.60%, ceteris paribus. In terms of the magnitude of the coefficient estimation results, the amount of capital is recorded to be the most dominant factor affecting the increase in the aquaculture production in South Aceh District. Without having any capital, aquaculture fisheries growing efforts would fail. Capital is needed in every aquaculture production process, starting from the cost of providing and maintaining land, providing fish seeds, feed, and medicines, managing water debit, paying workers' wages, and so on. Thus, it is very reasonable if the capital adequacy is found as the most critical factor in increasing aquaculture production because capital is the primary driver in each chain of the aquaculture production process [5].

The results of this study are supported by previous studies [27], [5], and [28]. In their research in the states of Abia, Nigeria, [27] found that the amount of available capital that was used efficiently
could help farmers to realize the maximum fish production. The availability of adequate capital following the needs of fish cultivation is one of the main determinants of increasing fish production [5]. Likewise, supported by proper capital management was able to increase fish production [28].

Overall, the results of this study indicate that, except for the number of fish seedlings, the factors of land area, the number of labor, and the amount of capital contributed significantly to the increase in aquaculture production in South Aceh Regency. The study also found that the amount of capital was the most crucial factor in increasing aquaculture production. This result implies that fish farmers must provide adequate capital, and this is usually the main obstacle faced by small-scale fish farmers. To that end, the government must help fish farmers by giving soft loans in coordination with local government-owned banking institutions, such as Bank Aceh Syariah. Furthermore, the government must also assist in the provision of adequate land through the conversion program of vacant land and spread into fish ponds. Finally, socialization and training on fish cultivation and its management, which are free of charges, must be regularly and continuously provided by the government through the marine and fisheries agencies. The training on handling aquaculture is intended to make fish farmers responsive and able to adapt to climate change and the emergence of new fish diseases to ensure fish healthiness, minimize the number of fish deaths, and increase the amount of aquaculture production.

4. Conclusion
This study empirically explored the determinants of the aquaculture production in South Aceh District, Indonesia, using the multiple linear regression analysis. The study found that, except for the number of seedlings, the size of land area, the number of workers, and the amount of capital had a significant effect on increasing aquaculture production in the district. The study also found that the amount of capital was the most crucial factor in increasing aquaculture production. These results suggest that to increase the production of aquaculture, fish farmers must provide adequate capital, sufficient land size, and the number of workers capable of supporting each stage of the production process. The government should support the fish farmers by providing soft loans and adequate land by initiating a program to convert vacant land and spread it into fish ponds. Besides, free of charges of various capacity-building programs for aquaculture farmers should be continuously initiated to produce skilled, persistent, and professional fish farmers. To enrich the existing empirical findings, future studies on this topic are suggested to consider fish farmers' characteristics and macroeconomic factors affecting the aquaculture production in their analyses, extend periods of research and the number of aquaculture areas and compare the determination of aquaculture production between across districts/cities and provinces nationwide.

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