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The impact of aquaculture field school on the shrimp and milkfish yield and income of farmers in Demak, Central Java

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Abstract

Traditional farmers of milkfish and shrimp use 80% of Indonesia's shrimp production area, but produce only 10% of its shrimp. A coastal protection project funded a 16-day aquaculture field school (AFS) in order to train 277 farmers in Low External Input Sustainable Aquaculture (LEISA). Its cost was 1,060 USD per farmer. In 2017 and 2018, the project monitoring database completed records of yields and practices of 125 participants and monitored finances and water quality in a 10% sample. LEISA was adopted by 85% of the 125 participants. The two annual datasets of the sample were merged and trimmed from three outliers; this was done before statistical analysis. Compared to the baseline, LEISA adopters among the 125 tripled their shrimp' yields. Within the sample, the milkfish yields of adopters and non-adopters were about identical. Sampled adopters significantly increased their gross margin by 927 USD ha^{-1} $year^{-1}$ due to three- and fivefold yield increases for milkfish and shrimp compared to that of the baseline. The rate of return was 1.3 for the 277 participants and 1.8 for the sample, indicating a payback time of <1 year. Enriching the farmers' skills with AFS can double Indonesian milkfish production and increase its shrimp production by 25–50%.

KEYWORDS

efficiency, Indonesia, production, sustainability, training

1 | INTRODUCTION

Farming shrimp in brackish water ponds provides food and livelihoods, but, if not done properly, it delivers high benefits only for some years (Phillips, Lin, & Beveridge, 1993). As a result, the long-term contribution to economic development is mostly negative (Rivera-Ferre, 2009) due to increased inequality (Adger, 1999), income-decimating diseases (Shinn et al., 2018), and negative environmental impacts (Primavera, 1991). In Indonesia, the latter is aggravated by the abrasion due to the quasi-removal of mangrove forests to build ponds (Bunting, Bosma, Zwieten, & Sidik, 2013; Wilms, van der Goot, & Debrot, 2017) and soil subsidence (Abidin, Andreas, Gumilar, Sidiq, & Fukuda, 2013). Although forbidden by law, farmers have cleared the mangrove forest almost up to the coastline, thus reducing sedimentation and increasing exposure to abrasion. The impact of land subsidence, because of groundwater extraction by nearby industries, broiler production, and some intensive shrimp farms, is larger than sea level rise.

In Demak district, Central Java, Indonesia (Figure 1), the average yields of shrimp and milkfish at final harvest were 47 and 234 kg ha^{-1} year^{-1}, respectively, in 2015 (sample of 113 farmers of which 1/3 farmed shrimp; Ariyati, Widowati, & Bosma, 2016). Considering an average operational cost of 240 ± 400 USD ha^{-1} year^{-1}, the farmer's average gross income was 600 ± 760 USD ha^{-1} year^{-1}; the 36 farmers stocking both milkfish and shrimp earned 630 ± 650 USD ha^{-1} year^{-1} after having spent 420 ± 1,130 USD ha^{-1} year^{-1} (Ariyati et al. 2016). Originally, most of these brackish water pond farmers were either fishermen or traditional rice farmers, who by lack of knowledge, disregarded the importance of mangrove forest (Bosma, Sidik, Zwieten, Aditya, & Visser, 2012), and by lack of proper training, do not apply good aquaculture management practices (Elfitasari & Albert, 2017).

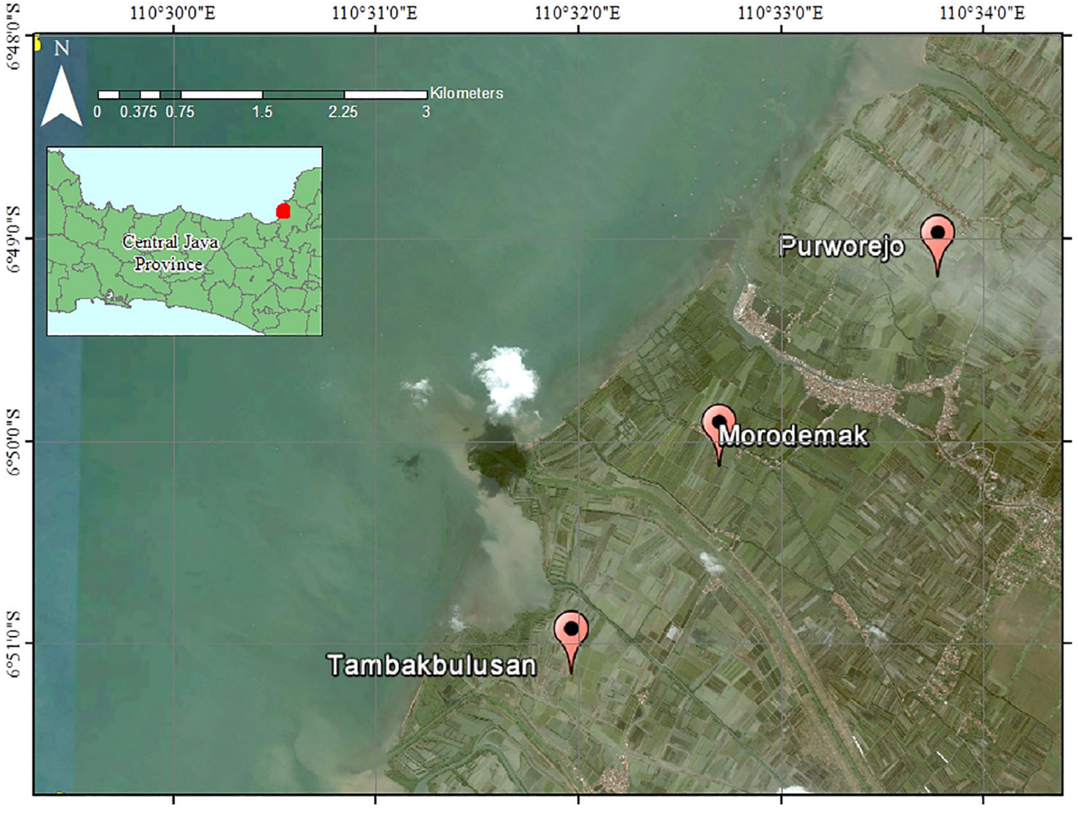

FIGURE 1 The location of the three villages in Demak regency, Central Java, Indonesia

To make the aquaculture-based livelihoods sustainable, the *Building with Nature* project (BwN-Demak) conceived a plan with four goals: protect the residual coastal mangrove, give up ponds along sea and rivers for mangrove rehabilitation, reduce groundwater extraction, and make aquaculture more productive. To reach the latter, BwN-Demak implemented aquaculture farmer field schools (AFSs). AFSs, which train farmers for one culture season, have a good track record and promote social interaction among farmers after the AFS (Braun & Duveskog, 2010; Van de Fliert, Ngo, Henriksen, & Dalsgaard, 2007). Next to good aquaculture practices, the project's AFS teaches farmers to manage their pond by using LEISA (Low External Input Sustainable Aquaculture) principles promoted by the NGO Blue Forest that was contracted as AFS implementer (Brown & Fadillah, 2013). The methods specific to LEISA are the production of home-made liquid compost from wasted vegetables and fruits, which is annually applied to the dried pond bottom together with manure, and used to manage water quality as needed, based on changes in the water color (Ariyati, Rejeki, Widowati, Elfitasaria, & Bosma, 2019).

The main hypotheses are that the pond's yield and farmer's income would increase effectively after an AFS training, and that the program is cost-efficient, that is, the societal gain of the training will be higher than its cost. The underlying assumptions are that the LEISA practice is effective and would allow farmers to increase stocking density and apply feed, and thus sustainably increase the productivity of their ponds. After presenting the methods used to collect and analyze the data, we present the sample and project cost in the chapter materials, and thereafter give and discuss the results before concluding.

2 | METHODS

To determine the effectiveness of training on pond farming, we used three datasets: a baseline of 113 farmers from seven villages collected in 2015 (Ariyati et al., 2016), the BwN monitoring dataset and a sample of 18 farmers among those trained in 2016 (see below). Before the observations began, we communicated our goal and the importance for them to monitor the pond's water quality that they have learned at the AFS. However, five farmers dropped out over time; two for lack of interest, and other dropout farmers shifted to a government-led program, which tested an intensive culture of *Penaeus merguensis*.

2.1 | Variables

To test the hypotheses, we used the following variables: the annual yield of the stocked milkfish and shrimp, the gross margin (GM) of the ponds, and the rate of return (RR) of the AFS. As variable of income, we used GM instead of net margin, as the calculation of the latter would require the accounting of the investment cost, including the value of the pond. The fixed value of the pond was either unknown, hard to estimate, or correlated to location and would create an undesirable covariable in the analysis. The yields of both groups of sampled farmers were compared with those of the baseline study (Ariyati et al., 2016) and those of BwN's monitoring database with 125 complete recordings. The RR was used to indicate the efficiency of the AFS program in recovering its cost through an increased margin of the AFS's alumni.

We also monitored the water quality parameters, and from those we report in this article the results that are relevant to the analysis of financial results.

2.2 | Data collection

To assess the effectiveness and efficiency of the AFS, we collected the operational cost, total production, and revenue of the pond. We considered the production of the pond as the sum of the final harvests in 1 year. Final harvesting of fish and shrimp was done with a dragnet. Farmers weighed the harvest in the village. We did not include small intermediate harvests and the shrimp catches in the gate of the pond when water was released during low tide and replaced at high tide. Selected marketable-sized milkfish were partially harvested with a broadcast net. In both 2017 and 2018, the average farm gate price of the shrimp was 5.7 USD/kg for size 40 pcs/kg, stocked tilapia was sold for 1.6 USD/kg and stocked milkfish for slightly less than 1 USD/kg.

To monitor water quality, the farmers measured salinity once a day with a refractometer; temperature, pH, and color thrice (morning, afternoon and evening). They then recorded the results on sheets that we provided them. Once a month, we conducted control measurements by collecting water samples for analyzes in the laboratory. The water samples were placed in a cooler and transported to a laboratory; levels of DO, TAN, P, nitrate, and ammonia were determined by using conventional methods (Ariyati et al., 2019).

Once a month, we verified the monitoring sheets, copied the data collected, and discussed the results with the farmers. We also collected other data required to calculate the RR of the AFS project from primary (implementer) and secondary (reports and the program database of the AFS) sources.

2.3 | Calculations

We encoded the data and calculated the main variables in MS-Excel. Data were explored by using averages, standard deviations and correlations. The averages of the amounts resulting from the calculations were transposed in USD by using a value of 1 USD = 14,000 IDR.

We used the following formula:

Revenue of production = {Σ (price of milkfish × total milkfish harvest) + (price of tilapia × total tilapia harvest) + (price of shrimp × total shrimp harvest)}/pond area.

Operational cost = {Cost of (chemicals, lime, fertilizer and manure for pond preparation + stocked shrimp and tilapia/milkfish + ingredients for liquid compost + feed + fertilizer + net + fuel + hired labor)}/pond area.

$$\text{Gross margin (GM)} = (\text{Revenue} - \text{operational cost})/\text{pond area}.$$

In computing the total cost of the AFS program for 10 villages, we added the value of the contract for the implementing NGO to the total cost for the government support. The latter was calculated from the monthly salary, the average number of working days, and the number of days contributed to the project. We weighted the cost of the AFS per farmer with the fraction of the AFS participants having adopted LEISA. This adoption rate of the LEISA technology was based on the 125 complete records of the project database. The increase in GM was defined as the difference of the GM obtained by LEISA adopters and that of the baseline study (Ariyati et al., 2016). The GM per hectare of the 125 LEISA adopters was estimated by approximating the changes in their yields to the yields and GM obtained by the adopters among the sample.

The efficiency is expressed as the Rate of Return and calculated as:

RR = (Increased GM per farmer − AFS cost per farmer/adoption rate)/(AFS cost per farmer/adoption rate),

in which:

Increased GM per farmer = Average area in ha × average of the difference in GM of adopters and non–adopters.

$$\text{AFS cost per farmer} = \text{Total program cost}/\text{total number of farmers trained}.$$

2.4 | Statistical analysis

Shortly after pond monitoring, we encoded the data in spreadsheets in which we did a first set of calculations. After cleaning the project monitoring database, we calculated the averages of yields and correlations between pond area and stocking densities. For the sample, we calculated separately for 2017 and 2018 the yields and economic variables per ha, as well as averages with standard deviations (SD), and correlations of the main variables with the pond area for each farmer. Given the high SDs and the small sample size (see Discussion), we merged the databases with the main variables of 2017 and 2018 in IBM-SPSS®-26.

In this dataset, we confirmed the abnormality of the distribution within the variables using the z-values of Kurtosis and Skewness (Field, 2009). We also calculated the correlations between area, operational cost, and GM.

After deleting three outliers, we obtained a trimmed dataset for which yields, revenues, and gross margins were normally distributed and the variables of both adopters and non-adopters of *LEISA* had equal variance. On this trimmed dataset, we performed a Univariate Analyzes of Variance to compare the *GM* of LEISA adopters and non-adopters with *Year* as a covariable, and we used the provided mean of the differences to calculate the RR for the small sample.

3 | MATERIAL

3.1 | Sample characteristics

In 2017 and 2018, we collected a complete set of data from, respectively, 17 and 13 ponds in three villages: Tambakbulusan, Purworejo, and Morodemak where the training was conducted in 2016 and 2017 (Table 1). Each year, we monitored only one pond per farmer. To determine our respondents, we used purposive sampling among the AFS participants within the three villages with three criteria: availability of a literate person in the household, accessibility of the pond, and willingness to collaborate. We started with a sample of 18 ponds, six from each village, but later, five farmers dropped out.

The average area of the ponds monitored was about 2.2 ha, but in Purworejo the ponds were on average smaller (Table 1). In 2018, the average pond area of the LEISA farmers was larger than that in 2017 (Table 3) because most farmers monitored in Purwerojo shifted to a government-led trial of intensive culture of *P. merguensis*. In general, large parts of the ponds were shallow, like most traditional ponds in Indonesian coastal zones; the average depths of the ponds of the LEISA and non-LEISA farmers were not different. In particular, the larger ponds had a deep area only along the bunds, while the central platform remained at the soil height of the former mangrove forest (Bosma et al., 2012).

3.2 | Culture practices and inputs

The AFS trained farmers, among others, to dry the pond, produce and use liquid compost. The farmers prepare their ponds at the end of the rainy season between January and March. LEISA technology recommends that after drying the pond, farmers apply 20 L/ha of liquid compost and manure from ruminants (Table 2). In 2018, only four farmers dried their pond for 1 to 5 days, while in 2017 only three farmers did so. Moreover, although they may dry the central platform of the pond, they mostly do not empty the ditches along the dikes for fear that the dike may collapse. The farmers were also trained to know how to use a chart where several recipes for management are found for several corresponding colors of the pond' water, and then follow the recommended practice for that color, including the use of liquid compost.

In 2017, three farmers of Tambakbulusan, all of Purworejo and one of Morodemak, implemented the LEISA technology, but two of Tambakbulusan and five in Morodemak did not. The latter, influenced by their leader and often assured of free fry, pursued the use of inorganic chemicals in preparing the pond bottom and in managing the water quality (Table 1). In 2018, all seven in Tambakbulusan and Purworejo applied LEISA; one in Morodemak used limited amounts of liquid compost while still using also chemical inputs.

TABLE 1 Sample sizes, characteristics of the ponds, the use of manure from ruminants, liquid compost, shrimp grow-out feed and chemical fertilizers (NPK, urea, and various P), and the stocking densities of milkfish and shrimp, in the three communities for 2017/2018

Village	Number of ponds	Pond depth (m)	Pond area (ha)	Manure (kg/ha)	Liquid compost (kg/ha)	Feed (kg/ha)	Fertilizer (kg/ha)	Stocking densities (*1000 N ha^{-1} $cycle^{-1}$)	
								Milkfish	Shrimp
Tambakbulusan	5/5	0.5	2.7/2.7	45/45	10/42	3/14	0/0	5/18	18/21
Purworejo	3/2	0.7	1.2/1.6	29/0	40/41	11/21	0/0	8/10	26/39
Morodemak	6/6	0.6	2.5/2.5	0/0	0/0	10/7	11/-	9/18	0/0

TABLE 2 The sample sizes, average area, the use of manure from ruminants, liquid compost, shrimp grow-out feed and fertilizers (NPK, urea, and various P), and the stocking densities of milkfish and shrimp for farmers applying LEISA or not in 2017/2018

	Sample size (*n* ponds)	Pond area (ha)	Manure (kg/ha)	Liquid compost (kg/ha)	Feed (kg/ha)	Fertilizer (kg/ha)	Stocking densities (*1000 N ha^{-1} $cycle^{-1}$)	
							Milkfish	Shrimp[a]
Control	7/7	2.8/2.4	0/0	0/0	10/7	6/4	9/12	24/0
LEISA	10/6	1.6/2.5	37/23	25/42	7/17	0/0	6/9	17/30

[a]These are the averages for *P. monodon* and *L. vannamei*; the latter is mostly stocked in two to four times higher densities than the first.

TABLE 3 Average yields (kg ha^{-1} $year^{-1}$) of milkfish and shrimp of the non-adopters (Control) of LEISA and the adopters (LEISA) for the baseline (2015), the monitoring data (2017/2018), and the trimmed dataset of the sample (*n* = 27; 12 Control and 15 LEISA)

	Milkfish			Shrimp		
Treatment	2015	2017/18[a]	Sample	2015	2017/18[b]	Sample
Control	234 ± 363	350 ± 527	721 ± 429	47 ± 47	31 ± 23	16 ± 55[c]
LEISA	-	243 ± 427	670 ± 285	-	134 ± 550	186 ± 133

[a]*n* for Control was 21 and for the LEISA 99.
[b]*n* for Control was 8 and for the LEISA 63.
[c]The average of the two who stocked shrimp was 225 kg ha^{-1} $year^{-1}$.

Four farmers among the 17 added feed to their pond in 2017, and 10 out of 13 did so in 2018 (Table 2). One farmer added also sugarcane; sugarcane stimulates the recycling of N and P into new natural feed for the animals.

3.3 | Stocking densities

In addition to drying the pond bottom, making liquid compost and adding feed, LEISA farmers were also trained to stock shrimp post larvae (PL) and fry of fish when the color of the pond water turns brownish green. This color indicates that the plankton, the natural food for shrimp PL and milkfish, is starting to grow. In Morodemak, most farmers culture milkfish for only one cultivation cycle of 5 to 9 months; however, in 2018 two among the six farmers stocked twice; their stocking densities varied between 5,000 and 20,000 fry ha^{-1} (Table 1). The farmers, who simultaneously cultured both fish and shrimp (polyculture), stocked the milkfish and/or tilapia once in densities of 5,000–20,000, and 5,000 fry ha^{-1}, respectively. Among these, only one and two farmers stocked tilapia in 2017 and 2018, respectively. These farmers stocked either tiger shrimp (*Penaeus monodon*) or white leg shrimp (*Litopenaeus vannamei*), the former at a density lower than that of the latter. PL stocking densities were highest in Purwerejo where farmers had smaller ponds (Table 1). One farmer stocked green mussel and another seaweed, but we did not include the mussel in our analysis and the farmer did not harvest the seaweed (Box 1).

Overall, the LEISA farmers increased stocking densities in 2018 compared to 2017 (Table 2). Moreover, in 2017 all farmers practicing polyculture stocked shrimp twice only, while in 2018, most of them stocked three times; two farmers did a complementary stocking of 5,000 PL ha^{-1} (See Box 1).

In particular in 2017, heavy rains and high tides caused flooding, which led to loss of stocks. Cost for restocking was accounted for.

BOX 1 Story of significant change in Tambakbulusan

In 2016, a farmer participated in the aquaculture field school (AFS). Before, he stocked milkfish, used chemicals to kill and prevent pests, and applied urea and phosphate to fertilize his ponds. Like most other farmers in the village, his yields were low; he stopped stocking shrimp since more than 10 years ago. At the AFS, he learned that inorganic chemicals kill also useful species and destroy the pond' soil. He heard also about the effect of seaweed on water quality.

In 2017, at the end of the dry season, he bought 1,000 kg of seaweed, which all disappeared during the heavy rains of January–February. But, after he prepared the pond by adding dry and liquid compost, and when salinity increased during dry season, he stocked shrimp and saw that the seaweed grew again. Yearly, he sees the seaweed apparently disappearing, but these grow again and keep the pond water clear. To manage salinity, he drastically reduces the frequency of water exchange and keeps water quality good by adding liquid compost every week. He stocks shrimp post-larvae in three nursery ponds and transfers the good sizes to his grow-out pond where he harvests big shrimp every 4 to 6 weeks from April to December. He waits until he can harvest more than 150 kg of the size of about 20 pieces per kg; that volume he can sell directly to a monger at Kobong market in Semarang. There, he fetches 50–100% more than the village collectors pay him. He is grateful for the improvements brought to his family and continues discussing and experimenting in an AFS' alumni group.

3.4 | Cost factors of the AFS

The NGO received 215,000 €, or about 242,000 USD, to implement the AFS in 10 villages. Two government extension staff contributed to the 16 training sessions in both 2017 and 2018. The extension staff received a salary of about 4 million IDR per month, and transport fees of 50,000 IDR for each day they participated in, or contributed to a training. The effective total number of monthly working days for these staff is on average 15 days.

4 | RESULTS

Both heavy rains and high tides, combined with preceding periods of droughts, led to swift changes in water quality. Although the average levels of the water quality parameters were within the recommended ranges for shrimp and fish culture, the DO content in two ponds was below the recommended level (>3 mg/L) for 1 month in Purworejo and Morodemak in both 2017 and 2018. In particular months, the pH level, the ammonia contents, and P contents were above the recommended ranges, respectively, 7–8.5, 0.3–0.6 mg/L, and < 0.1 mg/L. Both the averages and the peaks of the P levels in 2018 were higher than those in 2017. In 2018, the average P levels were above 0.5 ppm more than half of the time, and in about half of the ponds >1 ppm for several months.

4.1 | Yields

Within the trimmed sample, the non-LEISA and LEISA farmers harvested about the same volume of milkfish, around 700 kg/ha, which was about double and triple compared to that, respectively, of the BwN database and the baseline (Table 3). In 2017, two among the non-LEISA farmers stocked shrimp and harvested 225 kg ha^{-1} $year^{-1}$; in 2018 none of them stocked shrimp. In 2017, two among the sampled LEISA farmers did not stock shrimp, but in 2018 all did. The average shrimp harvest of the LEISA farmers in the sample was 186 ± 133 kg/ha, which is fourfold and sixfold compared to that, respectively, of the baseline and the non-adopters in the BwN database. Shrimp producers

TABLE 4 The means (USD ha^{-1} $year^{-1}$) and SD of operational cost (OC), revenues, and gross margins (GM) of the ponds with adopters of LEISA and non-adopters (Control), the merged and trimmed dataset of 27 ponds

Treatment	OC	Revenue	GM
Control	138 ± 57	505 ± 286	405 ± 267
LEISA	299 ± 257	1,643 ± 895	1,344 ± 763

among the adopters in the BwN database harvested 134 ± 550 kg/ha. However, in 2018 the two LEISA outliers having the smallest ponds improved their milkfish harvests to 2,667 and 4,000 kg/ha, and their shrimp yields to 820 and 1,580 kg/ha (Table A1).

In 2018, six of the farmers in the sample who did not apply LEISA lived in one village (Morodemak) and they cultivated milkfish only in both years (Table 1). In Morodemak, the two farmers with the smallest ponds (≤ 1 ha) had about 3x higher yield per ha than that of the farmers with ponds larger than 3 ha.

The improvement in the yields among the sampled farmers was higher than that among the 125 records in the BwN database, while the SDs of the average on the small sample were relatively less than those in the BwN dataset. Among the 125 farmers, 105 applied LEISA; 99 of the 105 who stocked milkfish did not have any yield increase, while among those who stocked shrimp, the 63 LEISA adopters harvested three to four times more, compared to the non-adopters (Table 3). In the BwN database, the correlation between area and yield is negative for both milkfish and shrimp: −0.13 and − 0.21, respectively, while the number of stocked shrimp was not linearly related with the pond area (r = 0.2).

4.2 | Cost and gross margins

Among the sample, the operational cost, revenue (p < 0.001), and GM (p < 0.001) of the LEISA adopters were higher than those of the non-LEISA farmers (Tables 4 and 5). Both revenue and GM of LEISA farmers, who stocked both shrimp and milkfish, were three times higher than those of the non-LEISA farmers. The average GMs for the non-LEISA and LEISA adopters were 405 ± 267 and 1,344 ± 763 USD ha^{-1} $year^{-1}$, respectively.

The cost, revenue, and GM of the milkfish farmers in Morodemak were lower compared to those of the other villages. In 2017, the farmers in Purworejo invested more in their smaller ponds (1.2 ha) compared to those from Tambakbulusan and Morodemak having ponds larger than 2.5 ha on average. In Morodemak, the two farmers with the smallest ponds (≤ 1 ha) had about 3x higher yield per ha than that of farmers with ponds larger than 3 ha; the former invested relatively more than the latter and had a higher GM. In 2018, the two outliers had doubled their investments compared to that in 2017, and their GM almost tripled. In 2018, the operational cost of the farmers in Tambakbulusan more than tripled compared to that in 2017, but their GM remained at the same level (about 1,700 USD/ha). The highest margins were reached by the LEISA farmers who also applied manure to the pond bottom, or cultivated green mussel or tilapia (see Discussion).

The correlation between operational cost and pond size was negative (r = −0.54; p = 0.002), and this attempt to make a decent income from the smaller area was successful as shown by the negative correlation between pond size and GM (r = **−0**.46; p = 0.01).

4.3 | Efficiency of the AFS

The LEISA practioners' GM in the trimmed dataset was 927 ± 755 USD ha^{-1} $year^{-1}$ higher than those of the non-LEISA farmers (p = 0.001), and 714 USD ha^{-1} $year^{-1}$ higher than that of the baseline (630 USD ha^{-1} $year^{-1}$). The progress in yields among all trained farmers who adopted LEISA was about similar (tripling of the shrimp yield), and

TABLE 5 The result of the univariate analysis of variance of the between-subject effects for the GM ha^{-1} of LEISA adopters compared to non-adopters with year as covariable, based on the type III sum of squares of the trimmed dataset

Source	Sum of squares	DF	Mean square	*F*	Sig.
Corrected model	1,505,688,460[a]	2	752,844,230	12.9	.000
Intercept	354,840,435	1	354,840,435	6.1	.021
Year	354,265,272	1	354,265,272	6.1	.021
LEISA	916,558,684	1	916,558,684	15.7	.001
Error	1,397,202,785	24	58,216,783		
Total	7,447,579,653	27			
Corrected total	2,902,891,245	26			

[a]*R* Squared = .52 (corrected R Squared = .48).

we may conservatively assume an average improvement compared to the baseline, that is, 714 USD ha^{-1} $year^{-1}$. The average pond size among the 105 trained farmers who had adopted LEISA was 1.9 ha, and that of those in the sample 2.1 ha. The estimated increase of the GM after an AFS would mean that one farm household could obtain a complementary gross margin of about 1,360 and 1,950 USD/year from one pond, respectively, for the 105 and the sample.

The implementation of the AFS in 10 villages for 3 years cost around 242,000 USD for the main contractor. The cost of the two government extension staff for 2 years, each in five of the 10 villages was about: $10 \times 16 \times 2 \times 2 \times (4 \times 10^6/15 + 50{,}000) = 101.3 \times 10^6$ IDR = 7,250 USD. Total cost is estimated at 250,000 USD. The program reached 277 farmers between November 2016 and June 2018. Within our sample, only about 60% adopted LEISA, but the project monitoring datasheets indicate that close to 85% of the trained farmers applied the LEISA technology. Thus, individual cost per adopting farmer is 250,000/(0.85 × 277), i.e., about 1,060 USD $farmer^{-1}$.

Above resulted in an RR of 1.3 (130%) for the BwN dataset and 1.8 (180%) for the sample. In other words, the cost of an investment in an AFS training program was recovered within 1 year through the increased GM of the adopters among the trained farmers.

5 | DISCUSSION

5.1 | Sample limitations

The SDs of most variables were high (Tables 3 and 4) and the generic solution is to increase sample size. However, the standard deviations in both larger datasets, that is, the baseline and BwN's monitoring, were relatively larger compared to those in the smaller sample. Thus, in the case of brackish water aquaculture, the high standard deviation seems inherent to the system due to the mentioned risks and the variation between the farming practices. Although the selection and monitoring process may have pushed farmers to follow the management practices that may have reduced the SD, the distribution within the observed variables remained not normal. Merging the data of the 2 years and deleting three outliers gave a database with normal distribution for the essential variables. Merging is preferable above a repeated measures procedure, because technologies shifted, water conditions changed, and some farmers dropped-out.

The size of sample of the monitoring was small (17 and 13), i.e., about 5% of the 277, which was mainly due to the limited availability of budget and staff. Without accounting the cost for the water quality analysis, the monitoring did cost close to 2,000 USD $farmer^{-1}$, which is double the cost for the training itself. The project's priority was training, not monitoring, and it chose to train more farmers than the numbers given in the impact pathway in a provision of drop-outs and non-adaptors of LEISA. Participation in the aquaculture field school (AFS) program would give the villages access to funding for greenbelt recovery; this may have incited the participation of persons who were not motivated to improve aquaculture. We may assume that adopters were convinced by the results in the demonstration pond that was at the core of the AFS in each village. Non-adoption of LEISA may have various individual reasons (e.g., no social support; not enough labor, manure or money). The general non-adoption in Morodemak was clearly related to the dominant leader who had another agenda: free milkfish fry from another project, and complementary support from BwN for investments in a mangrove tour as tourist attraction.

5.2 | LEISA versus non-LEISA

The application of LEISA increased cost, but the GM of farmers applying LEISA was more than three times higher (1,344 USD ha^{-1} $year^{-1}$) than that of the non-adopters (405 USD ha^{-1} $year^{-1}$), and more than two times higher than the average in the baseline (630 USD ha^{-1} $year^{-1}$). The cost, revenue, and GM were higher mainly because the LEISA farmers stocked shrimp successfully; they had stopped stocking shrimp several years ago because they did not recover the cost. The GMs of the non-adopters are similar to that of extensive farmers in Vietnam (Engle et al., 2017; Tran, van Dijk, & Visser, 2014). Likewise, the GMs of the LEISA farmers approximate with those found elsewhere in the region for improved extensive systems (Bosma, Nguyen, Siahainenia, Tran, & Tran, 2014), but are less than 10% of well-managed industrial complexes when shrimp prices were also about 6 USD/kg (Bosma & Tendencia, 2014).

Within the sample, the milkfish yield was not significantly higher for LEISA adopters compared to non-LEISA adopters, but this yield was more than double than that of all AFS alumni, and three times higher than that of the average found during the baseline (234 kg ha^{-1} $year^{-1}$). Most non-LEISA farmers in the sample were from one village; they applied a semi- intensive system with high stocking densities and used chemicals and artificial fertilizer (Table 1). The improvement of the milkfish yield in the BwN dataset converged with the doubling found in another region of Indonesia after an AFS (Brown & Fadillah, 2013).

The average shrimp yield of all 105 LEISA farmers was 134 kg ha^{-1} $year^{-1}$, and for the small sample, 350 kg ha^{-1} $year^{-1}$, which is about three and seven times higher, respectively, than that in the baseline (47 kg ha^{-1} $year^{-1}$), and yields reported by Bosma et al. (2012). The shrimp yields of the LEISA farmers are comparable to those of sylvo-aquaculture farms (Bosma et al., 2014) and extensive shrimp farms in Vietnam (Engle et al., 2017; Tran, van Dijk, Bosma, & Le, 2013), but less than 10% of well-managed intensive *P. monodon* farms (Bosma & Tendencia, 2014) and less than 5% of industrial *L. vannamei* producers (Engle et al., 2017).

Most records of the BwN monitoring were from the first year after the AFS. Within the sample, in the second year the LEISA farmers stocked shrimp more often and (more) farmers used (more) industrial feed (Table 2). The sampled farmers got more confident about their capacity to manage water quality, to stock shrimp, and to use feed for fattening the shrimp. In other words, the AFS and LEISA are first steps toward ecological intensification. The higher RR of the sample resulted mainly from the second year with 70% higher margins. These higher margins may also result from the feedback discussions with the research team and from social learning among the sampled farmers in what we may call innovation platforms. Social learning, stimulated by the AFS, can improve agricultural extension impact (Yishay & Mobarak, 2017). The high RR indicates ample space for cost-effective post-training support through, for example, farmer's innovation platforms (Klerkx et al., 2013).

5.3 | Aquaculture practices

The farmers with smaller ponds invested more per ha (r = −0.54), and this attempt to make a decent income from the smaller area was successful as shown by the negative correlation between pond size and GM (r = **−0**.46). This favorable result may be related to (1) the relatively larger area within a pond with good depth, that is, the ditches along the canals, and (2) the higher stocking density of the shrimp. Thus, the larger the pond, the smaller is the GM per ha, which also means that part of the difference between non-LEISA and LEISA might be explained by the higher number of ponds that are smaller than 1 ha in the LEISA sample, particularly in 2017. In general, this means that farmers interested in making more money from aquaculture should start with reducing pond's size and apply other aspects of good aquaculture practices, such as making ponds deeper than 80 cm (Engle & Valderrama, 2004).

The low yield of the milkfish in Morodemak in 2018 compared to that in 2017 could either be attributed to application of high levels of P, either caused by the application of (triple)phosphate, or by the high levels of polluted water inflow from urban or (bio-) industrial sources near the locations. In this context, the addition of P is unnecessary as P levels >1 ppm can stimulate cyanobactoria and lead to eutrophication (Wu & Yang, 2010), which reduces DO all together. These factors limit the growth of *lab-lab*, a biological complex of cyanobacteria, diatoms, filamentous algae, and associated invertebrates that occur as a periphyton film at the pond bottom (FAO, 2020). *Lab-lab* provides a natural feed source for milkfish.

The options to use green mussel and seaweed to improve water quality, and tilapia to reduce disease impact (Tendencia, Bosma, Verdegem, & Verreth, 2015), were mentioned during the AFS by guest trainers. These technologies are object of a research program in a station in one of the villages (Widowati et al., 2019). Several trained farmers also represented this stakeholder group at the kick-off and progress workshops of this research program, and some acted as early adopters with less or more success (Box 1).

5.4 | AFS and Indonesians' goal to double aquaculture production

The median of the Internal Rates of Return for 1,066 agricultural research and development innovations in developing countries is 41% (Rao, Hurley, & Pardey, 2019); the RR we got was 130–180%, which is in the highest 10 percentile. Thus, our results confirm the effectiveness of training farmers on the LEISA technology through the AFS (Brown & Fadillah, 2013; Dickson, Nasr-Allah, Kenawy, & Kruijssen, 2016; Murshed-E-Jahan, Beveridge, & Brooks, 2008; Pant, Barman, Murshed-E-Jahan, Belton, & Beveridge, 2014). In contrast, top-down knowledge transfer as used by local government extension services may increase the knowledge of the farmers, but may also create information gaps (Brown, Llewellyn, & Nuberg, 2018), discourage critical thinking that leads to undesired copy-cat behavior (Goldstone & Janssen, 2005), and prevent social learning that could improve agricultural extension impact (Yishay & Mobarak, 2017). AFS-trained farmers showed better know-how on sustainable aquaculture management and agro-ecosystem analysis, and more confidence in decision making and public speaking (Yuniati, Fadilah, Ariyati, Rejeki, & Bosma, 2019). Earning higher profit, these farmers were empowered to give up part of their pond to invest further on their livelihood resiliency by creating an Associated Mangrove Aquaculture System (Bosma et al., 2020).

Indonesia aims to double its aquaculture production (FAO, 2018), and its government tends to fund projects that mainly stimulate mono-culture using plastic pond lining, chemicals, feeds and aeration. However, only few farmers can afford this risky investment; and sustainability of this intensive system is uncertain (Boyd, McNevin, Davis, Godumala, & Mohan, 2018). In the Demak and surrounding regencies, most investors abandon intensive shrimp culture after 1 to 4 years leaving behind the plastic to increase its density in the oceans. Innovative shrimp enterprises in South-east Asia adopt already successfully more ecological systems that are premised on the principles of microbial management (Sorgeloos & De Schryver, 2019), integrated multi-trophic aquaculture (Neori, Shpigel, Guttman, & Israel, 2018), and "green-water" (Lio-Po et al., 2005).

In Indonesia, the extensive shrimp farmers represent 80% of the producers and occupy about 22% of the production area, but produce only 10% of its shrimp (Halim & Juanri, 2016). Using a more ecological approach ("green-water" principles, IMTA and LEISA technology via AFS training), these farmers can produce three times more shrimp and thus about 25% of Indonesia's production. Moreover, complementary learning, for example, through innovation platforms and reducing pond sizes, can bring shrimp yield to 400 kg/ha, or near to 50% more national production, without the financial risks inherent to the intensive and super-intensive shrimp farms (Halim & Juanri, 2016). Given that most Indonesian milkfish production is traditional, the aquaculture output of coastal districts like Demak can at least double. Moreover, farmers can earn at least three times their usual income from traditional practices giving them a first step out of the poverty trap, and, simultaneously, the country recovers its investment within 1 year.

6 | CONCLUSION

After having followed an AFS for one milkfish-shrimp culture season, the farmers who adopted the technologies such as using liquid compost to manage pond and water quality harvested higher yields and had significantly higher GMs. The AFS trained farmers became more confident in adopting innovations toward more sustainable and resilient aquaculture systems. The rate of return of such an AFS is much greater than 1, thus the project's investment was recovered within 1 year. Indonesian milkfish production can double, and shrimp production can increase by 25–50% at low risk and low cost by reducing size of ponds and by using field schools to train all farmers who practice extensive aquaculture.

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CONFLICT OF INTERESTS

The teams in charge of implementing (Blue Forest) and monitoring (University of Diponegoro and Wageningen University & Research) the aquaculture field school were contracted and not members of the consortium. Both had an output obligation only and have no direct financial interest in the outcomes and impacts of the action.

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APPENDIX A.

TABLE A1 The data of the main variables for the 30 farmers of the sample among the 277 farmers trained in the Aquaculture Field School of the NGO Blue Forest for the BwN project

				Yield (kg $year^{-1}$ ha^{-1})		Amounts (IDR $year^{-1}$ ha^{-1})		
LEISA	Pond	Year	Area	Milkfish	Shrimp	Variable cost	Revenue	Gross margin
1	T-B	2017	2.5	900	338	2,850	39,008	36,158
1	T D	2017	2	1,050	291	2,140	35,840	33,700
1	TG	2017	4	825	-	907	9,900	8,994
1	P-A	2017	0.5	1,000	300	8,440	39,500	31,060
1	P-B	2017	0.25	840	480	15,180	45,360	30,180
1	P-C	2017	3	600	220	1,539	25,133	23,594
1	P-D	2017	0.75	500	220	5,967	23,600	17,633
1	P-E	2017	1.5	67	55	1,637	5,227	3,589
1	P-F	2017	1	900	240	4,250	30,000	25,750
1	M-A	2017	0.6	1,000	-	3,200	12,000	8,800
1	T-A	2018	4	500	85	3,325	11,950	8,625
1	T-C	2018	2	500	110	4,540	13,700	9,160
1	T-D	2018	0.75	2,667	820	20,573	89,400	68,827
1	T-E	2018	2.5	540	190	3,050	24,024	20,974
1	T-F	2018	4	500	134	3,858	15,363	11,505
1	P-A	2018	3	333	120	1,850	14,350	12,500
1	P-C	2018	0.25	4,000	1,580	20,480	153,200	132,720
0	T-F	2017	4	75	190	1,700	16,100	14,400
0	T-H	2017	0.75	900	261	3,037	31,707	28,670
0	M-B	2017	1	750	0	1,891	9,000	7,109
0	M-C	2017	4	600	0	974	7,200	6,226
0	M-D	2017	3	500	0	1,369	7,000	5,631
0	M-E	2017	3	750	0	1,692	9,000	7,308
0	M-F	2017	3.5	857	0	866	10,286	9,420
0	M-A	2018	1	1,600	0	2050	8,000	5,950
0	M-B	2018	0.6	1,417	0	1715	7,083	4,225
0	M-C	2018	4	563	0	3,575	2,813	1,919
0	M-D	2018	3	783	0	3,200	3,917	2,850
0	M-E	2018	3.5	336	0	1800	1,857	1,343
0	M-F	2018	3	425	0	2,420	2,500	1,693