



Improvement of aquaculture systems in Sidoarjo, Indonesia

Results of a fact-finding scoping mission

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Title

Revision/distribution

Project: Improvement of aquaculture systems in Sidoarjo, Indonesia
Contractnumber:
Client: Rijksdienst voor Ondernemend Nederland (RVO)
Document number:
Date: 10-02-2023
Version: 2.0
Authors: van Maren, Bas, Susanto, Apri, Sihombing, Weny., Kismorodati, Weningtyas, and Bosma, Roel.

Revision

Revision	Date	Name and signature		
		Author	Checked	Authorised
1.0	20-01-2023	Bas van Maren et al.	Trang Vu	Fokko van der Goot
2.0	10-02-2023	Bas van Maren et al.	Trang Vu	Fokko van der Goot

Distribution list

Distribution list				
Copy	Role	Name	Revision	Remarks
	Client	Wendele van der Wiele	1.0	
	Client	Wendele van der Wiele	2.0	

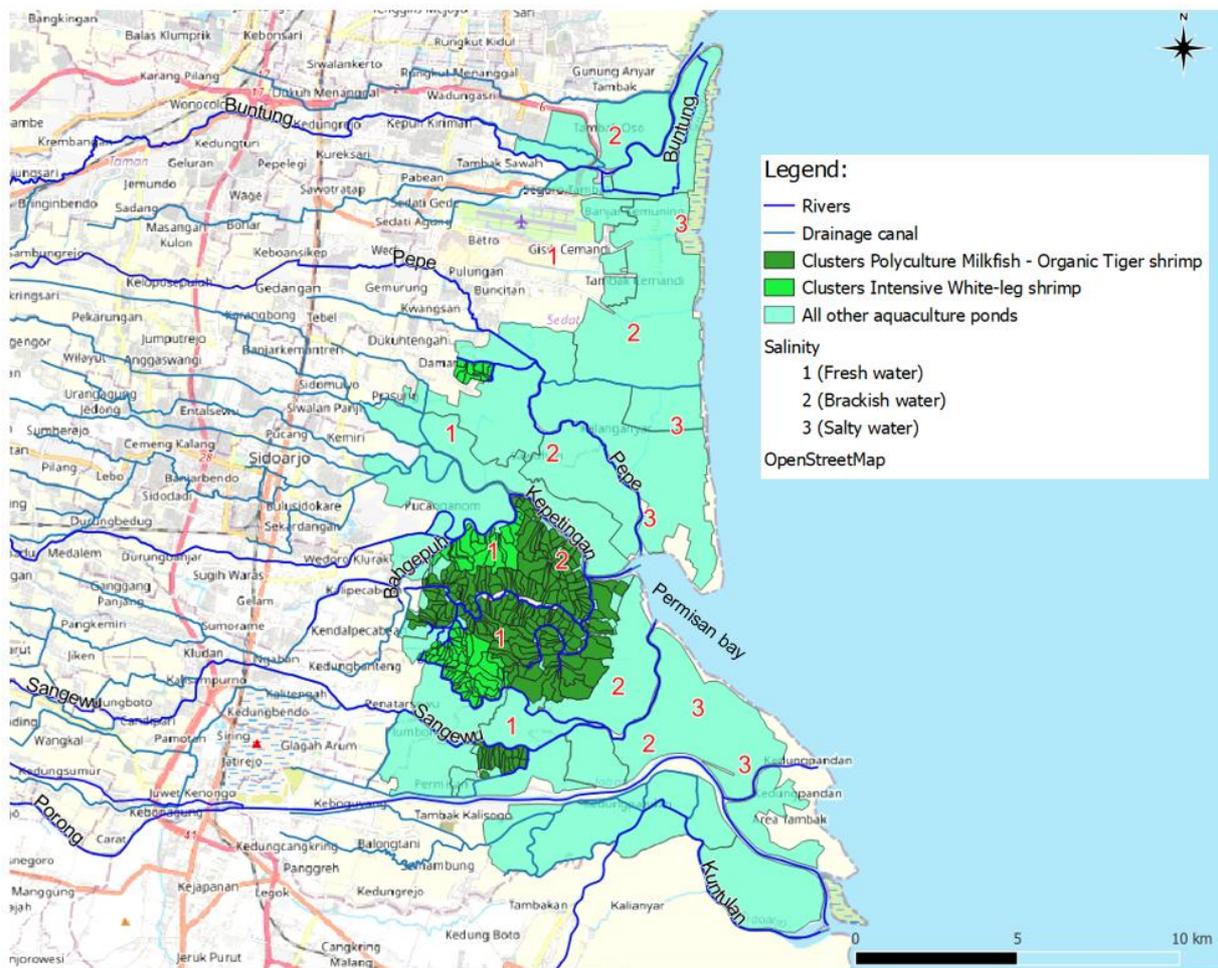
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Executive Summary

Project scope

The regency of Sidoarjo (situated in East Java, just south of Surabaya) produces traditionally grown tiger shrimp and milkfish, which are exported globally. The conditions for cultivating both species are deteriorating because one of the main river systems draining the ponds (the Kepetingan River) is becoming progressively less saline. This reduction in salinity is thought to be the result of shallowing of the riverbed due to sedimentation. As part of a long-lasting cooperation on water, the Indonesian Ministry of Public Works and Housing (MPWH) requested the Dutch Ministry of Infrastructure and Water Management (I&W) through the Partners for Water program at Netherlands Enterprise Agency (RVO) to conduct a scoping mission in Sidoarjo related to a decline in the productivity of shrimp and fish. RVO requested EcoShape, a consortium of the Dutch Water Sector, to undertake this mission and investigate the potential of solutions following Building with Nature principles. This report summarizes the main findings of this 5-day mission in December 2022.



Aquaculture pond types and salinity zones in Sidoarjo regency, east of the urban area of Sidoarjo

Problem description

The coastal plain of Sidoarjo Regency has been expanding seaward for centuries resulting from sediments carried by the distributaries of the Brantas river, especially the Porong river –

in the 20th century along the coastline moved 2-3 km in the seaward direction. In pristine conditions, such a coastal plain consists of an intricate network of tidal creeks draining tidal flats and mangrove forests. These tidal creeks are typically fed by small river systems draining the higher grounds of Sidoarjo regency, discharging fresh water during rainfall events. Fresh water mixes with salt water in the creeks, resulting in typically brackish water suitable for cultivation of tiger shrimp and milkfish. Most of the mangrove forests have by now been removed and replaced by aquaculture. One of the consequences is that the amount of water flowing in and out of the various creeks has strongly decreased, resulting in a reduction of the flow velocities as well. Because of the large availability of fine sediments these creeks fill up rapidly. Saltwater intrusion strongly declines as the water depth becomes smaller, and therefore the creeks become more and more fresh as sediments settle on the river bed. The decline of the Kepetingan river is an example of such an infilling creek. Dredging the river, as has been done in the past, will therefore only temporarily improve the hydro-sedimentary conditions favourable for aquaculture: the large availability of sediments and the low flow velocity in the river will lead to rapid infilling.

Nature-based solutions

Sustainable improvement of the Kepetingan river system may be realised by a combination of interventions such as the creation of wetlands along the creek (leading to more tidal discharge) and creation of mangrove forests in its river mouth (Permisan Bay) to concentrate river flow in a narrower channel and to trap the available sediments. Such measures are quite expensive and may not be compensated by only an increase in aquaculture yield. However, rejuvenation of Kepetingan river has additional positive impacts providing financial gains, and some of the measures may be combined with flood safety measures already planned in the area to mitigate urban flooding. Additional financial benefits include ecological value and carbon storage (more mangroves over an area up to several 100's of hectares), larger fish yield (with more fish nursery grounds), and possibly a reduction in flooding of both the fishponds and the municipality of Sidoarjo. Flood retention basins, which are now considered for mitigating urban flooding, may double as intertidal wetlands generating higher tidal discharge. Combining benefits and interventions in this way may lead to a financially sustainable solution. One of the first actions to be taken when continuing with such a system-based Building with Nature solution is to do a first-order cost-benefit analysis.

In addition to (or possibly instead of) rejuvenation of Permisan Bay, the yields of aquaculture will also benefit from (1) training through well-structured field schools of 16 sessions for groups of 20-30 persons during one cropping season, (2) local improvements of the ponds and (3) legislation put in place by the regency of Sidoarjo aiming to protect the fishponds. With relatively simple improvements of the ponds and the polyculture systems of milkfish / tiger shrimp, milkfish / white leg shrimp and tilapia / white leg shrimp, may increase sustainably. A difficulty related to such local improvements is that many of the fishpond users are renters rather than owners. This absentee ownership is a negative incentive, as the rent periods (5 years) are too short to recover investments in the pond infrastructure needing more dikes and gates, and, moreover, may prevent the rehabilitation of a riverine greenbelt.

Coastal erosion and subsidence

The main focus of the scoping mission was on environmental issues related to the polyculture of milkfish and tiger shrimp. However, two additional problems were identified during the scoping mission, which are related to aquaculture and coastal hazards but not specifically raised prior to the mission. These include the coastal erosion in the north of Sidoarjo regency and the effect of a mud volcano that became active in 2006. The coastline in the North of the regency has eroded by almost 1 km in a period of 10 years. A possible cause is subsidence,

but a more likely explanation seems to be that infilling of an estuary (the Buntung) has interrupted alongshore sediment transport, which led to erosion of the downdrift coastline to its south. The infilling of the Buntung estuary is caused by the same mechanisms driving infilling of the Kepetingan river, although the Buntung may have additionally deteriorated because some rivers were rerouted to extend the airport of Surabaya. The erosion of this coastline has probably also triggered the growth of a spit system now sheltering Permisan bay, thereby strengthening sediment deposition rates in Kepetingan river.

A drilled well started erupting mud close to the Porong river, some 20 km upstream of the river mouth. This initially resulted in infilling of local streams draining the vicinity of this mud volcano (Lusi), reducing salt intrusion and impacting aquaculture, similar to Kepetingan river, and later created land subsidence and influenced the dynamics of the Porong delta. Land subsidence may be caused by loss of subsurface sediment volume (following the eruption), which is a process that can be poorly mitigated. However, subsidence may also be (partly) caused by soil compaction resulting from the mud deposit (over 30 meter thick); if this is the case, the sediment deposit should be removed as fast as possible in order to minimize land subsidence. At present, the fresh mud erupting from the volcano is channeled to the Porong river. The increase in sediment load created new land in the Porong delta. An additional impact of this land formation is that the main river mouth appears to be abandoned in favor of a smaller distributary. This impacts flood safety through blockage of river flow during high rainfall events, due to riverbank erosion in the new main distributary and due to erosion of the old river mouth by marine processes. Moreover, the anticipated new river mouth is closer to Kepetingan river, thereby strengthening infilling rates of the Kepetingan river. Sustainably dealing with the mud volcano therefore requires a system-based management of sediment and land development.

Institutional aspects

Solutions need to be properly embedded along three governmental levels (regency, province, and national) and multiple ministries. On a national level the various ministries include the Ministry of Maritime Affairs and Fisheries (MMAF; also known as KKP), the Ministry of Public Works and Housing (MPWH, also known as PUPR), and the Ministry of Environment and Forestry (MoEF), while additionally these ministries have pendants on a provincial and regency level. Implementing solutions probably requires inclusion of all of these ministries (with MMAF and MPWH being most important) on all three levels of government. Inclusion of the Porong river requires engagement of other institutions with responsibility for river management and flood control.

Next steps

As immediate next steps for the Kepetingan River we recommended to start monitoring water levels and salinity, and to do a financial feasibility study for rejuvenation of Kepetingan River. For the additional potential project cases we recommend starting monitoring subsidence, and involve relevant stakeholders for discussions on the identification of solutions addressing the problems along the North shore of Sidoarjo as well as those related to the impact of the mud volcano. Such additional inventories should be followed by system analysis studies and more detailed mapping of stakeholders providing input to feasibility studies, preferably finalised with implementation. With regard to the fish ponds we recommend to do trials to (1) verify the impact of existing organic technologies such as LEISA on crop yield and (2) evaluate the potential of floating solar panels for pumping saline ground water, increasing revenues, and improving water quality.

1 Introduction

The Government of the Netherlands (GON) through the Ministry of Infrastructure and Water Management (I&W) and the Government of Indonesia (GOI) through its Ministry of Public Works and Housing (MPWH) have a long-term cooperation on water management. The current cooperation agenda is specified in the Memorandum of Understanding on Water (MoU-Water) for 2022-2027. Five main themes have been defined as the conceptual framework for the bilateral cooperation, namely 1) Resilient cities, 2) Integrated Water Resource Management (including River Basin Management), 3) Water governance, 4) Smart water and 5) Water for Food / Lowland Development. In July 2022, the Joint Steering Committee for the MoU Water took place in The Hague and agreed to start new projects in support of the Indonesian local and central governments. Several of them will be developed and financed by the Partners for Water program. This scoping study is related to one of these projects, in Sidoarjo - East Java Province. In Sidoarjo the productivity from especially shrimp farming is in decline, which conflicts with the national ambition of Indonesia to double the income from shrimp farming (pers. Comm. MMAF). This decline is believed to result from a reduction in water quality, partly resulting from high siltation rates in the rivers providing water to the fishponds.

Therefore, as part of the MoU, the Indonesian government through MPWH has requested I&W through the Netherlands Enterprise Agency (RVO) for technical support in the improvement of the regional aquaculture sector in Sidoarjo, whilst improving coastal sediment management and the conservation of the mangrove ecosystem. The objectives for this assignment are twofold:

1. This assignment provides a scoping for the potential of the implementation of Nature Based Solutions, including the technical, social, economic and institutional settings.
2. The lessons learned in this case study will also be used to improve the uptake of Nature Based Solutions on a larger scale in Asia. This will be done by actively sharing the results from this case with the Dutch and international water sector.

RVO requested EcoShape, a consortium of the Dutch Water Sector, to undertake a scoping mission in Sidoarjo related to a decline in its fishpond productivity and investigate the potential of solutions following Building with Nature principles. Specifically, the scoping mission needs to develop answers to the following questions, in close collaboration with the local stakeholders:

1. What does the system in Sidoarjo look like (physical, ecological, societal)
2. What is the existing quality and potential of the current aquaculture system?
3. What interventions can be taken to sustainably improve the prevailing aquaculture practices and overcome the problem of limited water supply, whilst at the same time ensuring conservation and protection of the existing mangrove forests?
4. What are the opportunities for applying Nature Based Solutions?
5. What are potential win-win opportunities (f.e. solar energy for a sustainable operation of fish ponds etc.)?
6. What does the institutional setting look like including stakeholders on local, provincial, national and international (IFI's) level?
7. What are the next steps and recommendations for further project preparation (this can also include policy changes)?
8. Which stakeholders should be involved and are there parties interested in financing / supporting such a project (such as ADB)?

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This report summarizes the main findings of this mission. These findings are based on various discussions with stakeholders (see Appendix A), available literature, and global data (historic maps and satellite images). The overall setting and history of the area is briefly summarized in Chapter 2. Chapter 3 provides an analysis of the decline of productivity in relation to environmental changes, focussing on environmental conditions, aquaculture practice, and socio-economic conditions. This analysis provides the basis for potential nature-based solutions to rejuvenate the area elaborated in Chapter 4. Chapter 5 sums up potential follow-up of this mission, and Chapter 6 summarizes the main finding.

2 Description of the Sidoarjo coastal zone

2.1 General Geographic setting

The city of Sidoarjo is situated in East Java, just south of the city of Surabaya. Its regency is characterised by an urban area including the city of Sidoarjo which largely runs from north to south along the railroad and the toll road. The remaining part is largely agricultural, with rice fields west of this urban area and mostly aquaculture in the east. The north and south boundaries are approximately the two distributaries of the Brantas River: the Porong River (the main distributary of the Brantas) to the south and the Mas River to the north. The discharge of the Porong river in the wet season (December – May) varies between 100 and 1000 m³/s but is typically between 500 to 700 m³/s; the river discharge is very low in the dry season (Nugrahadi, 2013). The larger part of Sidoarjo is drained by local rivers, mostly from the west to the east. These local rivers flow through the urban area of Sidoarjo, the central part of them joining together in the Kepetingan river and all flowing into Permisan Bay see Figure 2.1.1). The rivers and Permisan Bay are fringed by mangroves, the banks of local streams between the rivers Pepe and Porong are less vegetated by mangroves.

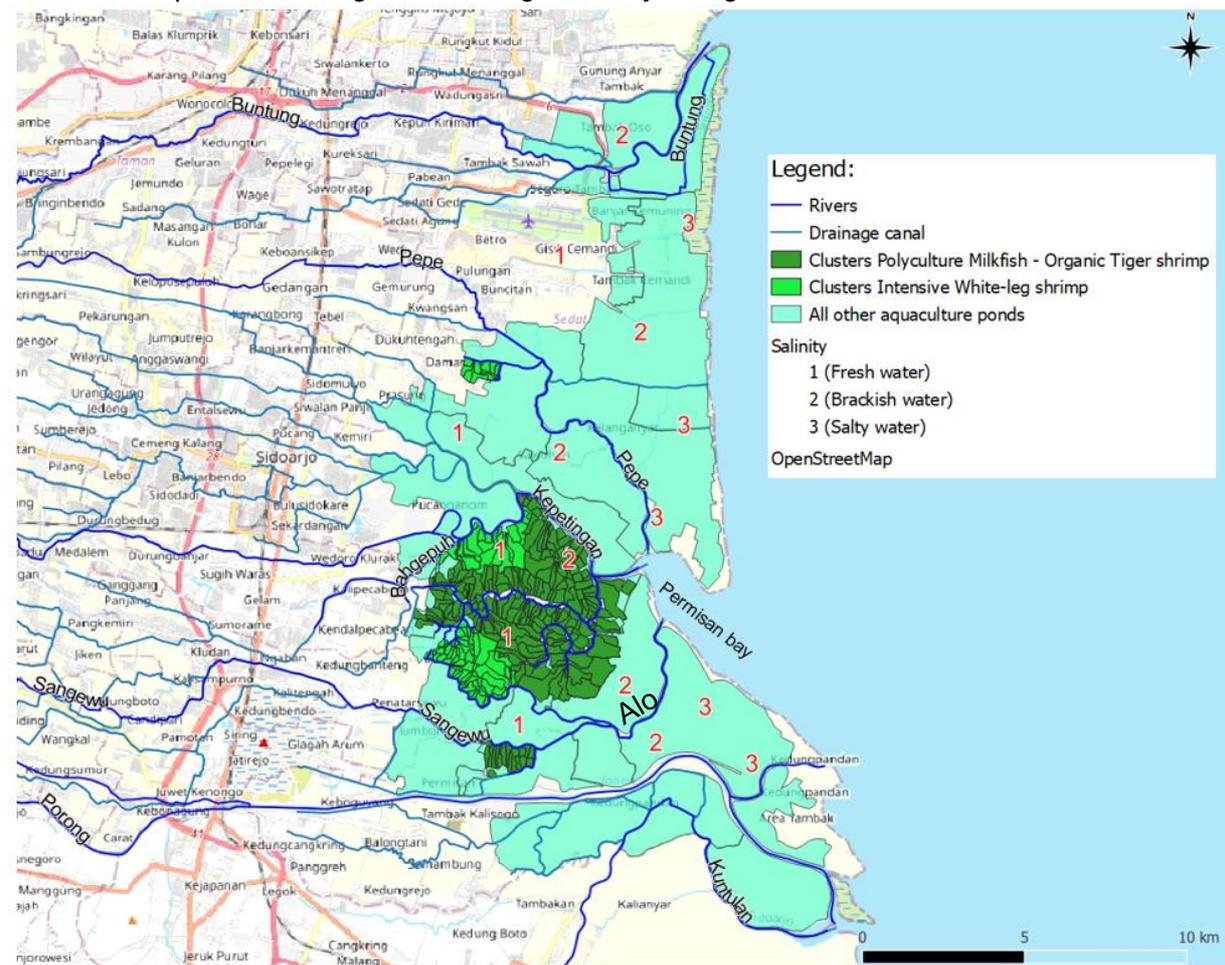


Figure 2.1.1 Aquaculture pond types and salinity zones in Sidoarjo regency, east of the urban area of Sidoarjo

All rivers drain into the Madura Straits, a mixed, mainly semi-diurnal, microtidal strait connecting the Java Sea with the Indian Ocean. A specific feature of these mixed tides is that have a large interannual variation in maximum tidal range peaking in June-July and December-January (van Maren and Gerritsen, 2012), referred to as King tides. The monsoon winds drive a pronounced flow through the Madura Straits, directed southward in the wet season and northward in the dry season (Nugrahadi, 2013).



Figure 2.1.2. Present-day coastline of Sidoarjo (yellow) and coastline in 1898 (Dutch map from 1898 retrieved from DavidRumsey.com) (orange). The white line depicts the landward limit of fishponds in 1898. The satellite image is from Bing.com, depicting a landward limit of aquaculture (dark grey tones on the satellite image) roughly corresponding to that in 1898.

The landward limit of the aquaculture has not substantially changed in at least the past 125 years (see Figure 2.1.2). The fishpond area did expand in the seaward direction, typically 2-3 km but up to 6 km in the mouth of the Porong delta. The expansion in the Porong delta is largely attributed to the river training networks completed around 1900, aiming at diverting water of the Brantas river through the Porong distributary. The total aquaculture area in Sidoarjo regency is now around 15.000 ha. For irrigation purposes, the northern aquaculture areas receive water from the Mas and only the two southern from the Porong; all others are creeks fed by local rivers. Most of the northern watersheds near Juanda airport, including Buntung (about 2,000 ha) are designated to become industry and urban areas. The central aquaculture areas receive water from Ombo creek (<100 ha) and through the network of the rivers Pepe (> 1,670 ha), Kepetingan (> 3,200 ha) and Alo (>2,100 ha) and drain into Permisan Bay. The Alo receives additional water from the Porong river (south of Tarik, Sidoarjo) since around 1900. The 1,000 ha of aquaculture south of the Porong, is connected to a separate river, the Kuntulan which joins the Porong river in its delta. This area does not appear to have problems because most farmers respond well to the advices on intensification from the extension services, according to Bappeda.

The land between the railroad and road running across the city of Sidoarjo and the coast has hardly any slope: 0 SL to +5m along the road and up to +25m further inland. Consequently, (1) the ground water near the coast has a salinity of up to 20 ppt, (2) the sediment easily accumulates in the rivers, the estuary and the bay, and (3) flooding quickly covers large areas when drainage of water is obstructed.

2.2 General description of issues and developments

Aquaculture in Sidoarjo uses various systems to produce, from brackish-water species (milkfish and tiger shrimp) to species thriving at low salinity (tilapia and white-leg shrimp) – chapter 3.2 for more details. Aquaculture is undergoing changes due to a combination of pollution by urban waste and of salinity reduction. The reduction in salinity is a crucial factor in the decline of traditional polyculture milkfish/tiger-shrimp farming; most farmers along the Alo River already shifted to tilapia/white-leg shrimp. The tiger shrimp has great value as its traditional farming method is considered organic which make this shrimp an international export product; the local milk fish is famous on a more regional / national level. Both products are so important that they are embedded in the logo of Sidoarjo regency (Figure 2.2.1). They therefore not only have important economic value, but are also culturally important. They are cultivated in around 3,000 ha, receiving water from the Kepetingan (Figure 2.1.1). The salinity in the rivers is decreasing since 1992 according to Atina (a food exporter, Branch of Alter Trade Japan), and it is believed this decline is related to the rivers and Permisan Bay becoming shallower. The last time both were dredged was in 1987. The river and its embayment are not dredged because of the associated costs, but also because obtaining permits from the Ministry of Environment is difficult because the banks are fringed with mangroves.



Figure 2.2.1 Monument to the tiger shrimp and milkfish, and logo of Sidoarjo regency

At present the salinity reaches 'brackish' levels near the sea only, while the delta is relatively flat (Figure 2.1.1). Moreover, ponds become shallower but lower compared to the rivers, shortening the window for natural tidal exchange of water. Thus, at present the regency's aquaculture zone has a fresh (0-7ppt), brackish (7-15 ppt) and salty (15-25 ppt) area; minima are reached in wet season and maxima in dry season. In about 600 ha of the central aquaculture area near the city, farmers cannot stock tiger shrimp anymore and this leaves

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about 2,000 ha for this brackish water shrimp that the regency wants to maintain. The regency expects that after an intervention in Kepetingan River and Permisan Bay, tiger shrimp can be cultured in close to 4,500 ha of the watersheds of the rivers Kepetingan and Alo (Bappeda Sidoarjo, 18-08-2022).

Although from a fisheries point of view the decline in water quality is the major concern, several additional developments are contributing to changes of Sidoarjo's coastal zone.

The first is a mud volcano which started erupting within the regency in 2006 and has been releasing mud ever since, burying complete villages. The eruption has led to local subsidence and to land growth in the delta, both influencing aquaculture.

The second is erosion of the coastline north of Permisan Bay, resulting in coastline retreat of 800 meter in 8 years. Although the affected area consists of fish ponds, the impact on aquaculture is limited because this area was projected to be developed for housing and industry because of its proximity to Juanda airport (3.2 km from the original coastline) (pers. comm. Mr. Fauzy Nasruddin). This coastline degradation may have also affected Permisan bay, however. These two aspects will be discussed in Chapter 3.1.

A third aspect concerns urban drainage. The local rivers flowing through the urban area cause regularly flooding of the urban areas and the rice fields to its west (approximately once / year). Flooding occurs when high river discharge coincides with high tides, and occurs a.o. due to obstruction of canals caused by:

- Waste disposal by households and industries; in particular where fishermen place nets, and where planted mangrove trees along dikes of drainage canals obstruct the waterflow.
- Illegal constructions in/above canals.
- Change of function of canals from provision of irrigation water to drainage of waste/rain water.
- Siltation downstream, also originating from mud dredged from the fishponds that is pumped out once or twice a year.

In order to mitigate flooding, the construction of tidal barriers and flood retention basins in the aquaculture areas are now considered (Bappeda, 2022a). The barriers aim at blocking the tidal flow. Retention basins will be constructed landward of these barriers to store the river discharge.

3 Understanding the system

Aquaculture and the functioning of the abiotic system are strongly interrelated. This chapter discusses how the physical system influences aquaculture and vice versa. The section on socio-economic conditions describes the financial importance of aquaculture, but also social-cultural constraints for adapting aquaculture to changing abiotic conditions.

3.1 The physical system

The rivers Alo, Kepetingan and Pepe provide fresh and salt water to a large number of traditional aquaculture ponds (see Figure 2.1.1). These rivers originate east of Sidoarjo, and flow through its urban area. The water quality of the is in decline because of urban pollution including plastic waste, and a reduction in salinity. The degree of pollution is unknown and needs to be improved through environmental wastewater treatment in Sidoarjo. Wastewater pollution is not part of the project scope.

The decline in salinity is not caused by changing river drainage in the past ~40 years because this has not changed a lot (pers. Comm. Drainage Department). It is probably caused by infilling of the Alo river, Kepetingan river, and Permisian Bay. Infilling of these rivers is primarily caused by the conversion of the coastal zone into fishponds (Box 3.1.1). More recently the mud spill of the mud volcano (see Box 3.1.3) contributed to infilling as well. Infilling may lead to a decline in salinity because it weakens estuarine circulation, Estuarine circulation is a process where salt water flows into Permisian Bay close to the bed while fresh water flows out close to the surface. The present-day water depth is 2 meter below low water in Permisian Bay (down to 0.8 meter in September) and 3-4 meter in Kepetingan River (numbers provided by local boat driver). Estuarine circulation will be negligible in such shallow water. Fresh water is then trapped and only leaves the system through tidal mixing. Tidal mixing is less effective than estuarine circulation in an area with a low tidal range such as Sidoarjo. The importance of infilling is further suggested by the fact that the decline in water quality was reported since 1992, five years after the river was dredged.

The salinity also influences the settling velocity of sediment particles. In fresh water, the clay particles carried by the rivers settle very slowly. When the water becomes more saline the smaller clay particles stick together, forming aggregates which settle much faster. As a result, sediment settles on the bed in the transition zone of fresh to salt water. The transition of fresh to salt water is fairly close to the sea in the wet season. Most sedimentation takes place at the end of the dry season when salt intrudes further inland (personal communication local boat driver).

Many of the ponds flood around King tides (June, December). The pond owners say such flooding is becoming more common. It is not known whether the flooding is caused by increasing high water levels or sinking of the ponds (subsidence). Higher tidal water levels may be caused by changing bathymetry or through loss of intertidal area.

Box 3.1.1: Sedimentation in Kepetingan River and Permisan Bay

There is no data to confirm the shallowing of Kepetingan River and Permisan Bay. However, shallowing is a logical consequence of human activities in the coastal zone of Sidoarjo from a physical point of view. An anthropogenically modified coastal zone is experiencing much lower flow velocities due to a reduction in tidal discharge and peak river discharge (see Figure 3.1.1). Sediments transported by the Kepetingan river therefore more easily deposit, and once deposited the flow velocity is too low to resuspend them. Sediments may be additionally provided by the Porong River, when the seasonal northward flow in the Madura Straits carries Porong's fines northward. Sedimentation may have therefore accelerated because of the eruption of the mud volcano (see Box 3.1.4). Sedimentation in Permisan Bay was likely accelerated because of erosion of the shoreline to its north (see Box 3.1.3).

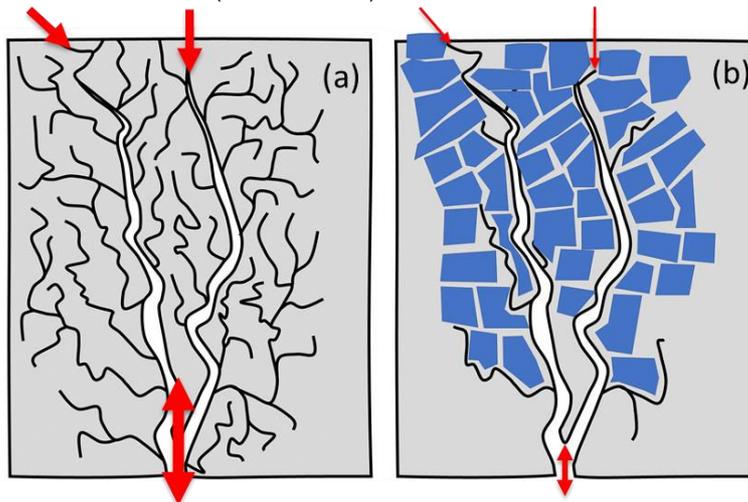


Figure 3.1.1. A natural intertidal area with a large drainage area (a) has large tidal flow velocities. An anthropogenically modified coastal plain with a sharp reduction in intertidal areas due to construction of ponds (b) experiences much lower tidal flow velocities.

This infilling has likely been going on for a long time (with the fishponds already existing by 1900 – see Figure 2.1.2 but until recently not noticed for several reasons:

- The original channel was likely much deeper, and decreasing depth due to continuous infilling may have gone unnoticed for a long time;
- The channel was last dredged in 1987. It is likely that the river filled in with sediments much faster than the decades before that because (1) The dredged channel was relatively narrow and therefore could fill up rapidly, (2) the system was saturated with fine sediments available, and (3) the dredged material was probably disposed close to the dredged area (no information available, but this is common practice).

The regency has the tertiary canals dredged every two years (10,000 m³ for 1,5 Euro/m³), but the mud is not dispersed very far and rapidly returns. Sidoarjo regency is also responsible for the maintenance of secondary waterways in an area with 6,000 ha of aquaculture. Infilling of estuaries is therefore characteristic for the entire coastal plain unless they are flushed by high river discharges (as the Porong river). Another characteristic of the area is the natural growth of mangroves (section 3.2), especially along the Kepetingan river.

The fishpond area north of Permisan Bay suffers from large-scale erosion, resulting in flooding of fishponds up to 1 km from the original shoreline (Figure 3.1.2 and Figure 3.1.3). Although responsible mechanisms need to be investigated in more detail, a first appraisal of available information suggests that coastal erosion results from loss of tidal flow in the Buntungan estuary which is filling up and thereby deprive the downdrift coast of sediment (Box 3.1.3). Destabilization of the coastline releases sediment which in turn leads to expansion of the spit system sheltering Permisan Bay (Figure 3.1.2), thereby contributing to the salinity decrease in the rivers. Salinity and siltation issues may therefore not only be caused by local land use, but also by changes further north. This illustrates the complexity of the system, and the need to fully understand its dynamics.

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Figure 3.1.2. Top panels: Coastline north of Permisan Bay in 2013 and 2018, showing a large-scale ingress of seawater. Lower left: Development of a spit North of Permisan Bay between 1984 and 2020.



Figure 3.1.3 Newly developed inlet along the northern coastline (see inset for location). Source: drone video by Dinas Perikanan Sidoarjo

Box 3.1.2: Potential mechanisms leading to erosion of the northern coast

Erosion of the coastline North of Permisan Bay may result from subsidence or from a shortage of sediment. Although subsidence may be responsible (and indeed even suggested by the subsidence map by Aditiya et al. (2017) there is not an obvious reason for subsidence (there is no groundwater extraction), and a more likely mechanism is a shortage of sediment. The coastal geomorphology suggests a dominant transport direction from the north to the south (section hereafter). In pristine conditions, sediment bypasses the Buntungan estuary depicted in Figure 3.1.4, because it is energetic and sediments do not easily settle. It is likely that, similar to the Kepetingan River, the tidal flow was reduced (by construction of fishponds or by rerouting of streams during the construction or extension of Surabaya airport) and sediments could easily settle. As a result, the estuary completely filled in with sediments, and the southward transport is blocked. Without supply of sediments, the coast erodes. The apparent subsidence computed from satellite images by Aditiya et al. (2017) may be erroneous and caused by the increase in water surface.

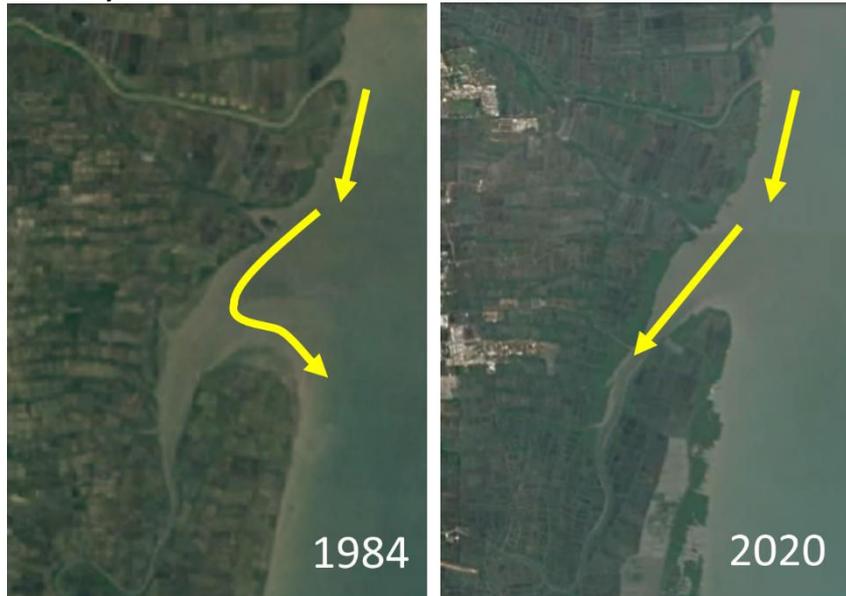


Figure 3.1.4. Interruption of southward sediment supply (yellow arrows) by infilling of an embayment.

Another illustration of this complexity is the Sidoarjo mud volcano. The initial mud outflow was mainly locally contained (possibly leading to subsidence, see Box 3.1.3) or discharge into smaller rivers such as the Alo (leading to their infilling). In a later stage the newly released sediment was released to the Porong river, resulting in significant expansion of the delta (see Figure 3.1.6). Plans are being developed to reclaim the newly developed land indicated with the white circle in Figure 3.1.6. A drawback of this new land development is that it reduces the flood conveyance capacity of the delta. As a result, the main outlet of the Porong river appears to switch from its present location to a northern branch (see also Figure 3.1.6). The southern outlet would then receive less sediment, which could lead to erosion of the newly developed land (which is crucial knowledge given the plans to develop this new land). Additionally, the Northern outlet will convey more sediment to the North thereby contributing to sedimentation in Permisan Bay.

Box 3.1.3: Subsidence by Sidoarjo mud volcano

The Sidoarjo mud volcano initially released 120,000 m³ per day (2006) but this was reduced to 50,000 m³ per day by September 2011. Initially the mud was discharged through local streams which rapidly filled up. This caused blocking of the flow and a salinity decline in the Alo river. Therefore fresh mud is now mixed with water from the much larger Porong river and discharged back into the river. In 2011 between 1 and 2 million m³ of mud was released into the Porong River (Sidik et al, 2016 and references therein). The area around the mud volcano is now subsiding, illustrated by raised doorways (Figure 3.1.5), houses under construction being a meter higher than old houses, and installation of pump systems in the drainage channel. Subsidence may result from 2 mechanisms (or a combination): squeezing of the topsoil by the pressure of the contained mud discharged by the volcano (locally up to 30 meter high), or by the loss of volume in the subsoil following the release of mud. Knowing the responsible mechanism is important – when subsidence is caused by the local sediment deposit, removing the sediments should become a key priority.



Figure 3.1.5 Raised doorways to prevent flooding at Banjarpanji Village



Figure 3.1.6: Impact of the mud volcano on the delta. The increase in sediment led to accretion in the river mouth forming Lusi island (left, white circle). It also seems to initiate a flow redistribution in a fork (yellow square) from the main outlet to a northern outlet (figures below): the main channel reduced from 120 to 95 meters; the northern channel expanded from 80 to 105 meter.



All aspects related to coastal development should account for future relative Sea Level Rise (SLR). Expected SLR on the north coast of Java is 6 cm in 10 year, and land subsidence along the coast of Surabaya-Sidoarjo varies between 0 and 27 cm in 10 yr (Willemsen, Lelij and Wesenbeeck, 2019). To protect Sidoarjo from these changes (and more flooding), all low-lying and valuable land between the present city limits and the coast should remain free from ground water extraction and heavy buildings, and thus remain a priority area for aquaculture, mangrove and water storage. Given the large potential impact of relative SLR it is surprising that SLR is hardly mentioned in plans.

3.2 Aquaculture

Milkfish and shrimp are the ikons of Sidoarjo, but the produced species in 2021 included also seaweed, crab, tilapia and other fish (Table 3.2.1). The local milkfish, which represents about half of the produced volume, has a reddish mouth and is sold nationwide after smoking. Moreover, the tiger shrimp grown in traditional ponds is exported as organic shrimp, among others to Japan by the seafood processor Atina which has a stronghold in Sidoarjo. The aquaculture ponds of our main concern are located in the watershed of the Kepetingan River between the town and the sea (Figure 2.2.2). Below, we describe also the other aquaculture systems prevalent in Sidoarjo, thereafter we give information on the productivity and finally we expand on the issues.

Table 3.2.1: Sidoarjo regency's marketed aquaculture species in 2021 (tons).

Milkfish	34,549
Tilapia	15,396
Other fish	5,222
White leg shrimp	5,821
Tiger shrimp	4,171
Other shrimp	3,170
Mud crab	235
Seaweeds	10,545
Total	78,874
Source: Bappeda, Sidoarjo	

The farm sizes may vary from 2 to over 40 ha: about 60% is less than 10 ha, 30% 10-20 ha and 10% more than 20 ha (Fitrianto, 2019). The farms are mostly composed of several ponds. Most farmers still practice the traditional polyculture of milkfish (*Chanos chanos*) and tiger shrimp (*P. monodon*) and part of those deliver their shrimp to Atina (Box 3.2.1). But to adapt to changing conditions, including disease pressure, many replaced the latter with white leg shrimp (*L. vannamei*). Other polyculture farmers, mostly in the watersheds of the Alo and Kuntulan, adapted to the decreasing salinity levels by replacing milkfish with tilapia. Many of those shifted to a traditional-plus system by feeding their tilapia, and make good profits (Box 3.2.2). About 10% of the white leg shrimp is cultured by less than 2% of the farmers in intensive systems using brackish groundwater (Box 3.2.3). Most of the latter are located in the southern areas linked to the Porong and use brackish ground water.

Box 3.2.1. A milkfish-shrimp farmer in the brackish water zone.

Mr. Yusuf rents three aquaculture farms. The one we visited has 12 ha, for which he pays 70 million IDR/yr, for 5 years. At the start he invested in dike enlargements and gate repairs; after 4 years he has not yet reached the break-even point. On this farm, 3.4 ha is too shallow for tiger shrimp. There he stocks milkfish and white leg shrimp that he harvests, resp. two and 3-4 times per year. In the 8.6 ha he stocks milkfish and tiger shrimp and sells all tiger shrimp reaching the stage of 25 pcs/kg to Atina, because they pay more (at present 122,000 IDR/kg). On average he gets good harvest, yielding about 125 kg/ha, only once a year. Due to disease outbreaks, he harvests the other two stockings too early; these shrimp also, he sells at the local market (25,000 to 30,000 IDR/kg). His total milkfish yield is about 2 tonnes (about 335 kg/ha/year). Every September, Mr Yusuf pumps about 20 cm of mud from the pond' bottoms through the gates using a central canal in all ponds, and he hauls the mud from the sides on the dikes to reinforce these. The mud contains about 30% Total Suspended Solids. As he is not feeding the ponds and his stocking density is low, this sediment originates mostly from the inlet water. After some drying, he adds dolomite to the smelly spots to kill harmful bacteria. He does not use any other products. On each farm, Mr Yusuf has a caretaker staying on the farm, mostly alone. The caretaker just manages the gates and does the regular maintenance of the dikes. He earns 15% of the harvest value. After harvest the caretaker joins his family for some days.



Fig. 3.2.1: Organic shrimp farm with a small settling pond at the foreground.

The available information on the productivity is not consistent, which might be due to the fact that the three systems are aggregated in many statistics. In all areas the milkfish productivity remained about the same: 500-700 kg/ha/yr in one or two harvests. Farmers can harvest 100-160 kg/ha/cycle of tiger shrimp (30 pcs/kg) and complete 2-3 cycles, while they harvest 300 kg/ha/cycle of white-leg shrimp (60 pcs/kg) and complete 3-4 cycles. However, not all cycles are completed. The average survival rates are low, respectively 11 and 20%; meaning that farmers lose a huge part of the invested capital. In most districts those productivities were stable or improved. However, in the centre of the aquaculture area, since 2008 the productivity of tiger shrimp declined by about 25% (Susanto, 2022). Since 2013, the polyculture farmers of organic tiger shrimp, delivering to Atina, harvested only an average of 89 kg/ha/yr, which is substantially less than the above. Although there was an increase from 2014 to 2020, yields have since decreased again (Figure 3.2.2). Even the sizes of the delivered shrimp were smaller, after the usual production cycle.

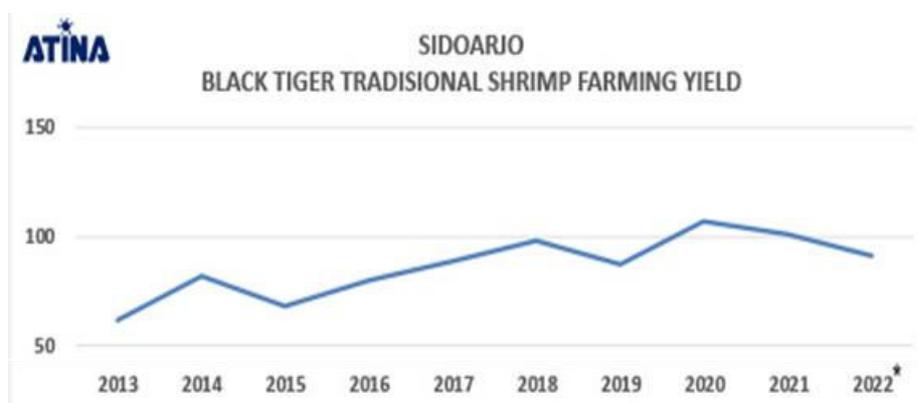


Fig. 3.2.2: The average yields (kg/ha/yr) of tiger shrimp that farmers delivered to Atina since 2013; the data for 2022 are preliminary, until November (Source: Atina, 2022b)

The organic polyculture with tiger shrimp is at present practiced in close to 2,000 ha of the central area of the Sidoarjo's front delta but could cover 4.487 ha if salinity levels were high enough (Bapeda, 2022b). The organic poly-culture farmers stock at low density (<5 pcs/m²), never use feed but may use dolomite, organic fertilizer and sugar cane residues, resp., to disinfect the pond bottom, to improve soil and water quality, and to stimulate the conversion of feces into natural feed. In this area the villages have electricity, but most ponds do not.

As mentioned above, since 1998, even in the Kepetingan watershed many ponds can not reach a salinity of 8-15ppt all year round, and in those, farmers can not harvest tiger shrimp 2 to 3 times per year anymore. Moreover, nowadays, almost all ponds, also in the Alo watershed suffer from floods every 13-15 day; then the water flows over the dikes needing frequent repairs. At the two king-tides the flooding is worse and part of the stocked fish and shrimp may be lost. These floods damage the gates and dikes which leads to higher maintenance cost.

Box 3.2.2. Tilapia-shrimp farms in the fresh water zone.

Low salinity levels fit well to white leg shrimp and tilapia, either *O. nilotica* (nila) or *O. mocambicus* (mujaer). Per year, they grow 4 cycles of shrimp and 2 cycles of tilapia, that grows faster than milkfish. The farmers add tilapia feed to the ponds; the shrimp will eat the leftovers and natural feed. This co-cultivation is beneficial because tilapia mucus can suppress pathogenic vibrio bacteria and reduce diseases. Still, shrimp may get WSSV or WFS, but not as bad. Farmers complain about the declining water quality and the garbage in the shallow canal that links them to the Alo River. To prevent drastic changes in water quality, some farmers created a settling pond. Since 2000, they need pumps to complete the annual drying of the pond in August/September, and that increases their cost. The majority of the farmers rents the ponds with only one main gate for about 20 million IDR/ha/yr. Most tenants hire a caretaker who receives 4% of the net yield per harvest; the tenant buys all inputs such as the seeds and feed. Per year, if all goes well, white leg shrimp yields 600 kg/ha/yr and fetches 50,000 IDR/kg, and tilapia 2.5 tons/ha/yr. Tilapia prices vary between 13.000 and 40.000 IDR/kg according to seasonal festivities, Mujaer may grow a little slower but may fetch a higher price than Nila. Feeding cost are high but the profits are good.



Fig. 3.2.3: The zone with tilapia and white leg shrimp.

A productive aquaculture depends on clean water. However, the levels of fecal coliform, nitrite, phosphate, and both COD and BOD exceed acceptable norms for aquaculture in both watersheds (Atina, 2022b). In Kepetingan River, levels of ammonia, cadmium, chlorine, lead and total dry solids are also too high in the river sections linked to the ponds, and that of chromium locally in those sections of Alo River.

The main diseases are e.g. White spot syndrome virus (WSSV), White feces syndrome (WFS) and Acute hepatopancreatic necrosis disease (AHPND) for shrimp, and aeromonas for tilapia. Outbreaks of these diseases can be triggered by mud flowing from the dikes during prolonged heavy rains, and abrupt shifts in water temperature and salinity. Disease outbreaks may lead to loss of all stock or to low yields (sometimes after early harvest).

The ponds' yields are sold to middlemen and collectors, or to mongers at one of Sidoarjo's fish markets. At the latter, the farmers have to present a minimum quantity of a specific size, but then they get a better price than from the middlemen or collectors. Farmers complained that middlemen and collectors may harm the animals as during the selection of the required sizes

they throw the small back in the pond; this has led to losses of stock. Middlemen and collectors are often also sources of inputs and short-term credits. Credits for aquaculture are not easy to obtain from banks.

The design of most traditional ponds is poor and the management of pond soil and water is weak. Almost all farms have only 1 gate serving both for water inlet at high tides and outlet at low tides for all their ponds, which prevent proper water management. The water is filtered at the inlet with a solid wide mesh net to prevent waste entering, and during outlet with a fine meshed net to prevent his stockings to escape. Some farmers use a small storage pond (tandon). Part of the ponds still has a shallow centre and only ditches along the dikes; this leads to high water temperatures above the central platform and limits stocking density. In the other ponds, the owners or farmers have removed the central platform and created a central canal (Box 3.2.1). Many ponds are deeper than lowest tide, which leads to insufficient drying of the pond during the required annual soil preparation, unless a pump is available and dikes can resist the pressure from the water in neighboring ponds and canals. Some farmers hire a pump to empty their ponds, but not all seems to be able or willing to pay for that. Knowledge on the options to manage soil and water quality, with organic methods also, seem limited. Some farmers or caretakers never went to a training. Those who did assisted either at massive meetings or unstructured “field-school” gatherings which are only limitedly effective.

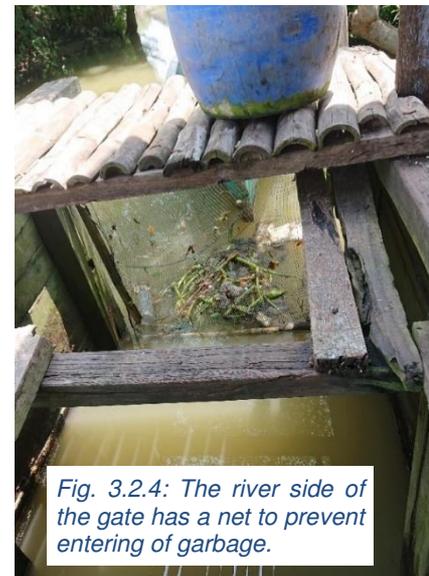


Fig. 3.2.4: The river side of the gate has a net to prevent entering of garbage.

Box 3.2.3. An intensive Vannamei farm in Jabon district.

The farm of 5 ha has 28 cultivation ponds of 1000-1300 m². Someone from Surabaya rents the land from local owners and hires a technician to manage the farm with six workers. Brackish water (20 ppt) comes from two drilled wells with a depth of about 18 m. This water is stored in some settling ponds before being pumped to the ponds through pipes. The monthly cost for electricity can reach 30 million IDR and of feed 84 million IDR.

The target is to harvest every 3 months about two tons of shrimp with size 30/kg fetching 70,000-80,000 IDR/kg; Any size of healthy shrimp is sold to a cold storage factory in Gresik. The farm has 2 or 3 good harvests per year from each pond. Diseases, such as WSSV, WSV and AHPND (Acute Hepatic Pancreatic Necrosis Syndrome), may interrupt a cycle; when exposed all shrimp are killed and buried, the diseased pond is disinfected and flushed. All outlet water is discharged through the central drain in a canal linked to Alo River, while the farm is located on the road along the dike of Porong River.

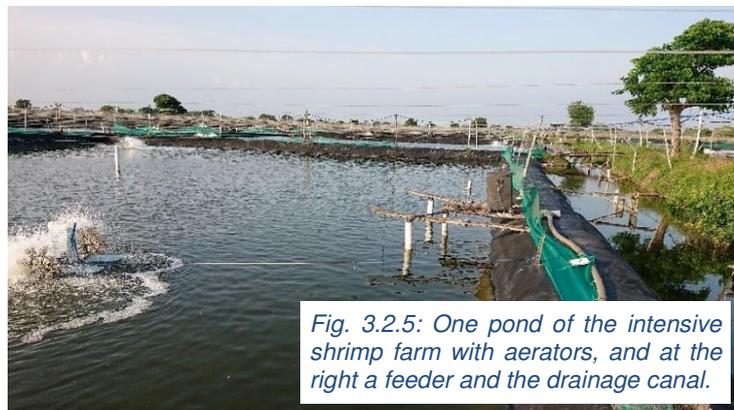


Fig. 3.2.5: One pond of the intensive shrimp farm with aerators, and at the right a feeder and the drainage canal.

Moreover, most farmers are not motivated to invest in major pond improvements. The latter is mainly due to the wide-spread absentee-ownership of the ponds; according to a small sample of Fitrianto (2019) more than 60% of the ponds is rented. Owners, or families owning the farm either use a caretaker (locally called pandega), or rent their pond. For some family-owned ponds the brothers may take turns for the pond management, as a side job, and share benefits.

All of the renters we met had caretakers as well. As the rent may not be extended beyond the usual period of 5 years, the attitude of the tenants is understandable.

In summary the problems preventing an increase in production, even of the traditional system, are not only the salinity level. The low yields can also be explained by polluted water, losses of stock, lack of dike maintenance, no electricity, low access to credits, diseases, poor pond design, weak training of farmers and caretakers, and the absentee ownership.

3.3 Mangroves

The area of mangroves in Sidoarjo Regency is 1,843 ha (Geospatial Information Agency, 2016; MEF, 2021). Most of this total area (1,697 ha) has a medium tree density whereas 110 ha has a high tree density and 37 ha a low tree density (Fig. 3.3.1). From 2010 till 2016 the area of mangroves in Sidoarjo Regency decreased with 15% (Hanggar Hadi Putra, 2016). In Pitu Gajahan Island the mangrove diversity index (0.61-1.35) was categorized as low to medium (Noor & Wulandari. 2018). The tree density was close to 115,900 mangroves/ha, which is good; the main observed species were *Avicennia alba*, *Avicennia marina* (api-api), *Sonneratia alba* and *Sonneratia caseolaris* (bogem pidada).

Around Kepetingan River we observed *Rhizophora*, *Avicennia*, *Accanthus*, as well as *Nypa* and several types of associated mangroves. In the field, the team observed that on the banks of Permisan Bay some mangroves had deteriorated (Fig. 3.3.1). The loss of leaves, i.e. dying of the mangrove trees, is probably due to local ecological shifts, such as: change of inundation period and frequency, accumulation or erosion of sediment, or waves (but the last seems excluded for the ones on Fig. 3.3.2). Other factors that can have affected the health of those mangroves are their use as firewood or the transformation of the area for aquaculture (although for both explanations the dead trees are too close to the coastline).



Fig. 3.3.1.: Dead mangrove trees on the banks of Permisan Bay.

Mangroves have many beneficial effects. They provide a nursery ground for juvenile fish, shade (benefiting older fish as well), improve the water quality, strengthen the soil, and provide shelter from storms (although this latter is not very important). Therefore mangroves are protected on a government level. The presidential decree (2016-51) supports the maintenance of a greenbelt of 50 meters along waterways (rivers and creeks) in the estuaries, and 100

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meters (counting from the line reached at the highest tide, along the coast). However, once the land has been given over to private property ownership, formal control over actual land use is lost, and the law is difficult to enforce, unless contractually specified. Moreover, the decree applies to the marine area, while the provincial government mandate extends only up to the flood-line at high tide.

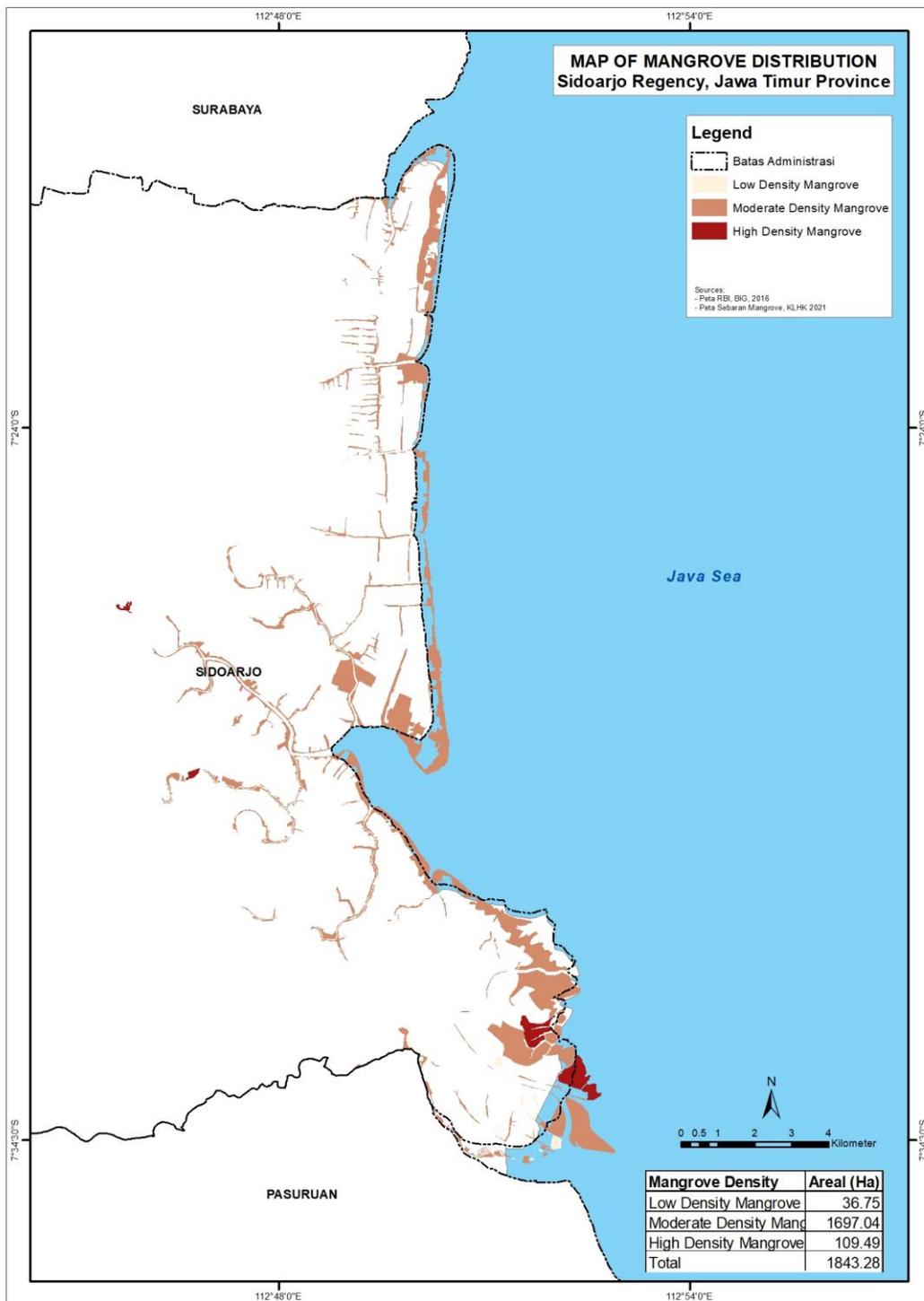


Fig. 3.3.1 Map of mangroves distribution in Sidoarjo Regency

Because of their beneficial effects, mangrove areas are also required to obtain organic shrimp certification. From 2002 to 2008 the farmers in Sidoarjo regency related to ARG (Ali Ridho Group; see next section) had a Naturland certification but this was not extended (Fitrianto, 2019). The latter might be due either to quality issues, as Atina is worried about quality also, or to other reasons, such as the cost of Naturland certification. According to the official organic certification standards used by Naturland, a farm needs to have at least 10% of natural vegetation on the farm. This seems not the case on the farm we visited, unless the fringes alongside the farm are included in the count, or if the 3.4 ha shallow ponds have mangrove on the central platform. Another explanation could be that the rules for certification are not strictly enforced, thereby facilitating greenwashing. The ASC label for sustainable shrimp aquaculture is much stricter on mangroves. Shrimp farms created after May 1999 on a new location in a mangrove area cannot receive an ASC certificate. Shrimp farms created before May 1999, should have at least 100m of mangroves along the seacoast and at least 25m along the rivers and estuaries, and if the farm is larger than 50 ha it should have corridors of at least 20 m for wildlife. If a farm has physical limits to realize the above indicators, the farm should compensate this by rehabilitating mangroves in other locations.

Mangroves may also have negative impacts. Natural growth of mangroves may block drainage / ternary canals and therefore limit water drainage. However, the cutting of mangroves is prohibited because of their ecological value. Mangroves will also need to be removed when the Kepetingan River is dredged. This introduces institutional complexities. The Ministry of Marine Affairs and Fisheries may require dredging of Kepetingan River to improve water quality in the fish ponds. Dredging should then be executed by the Ministry of Public Works and Housing, who then needs to apply for a permit to cut mangroves from the Ministry of Environmental and Forestry (which apparently is difficult). A solution, especially as part of potential solutions discussed in the next chapter, may be to compensate mangrove clearance in one area with mangrove rejuvenation in another. However, at this point it is not yet clear if such nature compensation can be used to obtain permits for removing mangroves in an area.

3.4 Socio-economic and Institutional Context

General description

Geographically, Sidoarjo Regency is a strategic area because it is a buffer for Surabaya City and is also bordered by Gresik Regency in the north, Pasuruan Regency in the south, and Mojokerto Regency in the west. This strategic position makes the economic turnover in Sidoarjo Regency more promising. The regency is a low delta plain: in the east almost 30% is covered by aquaculture ponds, while its central axis shelters settlements, shops, offices and industry; its western side is dominated by crop farming. The regency's population surpassed the two million: about 1,036,700 men and 1,027,500 women (BPS, 2022).

The main economic sectors in Sidoarjo Regency are (Fitrianto (2019), using data of the year 2014) manufacturing industry (47% of the gross regional domestic product or GRDP), wholesale, retail and services (16%), transportation and warehousing (11%). The primary sector (agriculture, forestry and fishing) accounts for 2% of GRDP. The fisheries sector's mainstay commodities are shrimp, seaweed, fish and crab. The industrial sector is also quite developed due to its proximity to Surabaya's business centers, Tanjung Perak Port and Juanda Airport. One of the main livelihood options for coastal communities in Sidoarjo Regency is aquaculture in ponds. In addition to raw and deep-frozen shrimp and fish, the fisheries industry in Sidoarjo Regency processes seafood in products such as smoked milkfish, otak-otak, smoked tilapia, prawn crackers, shrimp paste and others. Some of these are exported.

The pond owners in Sidoarjo Regency generally inherited the farms. At present, the owners tend to rent ponds to be managed by other parties, both local residents and people from outside the regency. Pond rental prices vary depending on location access between IDR 6 and 20 million/ha/yr. Most owners (absent and non-absent) of land and ponds near cities, hope that one day the city will need their plots for industrial or residential expansion, and that then they will fetch a good price for the land. Already at the edge of the fresh water zone huge warehouses have been build. Therefore, (1) the land-owners are not interested in more, larger, higher pond dikes and more gates. One can not expect such investments from the renters because they can't recover such investments during a rental period of just 5 years. (2) Neither will these owners contribute to the rehabilitation of mangrove greenbelts in the estuary, unless financially well compensated or legally forced as their land-claim of the mangrove fringe was illegal.

Stakeholder overview

Local stakeholders involved in aquaculture activities in Sidoarjo Regency (Fig. 3.4.1) include:

1. Farmers: pond owners or tenants, pond caretaker (*pandega*) and laborers for various types of work. Pond management in Sidoarjo is generally carried out by pond owners or tenants and assisted by *pandega*, depending on the farm size. *Pandega* have know-how in shrimp or fish farming, and are responsible for the cultivation process and the security of pond. Laborers are needed for cleaning and drying the pond, raising dikes and for harvesting.
2. Market players: middlemen (*pengepull/tengkulak*), collectors of shrimp and fish (*burih*), warehouse/cold storage, processors and exporters. *Burih* collect the shrimp or fish that the pond owner did not harvest with its dragnets. The middleman acts as a collector of the harvest, both shrimp and fish, and also as a distributor to warehouse and salesmen of inputs such as disinfectants and feed. Warehouse or cold storage play a role in processing and packing to be exported, where exporters will use this warehouse to collect and pack shrimp to be exported abroad. Main market players are: PT Alter Trade Indonesia (ATINA) and UD Ali Ridho Group (ARG). ARG focuses on wholesale and export of shrimp. PT ATINA, the Sidoarjo branch of Alter Trading Japan, focusses on export of organic shrimp to Japan. PT ATINA also assists farmers in respecting the organic methods for the Japanese market. In addition, PT ATINA trained farmers in cultivation techniques by involving fisheries experts from BPBAP Situbondo and Jepara.
3. Farmers organisations, such as Pokdakan (Kelompok Pembudidaya Ikan or fish farmers group), Airlangga, KPTOS (Kelompok Petani Tambak Organik Sidoarjo / Sidoarjo Organic Shrimp Farmers' Association) and Pokmaswas (Kelompok Masyarakat Pengawas or community supervisory group). KPTOS regroups farmers who sell to ATINA. Pokdakan can access funding from the national (APBN)/local (APBD) budget by submitting a proposal to the Fisheries Agency. Most of the funds are used for physical activities such as pond infrastructure, bridges etc. Pokmaswas has the role of supervising, monitoring and maintaining fishing activities in public waters, as well as protecting the public waters environment from human activities that can damage the environment. Pokmaswas that have been identified in Sidoarjo, among others Pokmaswas Juanda Lestari in Sedati Sub-district, Ketingan Jaya in Kepetingan, Pucuan Lestari in Pucuan area, and Pokmaswas Akar Delta Ujung in Jabon area.
4. FKMT (Forum Komunikasi Masyarakat Tambak, Aquaculture Community Communication Forums), consisting of representatives of farmer' groups, business and government, and under supervision of Fisheries Agency of Sidoarjo Regency. This

forum is an independent organization built by the Pokdakan (Kelompok Pembudidaya Ikan/Fish Farmers Group).

5. Regency and provincial government of which Bappeda (development planning agency) plays a role in planning, budgeting and supervision, as well as coordination between local government agencies. The Marine and fisheries agency (DKP/Dinas Kelautan dan Perikanan) implements programs related to aquaculture and coastal fisheries. The Public works agency implements programs related to water resources management including the development and management of irrigation at the provincial level (areas of 1,000-3,000 ha, across provinces and across districts/cities) and districts (areas of under 1,000 ha or within district/city administrative boundaries). The Environmental agency (DLH/Dinas Lingkungan Hidup) implements programs related to watershed management and environmental pollution. The Forestry agency (Dishut/Dinas Kehutanan) implements programs related to forest area management especially mangroves. The spatial planning agency regulates spatial regulation policies, especially in coastal areas. The Community empowerment agency implements programs related to the empowerment of communities. The Industry and commerce agency implements the trade program, a.o. for aquaculture products. The Agriculture agency plays a role through the supervision of agricultural activities that have the potential to produce pollutants of water in canals and rivers.
6. Education and Research: Politeknik Kelautan dan Perikanan Sidoarjo (PKPS), Institut Teknologi Sepuluh November Surabaya (ITS), University of Brawijaya (UB). Schools and universities can take roles in research and community service, as well as provide experts related to aquaculture, fisheries and coastal ecosystems.
7. Local NGO's, such as, Lembaga Maritim NU Sidoarjo, can play a role in building communication and cooperation with local communities.
8. Five other institutions and agencies are of interest for the issues at stake. The River Basin Office or Balai Besar Wilayah Sungai (BBWS) Brantas (agency of MPWH) has a role in management of water resources in river basins. The Brackish Water Aquaculture Fisheries Center or Balai Perikanan Budidaya Air Payau (BPBAP) of Situbondo and Jepara are R&D centers of MMAF implementing programs related to brackish water aquaculture, which includes the provision of fisheries experts. The Pusat Penanggulangan Lumpur Sidoarjo or Sidoarjo Mud Control Center has a role in controlling the Sidoarjo mudflow with a focus on social management, eruption control, mudflow and infrastructure.

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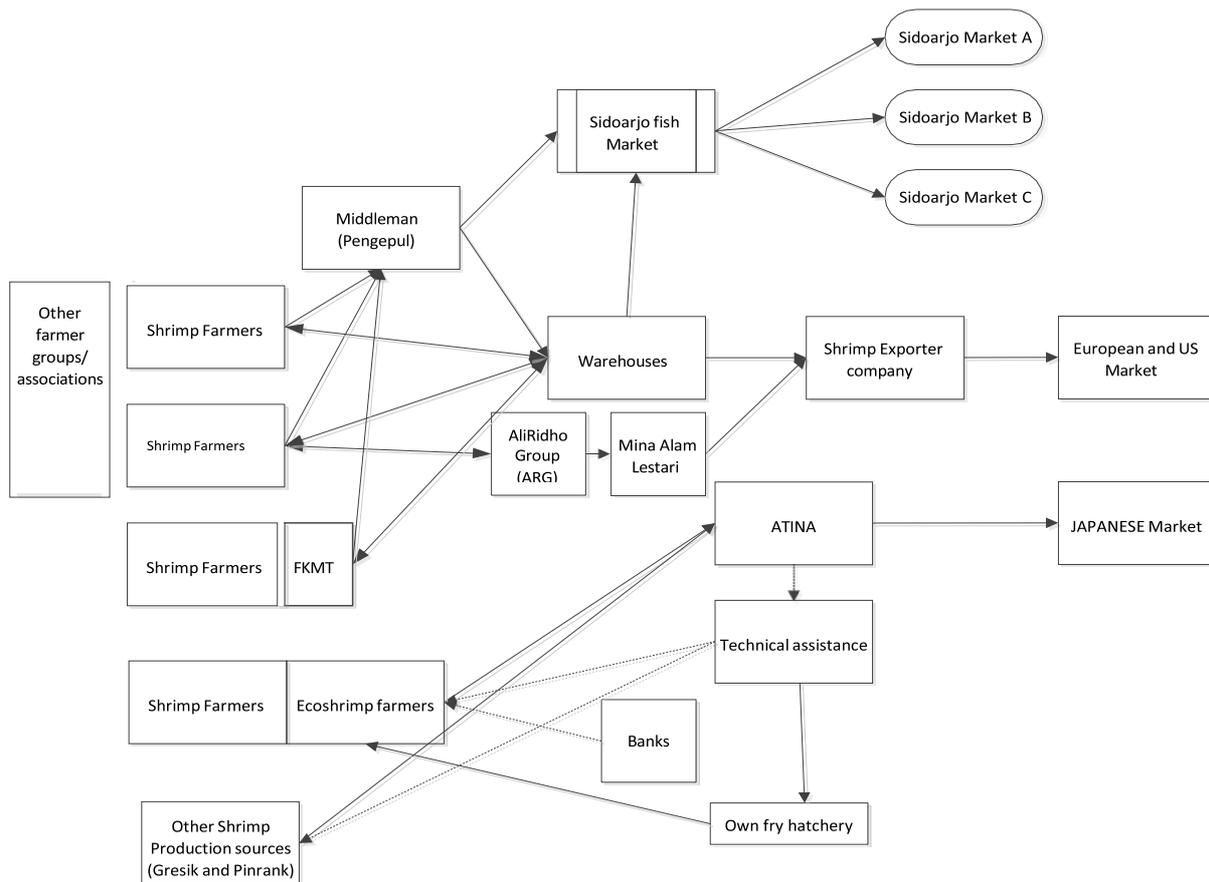


Figure 3.4.1: The shrimp supply chain in Sidoarjo (Fitrianto, 2019).

At national level the following ministries and institutes are of interest:

- Ministry of National Development Planning (BAPPENAS) plays a role in planning, budgeting and supervision, as well as in coordination between national government agencies.
- Ministry of Marine and Fisheries (MMAF) coordinates with local governments regarding policies and program implementation related to aquaculture and management of coastal areas and fisheries.
- Ministry of Public Works and Housing (MPWH) coordinate with local governments on policies and program implementation related to water resources management, including the development and management of irrigation at national level (areas more than 3,000 ha, across country, across province, and national strategy (more than 10,000 ha)).
- Ministry of Environmental and Forestry (MoEF) coordinates with local governments on policies and implementation of programs related to watershed management, environmental pollution and forest area management.
- The National Land Agency or Badan Pertanahan Nasional (BPN) together with Bappeda and public works offices at the local government level coordinate together with regard to spatial planning arrangements.
- Institutions at national level that can provide data and information, include BIG (Badan Informasi Geospasial / Geospatial Information Agency), BPS (Badan Pusat Statistik / Central Statistics Agency), BMKG (Badan Meteorologi, Klimatologi dan Geofisika / Meteorology, Climatology and Geophysics Agency) and BNPB (Badan Nasional Penanggulangan Bencana / National Disaster Management Agency).

4 Nature-based solutions

4.1 Building with Nature

Building with Nature provides holistic solutions integrating system-based physical and ecological aspects of an area with all relevant stakeholders and within the institutional setting, and may be summarized as (Wilms et al., 2020):

Building with Nature integrates Nature-based Solutions into water and marine engineering practice. The essence of Building with Nature is to work with nature rather than against it by considering both engineering and ecological principles in the design process. Implementation of Building with Nature projects requires transdisciplinary cooperation and active involvement of stakeholders which jointly follow a range of iterative steps and phases to develop a Building with Nature project. The Building with Nature approach differs from conventional, single-purpose infrastructure because it demands detailed site-specific understanding of the natural, socioeconomic and institutional systems, as well as business cases and capacity building.

A successful example of a Building with Nature solution is provided by the coastline of the Demak regency near Semarang, Java (see e.g. Tonneick et al., 2022). The coastline of Demak is suffering from flooding and land through land subsidence and poor land use. Existing strategies aiming to counteract these developments (such as construction of hard seawalls and plantation of mangroves) failed. Therefore a building with nature-based approach was adopted through a public-private partnership involving the Indonesian government, the Ecoshape consortium, and Wetlands International (a non-governmental organization). This consortium developed novel nature-based solutions to reduce land loss (permeable structures to trap muddy sediments and thereby revitalize mangrove vegetation) and optimized land use through stakeholder engagement and training of local farmers. This approach was subsequently scaled up to a large number of sites elsewhere in Indonesia.

An important lesson learned from the Demak project is the importance of a participative approach for Building with Nature solutions. Given the short duration of the scoping mission the potential solutions discussed throughout this chapter are based on limited interaction with stakeholders and limited system knowledge. In all aspects, these solutions need to be refined and improved as part of follow-up projects and are at this point a first step only in an iterative, multi stakeholder approach that should eventually lead to sustainable interventions based on thorough system understanding. Based on the (limited) system understanding and stakeholder perspective obtained from the field visit (Chapter 3), we have developed outlines for a number of potential nature-based solutions to improve the functioning of the system. Successful nature-based solutions rely on the six enablers of Building with Nature (illustrated in Figure 4.1.1): system knowledge, management and monitoring, a stakeholder approach within the institutional setting, projects are financially feasible and include capacity building. The potential solutions outlined below (sections 4.2 – 4.4) primarily rely on system knowledge (could the solution work from a physical / ecological point of view?) and on socio-economic factors (absentee ownership and change in aquaculture practice). When expanding these outlines into full solutions as part of future feasibility studies, all enablers need to be addressed in more detail.



Figure 4.1.1 The six Building with Nature enablers (<https://www.ecoshape.org/en/enablers>).

We differentiate between three types of solutions: (1) a system-based rejuvenation of Kepetingan River and Permisan Bay (section 4.2), (2) adaptation of aquaculture practice (section 4.3), and (3) other system-based interventions (section 4.4). The first two types of solutions are in line with the scope of the assignment (aiming at improving aquaculture in areas with polyculture of milkfish and organic tiger shrimp). The third set of potential interventions address environmental issues identified during the scoping mission, but not specifically raised prior to the mission (the coastal erosion in the North of Sidoarjo regency and the complex system response to the Sidoarjo mud volcano). We synthesize these solutions in section 4.5 following the Building with Nature enablers.

4.2 Rejuvenate Kepetingan River and Permisan Bay

Description:

The reduction in salinity in the Kepetingan River is likely resulting from its infilling with sediments. This is the common perspective among all stakeholders and experts and makes sense from a physical point of view. The generally envisaged solution is to deepen the channel of Kepetingan River and Permisan Bay (by dredging). We believe this solution will lead to an improved balance of salt- and fresh water availability, but will be very short-lived because the large availability of mud (especially on the flats of Permisan Bay) will lead to rapid infilling. We propose to rejuvenate Kepetingan River and Permisan Bay through a set of measures (see Figure 4.2.1).

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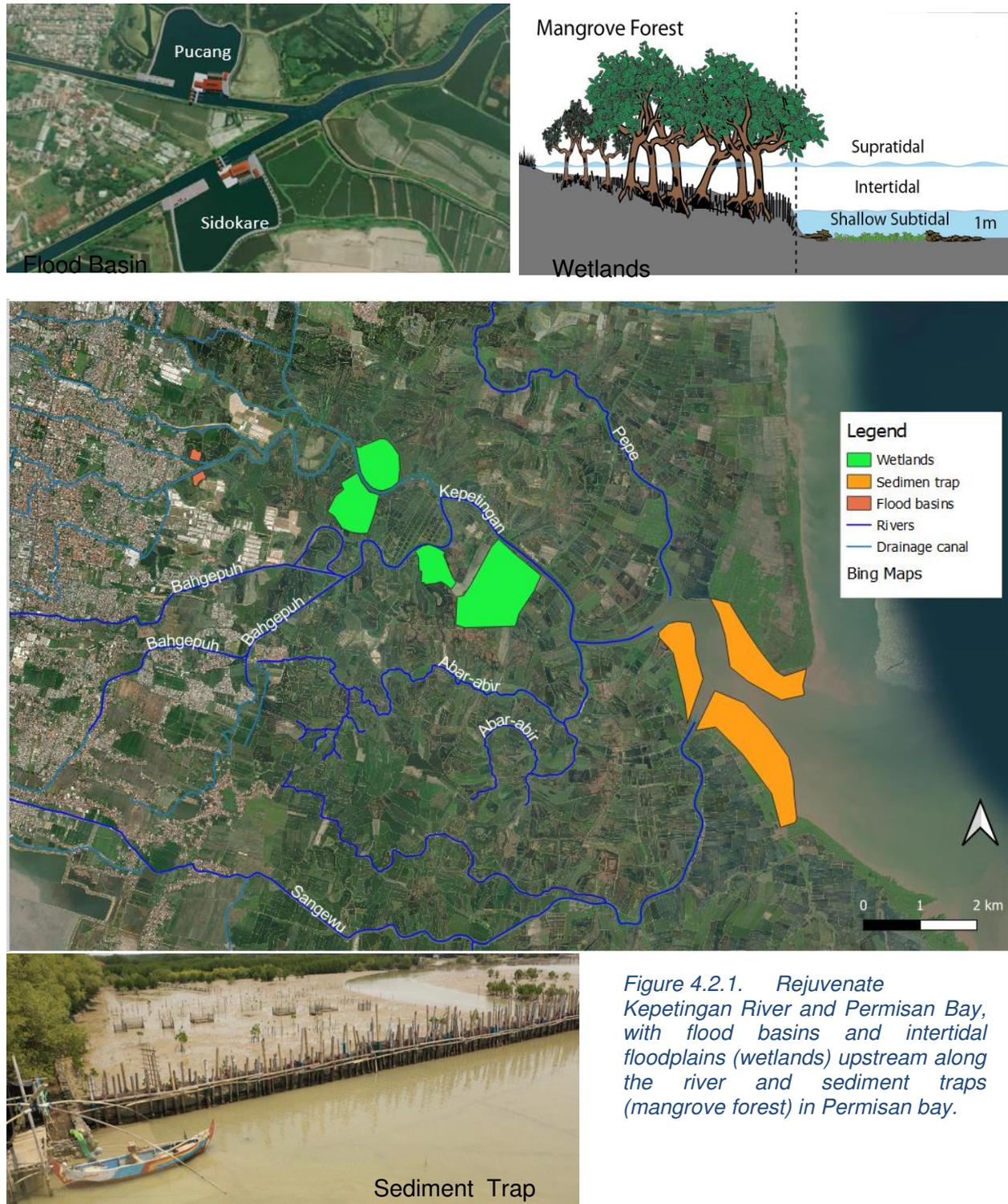


Figure 4.2.1. Rejuvenate Kepetingan River and Permisan Bay, with flood basins and intertidal floodplains (wetlands) upstream along the river and sediment traps (mangrove forest) in Permisan bay.

These measures aim at:

- Creation of wetlands (intertidal areas) to increase the tidal discharge. The increased discharge prevents sediment to settle on the river bed. Wetlands created in the most upstream areas are most effective (since the resulting tidal discharge benefits the whole estuary), and have as additional advantage that they can be combined with flood retention basins (which may be constructed to reduce flooding in urban areas – see section 2.2).

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- Impacting a large part of the river. The relative impact of such wetlands decreases in the seaward direction (as the additional tidal discharge dilutes with the existing tidal discharge). Wetlands should therefore preferably be created along the course of the Kepetingan river.
- Narrow the flow in Permisan Bay by converting the existing extensive tidal flats into mangrove areas. This could be achieved following strategies developed in Demak and subsequently applied elsewhere in Indonesia.
- Trapping sediment in the mangrove areas which would otherwise contribute to channel siltation.

Whether these measures are also sufficient to erode the river bed depends on the strength of the river bed deposits, and therefore whether they should be combined with additional dredging. Such aspects should be part of a feasibility study.

Potential benefits:

- A deeper river will lead to higher salinities, thereby increasing the yield of shrimp ponds.
- A deeper river will probably lead to lower water levels at high tides, reducing flooding in the fishponds but possibly also in the urban areas of Sidoarjo.
- The water will become clearer, benefitting fishery and aquaculture
- The creation of wetlands in the landward areas and creation of mangrove has important ecological benefits: provide nursery grounds for fish and habitat for birds, and sequester carbon (carbon credits could contribute to the business model).
- Some stretches of the coastline along Permisan Bay erode. Creating mangrove fringes prevents that.
- Mangrove rehabilitation contributes to sustainable, ecological development which may improve future livelihood options of local communities.

Potential negative side effects:

- Downstream of these new intertidal areas the relative increase in tidal discharge is largest, which will result in erosion of the riverbed. Sediment eroded from the river bed may quickly lead to infilling of the intertidal area (resulting in a loss of tidal discharge)
- The area is populated, with traditional houses and simple boat quay structures along the river banks. Rejuvenating tidal flow will lead to higher flow velocities to which local people need to adapt. Possibly bank erosion may occur.
- Funneling of the flow in Permisan Bay may reduce tidal dynamics in the Kepetingan River
- Increased salinity strengthens flocculation, and therefore moves sedimentation from the Bay to the river
- When combining flood retention basins with wetland functions: the flood retention basin will fill in with sediments which need to be removed (otherwise the basin does no longer provide storage for floods).
- When the tidal barrier is poorly constructed or maintained it may reduce the tidal discharge. The construction of the barrier-flood retention basins therefore needs to be closely monitored when developing Building with Nature solutions.

Stakeholder involvement and institutional setting (underlined stakeholders and institutions were met during the scoping mission)

Key stakeholders at the local level:

- Local farmers;

- Farmers organizations;
- Processors and exporters, such as Atina., are important beneficiaries and may have the financial means to contribute. At minimum they could share their data.
- Universities, schools and institutes.
- Regency's Bappeda, Fisheries Agency (Dinas Perikanan-DP), Public Works, Highways and Water Resources Agency (Dinas Pekerjaan Umum Bina Marga dan Sumber Daya Air-DPUBMSDA), Environment and Hygiene Agency (Dinas Lingkungan dan Kebersihan-DLHK), Settlement, Housing, Create Works and Spatial Planning Agency (Dinas Perumahan Permukiman Cipta Karya dan Tata Ruang-DPPCKTR).

Institutions at the provincial and national levels:

- Provincial level: Bappeda, DKP, Public Works and Water Resources Agency (Dinas Pekerjaan Umum dan Sumber Daya Air-DPUSDA), DLH, Dishut, Public Housing, Residential Areas, Create Works, and Spatial Planning Agency (Dinas Perumahan Rakyat, Kawasan Pemukiman, Cipta Karya, dan Tata Ruang-DPRKPKTR).
- BBWS.
- National level: MMAF, MPWH, and MoEF.

Recommended activities

- Execute a financial pre-feasibility study. The required investment may be larger than the increase in revenue from fisheries. However, when additionally accounting for the increase in ecological values (and resulting financial gains such as fisheries and Carbon Credits) and food safety, this proposition may become realistic
- Start monitoring. Measure the bathymetry of Permisan Bay and Kepetingan river and install two tide gauges (one in Permisan Bay, and one in the upper reaches of Kepetingan river. Develop a database in which salinity observations that are regularly carried out are stored (or, preferably, equip the tide gauges with a salinity sensor).
- Explore the potential of combining measures aiming at improving environmental conditions with measures to improve safety on an institutional level.
- Execute a numerical model study on the potential effectiveness of wetlands in Kepetingan river and mangrove development in Permisan Bay on tidal dynamics, salinity, and scouring / siltation potential.
- Conduct a feasibility study

4.3 Adaptation of Aquaculture practice

Some of the yields reported in Sidoarjo, both orally and in reports, go beyond what is practically possible for aquaculture in optimally designed ponds without aeration. Without feeding, traditional earthen ponds as used in Sidoarjo can sustainably yield from 500 to 3,000 kg/ha/yr, depending the design of the pond, the (mix of) species, and the quality of available soil, water and its management. In traditional polyculture with well designed ponds, without feeding, these maxima for shrimp and milkfish will be, resp., 800 and 700 kg/ha/yr, given their place in the food chain. MMAF aims for shrimp yields of 600 kg/ha/yr in traditional polyculture, and this might be more realistic for Indonesian conditions. When conventional concentrated feeds are added, but without supplemental aeration, such ponds can sustainably generate 2 to 4 ton/ha/yr (Bosma & Verdegem, 2011). In Sidoarjo, the maxima that can be reached with feeding for tiger shrimp and milkfish are, respectively, 1,800 and 900 kg/ha/yr, in polyculture with seaweed using Good Aquaculture Practices or Cara Budidaya Ikan yang Baik (Ariefa et al, 2015). Using the up-coming 'Nutritious Pond' feeds (Joffre and Verdegem, 2019) could save 15-20% on cost of feed and medicines, and increase the yields with 20%. Higher yields can

only be reached if more feeding is done together with intensive aeration and management. Otherwise soil quality will decrease in long term. More feeding increases risks on loss of harvests and investments, and might not lead to higher income of farmers. Therefore, many larger aquaculture companies either stock shrimp only in half of their ponds, or use their ponds 6-8 month only.

The low yields of the traditional polyculture of milkfish/tiger-shrimp are mainly caused by the (1) poor water quality, (2) poor pond and dike design as well as maintenance, (3) poor pond management due to weak training of farmers and caretakers (4) ownership structure. Good pond design, maintenance and management can reduce the losses due to floods and disease outbreaks. The pond reconstructions require financial capital; for this the farmers may need loans, which banks hesitate to give to the risky aquaculture enterprises. The potential interventions to relieve the above problems require actions at three levels: individual farmers, watersheds and regency. Those at the level of the watersheds have been presented above in section 4.2. To get the farmers moving, first of all the regency needs to initiate an appropriate training program. However, various accompanying measures are needed at institutional level to make changes happen. The following three sections start with a description of the activities.

4.3.1 Train farmers and caretakers in Coastal Aquaculture Field Schools.

To improve the management of pond soil and water, the renters and non-absent owners need to be trained in Coastal Aquaculture Field Schools (CAFS) with a consistent program, as done by Blue Forest in e.g. Sumatra (Brown & Fadillah, 2013) and BwNI in Demak (Widowati et al, 2021). A well-structured experiential, participatory and learner-centered CAFS has 16 sessions addressing each time the same group of 20-30 farmers of a community. After going through such an CAFS, the farmers will understand the biological and ecological factors that influence the yields, will have learned good management practices, and will have enhanced their capacity to analyse and to find solutions. With these capacities and the technologies learned, renters and non-absent owners, could increase their yields and income through improved pond management. Farmers in Demak who harvested a substantial quantity of similar size, marketed their harvest themselves in nearby Semarang. For their organic shrimp they fetched 150,000 IDR/kg. Exporters of organic shrimp in Tarakan (Kalimantan) even pay up to 350,000 IDR/kg (PC Prof Dr Sri Rejeki, UNDIP). With such prices incomes will increase further. It is unknown whether the exporters in Tarakan provide advice and training, like Atina does in Sidoarjo.

In the farmer-centered learning environment of the CAFS the farmers learn organic technologies based on LEISA (Low External Input Sustainable Aquaculture). But, once the farmers get the basics, they can intensify ecologically without compromising sustainability. Thus, CAFS are first of all relevant for the farmers who remain producing for Atina. In Demak, the yields of milk fish didn't increase but in Sumatra these improved by 20%, and those of tiger shrimp were three to four-fold (Table 4.1). In Demak, those improvements helped to double farmers income. However, the baseline of shrimp production in Sidoarjo is much better; which shows that the quality of pond and water are not as bad as in Demak. Nevertheless, progress can be made but trials have to show whether the expected gains can indeed be reached by managing soil and water quality using organic liquid compost. This compost is made of waste of vegetables and fruit, and chopped leaves of specific mangrove trees (Ariyati et al, 2019 and Ecoshape reports Bosma et al, 2020; 2021).

Table 4.1 : Expected effect of a coastal aquaculture field school on yields of organic polyculture, based on the results reached in Demak and other literature (GM = Gross Margin).

Treatment	Milkfish (kg/ha/yr)			Tiger shrimp (kg/ ha /yr)			GM (USD/ha/yr)
	2015	2017/18	Sample	2015*	2017/18	Sample	Sample
Control in Demak *	234 ±363	350 ±527	721 ±429	47 ±47	31 ±23	16 ±55	405 ±267
LEISA in Demak *	-	243 ±427	670 ±285	-	134 ±550	186 ±133	1,344 ±763
Data Sidoarjo 2021**	350			100			
Potential Sidoarjo ***	700			600			

* 2015: average of 113 milkfish farmers of whom 1/3 stocked shrimp; 2017/18: average of CAFS alumni applying the technology; Sample: 14 closely monitored farmers (Widowati et al, 2021).

** Data from Atina and Dinas Perikanan.

*** These do not consider a reduced pond area (see next section); this shrimp yield follows MMAF, but is lower than yields given by Bappeda after 'normalisasi'.

In Demak, the cost of the CAFS program (close to 1,100 USD per trainee) was recovered within a year through the improved income of the farmers only. Such a recovery rate is very rare in training for rural development; most of the time, cost recovery takes more than 3 years, even if program costs are much lower. In Sidoarjo, both the hired caretaker and the renters or non-absent owners need to be trained, which doubles the cost and extends the cost recovery period of the program from one to two years. Moreover, if the contract of the rent or the labor contract of the caretaker, are not extended this investment in training might be lost.

Potential benefits:

Next to the expected increase yields from milkfish and shrimp, the expected benefits for the economy of the regency are:

- The increased turn-over of trade and processing. The tax incomes of those will indirectly pay for the cost of the CAFS program.
- Improved soil and water management will make the production more sustainable.
- The acquired soft-skills give farmers more confidence in decision-making and in public speaking. Farmers can decide to use seaweed and/or mussels to improve water quality and income, can themselves organise feed-back meetings to discuss their innovations, and can also approach experts for the training.
- When the AFS alumni become aware of the positive effect of the changes they will be willing to take other actions (see next sub-section).

Potential negative effects

- The land-owner might increase the rent or offer the contract to other persons. Thus, the investment in training is lost, as well as chances on expected positives trade-offs, unless renter or care-taker find another (better) contract for aquaculture farming.
- The trained persons could move out of aquaculture.

Stakeholder involvement and Institutional setting (stakeholders and institutions that were involved in the discussions during the scoping mission are underlined)

- Bappeda Sidoarjo
- Dinas Perikanan Sidoarjo (DP) and Atina, and their trainers and extension agents
- Farmers organisations and organisations at community level.
- Monitoring agency, e.g. from the Aquaculture department of UB, ITS or PKPS.
- Trainers from UB, ITS and PKPS or from BPBAP Situbondo or Jepara.

Recommended activities:

- Fund a trial to verify, together with some of the farmer organisations, the impact of the technologies, such as LEISA, that the farmers learn in the CAFS.
- Make an inventory of the interest, willingness and capacity of DP, farmers organisations and businesses to participate, manage and co-fund an CAFS program, and of the willingness of farming-owners, renting-farmers and caretakers to participate in 16 sessions of an AFS during 6-8 month.
- Formulate, together with the stakeholders listed above, a co-funded proposal of a well structured AFS program, identify donor(s), and implement an CAFS program.

4.3.2 Interventions by individual farmers

Next to participating in an CAFS training, farmers themselves can contribute to improved salinity levels in four ways:

1. Buying brine (wet salt) collected in the salt ponds in the saline areas (zones 3 in figure 2.2.2) to increase the salinity level. This might not be cost-effective, given the huge pond area each farm has.
2. Pumping brackish groundwater to bring the salinity level of the storage pond up to the required level. This investment is not cost-effective for the traditional ponds with the present yields, but could become accessible if the farmer produces electricity with solar panels and can sell the excess of electricity (see below). Note that pumping salt water will lead to subsidence and therefore aggravate flooding.
3. Giving up part of their plot along the waterway for mangrove rehabilitation to contribute to increased river flow. Given the mostly large farm area, this will hardly impact their yields. At long-term this area will become an estuarine mangrove fringe, and make the organic farm ready for demands of consumer organisations to increase the mangrove cover on farms producing organic products. Making such an Associated Mangrove Aquaculture (AMA) system provides farmers with some benefits: cleaner water, catches of fish in the gate, and mangrove products (Yuniati et al, 2021; Bosma et al. 2020). In Demak this set-aside for mangroves was supported by a bio-rights program (Eijck & Kumar, 2009; Bosma et al, 2020, page 32).
4. Reserving a huge pond to store brackish water in the season with the highest salinity levels. This pond should be much larger than the present storage ponds. This decreases the effective area for shrimp but the storage pond could be stocked with floating seaweeds (reducing evaporation), mussels (cleaning the water) and saline tolerant tilapia (decreasing harmful bacteria in the water). Such a diversification increases the resilience of the farmer's income.

Moreover, this storage pond could be covered with floating solar panels. This has two or (potentially) three benefits: decrease of the evaporation, provision of electricity (see 4.) and provision of supplementary income. For the latter to become concrete, the excess of electricity produced by the farmers solar panels needs to have an outlet, i.e. infrastructure linking the ponds to the villages and cities needs to be available.

Improving the pond lay-out, can be done stepwise, starting with 3 and 4 above, and then:

- making dikes higher,
- building an extra main-gate,
- building canals to separate inlet and outlet water,
- reducing shrimp-pond sizes; smaller ones for nursery and larger for grow-out,
- providing separate in- and outlet for each pond.

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Many farmers might have no means for the interventions proposed above, or might be limited by the ownership structure and the short rent periods. These farmers could alternate seasonally their polyculture products:

- In the season with good salinity levels, they stock milkfish and tiger shrimp, as usual.
- in the season with low salinity levels, they shift to polyculture of tilapia and white leg shrimp.

This is good for two purposes: disease prevention and resilience to shifts in salinity levels.

Potential benefits:

- After the expansion of mangrove greenbelts, the catch-fisheries in the estuarine, near-shore and coastal water of Sidoarjo and proximity can increase up to 37,500 USD/ha/yr. Present values are most probably lower (available statistical data always increase slightly from year to year and do not fluctuate, and are thus not based on recorded actual catches or landings, and unreliable).
- The one-time investment of 235 USD/ha in rehabilitating the mangrove fringes will within some years generate about 400 USD/ha/yr (Hakim et al, 2018).
- The society gets complementary gains come from the increased turn-over of trade and processing. The tax incomes of those will indirectly pay for the cost of the AFS program.
- The improved soil and water management will assure the sustainability of the aquaculture economy of the regency.

Potential negative effects:

- The land-owner might increase the rent or offer the contract to other persons.
- Pumping of ground water leads to subsidence and therefore more flooding

Key stakeholders (underlined stakeholders were met during the scoping mission)

- Farmers
- Land-owners
- Financial institutions
- Farmers organisations
- Dinas Perikanan (DP) and their Extension agents,
- Atina and other buyers of aquatic products, and their Extension agents
- Aquaculture experts from universities and or from BPBAP Situbondo or Jepara.

Recommended activities:

- Make a cost estimate, including forgone harvests, of the increased size of the storage pond and of the rehabilitation into mangrove greenbelts of part of the ponds located along the rivers, canals and creeks in the estuary, and thereafter do an inventory among the owners and farmers of the willingness and constraints to change and invest.
- Raise awareness and willingness of the farmers along the river through CAFS training, and use bio-right financing to support the building of new dikes and sluice gates needed to separate the to-be mangroves from the ponds.
- Make an ex-ante cost-benefit analysis (CBA) of using brine to increase salinity levels
- Make a feasibility study including an ex-ante CBA of the enlargement of the storage pond to store brackish water and to cover this with solar panels to provide power for a brackish water well and to supply electricity to the existing electricity distribution net.
- Asses potential negative impacts of floating solar panels on water quality.

4.3.3 Accompanying measures at the level of the regency.

The biggest hurdle to apply the technologies proposed above is the absentee-ownership of the aquaculture farms. Regarding the solutions related to wetlands/mangroves and water-storage proposed in earlier sections, this (absentee-)ownership structure increases the cost of land-acquisitions. Accompanying measures might enhance land-owners willingness either to invest in their ponds or collaborate with mangrove and wetland development.

We suggest three actions at regency level that might increase the owner's willingness:

- *Oblige longer farm leases or stimulate longer leases through tax measures:* Rent periods of five years are too short to recover investments in major pond improvements. The easiest way to enable cost recovery by renters of farms is to allow only lease periods of 20 years or longer (if indeed the renter makes major improvements on the farm). If long leases can not be made compulsory, the regency might consider tax incentives/disincentives: lower tax rates for long leases and high taxes rates for short leases. Whether such measures are legally possible has to be studied.
- *Discourage expectations of land-owners on high land prices.* To protect Sidoarjo from the risk of tsunami floods and future sea level (inducing more flooding and higher peaks of rainfall) its delta should remain free from ground water extraction and heavy buildings and traffic. This is best achieved by reserving the delta for ecological aquaculture, mangrove and water storage. First, the regency could state firmly in its Five-year plans that its coastal zone has a protected status where next to nature (wetlands and mangroves), only ecological aquaculture will be allowed. As a second step the regency should make this protected status recognised by the Indonesian state. The (absentee) landowners will lower their expectations on easy gains if the delta gets such a destination, and this will make the creation of wetlands, water storages and mangrove greenbelts easier.
- *Differentiate land taxes:* Make land taxes lower for aquaculture farms having the required mangrove belt along the water ways.

Potential benefits:

- First gain for society come through the reduced cost of land acquisition.
- Medium term gain for society come through the reduced losses due to abrasion. In Demak, the cost of to loss of land, infrastructure and livelihoods due to abrasion was estimated at 135 USD/ha/yr (Hakim et al, 2018).
- Long term gains will come from investing once 235 USD/ha in recovering mangrove and improving aquaculture: this will generate about 800 USD/ha/yr (Hakim et al, 2018).

Potential negative effects

- The land-owner might increase the rent or offer the contract to other persons.
- Land prices on other locations might increase.

Stakeholder involvement and Institutional setting (stakeholders and institutions which were involved in the discussions during the scoping mission are underlined)

Key stakeholders at local level:

- Regency level: Bappeda, BPN, DP, DPUBMSDA, DPPCKTR, and DLHK.

Institutions at higher level:

- Provincial level: Bappeda, DKP, DPUSDA, DPRKPKTR, DLH and Dishut.
- National level: MMAF, MPWH, and MoEF

- Legal expert centre from e.g. Surabaya University.

Recommended activities

- Organise a Visualisation Workshop, with Bappeda Sidoarjo on the expected impact of sea level rise due to climate change, on the potential impact of a tsunami as in 2004 and on the adaptation measures, such as making the delta a conservation area for ecological aquaculture and wetlands to store water and harbor nature, that can prevent disasters and maintain the city's delta for the future generations.
- Initiate a study to stimulate longer land lease. For instance, an assessment by legal and tax experts on the potential of obliging longer land lease or the implementation of taxation levels that stimulate longer lease.

4.4 Other system-based interventions

4.4.1 Rejuvenation of the coastline North of Permisan Bay

Description:

Coastline erosion in the North of Sidoarjo Regency appears to be triggered by estuarine infilling (see section 3.1), likely in response to loss of tidal discharge and / or reduction in fresh water flow. The tidal discharge may have been reduced in response to the construction of fishponds, but also because of rerouting of rivers in response to urban development (such as the construction of Juanda airport). If this is the case, there is a need to restore the tidal flow in the Buntungan estuary. A nature-based solution for the eroding coastline would then consist of two parts (see Figure 4.4.1):

- Create intertidal wetlands in the Grand afvoer (Indonesian name of channel type) and Buntung river upstream of the estuary to increase the tidal discharge, scour sediments that previously deposited there, which are subsequently transported southward (especially in the wet season).
- Trap sediment along the eroding sections through the construction of permeable dams

This part of the Sidoarjo coastline will be developed for industry and housing. The resulting pressure on available land, and likely increase in price of land, might imply that creation of wetlands is too costly. On the other hand, it may also provide an opportunity, when nature restoration is a requirement for urban development.

It should be noted that it cannot be ruled out at this point that subsidence is (additionally) responsible for coastal erosion. If so, estuarine restoration is probably not sufficient to counteract erosion rates (although this depends on the overall sediment balance).

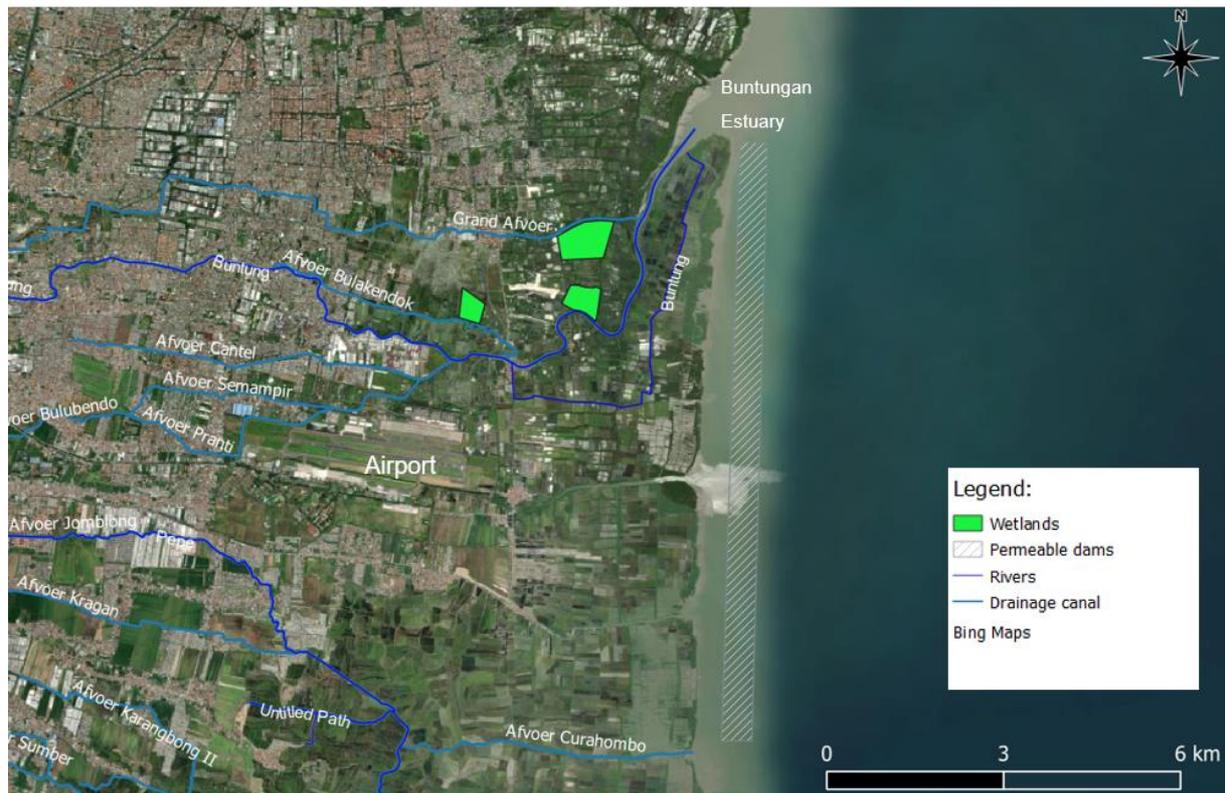


Figure 4.4.1 Rejuvenation of the coastline North of Permisan Bay

Potential benefits

- Reduction of erosion rates along the downdrift coastline, and probably even expansion of the eroded sections. Such an erosion reduction is a crucial boundary for any future urban / industrial development in the area. In time, erosion could even threaten Juanda airport which is 3.2 km from the old coastline (although so much erosion will probably require subsidence to play a role as well).
- Rejuvenation of the coastline may restore the sediment balance in such a way that sediment is no longer transported towards Permisan Bay (thereby benefitting Kepetingan River)

Potential negative side effects:

- Expanding the estuary will lead to erosion of the mangrove area that developed in response to estuarine infilling. Apart from the loss of natural areas, this may lead to legislative problems.

Stakeholder involvement and institutional setting (stakeholders and institutions were involved in the discussions during the scoping mission are underlined)

Stakeholders:

- Surabaya airport (Bandar Udara Internasional Juanda)
- Local farmers
- Farmers organizations
- Universities

Institutions:

- Regency level: Bappeda, DP, DPUBMSDA, DLHK, and DPPCKTR.

- Provincial level: Bappeda, DKP, DPUSDA, DLH, Dishut, and DPRKPKTR. National level: MMAF, MPWH, and MoEF

Recommended activities

- Start monitoring subsidence. Whether or not subsidence contributes to or even dominates erosion rates is crucial for future activities.
- Connect with institutions responsible for urban / industrial development in the area threatened by erosion for potential joint development
- Execute a study on sediment transport directions in the dry and wet season. Differentiate between coarser particles (sand, coarse silt) that directly impact coastline stability and of which transport is largely driven by waves, and fine material (fine silt, clay) that is transported by residual flows.
- Conduct a feasibility study

4.4.2 Sustainable land development Porong delta using mud from the mud volcano

Description:

The eruption of the mud volcano has led to subsidence in the immediate vicinity of the volcano, and discharging its sediment into the Porong river has led to a sharp increase in land development in the Porong delta. For the subsidence, a major issue is whether it is caused by compaction (by the weight of the contained deposit) or by loss of volume at greater depths. In case of the first, removing the sediment should be given key priority as it may reduce or even stop subsidence. Also when its weight is not driving subsidence the sediment should be eventually be removed.

The volcano deposits have little economic value as construction material. A cheap way of removing the mud is to flush it seawards via the Porong river (in addition to the fresh mud outflows which are already flushed seaward at this moment) – see Figure 4.4.2. This would create large amounts of new land, especially when the amount of discharged sediment is significantly increased relative to the present amount (1-2 million m³ of sediment per month).

Even when not increasing the sediment load by discharging sediment loads, sustainable development of the Porong delta requires in-depth understanding of its dynamics. For instance, the newly developed land (Lusi Island) may start eroding when the Porong switches from its main distributary (now the southern outlet, but a northern outlet appears to be taking over) – see Figure 4.4.2. Land reclamations for aquaculture (for which plans are under development) not accounting for such dynamics may be quickly eroded once the main outlet switches.

A Nature-based solution is to sustainably develop the delta, accounting for natural dynamics when converting new land to aquaculture, either under current conditions (with the Porong discharging mud freshly released by the volcano) or with additional sediment resulting from the existing deposit. Discharging the existing sediment deposits has technical aspects (dilution of the compacted mud with river water and subsequent transport into the Porong via pipelines) but the most challenging aspect is to make sure the river mouth is not blocked by sediment to a degree that flood risks increase.

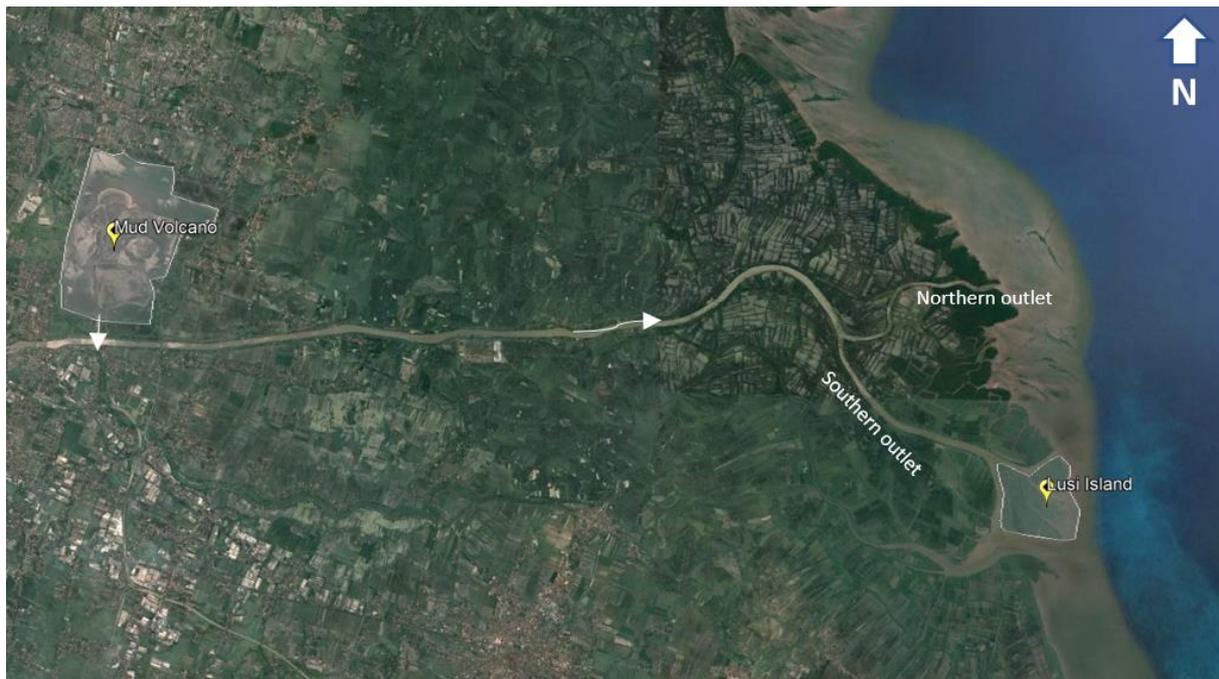


Figure 4.4.2. Overview of land development in the Porong delta using mud from the mud volcano

Potential benefits

- Sustainable creation of new land and nature
- Mitigating subsidence rates around the mud volcano when removing sediments

Potential negative side effects

- If subsidence results from compaction by weight of the contained deposit, sediment probably needs to be removed faster than the Porong river is able to sustainably discharge.
- Rapid delta development may be erratic and cannot be exactly predicted – this requires the adoption of sufficiently large safety margins (i.e. slowly convert new land into aquaculture)
- Flushing of sediments may lead to the Porong river becoming shallower, and/or rapid developments of new islands. Both lead to a reduced discharge capacity. This may lead to a reduction in flood safety.
- When the channel switches to a northern position more sediment may be transported to Permisan Bay.

Stakeholder involvement and institutional setting (underlined stakeholders and institutions were met during the scoping mission)

Stakeholders:

- Local community
- Universities

Institutions:

- Regency level: Bappeda, DP, DPUBMSDA, DLHK, and DPPCKTR.
- PPLS.
- BBWS.
- Provincial level: Bappeda, DKP, DPUSDA, DLH, Dishut, and DPRKPKTR.

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- BNPB or Regional Disaster Management Agency (BPBD).
- Center for Coastal and Marine Resources Management or Balai Pengelolaan Sumberdaya Pesisir dan Laut (BPSPL) Denpasar.
- National level: MMAF, MPWH, and MoEF.

Recommended activities

- The first activity needs to be monitoring of the scale of subsidence and the mechanisms responsible for subsidence – this determines the speed at which action need to be undertaken. The rate may be mapped using satellite imagery, the type of compaction requires a geotechnical study.
- Discuss the potential of flushing mud volcano sediments with stakeholders, and inventorise the willingness among stakeholders and institutions to convert new land into aquaculture following the natural dynamics of delta development
- Quantify sediment budgets and determine the sediment composition and pollution level of volcano sediments to estimate the potential of using the Porong to flush sediments- from a physical and environmental point of view.
- Closely monitor the dynamics of the delta using satellite images and preferably in situ measurements
- Quantify delta dynamics for various scenarios of mud supply and assess flood safety issues using numerical models.

4.5 Synthesis

As mentioned in section 4.1, Nature-based Solutions are a combination of socio-economic and technical measures that address the root cause of the problem, based on a solid understanding how the system functions. Successful Nature-based Solutions should build on six categories of Building with Nature enablers (Figure 4.1.1). The solutions brought forward in sections 4.2 to 4.4 adhere to these enablers as follows.

Technology and system knowledge

The coastal plain of Sidoarjo Regency was formed by abundant fluvial sediment supply from the Porong river, shaped by tidal dynamics into a system of creeks and mangrove forests, which was subsequently converted into an aquaculture landscape. The present-day coastal plain is still adapting to its conversion to fishponds and modification of upstream river courses, resulting in infilling of creeks and degeneration of rivers. Such a response may take a long time through complex interacting mechanisms, such as disruption of alongshore sediment transport by infilling of estuaries leading to downdrift coastal erosion. The system is further disrupted by the relatively recent eruption of a mud volcano, leading to subsidence, infilling of smaller rivers, and instability of the Porong river mouth. Improving the environmental state of the Kepetingan river and Permisan Bay in a sustainable way therefore requires system knowledge on how the system responded to earlier interventions and thereby also to future interventions. The solution brought forward in section 4.2 is based on a limited amount of information, which needs to be expanded before implementation takes place.

Multi-stakeholder approach

The main stakeholder are users and owners of the fishponds. In Sidoarjo the users are often not the owners of the fishponds, which complicates investments in these fishponds. An important local player is ATINA, exporting traditionally grown tiger shrimp. When the aquaculture yield is improved through rejuvenation of river systems, the number of stakeholders increase because flood safety is influenced (due to a change in water levels, but

possibly also through joint use of flood retention basins for improving tidal dynamics). This will especially concern Bappeda. Rejuvenation of rivers, especially when combined with creation of mangrove forests, will lead to higher fish stocks, benefiting fishery.

Management, monitoring and maintenance

Available data is scarce and therefore monitoring is, at this point, key to understanding the system. It is strongly recommended to start monitoring as soon as possible, especially land subsidence, water levels, and salinity levels. Interventions can only be properly managed (and adapted, if necessary), when monitoring starts prior to execution of interventions.

Institutional embedding

Solutions need to be properly embedded along three governmental levels (regency, province, and national) and multiple ministries. On a national level the various ministries include MMAF, MPWH, and MoEF. See details above for related institutions on a provincial and regency level. All aspects related to fisheries and aquaculture are primarily the responsibility of MMAF. However, deepening of rivers and safety against flooding belongs to MPWH, large-scale development to MNDP, while permits may require involvement of MoEF. By adding the Porong river more institutions responsible for managing the river and flood control, need to be engaged.

Business case and financing

Large-scale rejuvenation of Kepetingan River and Permisan Bay may be more costly than only the increased revenue from aquaculture. Therefore, a business case aiming at rejuvenating the system needs to explore additional benefits (such as carbon storage, flood reduction, increase in fish stock) but also joint developments (such as joint use of flood retention basins as intertidal storage). Adaptation of aquaculture practice is less costly than rejuvenation, and associated costs may be carried by the increase in aquaculture revenue. The north coast of Sidoarjo regency is going to be industrially developed, even though the area is presently suffering from extensive erosion. This industrial development does, however, provide financial means to rejuvenate the coast. The business case related to the mud volcano is again completely different, since this includes revenues resulting from increased land development, costs resulting from bank erosion (channel switching in the delta), flood risk (resulting from excess deposition in the mouth), and subsidence (already leading to adaptation of hydraulic works and adaptation of houses).

Capacity Building

The improvement of aquaculture practice depends strongly on training and capacity building of local aquaculture farmers. An important issue here is ownership, as a large part of the ponds are rented. The required changes in pond infrastructure will be difficult to achieve by renters, because the short rent periods do not allow to recover large investments.

It should be reiterated that the potential solutions described here are based on a site visit, discussions with local stakeholders and experts, and global databases. The proposed solutions are not yet ready for implementation because they are based on insufficient knowledge of the functioning of the system. They do illustrate the potential for developments in the area and provide directions for follow-up work.

5 Next steps

The main purpose of the scoping mission is to evaluate whether Nature-based solutions can contribute to solving aquaculture problems in Sidoarjo, especially in areas with organic tiger shrimp farming. This scoping mission identified Building with Nature strategies which may resolve the salinity problems and thereby improve aquaculture revenues. However, this scoping study also revealed that:

- The effort (and therefore costs) to rejuvenate the river suffering from siltation and low salinity is substantial. An easier solution may be to change the existing type of aquaculture.
- Additional erosion and sedimentation issues exist North and South of the initial main area of interest, which may influence the aquaculture in the main study area through a complex cascade of cause-effect mechanisms which are poorly understood.
- These issues will probably become progressively more important in the future and require a Building with Nature approach to solve in a sustainable way.
- Such upscaling would require involvement of additional institutions, which have not been part of this scoping mission.

This chapter provides an overview of the various stakeholders / institutions which are already involved, or which need to be involved in the future, for the various nature-based solutions identified in Chapter 4 (section 5.1). Section 5.2 proposes follow-up projects required to move towards implementation of nature-based solutions. Potential financial structures in both the Netherlands and in Indonesia are briefly summarized in section 5.3. Concrete recommendations follow in section 5.4.

5.1 Stakeholder involvement and institutional setting

Rejuvenation Kepetingan River and Permisan bay

The process of rejuvenation Kepetingan River and Permisan Bay can be carried out by the Fisheries Agency (DP) and the Public Works, Highways and Water Resources Agency (DPUBMSDA) through Bappeda coordination at Sidoarjo Regency level. DP can focus on revitalizing aquaculture, mangrove rehabilitation and spatial planning in coastal areas. Meanwhile DPUBMSDA focuses on river and flood management which includes deepening of rivers, maintenance of river embankments, tidal barriers, flood retention basins, urban flooding and rural flooding. Regarding river management, BBWS can also take a joint role with DPUBMSDA. To assist planning, support from local universities such as ITS and UB can be involved through research related to the program to be implemented. Allocation of funds for activities can use related agency funds at the district, provincial and even national levels. Coordination also needs to be carried out with the MMAF and MPWH at the provincial and national levels, to ensure that the programs to be carried out are aligned with the programs implemented at the provincial or national levels.

Adaptation of Aquaculture practice

The process leading to the adaptation of aquaculture practices needs to be started by DP with support from Bappeda, both in Sidoarjo (process leaders). We recommend the leaders to ask support from Blue Forest and to identify and engage a coordinator with expertise in the field school approach, and to do three preliminary studies (see 5.2). ITS and UB might be interested to do these studies. Part of the funding should come from reallocations in the budget of DP.

After the provincial and national offices of MMAF and Bappeda agree, and DP intends to actively participate in the program, a temporary external organisation (project) should still advice on the AFS program and its preliminary steps (see below). If DP supports and participates in the program, a temporary organisation (project) could take the lead in starting DP's AFS program.

The leaders need to involve the organizations of farmers and processors in the formulation of the program proposal. The leaders need to inform and get authorization from the Ministry of Marine Affairs and Fisheries (MMAF) through its provincial offices, also for potential complementary budget allocation. Once the program is approved and funded expertise for specific training sessions in the AFS curriculum can be found at UB, PKPS, ITS, BPBAP of Situbondo or Jepara, or the aquaculture department of UNDIP (Universitas Diponegoro).

Rejuvenation of the coastline North of Permisan Bay

The agency that can carry out the rejuvenation process of the coastline North of Permisan Bay is the Fisheries Service (DP). In addition, the agencies that can be invited to work together are the Public Works, Highways and Water Resources Agency (DPUBMSDA) and the forestry service (Dishut) through the coordination of the local Bappeda. The DP will play a role in the management of coastal areas which includes handling erosion/abrasion, mangrove rehabilitation, aquaculture (brackish and marine), and spatial planning. DPUBMSDA can support flooding measures such as tidal barriers, while the Dishut can also support mangrove rehabilitation. Apart from at the district level, coordination also needs to be done with the MMAF, MPWH and MoEF at the provincial and national levels. Meanwhile, the allocation of funds can use the budget of the relevant agencies at the district, provincial and even national levels. If research supports to understand the system so that planning can be carried out better, then local universities such as ITS and UB can be involved. In addition, Juanda International Airport can also be involved, because the planned activities can provide benefits for the existence of the airport in Sidoarjo.

Sustainable land development in the Porong Delta using the mud volcano

The process of sustainable land development in the Porong Delta using the mud volcano can be led by the Sidoarjo Mud Control Center (PPLS) by involving various agencies such as the Public Works, Highways and Water Resources Agency (DPUBMSDA), Marine and Fisheries Agency (DKP) and the Environment Agency (DLH). PPLS as part of the ministry of public works can cooperate with BBWS by taking a major role in Sidoarjo mudflow management which includes social management, eruption control, mudflow, and infrastructure development. Meanwhile, DKP or MMAF also plays an important role in management of the new island formed by Sidoarjo mudflow, and works closely with BPN regarding the legality of new island. Given the system changes that have occurred, an environmental study needs to be carried out for this activity, so that DLH and also local universities such as ITS and UB can take this role. Allocation of funds and coordination of activities can be led by Bappeda at each level of government, from district to national level.

5.2 Potential follow-up projects Kepetingan River

A first recommended follow-up project is to investigate in greater detail what solutions for revitalizing the aquaculture along Kepetingan River are most realistic from a physical, stakeholder, institutional and financial perspective, and, to support this decision making process, to start monitoring as soon as possible. This potential follow-up project should include the rejuvenation of the river, but also the changes in aquaculture practice.

We recommend executing the following studies as part of (pre-)feasibility assessment (see section 4.2 for details) on a short term:

- Estimate of the costs of the various nature-based solutions, expected financial gains (based on existing information) for aquaculture, but also the potential financial gain resulting from reduced flooding.
- Start monitoring. Measure the bathymetry of Permisan Bay and Kepetingan river and install two tide gauges (one in Permisan Bay, and one in the upper reaches of Kepetingan river. Develop a database in which salinity observations that are regularly carried out are stored (or, preferably equip the tide gauges with a salinity sensor).

With respect to aquaculture, we recommend to

- Make a feasibility study, including an ex-ante cost-benefit analysis (CBA) of the enlargement of the storage pond to store brackish water and to cover this with solar panels to provide power for a brackish water well and to supply electricity to the existing electricity distribution net.
- Make an ex-ante CBA of increasing storage pond area and rehabilitating mangrove greenbelts in ponds located along the waterways, and study the possibilities to oblige longer land leases or/and to implement differentiated tax levels stimulating longer leases. Thereafter do an inventory of pond ownership and of the constraints and the willingness among owners and farmers to change and invest under scenarios of longer leases and differentiated tax regimes.
- Fund a trial in six repetitions to verify, together with some farmer organisations, the impact of LEISA and other technologies farmers learn in an Aquaculture Field School (AFS), and make an inventory of the willingness and capacity of the Fishery Agency, farmers organisations and businesses to participate, manage and co-fund an AFS program of 16 sessions during one culture season for groups of 20-30 farmers.

On an institutional level, we recommend to

- Explore the potential of combining measures aiming at improving environmental conditions with measures to improve safety on an institutional level (for instance, is it realistic to assume that flood retention basins may serve as tidal wetlands?).
- Organise a Visualisation Workshop with horizon 2100, together with Bappeda, on the expected impact of sea level rise, on the potential impact of a tsunami and on the adaptation measures, such as making the delta a conservation area for ecological aquaculture and wetlands to store water and harbor nature, that can prevent disasters and maintain the city's delta for the future generations.

Any further steps in physics-based solutions require more quantitative insight into the potential benefits of solutions. We therefore recommend to

- Execute a numerical model study on the potential effectiveness of wetlands in Kepetingan river and mangrove development in Permisan Bay on tidal dynamics, salinity, and scouring / siltation potential.

These studies and activities provide input for a full physical, environmental, social and economic feasibility study.

5.3 Additional potential follow-up

Although the scoping mission focused primarily on Kepetingan River and Permisan Bay, the team also identified coastal developments with potentially greater ecological and safety impact

than those in Kepetingan River, which would strongly benefit from nature-based solutions: coastline erosion north of Permisan Bay and the impact of Sidoarjo mud volcano. These developments are not explicitly mentioned as problematic by stakeholders met during the scoping mission, and therefore discussed here on a lower level of detail.

For the coastline North of Permisan Bay the following next steps are recommended as part of pre-feasibility activities / projects:

- Start monitoring subsidence and/or compute subsidence rates using historic satellite images. Understanding whether subsidence does or does not play a significant role in erosion is crucial for mitigating erosion.
- Discuss the apparent level of urgency of the with relevant stakeholders: Juanda airport (which is partly a military airport as well), commercial and government bodies aiming to develop the eroding coastlines in the near-future, and stakeholders which are relevant for current land use (aquaculture).
- Conduct a pre-feasibility study on rejuvenating the streams responsible for infilling of the Buntungan estuary
- Conduct a first-order sediment transport study to estimate the relevant sediment sources and sinks, and transport rates of sand and mud for dry and wet season conditions

For the mouth of the Porong in combination with the mud volcano, the following next steps are recommended as part of pre-feasibility activities / projects:

- Start monitoring subsidence rates and determine the reasons the area around the volcano is subsiding. If earth surface compression by the volcano deposit is important, then key priority needs to be given to removing it
- Discuss the potential of flushing volcano sediments with stakeholders, and make an inventory of the willingness among stakeholders and institutions to convert new land into aquaculture following the natural dynamics of delta development
- Quantify sediment budgets and determine the sediment composition and pollution level of volcano sediment to estimate the potential of using the Porong to flush sediments

These studies and activities provide input for a full physical, environmental, social and economic feasibility study

5.4 Recommendations

With reference to the original scope related to the aquaculture problems around the Kepetingan river we recommend to first:

1. Start monitoring salinity and water levels in the Kepetingan river
2. Execute a financial pre-feasibility study on measures in Kepetingan River and Permisan Bay (see section 4.2 for details) as part of a relatively small-scale follow-up study. This will identify whether it is realistic to continue developing Nature-based solutions for this area.
3. Fund the trials and studies related to pond improvement and technologies to be learned and formulate, together with the stakeholders listed above, a co-funded proposal of a well-structured AFS program (section 4.3).
4. Quantify the approximate impact of measures as part of follow-up studies.

With reference environmental threats related to the mud volcano and the eroding coastline north of Permisan Bay we recommend to first:

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1. Start monitoring subsidence around the mud volcano and along the eroding coastline in the North.
2. Extend the stakeholder community to discuss enlarging the focus area to (1) include the eroding coast in the North of Sidoarjo regency, and / or management of land subsidence, and of sediment (removal of mud volcano sediments and sustainable land development in the Porong delta).
3. Improve system understanding at both sides by carrying out more detailed sediment transport studies.

As a second step, and depending on the outcomes of these first steps, we recommend carrying out a selection of the activities described in more detail in chapter 4.

6 Conclusions

This report provides the findings of a scoping mission executed by EcoShape from 5 to 9 December 2022, aiming to investigate the potential of solutions following Building with Nature principles. The EcoShape team made an analysis of the Sidoarjo coastal plain and its aquaculture, covering physical, ecological, societal and institutional aspects, and of potential (nature-based) solutions. These solutions were analysed according to the six categories of enablers for successful Building with Nature applications. In our conclusions below we make reference to the research questions written down in chapter 1 (referred to as Q1, Q2, etc.).

The key problem is a stagnation in aquaculture productivity, largely resulting from a reduction in salinity in the main river draining the fishpond area (the Kepetingan river) leading to lower productivity than might be realised under more favourable conditions (Q2). This decrease in salinity is caused by excessive sedimentation on the bed of the river, leading to a reduction in landward salt transport from downstream Permisan Bay into the Kepetingan river (Q1). Solutions may focus on addressing aquaculture practice (such as changing to a more freshwater tolerant species or adjusting pond infrastructures to store brackish water) or improving the physical system (Q3). Deepening the river through dredging will momentarily improve salinity conditions, but probably rapidly deteriorate due to sediment infilling. More sustainable improvement of the system could be realised through Building with Nature solutions, such as a combination of developing wetlands, rehabilitating riverine mangrove belts and trapping sediments (Q4). Such modifications may be financially feasible when coupling them with flood safety issues (lowering of water levels through deepening, using flood retention basins as wetlands, accounting for secondary benefits such as increase in fish catches and green solutions such as carbon storage and solar energy generation) (Q5). Important stakeholders and institutions are Atina (an international shrimp exporting company, Bappeda at the regency level for coordination, and the Ministry of Maritime Affairs and Fisheries being responsible for aquaculture, although various additional ministries were identified playing a role on regency, provincial, and national level (Q6). We have summarized a number of next steps to be taken. A recommended first step is to do cost-benefit analyses to evaluate the financial feasibility of the Building with Nature solutions followed by additional studies on system understanding and extending stakeholder involvement (Q7). A range of potential financial structures were identified (Q8), but these should be explored in much greater detail in a later stage.

During the mission a number of additional threats to the physical system were identified which are outside the original scope of the mission but are strongly related to the original scope. These include the erosion of the North coast of Sidoarjo regency, probably in response to various human developments on land. The eroded land is presently used for aquaculture but is planned to be industrially developed. A second important threat to the physical system is a continuous release of mud from a mud volcano, leading to subsidence, bank erosion and enhanced flood risks, but also to the creation of new land. Both issues may be mitigated through Building with Nature solutions, of which outlines are presented in this report.

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Appendix A Summary of scoping mission activities

Overview Schedule

No	Date	Activity
1	5 Dec 2022	Meeting with DJPB (Direktorat Jenderal Perikanan Budidaya) at Mina Bahari IV buildings, Jakarta
2	6 Dec 2022	Workshop with stakeholder at Bappeda, Sidoarjo
3	7 Dec 2022	Site visit to Permisian Bay
4	8 Dec 2022	Internal team summarised the informations and findings from site visit
5	9 Dec 2022	Closing at Bappeda (Internal meeting share the findings and idea)

Meeting With DJPB

Date :	Monday, 05 December 2022
Place :	Mina Bahari IV buildings, MMAF, Jakarta
Participant :	EcoShape team and DJPB (Direktorat Jenderal Perikanan Budidaya) team. List of participants is attached.



Workshop with Stakeholders

Date :	Tuesday, 06 December 2022
Place :	Bappeda Building, Sidoarjo
Participant :	EcoShape team, Bappeda Sidoarjo, PUSDA Jawa Timur, Dinas Perikanan Kab Sidoarjo, Direktur Politeknik Kelautan dan Perikanan, PT Atina, Pusat Penanggulangan Lumpur Sidoarjo (PPLS), Lembaga Maritim NU Sidoarjo (local NGO), Pokdakan Sumberurip, pembudidaya. (the list of participants is attached)



Site Visit to Permisan Bay

Date :	Wednesday, 07 December 2022
Place :	Kepetingan river, Permisan Bay
Participant	EcoShape team, Bappeda Sidoarjo, PUSDA Jawa Timur, Dinas Perikanan Kab Sidoarjo, Direktur Politeknik Kelautan dan Perikanan, PT Atina, Pusat Penanggulangan Lumpur Sidoarjo (PPLS), Lembaga Maritim NU Sidoarjo (local NGO), Pokdakan Sumberurip, pembudidaya. (the list of participants is attached)

Several places are visited as summarised in the figure below. local villagers are interviewed (Pond owner, Pandega, Boat drivers) to get informations and confirmations on what is happening at the locations.

Permisan bay

1. Mangrove ecosystem (Rhizophora, Avicania, Nypa, Accanthus) is found in the estuary and at the dike of the ponds. However several dead mangroves are found at the west side and also the planted mangrove in the east side of the kepetingan Estuary.
2. The mangrove coverage area is decreasing from 1283,35 Ha in 2013 to 1058,25 Ha in 2016
3. The use of mangrove tourism is still in small-scale which is in Jabon regency.

Pond trained by Atina

1. Several communities (kelompok masyarakat pengawas (Pokmaswas)) are present: Pokmaswas Juanda Lestari di Kec Sedati, Pokmaswas Ketingan Jaya di Kepetingan, Pokmaswas Pucuan Lestari di daerah Pucuan, Pokmaswas Akar Delta Ujung di daerah Jabon.
2. There is 1 group of farmers, namely the Airlangga group.
3. Pond management system: Owner (unable to work on the pond / people outside the area -> Tenants -> Pandega (farm workers or supervisors). Pandega is paid 15% of the crop
4. The majority of ponds are rented from local people or outsiders from the village. The pond rental price is around Rp 70 million per year for the pond area is 12 ha.
5. Type of culture : Polyculture bandeng and windu. Sickness: White spot specially during rainy season.

6. Salinity currently reaches 6 ppt
7. Windu which should be harvested at the age of 3-4 months, is currently only harvested at the age of 2 months. If the yields are good enough, they can reach size 30 at a price of IDR 120,000/kg.
8. If the yield is good, farmers can get about 1 ton per harvest, but if the harvest is bad, they can only get around 100 kg. Meanwhile, milkfish can achieve a yield of around 1-2 tons per 6 months.
9. Pond technicalities in the Mrutu Pond area do not only have 1 pond gate which is used for inlet and outlet. The pond preparation process begins with drying by means of suction using a pump, but at this time the pond cannot be completely drained. Only the court can be drained.
10. In the middle of the pond courtyard there is a section to collect fish during harvest, because harvesting cannot be done in 1 day.
11. Pond design that has an area of hectares, allows farmers to make reservoir ponds as water filters before entering the cultivation location.
12. Fishermans do not fertilize the pond area because the cost of procuring manure to the location is quite high.
13. Fishermans do not provide additional feed intake and only rely on algae and natural feed that grows in the pond
14. Constraints for water supply in the estuary are quite shallow and the volume of water from the upstream is also large so that it cannot release or dispose of water optimally. The current normalization is only widening the estuary while farmers hope that normalization will be carried out by dredging or deepening the estuary.

Fresh water tilapia ponds + vaname (Banjar Panji, Kec Candi)

1. The majority are rental ponds with an area of 4-40 ha with rental costs reaching Rp 80 million.
2. Salinity reaches 10 ppt with vaname and mujaer scattering. This cultivation is considered beneficial by farmers because tilapia mucus can suppress pathogenic bacteria and break the disease cycle in vaname. Vaname shrimp can be harvested at the age of 1.5 months or 4x the cycle in 1 year and tilapia can be harvested 2x the cultivation cycle. Farmers themselves often do partial harvesting for vaname.
3. Price for Paname (1.5-2 months reach Rp 50.000/kg and sale to local market.
4. Pond management is carried out using the traditional plus system by adding additional feed, especially for low protein tilapia, while vaname will eat leftovers from tilapia.
5. At this location there is no milkfish cultivation because the density level is low compared to tilapia which can be stocked 40 fish per meter. The age of milkfish is also considered long enough to reach the ideal harvest size. Meanwhile, for tilapia, if you get good seeds, you can harvest it every 4 months.
6. Inlet and outlet become 1.
7. Ponds can no longer be drained, especially in the Caren area.
8. Vaname diseases : WS, White feces, that happens all the time.
9. Tilapia disease: Aeronomas.
10. Farmers complain about the decline in water quality. Rain and drastic weather changes can cause the death of plankton and emergence of Aeromonas pathogens. However, some fishermans have tried to rotate the water in 1 plot with a pump to regulate the temperature so it doesn't change too drastically.
11. Another obstacle is the shallow canal/river that empties into the Alo River which is used for pond operations. The condition of the river is higher than the pond so that the pond can no longer be drained. Ponds are drained only once a year and not

optimally. In the 2000s, ponds were completely drained, especially in the 8th month (August). Apart from the shallow river, another obstacle is the large amount of garbage that comes from upstream.

12. Constraints are not being drained because the majority of ponds are rented so that lessees reduce operational costs for drying.
13. Pond management pattern: tenant -> pandega with a wage of 4% net yield per harvest. Feed purchases are made by pond tenants.
14. Seeds were purchased outside Sidoarjo, including in Pasuruan.
15. Apart from tilapia, vannamei fish can be polycultured with mujaer. Mujair fish was chosen because the price can be more expensive than tilapia.
16. Vaname can produce 6 tons per 1 harvest cycle. While mujaer harvests can reach 30 tons per year (3x harvest).
17. For the feed itself requires 40-50 tons per month.

Intensive pond

1. Focus on vannamei shrimp farming
2. Total area of 5 Ha consists of 28 cultivation plots. Each plot has an area of 1,000-1,300 m.
3. Brackish water supply is obtained from drilled wells with a salinity of 20 ppt. The depth of the well reaches approximately 18 meters.
4. Diseases : WS, AHPND.
5. Treatment of shrimp when exposed to WS: all shrimp are killed, buried, water treatment is carried out in the diseased plots then thrown into the outlet channel which flows into the estuary to the Alo river.
6. The target harvest, if not affected by disease, is 2 tons per plot and sold to a cold storage factory in Gresik, of any size.
7. Target harvest once every 3 months for size 30 at a price of IDR 70,000-80,000 per kg.
8. Land owned by local people rented by people from Surabaya.
9. In a year you can experience 2-3 x harvest cycles.
10. The total feed requirement for 1 day requires 200 kg of 30% low protein feed which price of IDR 14,000/kg. So in a day it requires feed costs of IDR 2,800,000.
11. The need for electricity in a month can reach IDR 30 million.

Improvement of the aquaculture systems in Sidoarjo, Indonesia

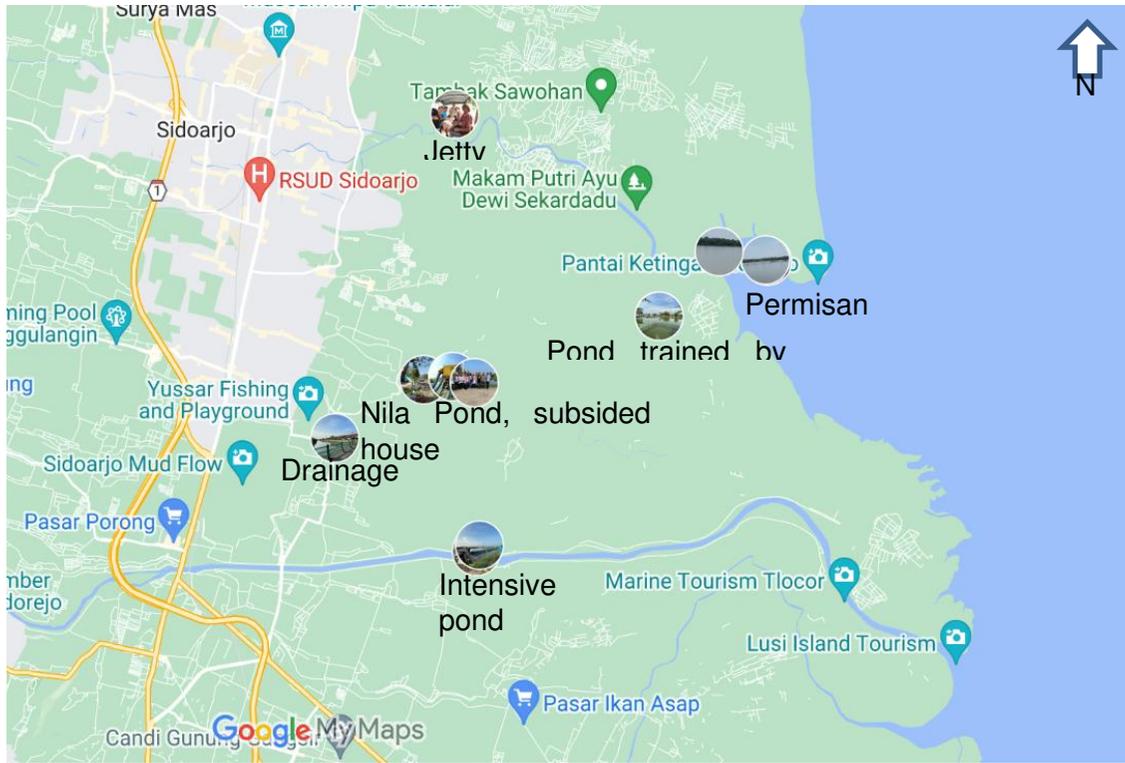


Figure 2 overview of visited location

Improvement of the aquaculture systems in Sidoarjo, Indonesia

Closing at Bappeda, Sidoarjo

Day/Date : Friday/09 December 2022

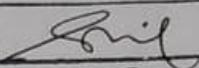
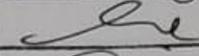
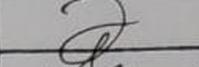
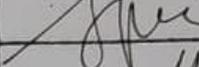
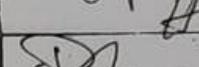
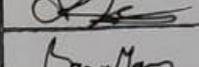
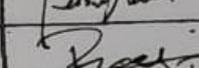
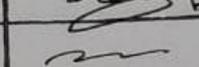
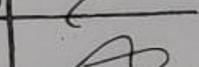
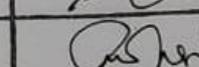
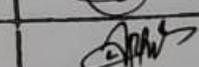
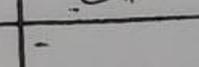
Place : Bappeda, Sidoarjo

Participant : EcoShape, Bappeda Kab. Sidoarjo, Dinas Perikanan Kab.Sidoarjo and
Dinas PU BM SDA Kab. Sidoarjo.
(list of participant is attached)



Appendix B List of Participants

List of participant on 5 december 2022

DAFTAR HADIR			
Hari, Tanggal		: Senin, 5 Desember 2022	
Tempat		:	
Agenda		:	
No	Name	Inatanel	Tanda Tangan
1			
2			
3	Erina Yuniarsih	Sesditsen PB	
4	Desie Yudhina	Setditsen PB	
5	Iman I. Benero	Dit Prodes	
6	Apri Susanto Astra	Wetlands International	
7	Weny Hamilton Sihombing	Witterveen + Bos	
8	Rien Dou	NL-RVO	
9	Bas van Maris	De Hoces	
10	Roel H. Bosma	Ecoshape	
11	Sjupizal	Dit Pol	
12	A. MARINO	Dit. Prodes	
13	Abdul Wahid	Dit. IKK	
14	Widya P. Sari	KKI	
15	Agus Sapani	BHRLN - KKP	
16	Artika Ayu W	HKH	
17			
18			
19			
20			

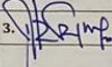
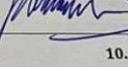
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List of participant on 6 december 2022


PEMERINTAH KABUPATEN SIDOARJO
BADAN PERENCANAAN PEMBANGUNAN DAERAH
 Jl. Sultan Agung No. 13 Telepon (031) 8961437 Fax. (031) 8956819
 SIDOARJO - 61211

DAFTAR HADIR

HARI/TANGGAL : SELASA, 6 DESEMBER 2022
 WAKTU : 09:00 WIB s/d SELESAI
 TEMPAT : RUANG RAPAT PEMBANGUNAN I DAN II BAPPEDA KAB. SIDOARJO
 ACARA : FGD REVITALISASI BUDIDAYA TAMBAK RAKYAT DI KABUPATEN SIDOARJO

NO	NAMA	PD/INSTANSI	NIP/NO. HP	TANDA TANGAN
1	Dian Kurniawati (Saras)	Perijemah	0817377318	1. 
2	Markhan	-	08123036018	2. 
3	Hari Pranoto	DUPD Proyektim.	081392370528	3. 
4	Silpi	P. Perikanan		4. 
5	Su. Yulda	Dag. Perikanan	08243544299	5. 
6	PIPI F	BAPPEDA Pro	081330588895	6. 
7	Theodore M.S.	Dinas PU SDA	081125897271	7. 
8	Suseno	Palkele KP Sidoarjo	081123606911	8. 
9	Hery Edy		081330207554	9. 
10				10.

NO	NAMA	PD/INSTANSI	NIP/NO. HP	TANDA TANGAN
11				11.
12	Gandhuw	Kuliner	08122670770	12. 
13	Dika	Perikanan	082139703737	13. 
14	Isqiyanto	PPLS	081216393751	14. 
15	Zuhrohah Diona Atta.	Dinas PU SDA Jatim.	081219830370	15. 
16	Vinda Widipati	Dinas PU SDA Jatim.	081221727920	16. 
17	GUSTIAN	PPLS	082117049379	17. 
18	Ashifa Gilang Kurniawati	PPLS	082120419751	18. 
19	Radiah Helmi	DUPD Jatim	081370208801	19. 
20	FAHRUL	P. PUMASDA		20. 
21	CHRISTINA	P. PUMASDA		21. 
22	MASTURI	PERIKANAN	081372630587	22. 
23	FATMUR RIZ	BUDURAN/Budi Daya	082338840795	23. 
24	Abdul Rafiq	Perikanan	08113710669	24. 
25				25.

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NO	NAMA	PD/INSTANSI	NIP/NO. HP	TANDA TANGAN
26	Tifin	Dinas PU SDA ATIM	197504151939012001	26.
27	Nuray R.	Bappeda		27.
28	Handa	Pr. Atura	0811337123	28.
29	HARRY Yuli	Pr. Atura	0811374804	29.
30	Moshun	Bappeda		30.
31	Badrul Samudra	BK AU	08123146773	31.
32	Indradini L.	Bappeda		32.
33	Fibriyanti	Bappeda	198509122010012029	33.
34	H. ACH. SYARIF	Petani	08589508215	34.
35	M. Ulman	Budi daya	082231647920	35.
36	M. Ibad	Budi daya	085101271662	36.
37	M. Alimudin	Budi daya	082337679000	37.
38	M. Shaf	Petani Tambak	08133228813	38.
39	Rusdi Darmawan	Petani Tambak	0838-3333-8830	39.
40	Faw M	PU SDA		40.

NO	NAMA	PD/INSTANSI	NIP/NO. HP	TANDA TANGAN
41	Weny H. Sihombing	Wittevoert Bos	085660450300	41.
42	Waningsas &	UM	08824800889	42.
43	Rost Boesma	WUR		43.
44	Lela Apriyanti	DHK	081531323872	44.
45	Ghonger Hamid	Atura	08117937017	45.
46	Aji Pudar	Budi daya	082143462969	46.
47	A. Muthalifi	Budi daya	081235512211	47.
48	Bos van Maan	Deltaco	0161520690	48.
49				49. .
50				50.
51				51.
52				52.
53				53.
54				54.

Improvement of the aquaculture systems in Sidoarjo, Indonesia

List of participant on 9 december 2022



PEMERINTAH KABUPATEN SIDOARJO
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 SIDOARJO - 61211

DAFTAR HADIR

HARI/TANGGAL : JUMAT, 09 DESEMBER 2022
 WAKTU : 08.00 WIB s/d SELESAI
 TEMPAT : RUANG RAPAT PEMBANGUNAN II BAPPEDA KABUPATEN SIDOARJO, JL. SULTAN AGUNG NO. 13 SIDOARJO
 ACARA : AUDIENSI DAN PENYUSUNAN REKOMENDASI REVITALISASI TAMBAK RAKYAT DI SIDOARJO

NO	NAMA	PD/INSTANSI	NIP/NO. HP	TANDA TANGAN
1	Fauzy Masuddin	PV-Gas. Jatin	19790102 200604 1008	1.
2	Dina Wintawati (Berk)	Pemerintah	0819597318	2.
3	Martani	---	0819529036058	3.
4	Munadiya	tim interpreting	085158775155	4.
5	Bos an Noun	Pelaris		5.
6	R.H. Boshua	Ecoshaper		6.
7	Weninghas k	WI		7.
8	Weny Hamilton Sihombing	lutte veen + bos		8.
9	Ana Kharanayus	Buppt	657803 nusun	9.
10	CARRINA	TWA		10.

NO	NAMA	PD/INSTANSI	NIP/NO. HP	TANDA TANGAN
11	Fahrel	pubans da		11.
12	SULIVAN70	---		12.
13	Gandhuw	Perikanan	19860310 200601 1021	13.
14	Tuo	Pu - SOA Jatin		14.
15	Nauang R	Upraswil		15.
16	Silfi	D. pika		16.
17	Tarina	Dini An ha.		17.
18	MASHURI	---		18.
19	Dika	---		19.
20	Sa. rdah	Buppt	19771120 199405 01209	20.
21	Widya Cahyani P.	P. DA	19970806202012 2016	21.
22	Ppa Kurniawaty	---	198302222001 2010	22.
23	Chindra S.	BAPPEDA	19970519 201703 2012	23.
24	Khusnul	Perencanaan & SOA	199206062019032014	24.
25				25.

Contact

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