Empowering Fish-Farmer through Coastal Field School: Towards Sustainable Aquaculture Practice

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Abstract. Central Java Province is among the largest aquaculture producers in Indonesia. This hefty contribution also comes with a challenge of degraded coastal areas primarily due to mangrove conversion into ponds, land subsidence, and raising sea surface. In Demak Regency, abrasion and robs flood have adversely affected the farmers' aquaculture ponds since the past decades. The changing coastal environment and lack of knowledge to adapt in aquaculture management led to declining production that hampered the community's resilience in the future. To help the farmers to thrive, an initiative called Coastal Field School (CFS) was implemented in 10 villages in Demak. Principally, CFS is a participatory learning method that emphasizes problem solving and discovery based on learning toward their production systems. The entire CFS program took place in 2015 – 2020, however this study only focused on the CFS conducted in Bedono village during May 2019 – September 2019. This paper discusses the CFS impact on the farmers' knowledge change using the indicators of farmers' program participation level, pre-test and post-test result to determine the knowledge improvement, aquaculture management technique, and productivity rate. The test was analyzed using a paired t-test where the knowledge level of farmers increased significantly ($p < 0.001$). The farming productivity rate also improved by nearly 30%. It is concluded that CFS can strengthen the farmers' resilience in the degraded coastal area in Demak.

1. Introduction

Aquaculture fisheries has been providing a vast contribution to Indonesia's economy and food production [1]. This nation is ranked second as the country with the longest coastline in the world and the second-largest fish producer after China. Considering its abundant resources, aquaculture is projected to overtake the capture fisheries for seafood consumption by 2030 [2]. The growing production is also followed by the increasing trend of seafood consumption. In 2011, Indonesia's fish consumption per capita was only 29 kg per year. A decade later, the consumption rate almost doubled to 55.95 kg per year [3].

The aquaculture sector's extensive development drives the aggressive mangrove conversion into ponds, and the existence of seafood processing industries with improper waste management [4,5]. A mangrove swamp is part of suboptimal land. As the name suggests, suboptimal land is often seen unproductive but is inherently has enormous ecosystem services, including potential for food production. Balancing mangrove conservation with aquaculture purpose will generate many critical services such as buffering land from storms and flood, preventing abrasion, providing a nursery habitat, and becoming the source of livelihood for the community.

Conversely, irresponsible mangrove logging has caused decades of severe degradation in the coastal region, as demonstrated in Demak Regency, Central Java [6]. In Demak, the farmers are at risk of losing its aquaculture lands along its 20 km coastline principally due to coastal erosion, floods and land subsidence [7]. During the 2015-2018 period, the land subsidence in Demak had been worsening, ranging from 0.8 cm to 17,91 cm/year [8]. This leaves the local coastal communities who largely engaged in small scale aquaculture farmers highly vulnerable to the rising seawater level [9,10]. The changing coastal environment and lack of know-how to adapt in aquaculture management led to declining production that hampered the community's resilience in the future.

The Central Java Province is among the largest domestic producers with nearly 500,000 tons of aquaculture yields in 2017 [11]. This hefty contribution also comes with a challenge as abrasion and robs flood have adversely affected the farmers' ponds. Coastal area in Demak is known for its brackish aquaculture commodities such as milkfish, tiger pawn, blue swimming crabs, and shellfish. However, the ponds embankment conditions, especially in Bedono village, have been severely damaged due to land subsidence, flood, and decreasing water quality. Despite the situation, the farmers were still seeking for solution to make their ponds productive again.

To empower the farmers, an initiative called Coastal Field School (CFS) was implemented during 2015 - 2020. In principle, CFS is adopted from an earlier approach called Farmers Field School (FFS) which is defined as a participatory learning method that emphasizes problem solving and discovery based on learning toward their production systems [12]. CFS facilitates the farmers to identify the problem they face and how to address them. The program duration typically lasts for one farming cycle or a year with a total number of meetings that might range from at least 12 up to 16 meetings [13].

In this context, CFS served as an empowerment tool that helped the farmers to observe what kinds of aquaculture products that are viable for their local condition, how to sustainably cultivate them, and produce higher yields which positively affect their income. The application of field school has been widely used and successfully increased ponds productivity and profitability through technical advice and training [14,15]. CFS is originally adapted from the Integrated Pest Management (IPM) Farmer Field School approach initiated by FAO in the 1980s, which provides small farmers with practical experiences in ecology and agroecosystem analysis to enable them to farm sustainably [13]. CFS was conducted to facilitate the farmers to identify their resources and empower them to translate their ideas into action. The paper attempts to measure CFS contribution to the farmers empowerment by analyzing their capacity improvement and practice to improve economic and ecosystem sustainability.

2. Materials and Method

2.1 Study area

The research focused on the CFS implementation in Bedono Village, Sayung Sub-district, Demak Regency, Central Java Province (fig. 1). The whole CFS program was implemented during 2015 - 2020, this paper only focused on assessing the program that was conducted during May 2019 to September 2019 in Bedono village, Demak Regency, Central Java. In the 1970s, the shorelines of the village had become the natural habitat of large mangrove forests. However, this ecosystems were massively converted into ponds in the 1980s and nearly disappeared due to increasing coastal erosion and exploitative aquaculture practice [16]. A severely damaged mangrove and ponds area like Bedono village is selected to be one of the CFS implementation sites because it is necessary to encourage farmers to maintain their ponds and convince them that there are possible ways to transform the ponds to be productive again. So that the farmers will not clear the mangrove forest in the different area to build another pond. Hence the mangrove and coastal region outside the degraded land would remain intact.

2.2 Data and analysis

During the observed period, there were 26 farmers involved as the CFS program participants. This program consisted of a meeting series that intended to cover at least one cropping cycle. In Bedono village, the participants had made a communal agreement to have a weekly meeting that lasted for 3 to 4 hours, with a total number of meetings ranging from at least 14 to 21 meetings. Among 26 participants in total, only around half of them had consistently attended the meeting. The rest participants either skipped some of the meetings or sent their family to represent them.

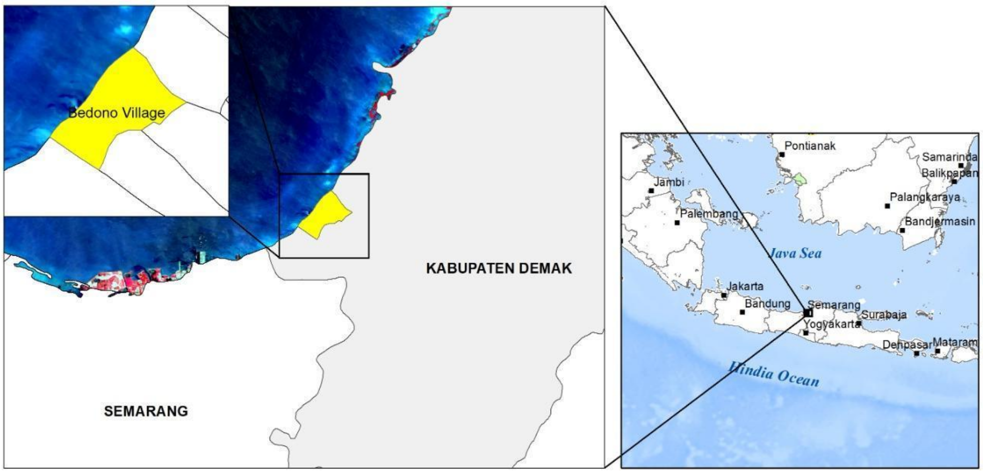

Figure 1. The maps of study location at Bedono, Demak, Indonesia.

Two parameters were used to assess CFS impact to farmer empowerment. The first is the farmer capacity enhancement through the CFS program in aquaculture practice. Empowered means having the capacity to make effective choices that result in desired outcomes. The farmers were gathered to enable group discussion, situation analysis, presentation, and collective action in building sustainable practice. The farmer grows milkfish (*Chanos chanos*) and shellfish like blood cockle (*Tegillarca granosa*), which the CFS try to improve the sustainability production of these commodities.

To determine the CFS contribution to farmer's empowerment, this research compared the before and after CFS was conducted. The farmer's knowledge was measured with pre-test and post-test to determine improvement. The pre-test was carried out in early May 2019 while post-test was taken in late September 2019 after the CFS was implemented throughout one cultivation cycle. Each test consisted of ten questions that were answered before and after CFS by the farmers. The questions ranged from ecosystem function, the role of crab and shellfish for ecosystem, and environmental factors that hamper productivity. The pre and post-test in this study was intended to solely focus on assessing the knowledge and skill change during the whole CFS activities. The data was collected through interviews with each participant in the beginning and in the end of the program. Among 26 participants, only ten farmers consistently attended the whole meeting series and took the pre-test and post-test (N=10). The collected data was then analyzed using a statistical approach. Shapiro-Wilk was applied first to examine if the data is normally distributed ($p > 0.05$). Thus, paired t-test is used to determine impact on farmers' knowledge after the CFS program.

The second parameter is measuring the sustainability practice on aquaculture. It is defined as a maintainable high yield productivity rate which linier with economic profitability, without harming the coastal environment. In this research, we measure the increase of productivity using the comparison of control plot business as usual (BAU) and Low External Input and Sustainable Agriculture (LEISA) scenario in the treatment plot. The measurement was conducted from May to September 2020. The productivity (in kg) and economic improvement (in IDR) was analyzed. Field interview and field observation also deployed to develop applicable aquaculture management.

3. Result

3.1 Improvement of the farmers' capacity

Pre-test and post-test are primarily designed to compare groups and/or measuring change resulting from experimental treatments [17]. According to the statistical result, there is a strong relationship ($p = 0.001$) that

CFS improves farmers' capacity. CFS provides coastal villagers with an opportunity to develop their potential, affecting changes in skills, knowledge, attitudes, and behaviors.

In terms of ecosystem adaptability, using biophysical parameters such as Chlorophyll-A, water temperature, and suspended solid charge, it is concluded that the area in Bedono village is suitable for aquaculture development [18]. The limitation factor for sustainable aquaculture practice is on the farmer's capability to utilize the biophysical parameters for optimal productivity under severe mangrove and coastal conditions. Improving farmers' capacity also faces many difficulties. In the CFS program, it was quite hard to make all the participants committed to attend each meeting due to various circumstances such as village events, family gatherings, working, or other reasons. Hence, the pre-test and post-test results of farmers with a high level of attendance showed a higher score compared to those who did not.

In traditional aquaculture, the farmers struggle to cope with environmental changes. Erosion in their pond halted the production and gave economical pressure to farmers [19]. The CFS can support the farmer to be resilient in Bedono village. The changing behavior will help them to adapt their aquaculture management. They would be more prepared in adapting to the changing environment especially due to climate change. Follow-up activities allow alumni to continue developing their potential and make permanent behavior changes. Follow-up activities focused on developing local CFS programs provide alumni with the room to institutionalize CFS at the village level.

3.2. Sustainable aquaculture practice

The definition of sustainability in aquaculture is unclear as many frameworks require different indicators. Principally, sustainable aquaculture practice must include the economic, environmental, cultural, and governance parameters [20]. It should be able to optimize the yield of productivity without harming cultural and environmental aspects [21].

Using economic perspective, it could be translated as a sustainable income with stable yield productivity. Intensive aquaculture can lead to declining productivity due to the leaching of pyrite soil. In the aquaculture process, it turns pyrite soil into sulfuric acid (H_2SO_4) from oxidation, which increases the pH of water and solubility of aluminum (Al) and iron (Fe) [22]. Hence, preventing soil oxidation on aquaculture practice has become a derivative of sustainability, including environmental parameters. The ponds should be repeatedly drained and flushed to obtain pH level >5; it is also possible to use ameliorant.

In the CFS, to maintain pond soil, water quality and improve productivity, the combination of fish farmer field school (FFFS) approach and LEISA were used for raising milkfish, shrimp, or shellfish. Essentially, LEISA enabled farmers to achieve higher income and attain sustainability through: a) Optimizing the use of locally available resources. In this program, local substances such as microorganism, rotten fruits, and saponin were processed to be the main ingredients for the fertilizer; b) Minimizing the use of external inputs, except where there is a serious deficiency [23]. LEISA's application is aimed to improve the yield and efficiency of fish ponds farming in the study area. The method boosted shellfish productivity up to 65% compared to the control plot (table 1). An increase in harvest yield is in line with the profitability rise by nearly thirty percent. The development of skills and knowledge will provide immediate results, such as higher yields. In the long term, the CFS impact will strengthen the community empowerment regarding economic and environmental aspects in Demak.

The interview found the ponds before CFS were either unproductive or abandoned. The farmers were no longer cultivating their ponds primarily because they were already damaged due to failure embankment and uncontrolled seawater on ponds. Therefore, the ponds were not productive anymore. The CFS program revamped aquaculture activities through improved farmer capacity. The study sampled the farming results of six CFS participants, where each of them has 0.5 – 2.8 hectares of ponds with productivity within the range of 1 – 3-ton shellfish per hectare after the CFS program. The profit per hectare ranged from IDR 330,000 to IDR 58,000,000 due to various circumstances described in table 2.

Table 1. The comparison of the control plot and treatment plot

Parameter	unit	Control plot	Treatment plot
Initial baby shellfish	Kg	100	100
Weight	g/piece	2	2
Harvest	Kg	102	120
Average weight after harvest	g/piece	6.2	10.5
Cost	IDR	872,500	963,300
gross profit	IDR	1,224,000	1,440,000
Nett profit	IDR	724,000	940,000

Table 2. Economic profitability of the CFS participants

Name	Pond Area (in Ha)	Species	Equipment Cost (in IDR)	Seeds Cost (in IDR)	Sales Revenue (in IDR)	Profit per Ha (in IDR)	Remarks
M Khaidir	1.2	Shellfish	5,000,000	9,000,000	84,000,000	58,333,333	11 months cultivation
Suminah	1.5	Shellfish	6,000,000	3,000,000	20,000,000	10,666,667	14 months cultivation (but many shellfish were stolen)
Mahmudi	0.5	Shellfish	6,000,000	6,000,000	30,000,000	52,000,000	Sluggish growth due to high pond density
Matsairi	1.8	Shellfish	22,975,000	697,000	594,500	330,278	9 months cultivation. Only a small part was harvested.
Slamet	2.8	Shellfish & Milkfish	10,625,000	625,000	2,240,000 and 5,460,000	2,750,000	Milkfish gone due to flooding. Most shellfish have not harvested yet.
Umar	1	Milkfish	1,970,000	960,000	5,500,000	5,500,000	Milkfish gone due to flooding.

Different pond areas, farming duration, natural feed availability, seeds quantity, and aquaculture treatment have made the farmers experience different results. Still, the most influential factors are flooding, population density, and feed availability to support shellfish growth. For example, Matsairi, the capital spent on repairing pond embankments and supporting equipment was very large but the purchase of seeds was still very small so that the yield was also small. He thought that the cultivation of shellfish should be carried out in stages because the ponds' conditions are unpredictable, so they are still conducting trials for shellfish cultivation.

Obstacles also came from external factors such as aquaculture theft and rob flood. The ponds are located at the shorelines that far from the farmers' houses. Small farmers cannot afford to fence their ponds or deploy a more secure system to protect the ponds, resulting in the cultivated species easily stolen. Thus, the rob flood has worsened the pond condition since the mangrove areas are degraded [24,25]. It adversely affected the milkfish ponds as the fish were carried away by flood current.

To strengthen the aquaculture resilience, mangrove forests have an essential role in providing a high nutrient ecosystem and protection against the rob flood [26]. The mangrove restoration will improve environmental sustainability and maintain stable productivity in the region [27]. In the future, restored mangrove forest will prevent coastal erosion and seawater intrusion. The restoration is also embedded into the cultural aspect, where the farmer and their communities guard the environment through sustainable agriculture practice.

4. Discussion

It is not easy to provide sufficient food for 7.6 billion people in the present and 9.7 billion people in 2050. The food does not only staple food like wheat and rice but includes fish as a protein source. Fisheries sectors worldwide are competing to meet the seafood demand, although it creates another threat of overfishing to some extent. The total catches in capture fisheries have stagnated at 90 million tonnes over the past decades. Hence the pressure to meet today's demand relies on aquaculture production that has been continuously increasing from 20 million tonnes in 1950 [28] to 114.5 million in live weight in 2018 [29].

Aquaculture largely depends on a healthy coastal ecosystem to be resilient. It takes adaptive management in farmers' knowledge and their practices to sustain the production. To that end, the CFS was aimed to build the capacity of small-scale aquaculture farmers to better manage their coastal resources within their own specific agro-ecosystem. This goal has been attained as the activities have brought tangible results in terms of aquaculture management and productivity.

In the CFS, participants learned about water quality maintenance. Water quality effects on shellfish or milkfish growth [30]. They also learned how to conduct regular observation, proper measurements, record the data, analyze the observation data, and conclude the pond agroecosystem's overall condition. Finally, they are able to decide the follow-up treatment. They were also trained to take action should sudden water change occurred. LEISA approach was very potential to be applied in the ponds, which can enable such farmers to achieve higher income and attain sustainability and achieving a synergetic effect among the various components of the farming system (soil, water, animals, plants, etc.) so that they complement each other in the production of output.

The increasing productivity was also resulted from the farmers' knowledge improvement on stocking density. Previously, they used to think the more seeds put into a single pond, the higher yields they gain. They tended to ignore the pond's carrying capacity, yet after participated CFS, they started to understand that high ponds density will drive food competition which impedes the shellfish growth. To improve the yield quality, they also learned to produce natural feed made from locally available resources such as domestic waste and local-microorganisms solution (MoL) [31]. This organic fertilizer was used to minimize environmental harm caused by synthetic fertilizer [32].

Farmer empowerment is essential to food security since they are the safeguard for both food availability and access. CFS facilitated the farmers to identify solutions and improve their skills on sustainable aquaculture. During the activities, farmers were exposed to the method and innovation they can develop using their local resources. As a result, farming schools are proven to empower farmers in critical aspects such as cost, production method, and environmental consideration [33]. The success of farmer school relies on transforming participants where they are now capable of revamping the ponds, they have to be productive again using environmentally friendly methods. It is advised that the farmers can continue the practice and even disseminate the knowledge for potential adopters. Empowering the farmer brings benefits not only to the community but also to the ecosystem.

5. Conclusion

This research indicated that farmers in Demak have shifted their approach and paradigm in farming. They can manage the transition between abandoned ponds to productive one. Hence sustainable aquaculture practices through CFS have potential to address the issue of food security. Not only to add the food production but add to food diversification and better food utilization that leads to decreasing malnutrition. Scaling up farmers' development effort, especially those who live in vulnerable areas such as suboptimal land, can be part of promoting actions to manage food and livelihood resources sustainably.

Based on the data above, it can be concluded that the implementation of the CFS has been evident to be effective to meet the objectives of improving the participants' knowledge and skills about improved aquaculture management practices. The most efficient result came from the ponds that have a proportional seeds density, decent ponds condition, proper treatment, and the species resilience to flood. The LEISA method is proven to be able to increase pond productivity because it creates a balance in the ecosystem that encourages the growth of natural food in the ponds.

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