The Scale Efficiency of Nile Tilapia Pond Aquaculture and Its Determinants in Tampaksiring District of Bali Province

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Abstract
Aquaculture has been playing an increasingly significant role to the Indonesian economy as alternative livelihood, particularly to provide nutritious food and to improve the living standards of rural communities. Since rice farmers in Bali face the competition with imported rice in the market, income diversification through Nile tilapia aquaculture in a non-permanent pond has got increasing attention in recent years. However, farmers still face inefficiency in aquaculture practices due to production constrains and other socio-economic factors. The main objectives of this study are to analyze the scale efficiency and to determine the factors that influence the efficiency of Nile tilapia aquaculture. To achieve the objective, this study applied data envelopment analysis (DEA) and Tobit regression model. The results of DEA showed that the average technical efficiency and scale efficiency score of nile tilapia aquaculture were 0.97 and 0.98, respectively. Furthermore, there were several factors found to have affected the scale efficiency such as age of farmers, formal education, farming experience, distance of farmer's pond to main road and the construction design of the pond. As the first study providing the evidence economic efficiency of nile tilapia pond aquaculture in Bali Province, this paper is expected to provide recommendations to support local farmers income diversification.
Keywords: Nile tilapia pond aquaculture, scale efficiency, data envelopment analysis, tobit regression

1. Introduction

Freshwater aquaculture started with the stocking of common carp in backyard ponds in West Java during the Dutch occupation, in the middle of the nineteenth century, and subsequently spread to other parts of Java, Sumatra and Sulawesi islands in the early twentieth century (Budhiman, 2007). However, a remarkable increase in production from freshwater aquaculture was only observed in the late 1970s. While capture fisheries has almost fully exploited, aquaculture still has high potential for growing in Indonesia (Rimmer et al., 2013). Indonesian aquaculture has developed rapidly with increasing rate of 14% per year. Nowadays, it becomes ranks fourth among the largest aquaculture producing countries with 2.304 million tons of productions in 2010 (FAO, 2012).

In Bali Province, freshwater aquaculture industry comprises of a wide range of producers from small backyard operators to supplier of the market for international tourism in Bali. Freshwater aquaculture began to squirm and triggered by lifestyles and consumption preferences change. Rising in per capita income has encouraged a strong motivation to consume many delicious cuisine that brought a high demands for culinary business along with the increased of tourism in Bali. In the period of January - December 2016, the number of tourists coming directly to Bali reached 4.927.937 visitor. It has increased by 23.14% over the same period in 2015 (Bali Tourism Agency, 2017). Since culinary tourism travel has been growing rapidly, Fried Nile tilapia with local sesame has becomes one of the favourite menu offered by various restaurants in the southern part of Bali Province. This has been a logical response to pattern changes of consumption society preferences that lately more fond to eat tilapia rather than seawater fish. Nile tilapia was first introduced to Indonesia in 1969. Then, it becomes important with production growing from 31.217 tonnes in 1999 to 71.789 tonnes in 2003 (DGA, 2004). It excites the fish farmers engaged in the business of enlarging tilapia to improve their productivity. However, efforts to increase the production of seeds are often constrained by the availability of this fish.

The aquacultures in Tampaksiring District are well known as the breeding center for Nile tilapia in Bali Province. It also is one of the source of the Nile tilapia seeds for aquaculture businesses in other locations in Bali Province such as Denpasar and Bangli district. Breeding efforts of tilapia farming in both areas are highly dependent on the supply of seeds from Tampaksiring District, thus the continuation of the nursery business in this district become increasingly important. Diantariningsih et.al (2015) suggest that increasing the scale efficiency of nile tilapia aquaculture is a logical answer to respond the high demand of tilapia seeds for enlargement activities, not only for the district mentioned above but also to support tourism industry in Bali. Stable and high tourist visit to Bali has created a huge opportunity for culinary-tourism business to grow especially for various fish dishes. As a consequence, delicate and refined cuisine made from Nile tilapia is hugely demanded in across the southern part of Bali Province, where most of the tourism activities, restaurants and hotels are located. Nile tilapia is a perfect substitute for dishes made from sea water fish as it is comparatively easier to be cultivated under aquaculture schemes, thus illustrates the positive multiplier effect to increase the intensity of Nile tilapia aquaculture in Tampaksiring District. Therefore, it will need both innovation breakthrough and systematic effort to increase the scale of the efficiency of tilapia fishing so that the business will continue growing in the future.

Aside from the promising potential of nile tilapia aquaculture to increase farmer's income in Tampaksiring District, a big question has emerges since this new business have not yet attract most of wetland rice farmers, even it has more promising income. Our preliminary survey in the area reveals that the farmers are very reluctant to be involved in Nile tilapia nursery business due to several factors. Wetland rice farmers have been less adapted to the development of productive economic enterprises and they are not motivated to respond the new techniques that are capable of providing greater economic incentives because they feel it to be a risky choice considering their current income and investment capability. The other factor is related to the initial investment that has to be spent in order to convert wetland farm to a non-permanent pond. On the other hand, it is without a doubt that production capacity of currently running tilapia aquaculture business needs to be increased in order to respond the increasing demand in both seeds and fish products. Question regarding scale efficiency has risen since the efficient production scale of nile tilapia aquaculture has not yet been determined, causing doubts whether the currently on going aquaculture business has been running efficiently.

Unfortunately, the answer to the question related to specific aquaculture business in non-permanent pond cannot be found in current literatures. Moreover, there was lack of comprehensive studies regarding variable that contributes to the scale efficiency of tilapia aquaculture in Indonesia. However, some research has been conducted to increase the production of tilapia nursery. Yuliati, et al. (2003) who studied the effect of stocking density on the growth and survival rate of tilapia, found that the best output production in the growth of tilapia fingerlings was on the ponds population density of 50 fish/ m2. However, it still becomes unsolved problem whether ponds population density of 50 fish per meter also has the best scale efficiency. Anggriani, et al., (2012) observed about the effectiveness of adding of Bacillus sp. which was isolated from disgestive duct system of Iridescent shark to the commercial fish feed on performance of survival and growth rate of red tilapia (Oreochromis niloticus). It was found that a survival rate of 70% and a growth rate of 2.92% showed when a commercial feed was added by Bacillus sp. at a dose of 100 ml / kg. Nonetheless, the results of the above mentioned research did not answered to the problems of the tilapia farmers, whether the presence of Bacillus sp. which acts as a probiotic has resulted in optimum scale efficiency for tilapia fish nursery business. The results of both studies have not been able to outline the factors that influence the scale efficiency

In line to this problem, the objectives of this study are twofold, i.e. to determine the scale efficiency for tilapia nursery bussiness in Tampaksiring District as a response to high demand of tilapia from the tourism and culinary industry and to analyze the factors that affect the scale efficiency of tilapia fish nursery in regarding to the creation of policy design and enhancement of attractiveness of tilapia nursery business to increase rural livelihood in Tampaksiring District.

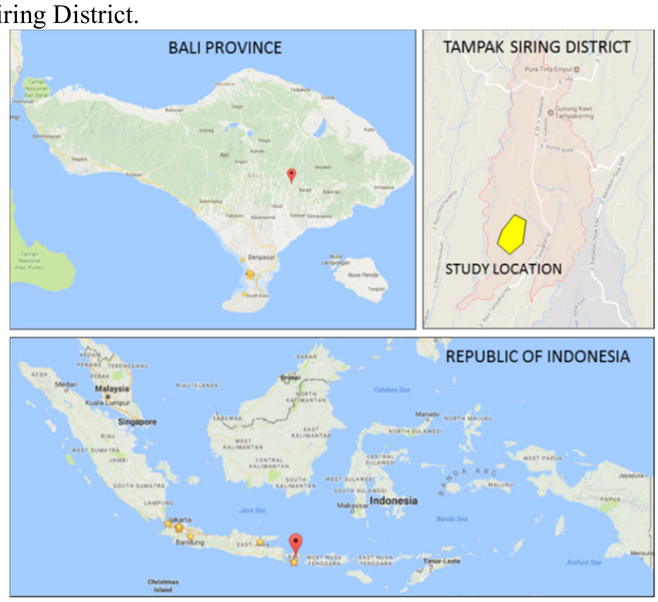

Figure 1. Study location at Tampaksiring District of Bali Province

2. Data and Methods

The research was conducted in the Sukawati Village, Tampaksiring District, Gianyar Regency of Bali Province in the Republic of Indonesia as shown in Figure 1. Selection of the research location was done on purpose based on the consideration that (1) Tampaksiring District has become the business center of tilapia nursery in Gianyar, (2) the nile tilapia aquaculture have been carried out under an income-diversification pilot project scheme in a sustainable manner, and (3) The aquaculture farmers has already established institution as a vehicle to expand the cooperation network with stakeholders.

Tilapia fish nursery business in Tampaksiring District was originally developed by some farmers in Sanding Village. The agro-climate location is very suitable for the growth and development of tilapia seeds. Ponds are built in rice fields at the backyard of farmer's residence, where a few already have permanent excavated construction but most of them still use a non-permanent construction in between their paddy fields. In subsequent developments, tilapia aquculture gets help from the government in the form of materials for the improvement of ponds, capital, as well as management of cultivation techniques.

Most residents of Tampaksiring District are farmers. Wetland farming dominates household livelihood with most of whom have an average age of 60 years. The average profit gained from wetland farming is below than 300 USD/ha/season where most of the remuneration obtained by the wage labor worker outside of the farmer's family particularly for tillaging and harvesting jobs. Only a small fraction of the remuneration falls into the hands of the aquaculture owners. Unlike wetland rice farming case, nile tilapia aquaculture is mostly managed by young farmers under 50 years old. There are 40 active tilapia farmers out of 46 who are registered and have established farmer group institutions to accommodate their activities and establishing partnerships with various stakeholders.

The examined populations in this study were all members of the group tilapia nursery business in the Sukawati Village, Tampaksiring District, Gianyar Regency of Bali Province. A survey was conducted using structured questionnaire by purposive sampling method for all 40 pilot project farmers who are active in the nursery business for the past two years in the study location. The data collection was conducted in 2016, by both direct interviews with respondents using a structured questionnaire, and collection of secondary data from the nile tilapia aquaculture business association. Collected data comprises characteristics of respondents, the use of fixed input and variable input in each cycle of production, the amount of each cycle of seed production as well as input and output prices as summarized in Table 1.

The factual condition shows that the profit gained from nursery tilapia area of 4 acres is USD 347 per production cycle of 42 days. If it is compared to the profit of wetland rice farming, then two cycle of nile tilapia nursery can be done in the same duration of one rice planting season of 105 days. In terms of profit, the 4-acre pond area can give twice the profit/ha/season than that of wetland rice farming which in total gives 50 times higher profit for 1 ha nursery area compared to wetland rice farming in one planting season on the same duration. It is not surprising then that Nile tilapia farmers have higher and more stable income levels compared to rice farmers.

Pond culture is usually done traditionally converting half of the wetland rice farm size to a excavated pond as shown in Figure 3. A pond has size around 416 m2 in average, with 5-10 pieces/ m2 of fish density which have 8-12 cm size of seed. The long duration of culture is 3-4 months. It also known that the pond shows an 80% of survival rate and 2 ton/crop production with a size of 250-300 g/piece. The farmers practice an extensive culture using low-yielding, low-input and low-level technology, and they lack the technical know-how or skill that would enable them to adopt new or improved production methods and techniques

Traditional fish marketing channels are dominant in distributing the end product of Nile tilapia nursing business in the study area where most of fish products end up in the domestic market. In most cases, farmers do not have access to a wide range of prospect buyer and processing opportunities, but they have maintained loyal customers from nearby processing center, hotels and restaurants in the center of tourism industry in Bali Province. Fish products are gathered through the farmer association to Village-based collectors who usually belong to the village themselves. They work as local agents supplying fish as raw material. However, the availability of credit is still becoming major problem due to stringent banking requirements, such as the need for collateral and high equity as also stated by Hishamunda et.al. (2009)

Table 1. Definition of variables used in the models

Variable	Unit	Definition
Output		
Amount of fish	Kg/year	The amount of fish output is measured in one production cycle
Input		
Fishpond area	m^2	The pool area is the size of pond for each farmer
Amount of seed	Unit	The number of seeds is the number of seeds stocked
Amount of feed	Kg	The amount of feed is measured in one production cycle
Labor	Man-days	The amount of labor used in one production cycle
Nursing duration	Day	Period of seed nursing
Independent variable		
Age	Years old	Age of tilapia farmers,
Experience	Year	The experience of doing tilapia farmers
Education	Year	Formal education of indigenous tilapia farmers
Distance	m	The distance of the pond from the main road
Pond Construction	N/A	Expressed as dummy variable, 1 = permanent and 0 = non-permanent
Ownership status	N/A	Pond ownership status is expressed as dummy variable, 1 = owned and 0 = rented

3.1 Data Envelopment Analysis

A data envelopment analysis (DEA) approach was used to analyze the scale efficiency, which is a non-parametric model serves as references for estimating the technical efficiency based on mathematical programming technique. The main characteristic of DEA model according to Coelli (1995) is its model does not require assuming the form of a specific function between the inputs to the output and does not require assumptions regarding the distribution of inefficiency as required in other parametric models. A number of researchers have used DEA model to estimate the technique efficiency among others Tipi et al. (2010); Heidari et al. (2011); Abatania et al. (2012); Jatto et al. (2012); Mahjoor (2013); and Karimov (2013). The analysis of tilapia nursery business in this study was focused on input oriented models because tilapia farmers have more control of the input compared to the output. According to Coelli et. al. (1998), model of constant returns to scale (CRS) in DEA only appropriate if all producers operate optimally. Market imperfections and financial constraints may cause non-optimally scale of manufacturers' performance. Furthermore, in the case of the fisheries sector, a rising of the amount of irrigation water and feed are not always followed by a proportional increase in the growth and production of fish. Based on those reasons, a model-oriented input variable returns to scale (VRS) DEA was used to calculate the scale of efficiency in this study. The DEA model developed by Banker et al. (1984) was used to assess the efficiency of the technique under the assumption of variable returns to scale (VRS) for a number of N farmers, which each produce M output using as K different inputs mathematically expressed as follows :

$$\begin{aligned} & \min_{\theta,\lambda}\theta, \\ st \quad & -\mathbf{y}_i + \mathbf{Y}\lambda \geq 0 \\ & \theta\mathbf{x}_i - \mathbf{X}\lambda \geq 0 \\ & \mathbf{N1}'\lambda = 1 \\ & \lambda \geq 0 \end{aligned} \tag{1}$$

To identify whether CRS or VRS was applied to production, DEA technique is used to calculate and compare the efficiency values under these assumptions. According to Coelli (1996), the relationship between VRS DEA scores, CRS DEA scores, and the scale efficiency (SE) scores of producers, can be calculated as follows:

$$SE = TE_{CRS} / TE_{VRS} \tag{2}$$

SE equal to 1 indicates that producers are efficient, while if SE <1 indicates an inefficient scale. The factors affecting the scale efficiency were analyzed using the Tobit regression model rather than OLS regression since OLS demands an assumption of normal and homoscedastic distribution of the free and disturbance variables and often show bias (Maddala, 1983). The standard Tobit used in this study model is as follows.

$$\begin{aligned} & y_i' = x_i\beta + u_i,\ i = 1,2, \ldots, n \\ & y_i = y_i' \ \textbf{if} \ \ y_i' > 0 \\ & y_i = 0 \quad \text{otherwise} \end{aligned} \tag{3}$$

where $u_i \sim N(0,\sigma^2)$, x_i is independent variable vector, β is a parameter vector, y_i' is a latent variable and y_i is DEA score (Amemiya, 1984). The DEA score is estimated using DEA Frontier Software developed by Zhu (2004, 2015).

Table 2. Descriptive Statistics

Variable	Mín	Max	Mean	Standard Deviation
Input				
Fishpond area (m^2)	300,00	600,00	416,67	78,59
Amount of seed (unit)	10000,00	17000,00	14166,67	2307,27
Amount of feed (kg)	300,00	550,00	448,61	95,67
Labor (man-days)	25,00	55,00	43,05	7,50
Duration of nursery (day)	55,00	63,00	58,56	2,47
Output				
Amount of fish (kg/year)	7100,00	12410,00	9927,28	1600,04
Independent variable				
Age of farmer (year)	39,00	62,00	51,17	6,94
Farming experience (year)	5,00	12,00	8,89	1,67
Formal education (year)	9,00	16,00	10,72	1,99
Distance to main road (m)	2,00	2000,00	328,50	559,13
Pond's construction (dummy)	0,00	1,00	0,38	0,33
Ownership status (dummy)	0,00	1,00	0,73	0,36

Note: Self surveyed 2016

3. Results and Discussion

3.1 Characteristics of Nile Tilapia Pond Aquaculture

Table 2 shows the descriptive statistics of inputs as dependent variables to output and pond aquaculture specific characteristics as independent variables used in this study. The input variables cover the number of production inputs used by farmers to operate their ponds, consist of fishpond area, amount of seed and feed, as well as workers employed during the operation. The largest fishpond area is 600 m^2, while the smallest is 300 m^2 with mean of 416.67 m^2. The construction of ponds is mostly non-permanent; with most farmers own the ownership of pond themselves.

The amount of required seeds is positively related to the pond area, accounted for 17,000 units of seed for 600m^2 area of pond. The amount of feed being spread also follows this trend where 448.61 kg of fish feeds were used in average. The average duration of nursery of 58.56 days can achieve 12,410 units of tilapia's maximum output and 7,100 units of tilapia's minimum output. The poor quality of the village land's infrastructure has made the distance of pond to the nearest main road became an important factor for fish transportation in maintaining the freshness of fish and the quantity of output that can be transported in a day. Longer distance may easily result in death of fish and required more labor to manually transport the fish products to the transport vehicle parked at the main road. The longest pond-to-main road distance from the sample population is 2 km which poses death threats of fish due to long transport time and would require a specific handling method. Meanwhile the closest distance is 2 meter to the main road while most of the ponds are located at a fair distance of 300 m to the main road.

Furthermore, the relative age of farmers is 51 years old showing that most of the farmers have more than 5 years of aquaculture experiences with an average experience of 8 years. The lowest degree of farmer's education is senior high school which is the majority of the sample although there are younger farmer who had a bachelor degree. This degree of education is important to determine the rough ability of farmers to accept new technology and counseling related to efficient aquaculture practice in the future.

Table 3. Estimation of technical efficiency and scale efficiency

Variable	Technical Efficiency			Scale Efficiency			
	TE_{CRS}	TE_{VRS}	TE_{VRS} =1 (%)	SE	SE = 1 (%)	DRS (%)	IRS (%)
Value	0,97	0,99	61,10	0,98	22,22	5,55	72,23

Where :
TECRS = technical efficiency constant return to scale
TEVRS = technical efficiency variable return to scale
SE = scale of efficiency
DRS = decreasing return to scale
IRS = increasing return to scale

3.2 Technical Efficiency and Scale Efficiency of Nile Tilapia Nursery

Technical efficiency and scale efficiency estimates are presented in Table 3. The average TE_{CRS} score is 0.97

showing that nile tilapia aquaculture business in Tampaksiring district was able reduce the use of input as much as 3% but still produce the same level of output. The input savings of 3% are relatively meaningful to contribute to the profit increasing of tilapia fish nursery business. Furthermore, the elimination of inefficiency can increase the average technical efficiency level from 0.97 to 0.99 to the tilapia nursery business in Tampaksiring District. However, a careful identification of factors which triggered inefficiency is needed to achieve the highest efficiency in tilapia nursery.

Since the current scale of business efficiency of tilapia nursery is relatively high, there is almost no urgent need to change the operation scale. The value 0.98 of scale efficiency score indicates that most of the tilapia nursery business is on or close to the optimal size. However, uniformity in operation has been noted and interesting to be examined as uniform aquaculture practice may be contributed by misallocation of inputs. According to Tipi, et al. (2009), the cause of inefficiency is the inaccuracy of scale or misallocation of resources. It has been known from the survey that there are different approaches and methods of input utilization used by the farmers. In this case, lack of resource allocation refers to a misappropriate combination of inefficient inputs by several farmers and the scale of inaccuracy causes the tilapia farmers to not profit from economies of scale. This result typically shows the needs for proper counseling so that tilapia farmers in Tampaksiring district may rearrange its' production scale including the use of combination of inputs to suppress inefficiency.

3.3 The Factors Determining Scale of Efficiency of Nile tilapia Pond Aquaculture

Tobit regression analysis is used to identify the factors that determine the scale efficiency of Nile tipalia nursery in Tampaksiring District, which is presented in Table 4. We found age of farmer's was negative and significant at 5% level, implying that younger farmer is operating the aquaculture more efficiently than older farmers. This finding is in agreement with previous researches by Mathijs & Vranken (2000) and Bozoglu & Ceyhan (2007), where older farmer has been mentioned to be less adaptive with newer technology and best farming practice. Moreover, the older farmer tends to be in their production peak, thus feels unnecessary to improve their production scale. This tendency is highly correlated to the formal education, which positive and significantly influencing the scale of efficiency. Younger farmers are more educated, with minimum of senior high school level of education and more encouraged to adopt new production technique obtained from counseling and literatures, which consentient with Mahjoor (2013). Educated farmers are also more responsive to the market demands, customer complaints, and innovation in farming practice and act efficiently when operating their nile tilapia nursery business.

Table 4. Estimated Tobit regression coefficient

Observed variables	Tobit regression coefficient	P-Value
Constant	1,4526 (0,6469)	0,0474*
Age (year)	-0,0957 (0,0246)	0,03339*
Education (year)	0,0736 (0,0214)	0,0412*
Farming experience (year)	0,0639 (0,0147)	0,0091**
Distance (m)	-0,06329 (0,0187)	0,03852*
Pond's construction (*dummy*)	0,0083 (0,0021)	0,03463*
Ownership status (*dummy*)	0,5437 (0,3241)	0,6365

Note: *, **, are significant at 5% and 1% level, respectively

However, the result pointed out that farming experience was negative and significantly influences scale of efficiency. We had found that the older farmers with high farming experience more than 10 years will have higher efficiency than the other farmer including younger farmer with higher level education, yet older farmer who started the nursery business less than 5 years tends to have the lowest scale efficiency. The farmers who have high farming experience above 8 years are relatively more appropriate in the use of production inputs because they have better ability to control over the production process than the farmers with shorter farming experience. This finding is in line with the result from Yusuf and Malomo (2007), stated that sustainable farming practices for a long period of time makes farmers more efficient in using production inputs.

As explained in the previous chapter, pond distance to main road has an impact to the quantity of output due to transportation problem. Longer pond's distance from main road may lower the scale of efficiency. This negative influence is contributed by longer duration of output handling and freshness of the fish output after being transported. Furthermore, ponds that located farther from the main road are relatively more difficult to manage so that the possibility of leakage of resources becomes greater. Unmonitored pond irrigation often leads to the discontinuity of water supply due to competition of irrigation water use with surrounding ponds and paddy fields, thus ultimately leads to the efficiency decreasing. From the above explanation, it can be concluded that the ponds located near to the main road are relatively easier to be monitored so that the use of inputs becomes more efficient.

Regarding to pond's construction, permanent pond construction has a high significant scale efficiency compared to the majority used; non-permanent pond. Permanent ponds are more efficient in utilizing irrigation water, so that the higher number of fish can survive because they have adequate water supplies. In addition, pest disturbances can be suppressed in permanent ponds since the cleanliness of the ponds can be maintained easily. It has also been noted that labor costs to maintain the pool cleanliness are lower for permanent ponds. The coefficient of pond's ownership status indicates that the pond with full ownership and lease status has relatively equal scale efficiency. However, regardless to the ownership status of the pond, the farmers are always trying to achieve the maximum profit so that the invested capital can return quickly, thus able to expand.

4. Conclusion, Recommendation and Future Research

The DEA result revealed the current average scale efficiency of Nile tilapia aquaculture is 0.97, but only 22.22% farmers out of total sampling population had optimally combines the use of its input to reach high scale efficiency index. It indicates that most of the farmers, particularly inexperienced farmers, need to readjust the combination of inputs to reach the optimum yield and suppress the inefficiency of input usage by 3% simultaneously in order to improve profitability of nile tilapia aquaculture business in the future as well as guarantee fresh supplies for local demand. There were several variables that influence scale of efficiency of Nile tilapia aquaculture in Tampaksiring District such as age of farmer, formal education received by farmer, farming experience, pond distance from main road, and pond construction. This study particularly pointed out that the nursery experience of farmers had outperformed in almost every other influencing factors including formal education and age of farmer whereas young and educated farmer have more quickly to adapt the new techniques from both literatures and counseling. The result happened since that the efficient combination of inputs which gained from long period of work of experienced farmer. Therefore, dissemination of the effective practice from experienced farmers through farmer's association as well as the involvement of the provincial counselor are in utmost needs to bring up overall profitability of nursery tilapia business in Tampaksiring District.

Based on the analysis result of the study, there are two recommendations that reflect to government and farmers. Since Pond distance to the main road is as much important as the other influencing factors to tilapia nursery business in study area, government should consider the infrastructure investment, particularly for the road and storage facilities. Thus, farmers can maintain their production and market access. Since many farmers are located far from the main road, it is necessary to farmers to be facilitated with adequate fish storage in order to preserve the freshness of fish. On the other hand, current applied non-permanent pond construction will decrease the efficiency in long term. Therefore, given the low financial support and technical knowledge, particularly to young farmer, is expected to increase scale of efficiency of nile tilapia aquaculture in the future.

Finally, the result has shown that Nile Tilapia pond aquaculture in Tampaksiring District have huge potential to be developed in a larger scale. Further research will be focused to examine the appropriate technological innovation to be implemented to furtherly enhance the aquaculture's scale of efficiency.

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