Associated Mangrove Aquaculture:

Farmers' Yields and Income

and Pond Water Quality

Building with Nature Indonesia

MONITORING REPORT

For: Project WI-NL 1354_019

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December 2020

Associated Mangrove Aquaculture:

Farmers' Yields and Income, and Pond Water Quality.

Training and Monitoring Report of Farmers
and their pond water quality, yields and income
A Project Piloted by the Building with Nature Indonesia

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Content

The image on the cover shows the AMA pond of pak Zaeni in Timbusloko, six months after building the dyke (BwNI).

The spreadsheets will be separately reported to Ecoshape and Wetlands International.

Summary

This Report details the results of the *Associated Mangrove Aquaculture* (AMA) system that was piloted by the Building with Nature Indonesia project (2016-2020). AMA is an innovative silvi-aquaculture system, where the mangroves do not grow in the pond or on its dykes, but along a waterway in a separated section of the aquaculture farm. Thus, this AMA is different from the usual silvi-aquaculture where mangrove leaves often fall into the pond and destroy the pond water quality. With AMA, the hydrological connection of the farm's mangroves to the natural waterways outside the pond enlarges the nursery and feeding ground for the marine species. Moreover, mangrove forest near the sea (1) improves the water quality, (2) reduces the power of waves, and (3) increases sedimentation; thus, protects the pond dikes.

In Demak, about 120 farmers implemented AMA in 2018. BwNI monitored 45 AMA ponds and the UNDIP-WUR team collected more data from 18 other ponds than those 45. In 2018 and 2019, the AMA farmers were able to maintain, on average, the yields of milkfish and shrimp, in contrast to the non-adopting farmers who since 2015, didn't even stock shrimp. However, the average yields were lower than those harvested from other ponds after the field school training in 2017 and 2018. The soil subsidence continued since 2015, and floods were more severe in 2019 and 2020 than the previous years. Nevertheless, the AMA farmers were convinced of the advantages: now they can harvest shrimp, and they have more catches of shrimp and fish in the main gates and from cane-fishing. Alongside AMA, this Report also discusses the application and benefits of Integrated Multitrophic Aquaculture (IMTA), the practice of simultaneously stocking shrimp ponds with seaweed, mussel or cockles and tilapia. Featured here are the 12 other farmers who were able to maintain their margins in the bad years of 2019 and 2020, in comparison to those they obtained in 2015.

Considering the farmers' shrimp/fish catch in the main gate(s) is an important income source for them, we advise them not to open the dike to the river. Instead, we recommend that they open two gates. These two gates will help protect their land property rights and reduce this barrier to broad-scale adoption. Finally, we recommend that future studies focus on the mesh sizes of nets and management optimal of gates considering catch, and the exchange of water and its contents with the surrounding waterways.

The Associated Mangrove Aquaculture (AMA) pond of pak Suhadi
in Tambakbulusan, six months after building the dyke (BwNI).

1. INTRODUCTION

AMA, Associated Mangrove Aquaculture, is an innovative silvo-aquaculture, or sylvo-fishery, system where mangroves do not grow along the dykes and/or in the middle of the pond (as typically found in Indonesia and Vietnam), but in mangrove belts that are established along waterways in an estuary (see cover and front pages). The main advantage of this AMA system is the hydrological connection of the mangroves with the natural waterways outside the pond, where the mangrove can provide nursery and feeding ground for valuable marine species. From the aquaculture's point of view, mangrove forest (1) improves the water quality due to the mangrove roots' capability to absorb pollutants from the water, (2) reduces the power of waves, and (3) increases sedimentation, and thus protects the pond dikes.

Within the project Building with Nature Indonesia (BwNI), AMA was implemented by over 100 farmers in ten coastal villages of the Demak, Central Java. To quantify the effects of the AMA implementation, BwNI requested the Prof. Dr. Sri Rejeki - Aquaculture Department, FPIK, UNDIP, Semarang, and Dr Roel H Bosma, formerly at Wageningen UR to monitor a sample of the ponds and the farm households from 2018 to 2019. The 100 farmers mentioned here converted their ponds to AMA systems in 2018; some completed in 2019 only, while the project was planned to close in June 2020. Thus the data that we collected serve as a baseline and show the results of implementation in the first two year.

In the framework of another project, we tested an IMTA system with 12 other AMA farmers in another pond. To give a broader picture, we provide also the data we collected for this test in this report.

In the next chapter, we report on the training that we provided to the AMA farmers. Thereafter, in two chapters, we give some details on the methodology and the material, and then describe and discuss the results. The reader can find most of the tables with the raw data in the Appendix. The large dataset with water quality measurement is submitted as an annex to the donors.

SUARA MERDEKA
Perekat Komunitas Jawa Tengah


SM/dok

DISKUSI: *Guru besar Undip, Sri Rejeki, memimpin diskusi dengan komunitas petambak di Wedung Demak, kemarin.('60)*

Model Budidaya Tambak Terhubung Mangrove Dipopulerkan

DEMAK- Model pengelolaan tambak yang terhubung ekosistem tanaman bakau semakin dipopulerkan. Undip menjadi pihak yang mendukung metode ini.

"Model tersebut dianggap pendekatan budidaya air payau, yang ramah lingkungan dan berkelanjutan.Selain itu bertujuan menyelamatkan ekosistem mangrove serta meningkatkan perlindungan pantai dari abrasi dan erosi," tutur Guru Besar Fakultas Perikanan Ilmu Kelautan (FPIK) Undip, Prof Dr Sri Rejeki, kemarin.

Dia menyinggung persoalan ini di tengah kunjungan lapangan di pesisir Karang Tengah dan Wedung. Dikatakan, budidaya tambak terhubung mangrove atau dikenal sebagai *associated mangrove aquaculture* (AMA), yang dilaksanakan dengan cara petambak menyerahkan sebagian lahan untuk restorasitanaman bakau di bantaran muara sungai. Langkah ini akan mengakibatkan sedimentasi. Namun manfaatnya besar melindungi tambak saat berhadapan langsung dengan laut atau berdampingan dengan muara sungai. Selain itu kegunaannya meningkatkan keragaman hayati dan meningkatkan peluang ekonomi lokal.

Perpres

Hal ini sejalan kebijakan Perpres 51 tahun 2016 tentang Sempadan Pantai. Di mana mangrove sebagai sabuk hijau ditanam sepanjang pantai menjorok 100-200 meter kearah daratan, atau sepanjang tanggul mulut sungai 10-20 meter kearah daratan.

"Petambak sadar mangrove sangat menguntungkan. Tanpa itu mereka akan kehilangan tambak, tanah, mata pencaharian, bahkan rumah," katanya dalam kegiatan yang juga program pengabdian masyarakat ini.

Selain Sri Rejeki tim dari Departemen Akuakultur FPIK ini melibatkan, Prof Dr Budi Prayitno, Dr Titik Susilowati, Dr Sarjito, Dicky Herwanto PhD, Lestari Lakshmi Widowati, serta Restiana Wisnu Aryati.

Peningkatan produksi dirasakan sejak diterapkan cara ini pada 2018. Setahun berikutnya, produksi posongan atau tangkapan harian udang meningkat. Dilaporkan kurang lebih 2-3 kg per hari, sehingga penghasilan petambak mencapai Rp 150.000.

Budidaya jugasemakin kaya biota, contohnya petambak mendapatkan ikan belanak yang dapat dijual di pasar dengan harga Rp 15.000 per kilogram.

Metode semacam ini termasuk pendekatan yang disepakati konsorsium pemerintah Belanda dan Indonesia. Adapun kegiatan berpola membangun bersama alam (*building with nature*/BwN) di Kabupaten Demak ini sudah dimulai sejak tahun 2016, yang didanai Dutch Waterfund, German IKI dan Ecoshape Foundation.

Salah satu kegiatan BwN Belanda dan BwN Indonesia di Demak adalah penerapan budidaya tambak terhubung mangrove.(H41-60)

Figure 1: One of the newspapers of Central Java reported on the AMA system and the training dispensed by Prof Sri Rejeki.

2. TRAINING AMA FARMERS

All AMA farmers were trained by the team. The team started by training those in Onggojoyo, Tambakbulusan and Surodadi before this monitoring (Table 1). Training sessions aimed at enhancing the farmers' knowledge about AMA and best aquaculture practices in pond culture.

Table 1. The training topics and the training schedule before AMA monitoring.

No.	Title	Date	Village
1.	Socialization of Associated Mangrove Aquaculture Program	11-10-2018 18-10-2018 22-10-2018	Onggojoyo Tambakbulusan Surodadi
2.	Assistance on the Use of Water Quality Checker and Data Tabulation	7-11-2018 14-11-2018 25-11-2018	Tambakbulusan Onggojoyo Surodadi
3.	Benefits of Associated Mangrove Aquaculture	5-12-2018 13-12-2018 20-12-2018	Tambakbulusan Onggojoyo Surodadi
4.	Discussion on Challenges of Associated Mangrove Aquaculture	27-12-2018	Tambakbulusan*
5.	Complementary Training in all BwNI-AMA villages		

* Participants of Surodadi and Onggojoyo were present.

After the first series of seven trainings in each of the three villages that were monitored, in 2019 the team also started training in the seven other villages with the same goal of improving the farmers' knowledge on best aquaculture practices in brackish water pond of the other farmers with AMA ponds (Figure 1). These were given to all other pond farmers and other interested persons from the seven villages that joined the AMA program. The subject of the trainings followed the farmer's main interest (See below). The frequency of the trainings differed in the villages here mentioned: Siklenting (3), Morodemak (5), Tugu (4), Timbulsloko (4), Bedono (3), Betahwalang (2), Purworejo (2). The occurrence of Covid-19 hindered us from completing our agenda.

Overall, in 3 to 10 villages, the coastal fields school alumni and other interested aquaculture farmers could receive training on the following topics:

1. Pengenalan BTN/AMA, i.e. Knowledge on AMA (Supplement-1)
2. IMTA, i.e. Integrated Multi-trophic Aquaculture (Supplement-2)
3. LEISA, i.e. Low External Input Sustainable Aquaculture (Supplement-3)
4. Budidaya Kerang Hijau, i.e. Green Mussel culture (Supplement-4)
5. Budidaya Nila Saline, i.e. Saline Tilapia culture (Supplement-5)
6. Budidaya Rumput Laut Gracilaria, i.e. Gracilaria culture (Supplement-6)
7. Budidaya Rajungan, i.e. Blue Swimming Crab Culture (Supplement-7)

Prof Sri Rejeki was also invited to introduce the AMA system to the district office of the Ministry of Marine Affaires and Fisheries in Brebes. This was charged to one of the NWO projects she was involved in.

3. METHODOLOGY

Before we started monitoring, we provided complementary training to the AMA pond farmers (See 2.3). Since our AMA budget wasn't large enough for a specific control; we decided to compare the results of this AMA monitoring with the BwNI baseline data which we collected before the start of the project. The BwNI baseline assessed the results of 113 farmers, with 1/3 of them raising shrimp (Ariyati et al. 2016). In 2015, the average yields of shrimp and milkfish at final harvest were 47 and 234 kg ha^{-1} $year^{-1}$, respectively. The farmers had an average operational cost of 240 ±400 USD ha^{-1} $year^{-1}$, and their 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. Unpublished).

3.1. Variables

Here, we assessed the effect of the new pond design through four main parameters: cost, yield, income, gross margin. Below are the variables we used to collect related data on the aquaculture production and the daily fisheries after the farmers converted their ponds to adjust to the AMA system:

- Production cycle(s)
- Cultured organisms (milkfish; shrimp: *monodon* / *vannamei*)
- Stocking density of each organism
- Cost of pond preparation and stocking
- Cost of feeding and other maintenance cost
- The weight of the harvested organisms per cycle
- Daily catch from the trap set in the sluice gate facing the pond when the water is flowing out of the pond during low tide (*posong*)
- Daily catch from the trap set in the sluice gate facing the river/canal (*impes*), when water is entering the pond at high tide.

To interpret the data above, we collected information on the following co-variables:

- Pond design (area; number of gates; number of canals; presence of a reservoir)
- Pond management (pond drying; fertilizer; pest and predator control)
- Physical, chemical and biological water quality variables (transparency, water color; temperature; DO; pH; salinity; TAN-NH_3; plankton).
- Production data of these and other farmers in the project area collected for and by the BwNI project, and from others studies by the UNDIP team.

3.2. Data Collection

The AMA farmers monitored water quality daily (Table 2) by filling up the forms provided to them. They described the characteristics of their pond and registered daily their water quality data and the information on the other variables. Next to the water quality data, the forms contained the information on cost, yields, catch and income. Once a month, the team also collected data to validate the data collected by the farmers. During the monthly visits, the team took water samples and related measurements, and verified the monitoring sheet filled out by the farmers.

Table 2. Water quality parameters, measuring methods, equipment, locations and frequencies used for the monitoring.

Parameter	Method	Location	Frequency	Responsible	Database
- Water transparency	- Secchi disk	- Ponds	- Daily	- Farmer *	Monthly researchers reviewed the farmers data before transcription in a database. During these visits the team collected water samples for further analysis, and (perhaps) sample products (e.g. fish, shrimp) for analysis.
- Water colour	- Visual observation using colour cart	- Ponds	- Weekly	- Farmer	
- pH	- Indicator stick	- Inlet, Ponds	- Weekly, at noon	- Farmer	
- Ammonia	- Test kit	- Inlet, Ponds	- Weekly	- Farmer	
- Dissolved Oxygen (DO)	- Oxygen meter	- Inlet, Ponds	- Daily at dawn	- Farmer	
- Alkalinity	- Test kit	- Ponds	- Weekly	- Farmer	
- Salinity	- Refract meter	- Inlet, Ponds	- Weekly	- Farmer	
- Temperature	- Thermometer	- Ponds	- Weekly	- Farmer	
- N-components, P, aquatic organisms	- Laboratory	- Inlet, Ponds	- Monthly	- Researchers	

* Farmers were given a ledger with forms and carbons. The UNDIP team assisted in stocking and harvesting to improve data quality whenever possible.

Because a DO meter is too expensive for most small pond farmers, the farmers were trained to read the DO at different water salinity and temperature; the table assumes an air pressure of 760 mmHg (Stirling, 1985; Annex A). The water colour is categorised according to a chart; the colours are indicators for the fertility status of the pond water (Annex B).

The baseline data on stocking and yields of the two groups of farmers we monitored were copied from the general monitoring database of the project BwNI. We are grateful for their assistance.

3.3. Calculations

From the data on operational cost, yield and income, the Gross margins were calculated by using the following formula:

Gross margin = Income from sales – Operational cost.

The calculation of the net margin required the accounting of the investment cost, i.e, the value of the pond.

4. MATERIAL

The sampled villages are located along the coast of Demak and distributed over the four project zones: Coast 0, I, II, and II (Figure 2 and Table 3).

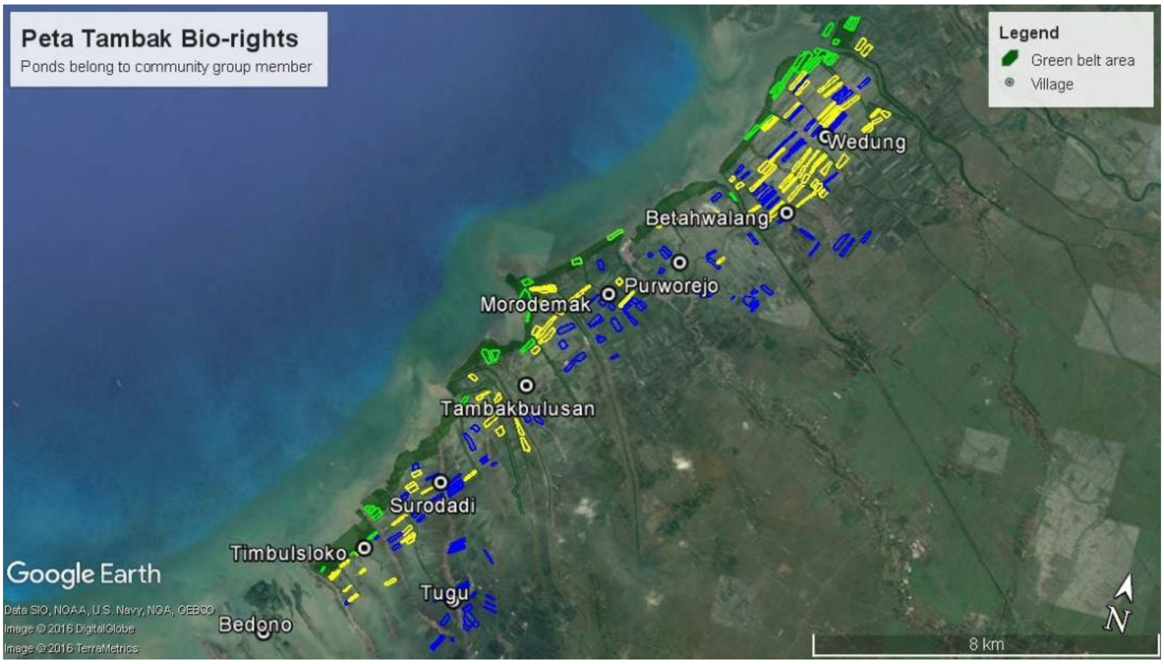


Figure 2. Location of the villages within Demak's coastal area; Onggojoyo is located near Wedung. The AMA ponds are marked yellow; blue indicates other LEISA ponds.

Table 3: The four villages sampled for the AMA and IMTA monitoring.

Project sector	**III**	**I/II**	**0**		
Sub-district	**Sayung**	**Sayung**	**Karang Tengah**	**Bonang**	**Wedung**
Villages		Surodadi	Tambakbulusan	Purworejo	Onggojoyo

4.1. Pond characteristics

In 2018 and 2019, we observed 18 ponds in 3 of the 10 villages where AMA was implemented: Tambakbulusan, Surodadi and Onggojoyo (Annex C-1, and Table 4). In these 10 villages of Demak, about 280 farmers were previously trained in Coastal Field Schools provided by BwNI. Most of them adopted LEISA in their traditional milkfish-shrimp management system. Note that the AMA ponds (marked yellow) are located nearer to the coast of Demak than the aquaculture revitalization ponds (Figure 2). As a practice, the more intensive aquaculture is mostly done further from the coast, where risks of flooding and high salinity are lower.

Table 4. Data collected before the 2018 stocking in the three villages and the sample: Average size, minimum, maximum and approximate means of some pond characteristics after building the new dike (For all data see Annex D).

Pond characteristics	**Tambak-bulusan**	**Surodadi**	**Onggo-joyo**	**Overall**
Pond area (ha)	2.8	2.3	2.1	2.4
Number of pond compartments	2-6 (3.7)	1-5 (3)	1-4 (2.5)	3
Reservoir availability	0-1 (0.8)	0-1 (0.5)	0	0.5
Dike height (m)	1	0.7-1.5 (1.3)	1	1.1
Pond water depth (cm)	40 – 70 (65)	40-115 (85)	40-60 (55)	55-85
Number of gates per compartment	1 – 4 (>2)	1-4 (<2)	2	2
- Inlet gate	1-2 (>1)	1-2 (>1)	1	>1
- Outlet gate	0-1 (<1)	0-2 (<1)	1	<1
Number of inlet canals	1-2 (1.6)	1-3 (1.5)	1	1.5
Number of outlet canals	0-1 (<1)	0-2 (<1)	1	<1
Water source (Sea / River)	1 / 5	1 / 5	0 / 6	2 / 16

In 2019-2020, we monitored 18 ponds belonging to different MMA owners in 4 villages. These were special ponds of 1 ha designed to test an IMTA system. These ponds were not always within the MMA system. As a baseline for these farmers, we provided the stocking and harvesting data of their MMA pond in 2018 (Annex C-2 and Table 5).

Table 5. The average size, and minimum, maximum and approximate means of some characteristics of the ponds in the three villages and the sample.

Pond characteristics	**Surodadi**	**Tambak-bulusan**	**Purworejo**	**Onggojoyo**
Pond area (ha)	1	1	0.75	1
Number of pond compartments	1	1	1	1
Reservoir availability	0-1 (0.8)	0-1 (0.5)	0	0.5
Dike height (m)	0.8-1 (0.9)	0.8	1.1-1.2 (1.1)	0.8-1 (1)
Pond water depth (cm)	40-65 (60)	40-65 (60)	55-75 (65)	60-80(70
Number of gates per compartment				
- Inlet gate	1	1	1	1
- Outlet gate	0-1 <1	0-1 <1	0-1 <1	0-1 <1
Number of inlet canals	1	1	1	1
Number of outlet canals	1	1	1	1
Water source (Sea / River)	1	1	1	1

4.2. AMA Pond Preparation and Cultivated Organisms

In the first year, the farmers concentrated more on reconstructing their ponds from an ordinary pond to an AMA pond. Most used the proposed mangrove area as a reservoir. Nevertheless, they cultivated milkfish and shrimp in their ponds after the usual preparations. In preparing their pond, they used the methods that they learned from their training in LEISA by the Coastal Field School and by the AMA monitoring team.

Farmers in Tambakbulusan dried the pond bottom partially, but those in Surodadi and Onggojoyo were not able to dry the ponds because of the present state of local pond dikes and availability of local technology. Morevover, many farmers were afraid that the dikes of their neighboring ponds might collapse.

For further pond preparation all farmers, except one, applied saponin for pest control and MOL both in different doses. The farmers in Tambakbulusan and Surodadi applied compost, and in Tambakbulusan, only one farmer applied molasses to favor bacterial growth; three applied lime to reduce soil acidity (Table 6).

Table 6. Pond preparation and management in the three villages.

Tambakbulusan	**TA**	**TB**	**TC**	**TD**	**TE**	**TF**
Pond area (ha)	4	3	2	2	2	4
Drying	-	-	-	-	-	-
Saponin (kg)	10	10	10	10	10	25
Liming	No	Yes	Yes	Yes	No	No
Compost (kg/ha)	50	50	50	50	50	150
MOL (liter)	20	20	20	75	75	75
Molasses (liter)	0	0	0	0	20	-
Surodadi	**SA**	**SB**	**SC**	**SD**	**SE**	**SF**
Pond area (ha)	2,5	2	3	2,6	2	1,6
Drying	No	No	No	No	No	No
Saponin (kg)	40	5	25	10	-	10
Liming	No	No	No	No	No	No
MOL (liter)	20	10	0	20	70	-
Onggojoyo	**OA**	**OB**	**OC**	**OD**	**OE**	**OF**
Pond area (ha)	2	2	1,5	3,5	2	1,5
Drying	No	No	No	No	No	No
Saponin (kg)	24	20	5	10	20	10
Liming	No	No	No	No	No	No
Compost (kg)	150	150	100	250	150	110
MOL (liter)	80	80	60	80	80	60

Except one farmer in Surodadi who stocked blood cockle, all farmers stocked milkfish once a year (Table 7). Between January and July, but mostly in April, the farmers stocked between 2,000 and 15,000 milkfish fingerlings. Depending on area, cash and experience, the farmers' average stocking density was about 5,000 pcs/ha. Most farmers harvested in November or December, but some already did in September and October. There is no relation between date of stocking and date of harvest, i.e., the number of days of culture, because after the milkfish reaches a marketable size, farmers would harvest whenever they needed money.

Table 7. The number of stocked milkfish and blood cockles, stocking and harvesting dates in each pond in the three villages.

Villages and parameter	Farmers					
	A	**B**	**C**	**D**	**E**	**F**
Tambakbulusan	Milkfish	Milkfish	Milkfish	Milkfish	Milkfish	Milkfish
Stocking dates	27/4/18 15/6/19	12/4/18 28/5/19	17/5/18 20/4/19	20/4/18 09/03/19	15/4/18 12/1/19	5/2/18 6/2/19
Numbers stocked	10,000 10,000	4,000 3,000	5,000 5,000	5,000 4,000	6,000 5,000	7,500 10,000
Harvest dates	11/11/18 15/12/19	10/11/18 20/12/19	1/12/18 19/11/19	21/11/18 09/10/19	6/11/18 14/11/19	17/11/18 12/10/19
Surodadadi	Milkfish	Milkfish	Milkfish	Milkfish	Blood cockle	Milkfish
Stocking dates	07/03/18 11/04/19	06/05/18 10/05/19	11/6/18 20/5/19	24/5/18 14/4/19	02/05/18 10/04/19	05/6/18 03/5/19
Numbers stocked	5,000 3,000	5,000 5,000	10,000 15,000	4,000 5,000	200 kg 300 kg	4,000 4,000
Harvest dates	19/11/18 28/12/19	12/11/18 02/12/19	11/12/18 14/12/19	11/10/18 15/11/19	05/09/18 11/10/19	05/12/18 22/11/19
Onggojoyo	Milkfish	Milkfish	Milkfish	Milkfish	Milkfish	Milkfish
Stocking dates	29/4/18 30/5/19	5/3/18 16/5/19	17/5/18 20/4/19	23/3/18 16/4/19	8/5/18 27/7/19	18/4/18 20/5/19
Numbers stocked	4,000 5,000	5,000 3,000	5,000 3,000	7,000 -	4,000 3,000	2,000 2,000
Harvest dates	10/11/18 21/12/19	9/10/18 18/11/19	20/10/18 12/11/19	12/10/18 10/11/19	29/11/18 10/12/19	1/12/18 22/11/19

Most farmers stocked 5,000 to 40,000 shrimp PL (post-larvae) twice a year; the average stocking density is about 5,000 PL/ha. Farmers harvested the shrimp at least twice within about 3 months after stocking. In 2018 and 2019, respectively 8 and 12 of the 18 farmers stocked shrimp.

4.3. IMTA ponds in 2019 and 2020

In 2019 and 2020, twelve AMA-adopting farmers also implemented LEISA-IMTA system in separate 1-ha ponds. These 12 farmers were located in four villages: 4 farmers in Surodadi; 3 in Tambakbulusan, another 3 in Onggojoyo, and 2 in Purworejo. This test was mainly funded by the researchers and the farmers. The baseline used for these farmers was also copied from BwNI (Table 8).

The culture seasons of the organisms cultivated in this IMTA varied according to proper season and seed availability (Figure 3). The farmers' actual stocking was synchronized in the villages (Table 8), according to specific stocking densities (Table 9).

The tilapia were stocked in 25m^2-cages, while the blood cockles and seaweed were broadcast all over the pond.

Figure 3. The general culture schedule of the IMTA farmers.

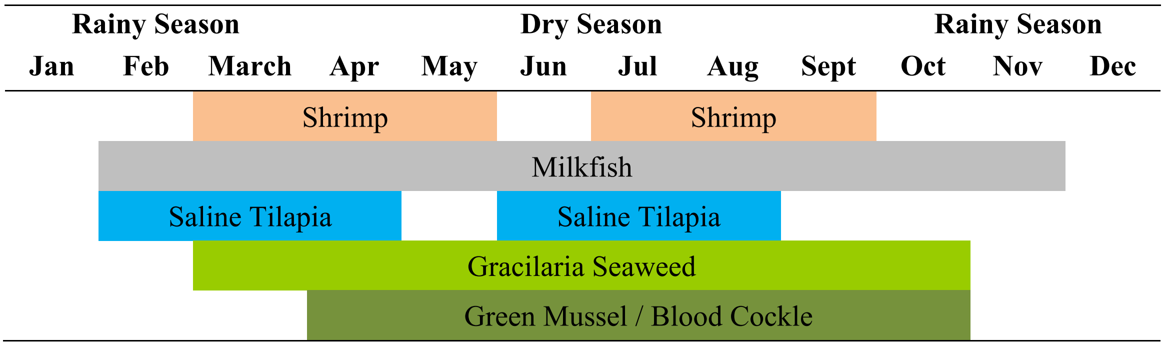


Table 8. The 2019 stocking calendar of the IMTA pond farmers.

Villages	Culture Organisms				
	Tiger Shrimp	Saline Tilapia	Milkfish	Gracilaria	Blood Cockle
Tambakbulusan	3 Feb	3 Feb	10 Feb	23 April	9 June
Surodadi	-	-	10 Feb	23 April	9 June
Onggojoyo	7 Feb	7 Feb	8 Feb	23 April	18 June
Purworejo	2 Feb	2 Feb	3 Feb / 24 Oct	23 April	18 June

Table 9. The cultivated organisms and their stocking density

Organisms	Growth stage	Stocking density / ha
Tiger shrimp	Juvenile	12,000 pp
Milkfish	Fingerling	12,000 pp
Saline Tilapia	Fingerling	5,000 pp
Blood cockle		200 kg
Gracilaria seaweed		200 kg

5. Results

5.1. AMA ponds

5.1.1. Yields and margins in 2018 and 2019

Over 2018 and 2019, the average yield of milkfish was 136 kg/ha across the 18-monitored-AMA farmers (Table 10). The farmers reported that their yields increased in 2020. For the blood cockle, the average yield was about 285 kg/ha. Not all AMA farmers stocked shrimp: 8 stocked shrimp in the first year (2018) and 12 in the second year (2019). Their average yield was about 40 kg/ha.

Table 10: The average harvested volume (kg/ha) by the mentioned number (n) of AMA farmers in 2019 and 2020 vis-à-vis their harvests in 2018 from their other ponds (average area 2.4 ha).

	Tiger Shrimp		Milkfish		Cockle		Gross Margin	
Year	**n**	**kg/ha**	**N**	**kg/ha**	**n**	**kg/ha**	**N**	**Million IDR/ha**
2018	8	38 ±20	17	114 ± 40	1	200	18	1.1 ±0.7
2019	12	43 ±34	17	158 ±162	1	375	18	1.9 ±1.1

The 2018 and 2019, the average gross margin of these ponds was 1.5 million IDR/ha. This revenue did not include those earned from the daily catches in the main water gate. To estimate the revenues, we used average selling price for the milkfish in 2018, 2019 and 2020, which might have reduced the variation, particularly for the milkfish.

5.1.2. AMA Pond Water Quality

The collected data on water quality by farmers and the team were submitted separately in an xls. Below we present and discuss minimum and maximum averages.

The monthly average Dissolved Oxygen (DO) levels of the 18 ponds were above 5 ‰ all year round (Table 11). Once, in one pond the UNDIP team measured a maximum of 8.4 ‰. In 6 ponds, in specific months, the team measured values between 3 and 4 ‰, which was mainly between October and January during pond preparation, but also twice in the dry season in full culture season. Only once in May a value below the recommended minimum was measured in one pond in Surodadi (0.3 ‰).

In the rainy season, from October to April, the averages of the measured water temperatures fluctuated between 30 and 32 ^{0}C (Table 11). Maximum water temperature measured was slightly above 34 ^{0}C. In the dry season, the average water temperature was at least 2 ^{0}C higher. The UNDIP team recorded 34 ^{0}C thrice in at least one pond, 36^{0}C twice in one month, and once 38 ^{0}C. Every period, at least one farmer measured a maximum temperature between 34 and 38 ^{0}C. The maximum water temperature indicates that in the dry season the temperatures during day time are above optimal range for shrimp (28-32 ^{0}C).

Table 11. The monthly averages of the daily measurements of water quality by the farmers and by the team from October 2018 till December 2019 for 14 monthly periods only (see figure 3 for the periods).

	Measured by UNDIP around the 20 of the mentioned month								Period averages of farmers			
Month	**T (°C)**	**DO**	**pH**	**Salinity**	**N**	**P**	**Ammonia**	**Plankton**	**T (°C)**	**pH**	**Salinity**	**Clarity**
Nov. 2018	32.1	5.6	7.8	18.8	1.6	0.7	0.3	8.1	32.0	8.1	23.7	63.1
Dec. 2018	31.6	6.1	8.0	16.1	1.3	0.6	0.3	6.7	31.6	7.8	21.9	63.6
Jan. 2019	30.1	5.9	7.9	15.6	1.4	0.8	0.3	5.4	31.7	7.8	22.1	60.6
Feb. 2019	30.4	5.6	7.9	16.4	1.5	0.7	0.3	6.5	31.4	8.0	22.3	59.7
Mar. 2019	31.3	5.8	7.9	20.3	1.9	0.9	0.3	6.3	31.0	7.9	24.0	58.9
Apr. 2019	31.6	5.7	8.0	24.6	2.3	1.0	0.3	8.6	31.5	7.9	24.2	55.6
May. 2019	32.3	5.4	8.1	27.3	2.3	1.0	0.2	8.6	31.8	7.9	26.0	53.3
Jun. 2019	32.8	5.7	8.1	32.1	2.4	0.9	0.2	9.7	32.1	7.9	27.6	49.2
Jul. 2019	33.7	5.2	8.3	33.6	2.6	1.0	0.2	8.7	32.4	8.1	30.6	46.7
Aug. 2019	33.9	5.2	8.1	33.2	2.5	1.0	0.2	9.6	32.8	8.3	28.8	45.3
Sep. 2019	33.3	5.6	8.1	31.7	2.1	0.9	0.3	5.7	33.2	8.0	27.6	45.6
Oct. 2019	31.8	5.8	7.9	27.3	1.9	0.9	0.3	5.8	33.3	7.9	29.3	53.3
Nov. 2019	30.4	6.1	7.7	20.2	1.4	0.7	0.3	5.3	32.1	8.0	27.3	54.7
Dec. 2019	30.3	6.1	7.6	14.7	1.1	0.7	0.3	5.7	31.4	8.0	24.4	60.0

Legend: DO, salinity are given in ‰, and N (Nitrate) P (Phosphate) and ammonia are given in ppm, plankton in 1,000 cells L^{-1}, and clarity in cm.

Both the farmers' and UNDIP's measured average pH values fluctuated within the range of those recommended for shrimp farming (7.5 - 8.5). Although the farmers' measured maximum pH values were slightly higher in the dry season, they also recorded a one-half (½) point higher value at the start of the second rainy season. Two Onggoyogo farmers, respectively, measured an average pH of 6.1 from January to May and 6.5 in December, which was below the recommended range.

The farmers' estimated average salinity was higher (22 to 24 ‰) than UNDIP's (15 to 20 ‰) between November to March (rainy season). The spread in the average of the estimates of the farmers was smaller than that measured once a month by UNDIP. In the rainy season, the average was far below the recommended range of 26-32 ‰, but from May to October (dry season), the average remained within this range. However, in dry season the average salinity was above 30 ‰ with peaks of 38 ‰; maximum salinity of 59 ‰ was observed in one pond of Tambakbulusan, and 40 ‰ in another pond of Surodadi. It is probable that most farmers managed their salinity levels by increasing the frequency of water exchange during high tides in the rainy season, and reducing it during low tides in the dry season. The latter is easier with MMA where ponds have closeable gates on the estuary-side.

In the dry season, Phosphate (P) and Nitrate levels were higher than those in the wet season, but ammonia was lower (Table 11). All year-round, the average nitrate levels were below their recommended maximum (< 200 ppm). Although the average P values remained in the recommended range (0,05-0,5 ppm), in all months the measured peaks in P levels (1.1 to 2.4 ppm) were above the recommended range. These peaks, as well as high monthly average, were found in several ponds of Tambakbulusan and Onggojoyo, mainly in the dry season. Particularly in Surodadi, the level of P remained within the recommended range in all months.

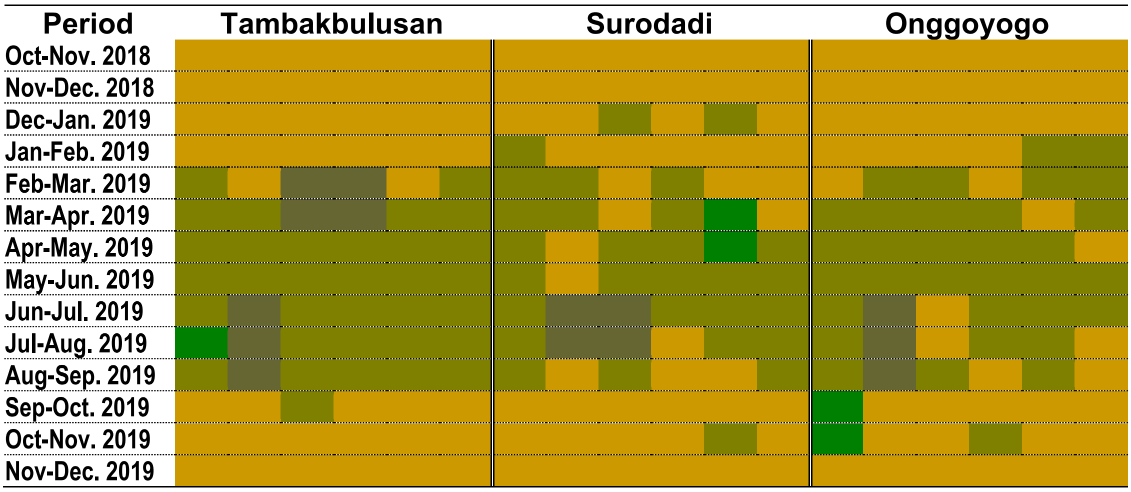
The average levels of ammonia were higher than the recommended level (< 0,1 ppm) but remained below the toxic level (>0.4 ppm). However, some farmers, mainly in Tambakbulusan, succeeded in maintaining the recommended ammonia range during the culture season. The average ammonia levels in Tambakbulusan were either 0.1 or 0.2 ppm, those in Surodadi, 0.2 ppm (only one month had 0.1 ppm), and in Onggoyojo, these varied between 0.2 and 0.6 ppm. Among the 280 measurements by UNDIP, 39 (14%) were above 0.4 ppm, i.e. outside the recommended range; a majority of these were recorded in Onggoyojo. The high ammonia level is probably related to the reduced frequency and quantity of water refreshment that regulate low or high salinity levels.

The farmers' measured daily average water clarity varied between 45 and 64 cm. The maximum values (70-75 cm) were measured in Tambakbulusan, and the minimum (40-45 cm), in Surodadi and Onggoyojo. Maximum values were measured in the beginning of the rainy season, and the minimum in the dry (culture) season.

The minimum for clarity from June to September (dry season) aligned with the high phytoplankton levels from April till August (8,600-9,700 cells/ml). Maximum phytoplankton levels in these months varied from 18,000 to 24,000 cells/ml. Maximum count in November and December (rainy season) was below 10,000 cells/ml, with an average of 6,000 cells/ml. However, in November 2018 the average count was 8,100 cells/ml.

Water was mostly brown (light chocolate) during the peak of the rainy season (Figure 4), and dominantly brownish green in the culture season. Brownish green is a good color to start stocking, e.g., shrimp. Rarely the water turned green, and more often dark green, which is the desired color later in the culture season. No farmer had observed the extremes: yellow, yellowish green, light-green, brown-red or black.

Figure 4: Farmers' observed water color for 14 monthly periods; colors are averages of those observed in the last ten and in the first 20 days of the mentioned months (See Annex B for the color references).



5.2. Implementation of LEISA-IMTA by other AMA farmers

The results discussed here come from another project. Most of the ponds were slightly further inland than the AMA pilot ponds.

5.2.1. Yields and margins

From the 1st week of May until the 2nd week of June 2020, a very high tide submerged almost all the brackish water ponds in Demak. Fortunately, in some of the shrimp ponds, milkfish and saline tilapia still remained in the ponds, which allowed the farmers to partially harvest and restock (Table 12). Only one farmer harvested the seaweed (50 kg/ha), mostly because there is not yet a value chain in the regency. The low density of seaweed helps to maintain the good quality of pond water.

In 2018 the total cost of saponin, fertilizer and seeds was 1.1 million IDR. In 2019 and 2020, the total cost of doing an IMTA was just above 4 million IDR, i.e., four times higher. Nevertheless, compared to the margins of 2018, just above 5 million IDR, their margins had improved (Table 12). According to the paired two-tailed T-test with equal variance, the differences between 2018 (before IMTA) and 2019, as well as between 2019 and 2020 were significant ($p<0.005$ and $p<0.01$ resp.). Over two years, the average gross margin of the IMTA farmers was 7.5 million IDR/ha. In both years, the farmer's earning from the IMTA pond was better than that in their other ponds. The tilapia and blood cockles, respectively, contributed about 12%, 0.8 and 1 million IDR to their gross margin.

Table 12: Comparison of 2019 and 2020 average harvested volumes (kg/ha) by the mentioned number of IMTA farmers (n) and their 2018 harvests from their other ponds (average area 2.4 ha).

	Tiger Shrimp		Tilapia			Milkfish		Cockle		Gross Margin	
Year	N	kg/ha	n	kg	ton/ha	n	kg/ha	n	kg/ha	n	IDR/ha
2018	7	36 ±22	0	-	-	11	218 ±233	0	-	12	5.1 ±4.2
2019	10	38 ±19	12	21± 7	8	12	452 ±280	5	78 ±45	12	6.5 ±4.0
2020	10	57 ±27	12	31±10	12	12	524 ±413	12	41 ±41	12	8.7 ±5.0

Table 13. Monthly average water quality measurements from January 2019 till June 2020.

Period	T (°C)	DO	pH	Salinity	N	P	Ammonia	Plankton
Jan. 2019	29.9	5.7	8.0	14.5	1.6	0.7	0.2	5.8
Feb. 2019	29.9	5.7	7.9	14.8	1.8	0.7	0.2	6.0
Mar. 2019	30.8	5.7	8.0	19.9	2.1	0.9	0.2	5.5
Apr. 2019	31.6	5.7	8.0	23.6	2.4	1.1	0.2	6.5
May. 2019	32.1	5.5	8.0	26.9	2.3	1.1	0.1	7.4
Jun. 2019	32.4	5.8	8.1	32.5	2.6	1.1	0.1	8.0
Jul. 2019	33.5	5.3	8.3	35.9	2.8	1.1	0.1	6.7
Aug. 2019	33.8	5.5	8.0	34.3	2.8	1.1	0.1	7.5
Sep. 2019	33.2	5.3	8.1	32.1	2.3	1.1	0.1	4.9
Oct. 2019	31.9	5.6	7.9	26.7	2.1	1.2	0.2	4.7
Nov. 2019	30.6	5.7	7.7	22.5	1.7	0.9	0.2	4.3
Dec. 2019	30.1	5.8	7.5	18.7	1.5	0.9	0.2	4.6
Jan. 2020	28.8	6.1	7.6	18.3	1.5	0.9	0.2	4.9
Feb. 2020	29.8	6.2	7.8	20.7	1.7	1.0	0.2	4.8
Mar. 2020	30.5	5.9	7.8	22.8	1.6	1.0	0.2	5.8
Apr. 2020	31.8	6.5	7.9	25.9	1.6	0.9	0.2	6.9
May. 2020	31.3	6.4	7.8	27.3	1.6	1.0	0.2	7.6
Jun. 2020	31.6	6.5	7.7	24.6	1.6	1.0	0.2	7.1

Legend: DO and salinity are given in ‰, N = Nitrate, P and ammonia are given in ppm, and plankton in 1,000 cells L^{-1}.

5.2.2. IMTA Pond Water Quality

In July-September, water temperature reached more than 33ºC in the IMTA ponds during dry season (Table 13). Then also, the salinities recorded were higher than 32 ‰. In July the salinity reached 36 ‰, which was above the recommended range (26 - 35 ‰). The mean pH values were slightly lower in the rainy season than that in the dry season, but these values remained within the recommended range.

The mean values of the nutrient phosphate, 0.7-1.2 ppm, were slightly above the recommended range. The mean nitrate levels (1.5-2.8 ppm) in the water, a nutrient for seaweed and mussels, were largely below the recommended maximum.

The measured average levels of ammonia reached up to 0.2 ppm in the water during the rainy season. However, during the dry season, ammonia levels above 0.3 were recorded 12 times in the ponds of six farmers. Of the 214 measurements, 12% were above 0.3 ppm; 1% only was above 0.4 ppm. Half of the latter measurements, outside the recommended range, were in Onggoyojo. These levels are at the least stressful and restricting to the growth of shrimp and fish.

5.3. Yields of other farmers in 2017, 2019 and 2020.

In 2018, the 42 AMA farmers monitored by BwNI harvested 224 ±322 kg/ha; 18 of them stocked shrimp and harvested 45 ±55kg/ha (Table 16). In that same year, the other set of 120 monitored farmers harvested 262 ±448 kg/ha, and the 71 among them, who stocked shrimp, harvested 122 ±520kg/ha. The latter sample included some farmers doing intensive shrimp culture, while all AMA farmers practiced LEISA to some extent.

In 2019, 45 BwNI-monitored AMA farmers from 7 villages obtained an average milkfish yield of 196 ± 196 kg/ha (Table 16). About 25 farmers who stocked shrimp were able to harvest 24 ±33 kg/ha shrimp.

Before making their AMA, the four farmers in Timbulsloko harvested 90 ±145 kg/ha of milkfish; afterwards they were able to harvest 128 ±62, and 111 ±20 kg/ha of milkfish, respectively in 2019 and 2020. The AMA farmers in Timbulsloko didn't stock shrimp but mussel. One farmer harvested 435 kg/ha in 2018, and two harvested an average of 174 ±10 and 247 ± 161 kg/ha mussel, respectively in 2019 and 2020.

6. DISCUSSIONS

Since 2015, the soil subsidence in the project area has dramatically increased, and a tidal lake which developed near Semarang, south-west of the village of Timbulsloko, made this village, as well as Bedono and Purwosari into shore villages (Figure 2, 5 and 6). Tidal and seasonal flooding increased in most of the project villages, except on the most north-eastern side. Although the inter-annual fluctuation was always large, the actual production could not anymore be compared with those of 2015's project baseline.

Figure 5: This tidal lake changed the livelihood of farmers from rice-growing and milkfish-raising into fishing. Despite trees on pond dikes, these trees did not prevent severe abrasion from occurring in these flooded areas (BwNI).

Figure 6: The villagers protect Bedono with many permeable dams (BwNI).

6.1. Water quality

The difference in the time of measurements by the farmers and that by the UNDIP team (the former, around 7 am, while the latter, around 9 am, about two hours later), explains the higher temperature measured in dry season, and may as well explain the slight difference in pH (higher in one season lower in the other), and the difference in salinity. This salinity difference may be related to the volume of water exchanged between the two time-points.

Phosphate (P) in nature comes from rocks eroded by wind or water and brought to the ponds by rainwater. However, the P levels are low in rainy season because the farmers reduce the frequency of water exchange to prevent low salinities. In contrast, in dry season, they prevent the salinity levels from getting too high by exchanging water more frequently during low tides; by doing this, unintended P from natural, urban and industrial sources goes into the pond. Some farmers also use phosphate fertilizer to favor growth of phytoplankton; to maintain the N/P balance they should use mono- or di-ammonium phosphate and not triple-phosphate. To avoid the precipitation of the P at the bottom, the fertilizer should be dissolved before application. High P levels can cause dominance of blue-green algae and limit the growth of *lablab*, the natural food of milkfish. The regular addition of the liquid compost MOL may favor the bacterial breakdown of organic matter, thus making N available for the growth of e.g., *lablab*, and thus reduce P levels as the algaes use also P for their growth .

Total ammonia, nitrogen, nitrate and nitrate are components of the nitrogen complex. If T, DO and pH are favorable, the toxic ammonia (NH_3) turns into nitrite (also toxic) and subsequently into nitrate. Both nitrite and nitrate may leave the water as N_2 gas (Figure 7).

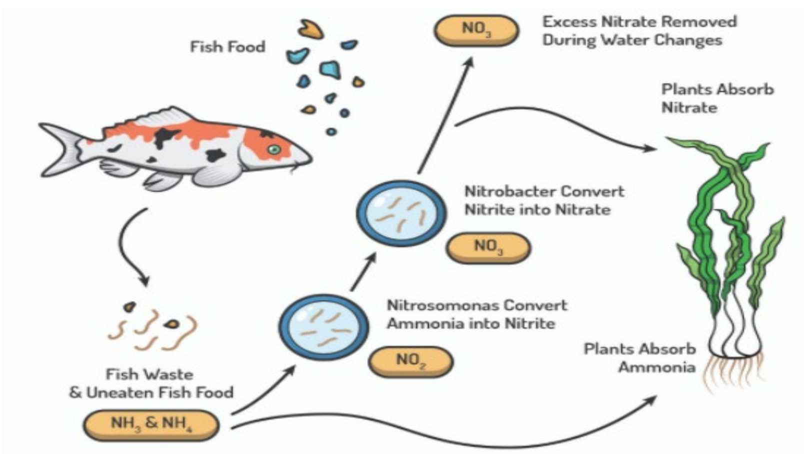


Figure 7: The aquatic nitrogen cycle where low pH and high DO favor the change of toxic NH_3 into NO_2, and then into NO_3; NO_3 can be absorbed by plants. At low DO, both NO_2 and NO_3 change into N_2. Excess can be removed by changing water, that may lead to loss of nutrients such as NO_3.

However, while high levels of both ammonia and nitrite may stress or kill the shrimp/fish (Table 14), neither in AMA nor in IMTA that nitrate, as a nutrient, reached toxic levels. At high pH, ammonia below 0.1 mg/l can be toxic for some fish species because then the proportion of NH_3 is higher, while at low, pH 7, the 300-400 times less toxic NH_4^+ (ammonium) becomes the dominant compound. At low salinity, usually in the rainy season, nitrite toxicity is reached at lower levels (>0.1 ppm) than in full seawater (>1.0 ppm). As the levels of nitrite and ammonia are interconnected, we didn't measure Nitrite (its analysis being more expensive).

Throughout the year, ammonia levels in the IMTA ponds were on average, 0.1 ppm lower than that in the AMA ponds. Although no feed was given in the AMA ponds, harmful levels of ammonia above 0.4 ppm were still observed more frequently in these ponds. About 14% and 1% peak levels of ammonia were recorded for the AMA and the IMTA, respectively. Low levels of ammonia were measured in the IMTA ponds despite the fact that feed was given to tilapia. The IMTA is thus effective in reducing organic matter, fermenting uneaten feed and excrements, and reducing the related ammonia and nitrite in nitrate and N_2. At times, nitrate levels might have been too low while phosphate remained sufficient for the phytoplankton growth.

The lower pH in rainy seasons might be due to mostly acidic rain water and the increased supply of organic material/waste (OM). The increased OM and low pH, are the cause of the increase in ammonia levels. Although, reaching stressful levels in some ponds during some months, as water remained brackish, values of ammonia and nitrite, mostly remained within the tolerance range for shrimp and milkfish (Table 14).

Table 14. Recommended ranges for T, Color, DO, pH, Salinity, N, Ammonia, P and the biological parameter phytoplankton for shrimp and milkfish.

T (°C)	**DO** (ppm)	**pH**	**Salinity** (ppt)	**Nitrite** (ppm)	**Nitrate** (ppm)	**P** (ppm)	**Ammonia** (ppm)	**Phytoplankton** (*1000 cells/ml)
28 – 32[a]	≥3[a]	7,5 - 8,5[a]	26-32[a]	<0,4[b]	<200[c]	0,05-0,5[d]	≤ 0,1[a]	4 - 20

Sources: a: PERMEN-KP, 2016 ; b: Gross et al. (2004) c: Kuhn et all, 2011; d: Erlina, 2006.

6.2. Yields and margins

In 2018 and 2019, the AMA farmers were able to at least maintain the milkfish yields of their ponds compared to 2015 (Table 15), but the average was lower than those harvested from other ponds in 2017 and 2018 (Table 16). This trend was similar for the shrimp (Table 15, 16 and 17). Nevertheless, the AMA farmers remained convinced of the advantages: they could at least harvest shrimp from their ponds (Figure 10). They also could catch, at the same time, both shrimp and fish in the main gates (including fish caught by cane). Overall, their yields considerably improved based on their stories. The UNDIP-monitored AMA farmers harvested lower milkfish yields (114 ±40 and 158 ±62 kg/ha) than the BwNI-monitored ones (262 ±428 and 196 ±196), respectively in 2018 and 2019. These yields are lower and in the same range, respectively, than those of the baseline in 2015 (Table 15 and 16).

Table 15. Average yields (kg ha^{-1} year^{-1}) of milkfish and shrimp for the baseline (2015), the BwNI monitoring (2018, 2019 and 2020), and those of the sampled AMA and IMTA farmers.

Source	Milkfish				Shrimp			
	2015	2018	2019	2020	2015	2018	2019	2020
BwNI Baseline & Monitor	234 ±363 (120)	262 ±428 (120)	196 ±196 (45)	111 ±20 (4)	47 ±47 (36)	122 ±520 (71)	24 ±33 (25)	-
UNDIP AMA & IMTA (2020)	-	114 ±40 (17)	158 ±62 (17)	524 ±413 (12)		38 ±20 (8)	43 ±34 (12)	57 ±27 (10)

Table 16. Average yields (kg ha^{-1} year^{-1}) of milkfish and shrimp of the LEISA adopters and non-adopters (Control) for the baseline (2015), the monitoring data (2017 and 2018) and the trimmed dataset of the sample (n=27; 12 Control and 15 LEISA; 2017 and 2018).

Treat-ment	Milkfish			Shrimp		
	2015	2017/18[1]	Sample	2015	2017/18 [2]	Sample
Control	234 ±363	350 ±527	721 ±429	47 ±47	31 ±23	16 ±55 [3]
LEISA	-	243 ±427	670 ±285	-	134 ±550	186 ±133

Legend: Table to be published in Journal of the World Aquaculture Society. 1/ n for Control was 21 and for the LEISA 99; 2/ n for Control was 8 and for the LEISA 63; 3/ The two farmers who stocked shrimp had an average yield of 225 kg ha^{-1} year^{-1}.

In 2015 most of these farmers didn't stock shrimp anymore in their ponds near the coast. However, thanks to their application of LEISA, AMA and IMTA, they earn the most from shrimp with high market value. The shrimp yields (122 ±520 and 24 ±33 kg/ha, respectively in 2018 and 2019) of the BwNI-monitored AMA farmers were higher than those of the UNDIP-monitored AMA farmers (about 45 ±27 kg/ha). The latter yields were in line with those of the 2015 baseline covering the entire Demak coastal area (Table 15), but lower than the averages of those recorded in 2017/2018 (Table 16).

In 2015, the milkfish yields and income from aquaculture of the two villages outside the project area were significantly higher than those inside the project area (Table 17). The pond farmers at Onggojoyo and Surodadi villages told us that this was the first time that they had a 'successful' shrimp harvest. Since most farmers can stock shrimp again, income from their pond remained in the same range or improved compared to 2015.

Table 17. Averages yields and income (with standard deviation) from aquaculture of five project villages and two other villages (Berahan Wetan and Babalan) in 2015.

Inside or outside project area	Yield (kg/ha/yr)		Income (in million IDR)
	Milkfish	Shrimp	
Outside (2 villages)	290	49	21.4 ± 20.3
Inside (5 villages)	192	43	17.5 ± 20.8

In 2020, the twelve farmers who practiced IMTA and managed their smaller ponds according to LEISA principles showcase the way ahead: their milkfish yields increased, their shrimp yields remained stable, and their harvests now has expanded to include green mussels, seaweed and tilapia. For example, a Surodadi farmer in who stocked blood cockles earned as much as those who stocked milkfish only. The financial value of the green mussels from the IMTA ponds was lower. Despite the floods in 2020, IMTA farmers maintained their gross margins from the ponds at the level of 2015. Some significantly improved their income from aquaculture, thus enabling them to further enhance their sense of well-being, as well as support the education of their children (See Box 1).

On the one hand, the high standard deviations of most samples reflect the difference between the conditions (quality of soil and water) of the ponds in different locations, and on the other hand, the differences in management practices as well as the opportunity for improvements as demonstrated by some farmers. Even in 2015, the variation within and between the villages was high: in Purwosari and Tambakbulusan villages that were in both samples, the farmer's milkfish yields were respectively 200 and 136 kg/ha only. This trend was similar for the shrimp yields (Table 18). Although yields were higher in Purwosari, cost (and risk) were also higher which led to lower margins.

Table 18: The yields and margins in two of the sampled AMA villages that were also included in the baseline of 2015.

	Yield (kg/ha/yr)				Margin (x Million IDR)	
Village	n	Milkfish	n	Shrimp	N	Aquaculture
Purwosari	17	200	2	160	17	7.6 ±7.0
Tambakbulusan	15	136	2	89	15	14.5 ±8.0

Moreover, building an AMA also increased the farmer's revenues from fisheries, either by the catch in the traps of their pond gates or by cane-fishing (Figure 8 and 11). In unstructured interviews, Onggojoyo farmers and those with IMTA reported that their daily catch in the old gate near the river increased two years after the AMA Program. One AMA farmer in Tambakbulusan caught more local shrimp (*merguensis*) in his traps and the household members caught more good fish with their canes. These are general observation in estuaries with more new mangroves.

Figure 8: Improved catch from cane fishing attributed to the recovery of mangroves (Dolfi Debrot).

BOX 1 Story of significant change in Tambakbulusan.
In 2016, a farmer participated in the aquaculture field school (AFS). Before, he used to stock milkfish, spray chemicals to kill and prevent pests, and apply fertilizers. Like most other farmers in Demak, his yields were low and he had stopped stocking shrimp. At the AFS, he learned that inorganic chemicals kill also useful species and destroy the pond soil. He also heard about the effect of seaweed on water quality. Three years ago, at the end of the dry season, he bought seaweed which all disappeared in January-February. But every year, after he has prepared the pond and stocked shrimp, when salinity increases during dry season, the seaweed grows again and keeps the pond water clear. To manage salinity, he changes less water 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. He waits until he can harvest more than 150 kg, or the size of about 20 pieces per kg; that volume he can sell directly to a monger in Semarang (about every 4 to 6 weeks from April to December). There, he fetches 50-100% more than the village collectors pay him.

6.3. AMA implementation

In general, the AMA system in the ponds of the participating farmers are not yet finalized or perfected. Although we planned to push farmers to open the main dike and remove the gate, the huge advantage they have from the catches trapped in these gates makes us hesitate. We rather plead for a study on the optimal mesh width and the optimal time-schedule of gate opening that combines the (daily) catch with an optimal water refreshment to manage water quality, and with an optimal exchange of species with the surrounding water. This might enhance the out-scaling of the innovation, as farmers do not risk to lose their land and acquire better livelihood options, while the estuary can partly recover. The exchange with the estuary might be improved by having two gates. We thus advise extension services to encourage farmers to make two gates/openings to every pond and two in the main dike: one for inflow and one for outflow. Basically, the mangrove section should have two clear waterways (Figure 9), with wider diversity of mangroves species than shown in the picture here.

Figure 9. Each pond should have two gates, one for inflow and one for outflow, and also the mangrove section should have these two gates for optimal management of the pond water (BwNI).

Figure 10: Pak Ghofur from Tambakbulusan proudly shows the big shrimp that was harvested from his AMA pond (Lestari Lakshmi Widowati).

Figure 11: A villager showing his improved catch from cane fishing attributed to the recovery of mangroves (Dolfi Debrot).

7. CONCLUSIONS

Aquaculture in the AMA ponds which were closer to the sea was generally exposed to higher risks of floods, higher salinity levels and lower pond water quality because of reduced options to refresh water. Although the milkfish harvests for these ponds were higher, the associated risks and cost were higher, and margins, lower than those for ponds far from the sea.

Since 2015, both the number of the floods and the height of the tidal waters have increased. However, the 60 AMA-monitored farmers were able to maintain their milkfish and shrimp yields from their ponds compared with the yields in 2015. These averages were lower than those found among the 90 LEISA-monitored ponds in 2017 and 2018. Nevertheless, the AMA farmers remain convinced of the advantages: now they can harvest shrimp from the ponds; they also can catch more shrimp and fish in the main gates and from fishing by cane.

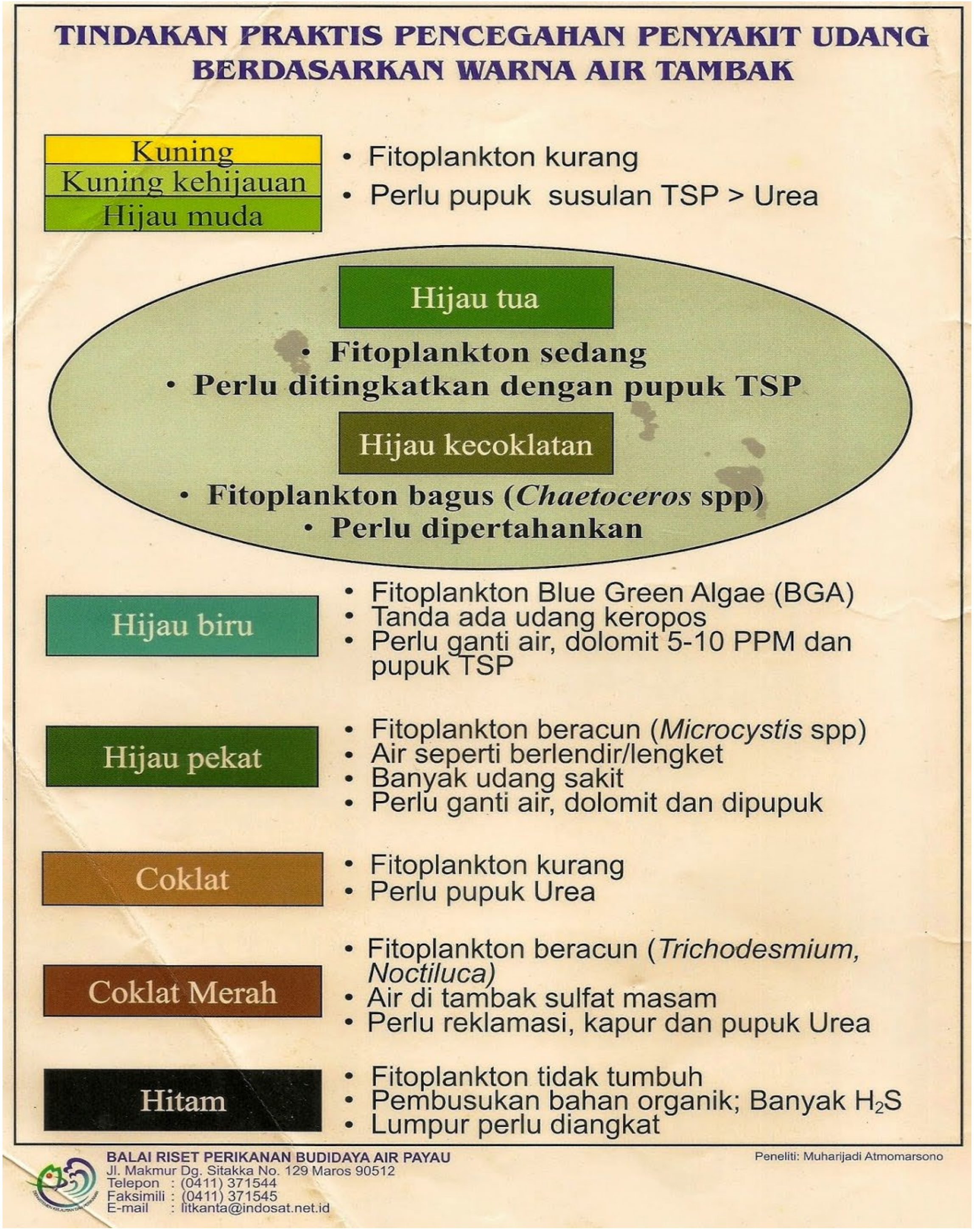
Notwithstanding the floods, the application of the IMTA principles and smaller ponds can help farmers improve their farm income compared with that in 2015. The extension and community service can support innovation platforms to enhance the expansion of these technologies.

In the present situation, we advise not to push farmers to open the dike to the river, but recommend them to open two gates. We also recommend that a project, together with the AMA farmers, will study the optimal management of these gates considering their catches and the exchange of water and its contents with the surrounding water.

Annex A. The approximate DO at different water salinity and temperature, at 760 mmHg air pressure (Stirling, et al. 1985).

Temperature ^{0}C	Salinity (ppt)							
	0	5	10	15	20	25	30	3
4	13,1	12,7	12,2	11,8	11,5	10,7	10,7	10,3
6	12,5	12,1	11,6	12,25	10,9	10,2	10,2	9,8
8	11,8	11,45	11,1	10,7	10,4	9,7	9,7	9,4
10	11,3	10,9	10,6	10,2	9,9	9,3	9,2	9,0
12	10,8	10,45	10,1	9,8	9,5	8,9	8,8	8,6
14	10,3	9,95	9,7	9,4	9,1	8,6	8,5	8,2
16	9,9	9,55	9,3	9,0	8,7	8,2	8,1	7,9
18	9,5	9,15	8,9	8,6	8,4	7,9	7,8	7,6
20	9,1	8,8	8,6	8,3	8,1	7,6	7,7	7,3
22	8,7	8,6	8,3	8,1	7,9	7,5	7,4	7,2
24	8,4	8,3	8,1	7,8	7,6	7,1	7,1	6,9
26	8,1	8	7,7	7,5	73	6,8	6,8	6,6
28	7,8	7,7	7,5	7,3	7,0	6,6	6,6	6,4
30	7,6	7,4	7,2	7,0	6,8	6,4	6,4	6,1
32	7,3	7,2	7	6,9	6,6	6,1	6,1	5,9
34	7,1	7	6,9	6,7	6,4	6,0	6,0	5,8
36	6,9	6,8	6,7	6,5	6,2	5,9	5,9	5,7
38	6,7	6,6	6,5	6,4	6,1	5,7	5,7	5,6
40	6,5	6,5	6,3	6,3	6,0	5,6	5,6	5,5

Annex B. The water colour is categorised according to a chart; the colours are indicators for the fertility status of the pond water (Kuning = yellow; Kuning kehijauan = greenish yellow; Hijau muda = light green; Hijau tua= green; Hijau beru = green blue; Hijau kecoklatan = brownish green; Hijua pekat = dark green; coklotan = brownish; coklatan merah = brownish-red; Hitam = black).



Annex C. The sampled farmers for the AMA and the IMTA.

Table C-1: Villages and AMA ponds owners who were monitored

No	Village	Name	Pond area (ha)
1.	Tambak bulusan	**Abdul Ghofur (TA)**	4
2.		H Sohibin (TB)	2
3.		Makruf (TC)	2
4.		Ugis Nur Herlambang (TD)	3
5.		**Suhadi (TE)**	2.5
6.		Mujahirin (TF)	2.5
7.	Suradadi	Nur Chomaidi (SA)	2.5
8.		Musya'atun (SB)	2
9.		**Mulyono (SC)**	3
10.		**Nur Aziz (SD)**	1.6
11.		**Maskan (SE)**	2
12.		Alfi Komarun (SF)	2.6
13.	Onggojoyo	**Maskur (OA)**	3.5
14.		**Syafi'I (OB)**	3
15.		**Kohar (OC)**	2
16.		Saefulmujab (OD)	2
17.		H. Asrofin (OE)	1.5
18.		Abudul Jalal (OF)	1.5

Table C-2: The 12 AMA farmers who implemented LEISA-IMTA

Surodadi:

1. Mulyono
2. Nur Khumaidi
3. Maskan
4. Nur Aziz

Tambakbulusan:

5. A Gofur
6. Kasmudi
7. Suhadi

Purworejo :

8. Attabiq
9. Yazid.

Onggojoyo:

1. Maskur
2. Abdul Kohar
3. Syafe'i

Annex D: The descriptions of the AMA ponds in the three villages.

F-1 Tambakbulusan	**TA**	**TB**	**TC**	**TD**	**TE**	**TF**
Pond area (ha)	4	3	2	2	2	4
Number of pond compartment	6	2	4	2	3	5
Reservoir availability	1	1	No	1	Yes	1
Dike height (m)	1	1	1	1	1	1
Pond water depth (cm)	40-65	40-70	40-60	50	60 cm	60
Number of sluice gates in each compartment	2	2	4	2	1	2
- Inlet gate	1	1	2	1	1	1
- Outlet gate	1	1	2	1	-	1
Number of canals	2	1	1	2	2	2
- Inlet canal	1	1	1	1	1	1
- Outlet canal	1	-	-	1	1	1
Water source	River	River	River	River	Sea	River

F-2 Surodadi	**SA**	**SB**	**SC**	**SD**	**SE**	**SF**
Pond area (ha)	2,5	2	3	2,6	2	1,6
Number of pond compartment	5	1	4	3	2	3
Reservoir availability	-	-	2			1
Dike height (cm)	100	80	150	150	150	75
Pond water depth (cm)	50 - 100	40	100	115	100	
Number of sluice gates in each compartment	1	2	4	1	2	1
- Inlet gate	1	1	2	1	1	1
- Outlet gate	1	1	2	-	1	-
Number of canals	1	1	3	1	2	1
- Inlet canal	1	1	2	1	1	1
- Out Let canal	-	-	2	-	1	-
Water source	River	River	river	River	Sea	River

F-3: Onggojoyo	**OA**	**OB**	**OC**	**OD**	**OE**	**OF**
Pond area (ha)	2	2	1,5	3,5	2	1,5
Number of pond compartment	4	1	1	2	4	3
Reservoir availability	-	-	-	-	-	-
Dike height (m)	1	1	1	1	1	1
Pond water depth (cm)	50-60	50-60	40-50	50-60	50-60	50-60
Number of sluice gates	2	2	2	2	2	2
- Inlet sluice gate	1	1	1	1	1	1
- Out Let sluice gate	1	1	1	1	1	1
Number of canals	2	2	2	2	2	2
- Inlet canal	1	1	1	1	1	1
- Out Let canal	1	1	1	1	1	1
Water source	River	River	River	River	River	River