Aquaculture field schools supporting mangroves for climate change adaptation of Indonesian milkfish-shrimp farmers

Woro Yuniati[1,] Ratna Fadillah[2], Sri Rejeki[3], Lestari Widowati[3], Restiana Ariyati[3], Apri Astra[4], Roel Bosma[5]

1. Freelance development practitioner, Yogyakarta, Indonesia. woro.yuniati@gmail.com; 2. Blue Forest, Makassar, Sulawesi, Indonesia ; 3. Aquaculture Dep., Fac. Fisheries & Marine Sci., Univ. Diponegoro, Semarang, Indonesia; 4. Wetlands International Indonesia, Bogor, Indonesia; 5. Formerly at Aquaculture & Fisheries, Animal Science, Wageningen UR, Netherlands, email: roel.bosma@xs4all.nl.

Mourning the loss of land and mangrove

The 1960s were years of prosperity in Demak regency, Java, Indonesia. Farmers cropped rice, vegetables and fruits. From their produce, they were able to build good houses and send their children to secondary schools. Back then, the sea was more than a mile away from the fields of villages, like Timbulsoko in Sayung near Semarang, Java's fourth largest city. Until 1972, layers of mangroves, with highly specialised root systems, protected the farmed areas from erosion and flooding. The delta was still a navigable estuary about 1,300 years ago, but sediments were captured and mangrove forests expanded. Halfway through the 20th century, the forests which were sited further from the sea were transformed into paddy fields, but a wide mangrove greenbelt still remained.

However, after farmers began cutting and converting mangrove forests into fish-shrimp ponds, the coastlines became more vulnerable to erosion, particularly during strong storms, waves and winds. Further worsening the toll to the environment, industries from Semarang city began relocating their operations to Sayung, a sub-district in Demak. These industries heavily extracted groundwater which resulted in sinking of the land (subsidence) that is more than a ten-fold of sea-level rise (Chaussard et al, 2013). The sinking greatly changed the village setting, and daily flooding changed the life of farmers. After 2000, with a few patches of mangrove forests left, the abrasion started eating away the coastline

Photo 1: Bedono, near Semarang, protects some of its remaining infrastructure with a series of permeable dams.

of Demak. Gradually, many farmers abandoned their ponds (Figure 1). In 2012, the first communities were evacuated, and after 2015 a tidal lake was formed (Photo 2).

Narrated by one farmer. “…the flooding began, the high tides came and wiped out all those rice fields, we had no choice but to transform our land into fish ponds… Our parents warned us that we should protect the mangroves [because] these mangroves provided many benefits like securing a place for the oysters, crabs and fish in their roots; and protecting the coastline from being swept away. But our people wanted to make more money to feed their families. So, the mangroves also became ponds for milkfish and shrimp.” One farmer lamented over the loss of his 10 hectares of pond which he bought in 2004, but which were swept away three years later (Photo 1).

Although the state forbids cutting of mangroves, investors and farmers tended to disregard the law by clearing the mangrove forests almost up to the coastline to farm shrimp. Efforts to plant mangroves on the bunds of the ponds, a type of silvo-aquaculture that is practiced by farmers in Demak (Figure 1), did not prevent land loss (Photo 2).

Training farmers

In the last five decades, over 30 million people along Java’s north coast have experienced subsidence and subsequent soil erosion. Consequently, the agri-and aquaculture sectors have incurred a multibillion-dollar loss. Practices such as heavy groundwater extraction by nearby industries and cities and clearance of mangrove forests are the key factors that have degraded the environment. Another contributing factor to this environmental decline is the lack of training among farmers. In their lifetime, most Indonesian shrimp farmers have never received a proper training on good aquaculture practices (Elfitasari and Albert, 2015). Thus, their benefits from shrimp farming were only short-lived.

Figure 1: The land use of the close to 5,400 ha in seven coastal villages of Demak regency in 2015. Only 3 ha of aquaculture was intensive.

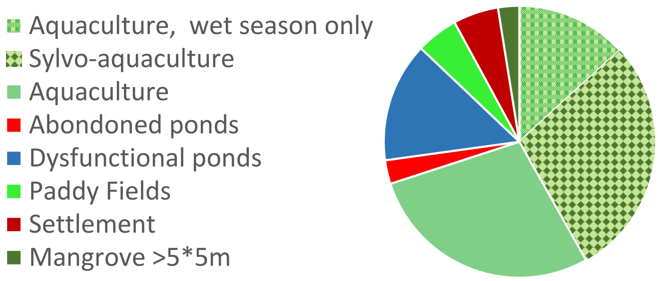


Photo 2: Section of the new tidal lake with mangrove rows lining along destroyed silvo-aquaculture ponds.

Looking at this these flooding episodes, farmers have realised that they could not continue with their past practices, one of which was cutting mangrove. “Since 2003, I have elevated our house three times. I told my son that he will be doing it next, as I have neither enough energy nor money to do it again. But thanks to the support of the Building with Nature project, we were able to increase the quality of our shrimp.”

Building with Nature: an integrated approach

In 2015, Building with Nature Indonesia (BwNI) started a coastal protection project in 10 communities of nine coastal villages of Demak regency. The households in the seven sampled villages owned an average of two hectares of ponds, but only about one-third of them still stocked shrimp. Farmers earned an average income of 600 USD ha^{-1} yr^{-1} from milkfish-shrimp ponds; those who stocked shrimp made 30 USD ha^{-1} yr^{-1} more.

To reduce coastal erosion and make the livelihood system sustainable, BwNI-Demak introduced four approaches in the pilot sites:

1. Protect the remaining coastal mangrove and capture sediments to create an ecology for natural mangrove regrowth.

2. Rehabilitate mangrove by giving up ponds along sea and rivers.

3. Improve aquaculture practices.

4. Reduce groundwater use.

Together with Indonesian institutions and villages, BwNI-Demak, funded by the governments of Indonesia and the Netherlands and the partners of the Ecoshape consortium, implemented the first three of these interventions, while starting advocacy for the last. These interventions were embedded in a community approach by a team of field-workers in collaboration with the government agents, among whom were the village authorities.

BwNI-Demak introduced protection measures in villages such as Bedono by using permeable structures (dams) that successfully capture sediment. In most locations these permeable structures support the natural recovery of mangroves within 4-5 years (Photo 3a, b). In the absence of land subsidence, this recovery could effectively counteract climate change that is induced by sea-level-rise; that is if the villages were to maintain these permeable dams for at least 5 years. In the 4th year of the project, most coastal villages integrated the cost for this maintenance in their village budgets. As for aquaculture, the project expected that improving yields and income of this activity were needed to motivate farmers to restore mangrove greenbelts and to contribute to the maintenance of the permeable dams and other measures.

Aquaculture Field School (AFS)

AFS is a learning process adapted from the Farmer Field School, an approach initiated by the FAO for Integrated Pest Management in the 1980s (Brown, 2015). To build the capacity of the local small-scale farmers, AFS trains them on good aquaculture practices. Here, during one production cycle, farmers learn, among others, the ecology of coastal waters and ponds, the low external input sustainable aquaculture (LEISA) and pond management.

AFS is field-based and lasts for a full cropping season. Its educational methods are experiential, participatory and learner-centered. Before developing a learning contract, AFS meets participants, determines their needs, recruits them and prepares a learning contract. Locally recruited AFS facilitators undergo an intensive season-long residential training to prepare them for organising and conducting field schools (Box 1). Between 25 and 30 coastal villagers, women and men, participate in an AFS. In this project, the number of women to men participating in the AFS was not always balanced; thus, BwNI had to organise some female field schools. In addition to gender representation, AFS also aims that at least 75% of the participants come from poor or vulnerable households.

An AFS meets once a week or fortnight for a half-day to one-day session, or a total of 12-16 sessions. To maximise their learning, participants learn together in small groups of 5 to 12. Each AFS meeting includes at least three activities: 1) agroecosystems analysis, 2) special topic and 3) group dynamics activity. The primary learning material is the pond, and the meeting place is close to the demonstration ponds, often in a farmer’s home (Photo 4) and sometimes beneath a convenient tree (Photo 5). Participants usually compare treatment and control plots. Depending on local problems, AFS

Photo 3: Permeable dams in in Timbulsloko (left) and Purworedjo (right), end 2019, 3-4 years after building and maintenance.

participants often conduct additional field studies. Resource persons (practitioners, academicians and government extension staff) may supplement the curriculum (Photo 6). All AFS curriculum includes a Field Day in which farmers present and discuss the results of their studies. The curriculum ends with a final meeting, among others, to plan for follow-up activities. To diagnose problems and identify follow-up activities, the AFS implementing program conducts a pre- and post-test.

While being enrolled at AFS, farmers study the agro-ecosystem, design aquaculture production systems, observe demonstration ponds, synthesise their data, and debate with their colleagues. Finally, they make informed decisions on the next steps of the pond management. By going through the process, the participants could already determine which new practice(s) would be practical for them to apply straight away. Moreover, in the farmer-centered learning environment, they acquire soft-skills such as having more confidence in decision making and in public speaking (Box 1). In this project, after finishing the curricula, AFS alumni continued to engage in post-field-school activities which included discussing their innovations practices, such as transforming their ponds into an associated mangrove aquaculture (AMA) and practicing forms of multitrophic shrimp aquaculture (MTA).

Photo 4: During each AFS session, farmers engage in participatory learning activities in classrooms and in the pond areas (see photo 5 below).

Photo 5: AFS participants assess the water colour of a demonstration pond.

Low external inputs sustainable aquaculture (LEISA)

Low yields in traditional Indonesian milkfish-shrimp ponds stem from poor soil and water management. For example, some farmers may use excessive or inappropriate chemicals such as pesticides. To correct these practices, farmers are introduced to LEISA by the AFS. LEISA as an ecological farming principle was first developed for agriculture, and aimed to reduce the excessive use of external inputs, particularly from synthetic chemicals harming the environment. Later, LEISA implementers adapted it for aquaculture; it advocates the use of locally available natural resources (soil, water, plants) and inputs (e.g., animal and organic wastes). With LEISA, farmers would be able to:

Maintain and enhance soil fertility by using solid compost or manure and liquid compost.

- Stimulate recycling of organic matters in the pond with liquid compost.
- Conduct pest and disease management through prevention and safe treatment.
- Produce good yields of healthy food for consumers.

At the AFS, farmers learn to use monitoring kits and prepare liquid compost from fermented vegetables and/or fruits. This liquid compost improves the soil and maintains water quality (Photo 7 and 8). It also enhances the chemical, biological, physical and structural properties of the soil, and complements the effect of manure as fertiliser. Moreover, the liquid compost adds energy, minerals and micro-organisms to the pond water; it facilitates recycling of both deposited and suspended organic matter; thus stimulating the growth of natural feed for shrimp and fish (Figure 2).

Photo 6: A university professor lectures at an AFS session.

Photo 7: AFS participants chop the waste of fruits and vegetables for the liquid compost.

Photo 8: The mixture of wasted vegetables and fruits fermenting into liquid compost.

Box 1: From farmer-learner to farmer-expert

Abdul (52) farms brackish water ponds near Tambakbulusan village. When he first joined in the AFS Training of Trainers in 2016, the master trainer told them that they were expected to be an agent of change for aquaculture practices in their village. At that time, he responded the expectation with skepticism. He did not think that he could be of such influence, because he was convinced that farmers would not be willing to listen to him.

Nothing could be further from the truth. As he proceeded in the training, he became confident in speaking in front of other participants and in facilitating the discussion session during the AFS class. In his milkfish-shrimp ponds, he tested the LEISA system and other innovations. Just to mention a few, his experiments included rearing green mussels and saline tilapia, and mud crab fattening. All along, he gathered knowledge of his pond production system.

Considering his potential, scientists from Diponegoro University recruited him as their partner in doing research since 2017. This collaboration has furthered his capacity as an aquaculture farmer with the eye of a scientist. His experience in discovering an effective production system immediately spread beyond the neighboring villages. Other farmers have called on him frequently for technical advice. The government fisheries agency has invited him to co-facilitate extension sessions or to speak in workshops. Abdul Ghofur, an AFS alumnus, is currently an active change agent for good aquaculture practices in Demak.

LEISA adopters

After training, 80% of the 177 AFS participants adopted LEISA and made gainful changes (Box 2). After having followed an AFS for one milkfish-shrimp culture season, the farmers who used liquid compost were able to harvest higher yields than those who didn't (Figure 3). From 125 LEISA adopters, we found that they didn't harvest more milkfish in 2017-18 than in 2015, the baseline yield. Nevertheless, they increased their margins because they could culture shrimp again; they also reduced cost for milkfish farming.

In the sample which we monitored financially, the non-LEISA farmers, who did not stock shrimp, continued using chemicals in their milkfish production. Although they harvested more, about 700 kg milkfish ha^{-1} yr^{-1}, they earned less compared to the sampled LEISA farmers who harvested thrice more milkfish than the baseline yield. The adopters also had six times more shrimp yield over the baseline data. In general, farmers with smaller ponds had 13-21% higher yields per hectare than those with larger ponds.

Return of aquaculture field schools

In a sample, the estimated gross margin of the AFS alumni-farmers who adopted LEISA was more than 900 USD ha^{-1} year^{-1} higher than that of the AFS alumni who did not adopt LEISA. Likewise, the gross margin of the LEISA adopters was also more than 700 USD ha^{-1} year^{-1} higher than that of the baseline (Figure 3). This higher gross margin could be attributed to lower cost but higher yields among the LEISA adopters over the non-adopters. Owning an average of about 2 hectares of ponds, AFS farm households gained about 1,400 USD yr^{-1} complementary gross margin.

The internal rate-of-return (IRR) of this AFS program is more than 130%, which means that the project's investment is recovered within one year. This IRR is in the highest ten percentile among the 1,066 agricultural research and development innovations in developing countries with a median of 41% (Rao, et al., 2019 cited by Widowati et al., 2021). Thus, incorporating LEISA technology training in the AFS is very cost-effective; this same trend was also documented by Brown and Fadillah in South Sulawasi (2015; Aquaculture Asia 18 (2): 12-19).

Figure 2. The mean specific growth and survival rate of *P. monodon* in ponds with liquid composts from vegetables, fruits or a mix, with or without mangrove leaves (*Avicennia marina*) versus those in a control (Adapted from: Ariyati, Rejeki, Widowati, Elfitasari, Bosma. 2019. DOI: 10.1007/s40071-019-00239-x/).

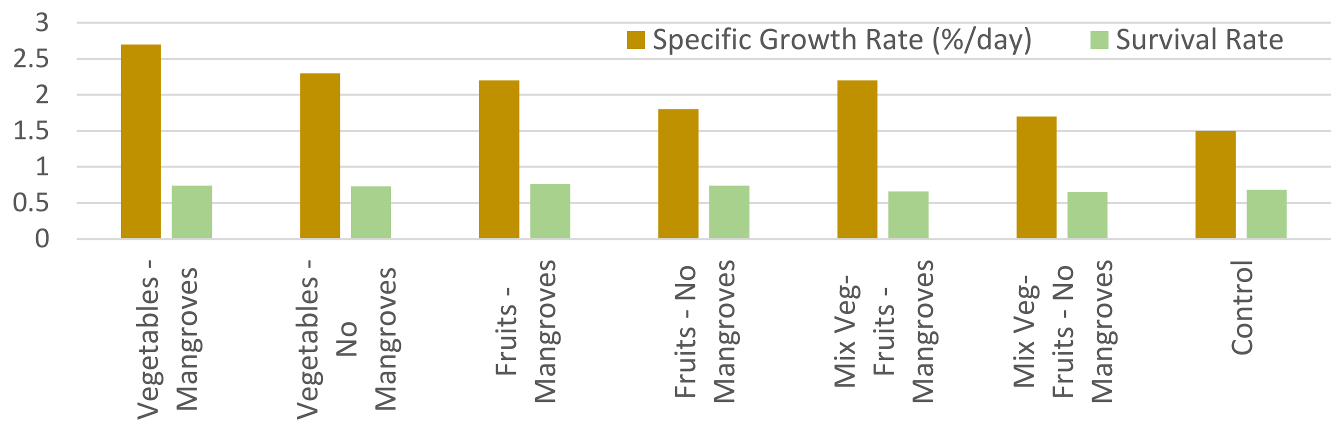
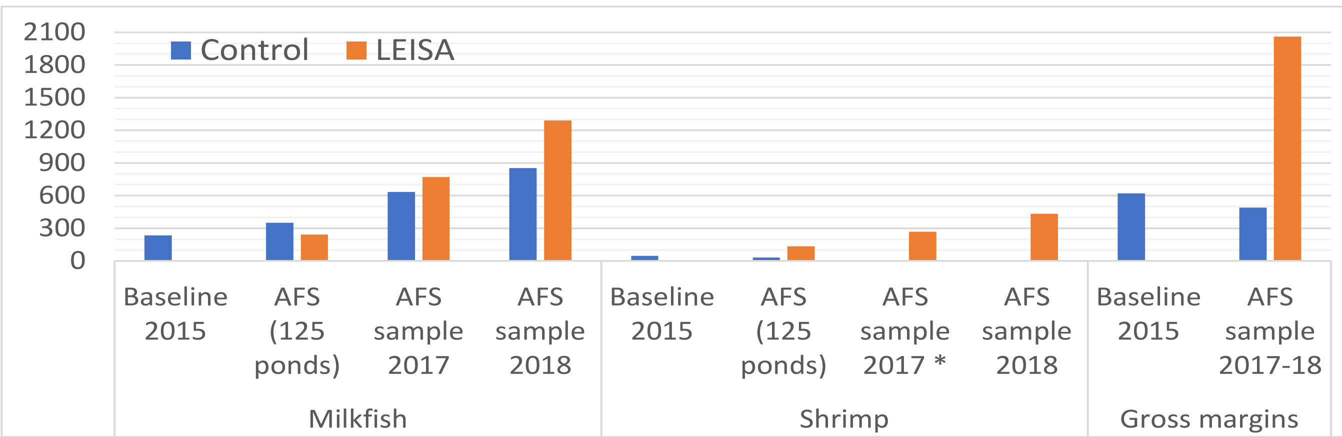


Figure 3. The yields of milkfish and shrimp and the gross margins of farmers applying LEISA and those who did not adopt this innovation (Adapted from: Widowati et al, 2021).



Box 2: Business booms after applying LEISA

I am Indah Purwanti, and I live in Purworejo village. My husband and I have a 1.5 ha pond. Until 2015, I was full-time housewife, but then I became a member of the Kartini Bahari womens group that organises skills training. To manage our milkfish pond, we used chemical fertiliser and pesticides. In March 2018, I joined the Aquaculture Field School (AFS) so I could help my husband in managing our milkfish production.

Through this AFS, I learned about managing the pond in an environmental-friendly way; I learned how to make home-made liquid compost, compost and other local feed additives. When we applied what we learned from AFS, we succeeded to double our milkfish harvest; in 2020 we harvested as much as two tons. Moreover, the milkfish gets fewer diseases and grows faster, thus the cultivation cycle is shorter.

We invested part of the income that we gained from our milkfish in buying a good cracker cutter and packaging tools for my business in making seafood crackers from shrimp, milkfish and squid since we live near the coastal area. The cutter shapes the crackers better, and the good packaging makes them more hygienic and more attractive to the buyers. Using these tools has tripled my production and sales of seafood crackers.

Given that most milkfish is cultured traditionally, the milkfish output of coastal districts like Demak can at least double. At present, 80% Indonesian traditional shrimp farmers occupy about 22% of the production area, but produce only 10% of its shrimp (Halim and Juanri 2016, cited by Widowati et al., 2021). After all these farmers go through AFS training, the Indonesian shrimp production is expected to increase by 25 to 50%, with low cost and low risk of disease outbreaks (Shinn et al. 2018, cited by Widowati et al., 2021).

In general, the yields and incomes of the farmers applying LEISA were higher in the second year than those in the first year (Figure 3). This can be explained by: i) farmers stocking shrimp more often, ii) more farmers using (more) industrial feed, and/or iii) other factors such as better application of their learning after discussions organised by the AFS alumni (Photo 6). After an AFS, any farmer can earn at least three times more than their usual income which they had from traditional practices; thus, giving them a first step out of the poverty trap; simultaneously, the country recovers its investment within one year. Moreover, we have observed that farmers, after finishing one season of the AFS training, became more confident in adopting innovations towards more sustainable and resilient aquaculture systems such as AMA, MTA and marketing (Box 3).

Associated mangrove aquaculture (AMA)

BwNI piloted the associated mangrove aquaculture (AMA) system proposed by Bosma et al. (2014). While traditional silvo-aquaculture could not stop the land loss (Photo 2), the practice of AMA could prevent land loss through a riverine greenbelt that is created by growing mangroves along the waterways in a separated section of the aquaculture farm (Photo 9). Thus, AMA hydrologically connects the farm’s mangroves with the natural waterways outside the pond and enlarges the nursery and feeding ground for the marine species. AMA is different from the usual silvo-aquaculture where mangroves are planted in the pond or on its dykes, shed their leaves onto the pond and adversely affect the pond water quality. Because the mangroves are grown in a separate section, with AMA i) water quality is improved; ii) the power of the waves is reduced, iii) sedimentation is increased, iv) pond dykes are protected and v) marine and coastal fisheries and other related livelihood opportunities are improved.

Figure 4. The average harvested volume (kg ha^{-1}) and gross margin (*10,000 IDR ha^{-1}) from 18 AMA ponds in 2019 vis-à-vis those in 2018 from the ponds (total average area 2.4 ha). In both years 17 farmers stocked milkfish and one cockle; in 2018, eight farmers cultured tiger shrimp and in 2019, twelve did.

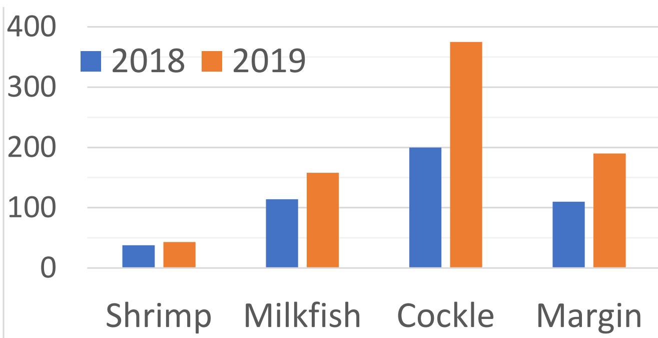


Photo 9: In the centre, the mangrove component of the AMA pond of pak Zaeni in Timbusloko, six months after building the separation dyke.

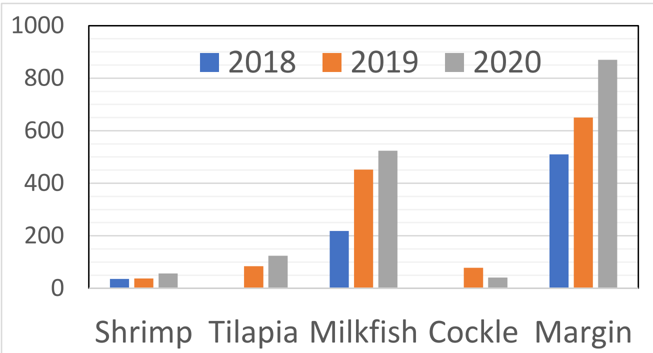
In 2018, about 120 farmers implemented AMA in Demak. Of these, 45 AMA ponds were monitored for inputs and yields, and from 18 other ponds, data on finances and water quality were also collected. In their smaller ponds, the AMA farmers were able to maintain, on average, the yields of milkfish and shrimp. This was in contrast to the yields that were obtained by the non-adopting farmers, who since 2015, didn't even stock shrimp (Figure 4). The soil subsidence continued since 2015, and floods were more severe in 2019 and 2020 than all those in the previous years; this may explain the lower average yields obtained from those obtained in 2017 and 2018 as reported above. Nevertheless, the AMA farmers were convinced of the advantages: Now they can harvest shrimp, trap more shrimp and fish in the main gates and catch more from cane-fishing (Photo 10).

Multitrophic shrimp aquaculture (Shrimp MTA)

A research project on multitrophic aquaculture (MTA) was introduced alongside AMA. MTA consists of simultaneously stocking milkfish ponds with shrimp, tilapia, seaweed and mussel or cockles (Photo 11). During the preliminary studies, even before a pilot was started, some farmers had already adopted stocking seaweed, mussels or cockles; and some had succeeded (Box 3).

Because of frequent floods and losses of aquaculture stock, 2019 and 2020 were difficult years for the farmers. Despite experiencing these deficient years, the efforts of twelve farmers venturing on shrimp MTA in a one-hectare-pond area paid off (Box 4). Unlike most farmers who lost their investments due to flooding, these twelve were able to maintain their margins during these bad years (Figure 5).

Figure 5. The average yields (kg ha^{-1}) and gross margin (*10,000 IDR ha^{-1}) of 12 MTA farmers in 2019 and 2020 from ponds of 0.5 or 1 ha, compared to their results in 2018 from their other ponds (average area 2.4 ha). In 2018 seven farmers stocked tiger shrimp and 11 milkfish, in 2019 10 stocked tiger shrimp, 12 milkfish, 12 tilapia and 5 cockles; in 2020 all 12 also stocked cockles.



Discussion

Our narrative here for the farmers' yields and gross margins does not include their shrimp/fish catch in the main gate(s), although they all said that this catch was an important source of food and income for them (Box 4). Some estimated the shrimp/fish catch value at the gate to be as high as that from the pond, especially when these were near mangrove areas, or the nearby AMA-transformed areas. Because of the importance of the catch in the gates, the farmers might neglect the original AMA advice to open the dyke to the river (Bosma et al., 2020); and thus, not remove the water-gates. Keeping the dyke is also a way to protect their land property rights and this reduces a barrier to broad-scale adoption of AMA. Studies

Box 3: After AFS, he by-passes the middlemen

In 2016, Kasmudi from Tambak Bulusan participated in the AFS. Like most other farmers in the village, he stocked milkfish, killed and prevented pests with chemicals and applied urea and phosphate fertiliser in his ponds. But his yields were still low. He had stopped stocking shrimps long ago. At the AFS, he learned the LEISA practices and also learned about the effect of seaweed on water quality.

At the end of the dry season in 2017, he bought 1,000 kg of seaweed - these all died during the heavy rains of January-February. But, after he had prepared the pond and stocked shrimp when salinity increased, the seaweed grew again. Yearly, the seaweed apparently disappears, but regrows and keeps the pond water clear. To manage salinity, he reduces the water exchange frequency and keeps the quality good by adding liquid compost weekly.

He stocks shrimp post-larvae in three small nursery ponds and transfers the good sizes to his grow-out pond. There, from April to December, every 4 to 6 weeks, he can harvest more than 150 kg shrimp of the size of about 20 pieces/kg. This volume he can sell directly to a fishmonger in Semarang, where he fetches 50-100% more than what the village collectors would pay him.

on optimising mesh sizes of nets, as well as the schedules for opening the gates, are needed to reach the goals of the farmers as well as those of the AMA to increase breeding and nursing grounds for estuarine and marine species.

The MTA with seaweed and mussels was tested because in most of Demak's ponds as incoming riverine waters contain high amounts of organic matter and thus nutrients. In our experience, combining 100 g m^{-2} seaweed and 60 g m^{-2} green mussel works best for both the reduction of organic matter and the growth of the cultured organisms. In our pilot ponds, the practice of feeding 50 saline-tolerant red tilapia in a cage of 25 m^{-2} ha^{-1} would sufficiently prevent noxious microbes from developing in the pond water, and thus reduce the risk of shrimp diseases.

In Demak, we have observed that several investments in shrimp monoculture using high technology sometimes lasted only for a year and left behind a destroyed landscape and a lot of plastic lining and feed bags littering the waters. Plastics are already found in most seafoods, and at the medium term, they may put human health at risk. Policies relevant to reducing plastic wastes, in general, and in aquaculture in particular, are thus urgently needed.

Policymakers may argue that for a sustainable food security, one must strive for much higher yields. In contrast, we view that to achieve a sustainable food security base, knowing and practicing LEISA, improving income and accumulating capital, are the first steps to sustainably increase yield. After complementary learning, in e.g., innovation platforms, reducing pond sizes and using limited amounts of manufactured pelleted feed for the last stages of the grow-out, farmers harvested up to 400 kg ha^{-1} yr^{-1}. However, in aquaculture only 20-40% of feed is retained by the animals; the rest is metabolised, excreted or wasted and pollutes ponds and the surrounding waters, because most pelleted feeds are formulated to optimise growth of shrimp and fish. Feeds can also be formulated considering both the culture species and the requirements of the pond ecosystem (Joffre and Verdegem 2019). Such nutritious pond feeds contain less

Photo 10: Catch of some hours of cane-fishing after the construction of AMAs; and enlarged greenbelts.

Box 4: AMA and IMTA changed family livelihood

Since 2000, pak Abdul Kohar did not stock shrimp or milkfish in his 2 hectare pond. In the second month after stocking shrimp, most of these died; while some he lost during spring tides. So, he just harvested the wild seafood that got trapped in his pond and in the gate traps at full moon. In 2017, BwNI proposed to the village group to apply AMA in ponds adjacent to rivers. The location of his pond matched the criteria, and he built the extra dyke and gates. In 2018, he started emptying his gate traps daily. The results made him very happy, next to fish, such as mullet and white snapper, he caught tiger prawns (*Penaeus monodon*) and white shrimp (*P. merguensis*); the last two he hardly ever caught in the last years. This made Kohar think that his pond could be used again for cultivation.

Also, in 2017, UNDIP-FPIK-Aquaculture looked for farmers who would pilot IMTA. In this IMTA, shrimp, milkfish, seaweed, cockle and a cage with tilapia are combined to take advantage of all nutrients in the water. Pak Kohar tried to grow all together the tiger prawns, milkfish, blood clams and seaweed. In the first cycle, the shrimp did not die; in the third month, he harvested 50 kg of tiger prawns and 500 kg of blood clams of which he initially stocked 200 kg. In addition, the milkfish harvest, which used to be only 200 kg before 2000, reached 600 kg. Pak Kohar also succeeded in cultivating seaweed, and in producing enough volume to interested factory buyers. Later, he proposed to several other farmers to add seaweed in their shrimp pond. This first success encouraged Kohar to manage his pond more seriously. After preparing the pond, he added tilapia to his other crops. His second year was even more successful: His yields doubled for shrimp and milkfish, and tripled for blood clams. In addition, the daily catches in his traps increased both in volume and variation: he caught also blue swimming crabs which have a high selling price.

This success gave Kohar the capital to improve his other pond; there he also applies AMA, IMTA, and his other learnings from the AFS. From the remaining money, he bought a new motorbike for the daily transport of his small family.

Photo 11: Farmers checking the growth of red saline tilapia in hapa in an MTA with milkfish, shrimp, seaweed and cockles.

protein and more carbohydrates, are 10 to 15 % cheaper, reduce feed waste and improve pond water quality. Moreover, similar studies in Bangladesh recorded a 21% increase in yields of tilapia. In Vietnam, although the shrimp did not grow significantly faster, the resulting better water quality reduced disease and led to a longer growth period with 10-15% lower cost for additives. Together with the lower cost of the feeding, the financial returns from the shrimp ponds improved, as well as other aspects of sustainability. The nutritious pond concept opens opportunities for further increase of the yields and benefits of the MTA for shrimp.

Conclusions

Based on our experience, aquaculture field schools are an effective channel to train farmers in adopting environment-friendly approaches such as LEISA, AMA and MTA systems. We found in our pilot areas that farmers, who learned and adopted these approaches at AFS, significantly increased their gross margin, with three-to-five times more yield for milkfish and shrimp compared to that of the baseline. The high rate-of-return guarantees the project donors a payback time of less than one year for an AFS program. Moreover, enriching the farmers' skills with AFS can potentially double Indonesian milkfish production and increase its shrimp production by 25 to 50%, without human and environmental health being put at risk because of the polluting effect brought about by the more capital-intensive high-tech innovations.

Using multitrophic systems, that is, simultaneously raising of shrimp, tilapia, seaweed and cockles or mussels in appropriate ratios, has been shown to reduce shrimp diseases and the high nutrient loads of the incoming waters in Demak. Moreover, the MTA increased the resilience of the aquaculture production, and thus improved farmers capacity to adapt to rising sea-level and sinking land.

The practice of dedicating an area to create a mangrove fringe along the waterway, as in the AMA systems, does not in any way reduce the margins, because smaller ponds give better yields. One of the impacts in using AMA is that more shrimp and fish are trapped in their water-gates and more fish are caught through cane-fishing -- resulting in more food and more income for the farmers. Because of this effect, villagers, in general, have a positive attitude towards AMA. In the long-term, farmers are assured that their catch of estuary and marine fisheries will be more, and floods will be less because of increased sedimentation and water storage capacity. These make the AMAs an effective tool to mitigate the impacts of climate change and land subsidence.

Associated mangrove aquaculture, Tambak Bulusan (Suhadi).

Acknowledgements

The authors are grateful to the farmers, in particular to those who expressed their feelings, posed for the photos and provided data, and to the other team members. In particular, we acknowledge the support of Dr. Femke Tonneijcke, Dr Fokko van der Goot, Dr. Nyoman I. Suryadiputra, Dr. Yus R. Noor and Dr. Ben Brown.

The photos (in chronological order) were made by: Eko Budi Priyanto (1, 2), Kuswantoro, Wetlands International (3a, 5, and 7), Apri Susanto Astra (3b), Woro Yuniati (4), Restiana W. Ariyati (6, 8, 11), Blue Forests team (9) and Dr Dolfi Debrot (10). The photos in the boxes in chronological order) were made by: Lestari L. Widowati (1), Restiana W. Ariyati (2), Dr Roel H. Bosma (3).

Building with Nature Indonesia is a programme by Ecoshape, Wetlands International, the Indonesian Ministry of Marine Affairs and Fisheries (MMAF), and the Ministry of Public Works and Housing (PU), supported by supported by the Dutch Sustainable Water Fund and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). For more information: www.Indonesia.buildingwithnature.nl

References

(Other used sources are listed on www.Indonesia.buildingwithnature.nl, or were cited by those mentioned below).

Bosma, R.H., Nguyen, Tin H., Siahainenia, A.J., Tran, Ha T.P. and Tran, Hai N. (2014). Shrimp-based livelihoods in mangrove silvo-aquaculture farming systems. Reviews in Aquaculture 6 (1) 1-18.

Bosma, R.H., Debrot, A.O., Rejeki Sri, Tonneijck, F., Yuniati, W. and Sihombing, W. (2020). Associated Mangrove Aquaculture Farms; Technical Guidelines Associated Mangrove Aquaculture Farms. Building with Nature – Indonesia / Ecoshape technical report, Dordrecht, The Netherlands. Available from: https://www.wetlands.org/publications/technical-guidelines-associated-mangrove-aquaculture-farms/

Brown, Benjamin (2015). Coastal Field School Prospectus. Blue Forests.

Chaussard, E., Amelung, F., Abidin, H. and Hong, S.H. (2013). Sinking cities in Indonesia: ALOS PALSAR detects rapid subsidence due to groundwater and gas extraction. Remote Sensing of Environment, 128, 150-161.

Elfitasari, T. and Albert, A. (2017). Challenges of Small-scale Fish Farmers for Fish Product Sustainability. Omni-Akuatika 13(2), 128-36.

Joffre, O. and Verdegem M.C.J. (2019). Feeding both pond and fish: a pathway to ecological intensification of aquaculture systems. INFOFISH International 3: 55-58.

Widowati, L.L., Ariyati, R.W., Rejeki, Sri, Bosma, R.H. (2021). The Impact of Aquaculture Field School on the Shrimp and Milkfish Yield, and Income of Farmers in Demak, Central Java. Journal of the World Aquaculture Society 2021: 1-16. DOI: 10.1111/jwas.12770.