

THE BALANCE BETWEEN AQUACULTURE AND FISHERIES IN BANDARHARJO, SEMARANG: ENHANCING THE ECONOMIC VALUE OF THE URBAN FISH INDUSTRY

Charlotte Eline Maria Beijer

Faculty of Architecture & the Built Environment, Delft University of Technology

Julianalaan 134, 2628BL Delft

abstract.

This paper aims to demonstrate an economic strategy for the cultural development of the current fish industry in Semarang. The research will apply a Material Flow Analysis (MFA) to illustrate the opportunities in the current material management. The research consists of two parts. The first part is based on the current situation in Semarang. The second part is about the possibilities of introducing a fish farm into the fishery culture of Semarang. It states that there is an ecological provided system, but not completely circular. The paper research a design solution that can both create a circular material flow system and be financially beneficial to the local community.

Keywords: aquaculture, fish industry, water, material flow analysis, MFA, fish farm, Semarang, Bandarharjo

01. Introduction

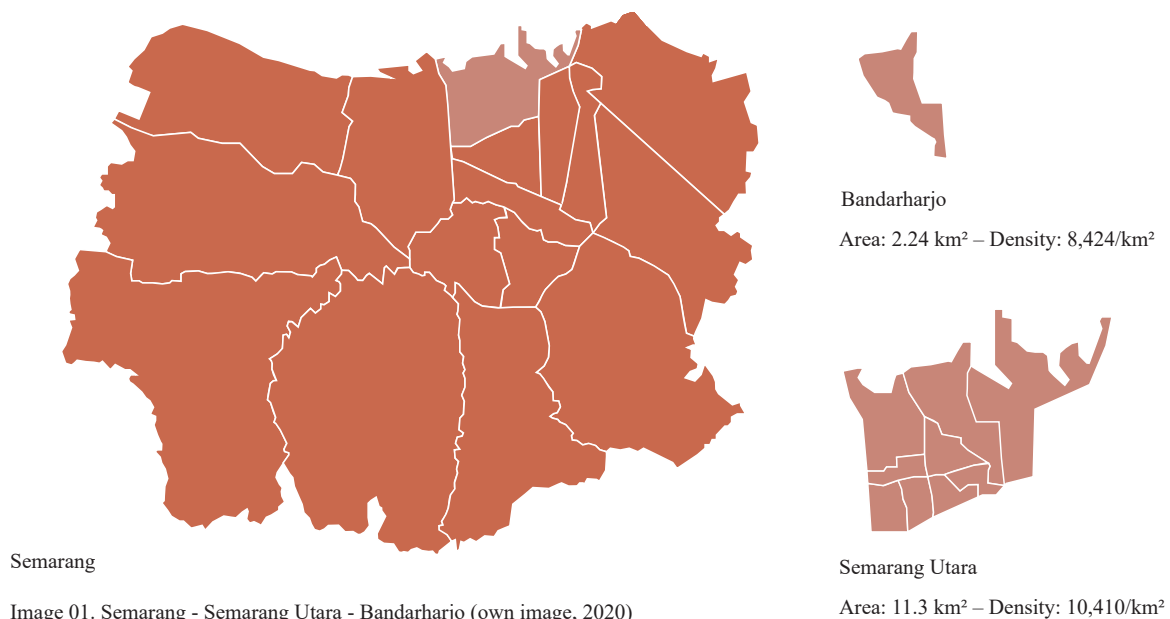


Image 01. Semarang - Semarang Utara - Bandarharjo (own image, 2020)

01.1 Context

The city of Semarang, Indonesia, is located on the north coast of Java and is known for being an industrial city. For several years the city was one of the biggest export ports during the trade era of Central Java. Nowadays, the western part of the urban area is home to many industrial parks and factories. Today the port of Semarang is still the main shipping port for the province of Central Java. Many small manufacturers are located in Semarang, producing goods such as textiles, furniture, and processed foods. In the north of Semarang, there are also many warehouses. These warehouses keep temporary storage for export and import. The population of Central Java moved to Semarang, forced by several factors, such as a lack of property, minimum land ownership in their previous home, or the promise of better economic conditions, but mostly the lack of job opportunities in their home village (Purnaweni, 2017). The focus in this research lies in solutions for fish management, and the balance between nature and the urban layout. The aim is integrating both to generate economic values to create a more public artificial landscape. The next paragraph provides more in-depth background on the specific problems around this topic in Bandarharjo, Semarang.



Image 02. People of Bandarharjo perform their daily activities in front of their homes photograph (own image, 2019)



Image 03. People of Bandarharjo utilizing their porch to sell their fish (own image, 2019)

background story - Bandarharjo

Bandarharjo is located on the north coast of Semarang in the province Semarang Utara. The kampung Bandarharjo has little opportunities for education. Instead, people are more oriented towards getting a job; however, there is a high unemployment rate in the community. People in this community are looking for an opportunity to contribute. Furthermore, the vital land subsidence is sinking 8 cm per year in the Bandarharjo district of Semarang, which is a big concern for the local community (Saharom, 2018). 95% of the people working in the fishing industry in Semarang are living in Bandarharjo. It is located in the coastal area of Semarang, close to urban areas. Where the livelihoods of people, which are living densely, depend on marine resources. Moreover, as a result of severely affected by periodic tidal inundations that are exacerbated by sea-level rise and land subsidence, the environment of this area is unhealthy (Hardiman, 2012).

The situation in Bandarharjo has transformed into a flooding area, resulting in a temporary building sector. In general, there is a secure work/life connection within the kampung. Furthermore, extensive waste pollution is causing health issues for the community. Additionally, there is a low amount of public spaces in the environment. The open spaces that are present are used as waste deposits areas. In the north of Semarang, there is a main road called Jl. Yos Sudarso that connect west and east Java. The connection between Bandarharjo and this road is secure, but in the kampung itself, the roads are small and compact. These paths function as a road for cars, motorbikes, pedestrian, and even residents use these paths as their public spaces (see image 02). The building fabric is a dense and yet low rise.

Furthermore, the buildings are in a bad state. Part of the residents has to live under their roofs as a result of the sinking houses. The residents continue rebuilding their houses on top of their existing ones. The houses of the people change, what first was the second floor becomes the first. The community lives with a mentality of flexibility and temporary use of the urban context. The houses are sinking so rapidly due to the high demands of groundwater pumping. The kampung is facing a shortage of usable drinking water.

Pain points of Bandarharjo and north coast of Semarang (see image 04)

- 1. Floods, land subsidence, sea-level rise. Potential vulnerability implications of coastal inundation as a result of sea-level rise in the coastal zone of Semarang City, Indonesia.*
- 2. Drinking water. Overpumping groundwater, illegal extraction of groundwater. Lack of safe drinking water.*
- 3. Unemployment, industry. Poor working-class neighbourhood.*
- 4. No heritage value of the livelihood, sinking houses, and temporary use of the buildings.*
- 5. Overfishing the Java Sea*

01.2 Opportunities

There are opportunities to combat the pain points in the fishing industry in Semarang. Firstly, a fish farm can improve the conditions of the poor working-class neighbourhood and the overfishing in the Java Sea. Smoked fish is one of Semarang's best output products on the market. This research will introduce a strategy for sustainable fish food production. A new production line can improve the fishing community and the livelihood of Bandarharjo. The north coast of Semarang reflects the industrial hub of the city. Today, the fish for the fish smokery is provided by the marine fisheries on the northeast coast of Semarang, called kampung Tambak Lorok. In this research, the opportunities for a more sustainable flow production will be analysed. This contribution will provide a better way of enhancing the flow diagram of the current fishing industry process by using a flow chart. With the introduction of a fish farm, the supply for the fish smokery can be provided sustainably, and increase the value of the livelihood. The new design concept can be an opportunity for the community on an economical level by providing additional jobs. It can also be utilised as a touristic activity to increase economic values. Secondly, focussing on clean water initiatives will decrease the overpumping of groundwater in the area. On a local level, utilising renewable resources occur to provide services for water access. By applying the concept of a circular water cleaning system, such as aquaponics, there are possibilities to provide clean water which will benefit the community.

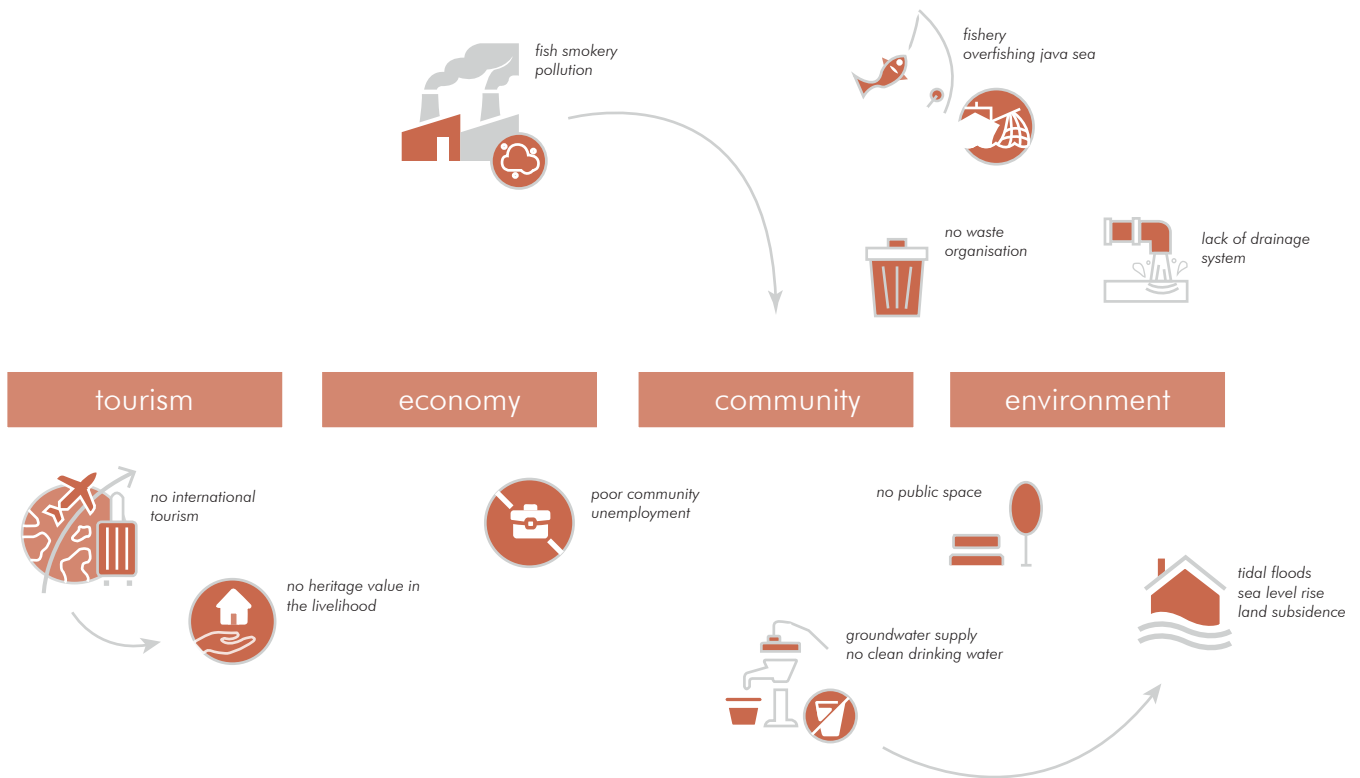


Image 04. Paint points diagram north coast Semarang (own image, 2020)

01.3 Thematic Research Question

Research question

The smoked fish is Semarang's best output product on the market. The system is currently ecologically provided, but the system is not entirely circular. How would the introduction of a fish farm increase the economic and environmental sustainability of the current smoked fish industry in Semarang and provide a closed cycle fish capacity?

sub-questions

1. What is the current material flow system of the fish industry?
2. How can this community profit from a fish farm?
3. What is the flow diagram of a fish farm?
4. What are the architectural and spatial impacts of these technologies?

01.3 Methodology

01.3.1 atmospherical

This paper is fundamentally based on a literature review. However, for this research, various methodologies have been applied. To understand the full field of the fish industry scientific articles were referenced, both to understand the status of the technology and mindset behind the aquaculture. Information about the Tambok Lorok and Bandarharjo areas came from interviews on-site. The method for the interviews was an atmospherical approach. While conventional architectural tools, such as plans, maps, and sections, may help to image some conditions for atmospheric spaces, they need to be complementary to other methods that address the complexity of architectural experience better. An atmospherical analysis requires a physical encounter with a place. We, as architects, should observe the atmosphere but also take note of the effect of our perceptions and associations. I gained a closer understanding of the needs of these communities, by analysing the culture, the city, and the industry on-site, and interviewing the workers on the smoked fish industry, as well as residents of Bandarharjo.

Moreover, the research will contain information about developments, their systems, and the elements involved in fishing. The atmospherical method gave insight into the current situation and flows of the industry, however, it has yet to touch upon the core of the research question. Several reference projects in other areas will need to be researched if a closed cycle fish capacity could work. These projects will give insight into various design possibilities. The atmospherical method resulted in better knowledge which answers parts of the research question. Continuing with an improved system will benefit the industry. The first part would be a brief introduction about the north coast area of Semarang. Later on, the paper will continue with a material flow analysis of the fishing industry in Semarang. To understand why the current system is not working on its full potential, an explanation of the advantages and disadvantages of the system will be provided.

01.3.2 Material Flow Analysis

Kaufman explained in the Metropolitan Sustainability that the “Material flow analysis is one of the critical tools in industrial ecology and certainly of high importance when considering sustainability issues in metropolitan areas.” (Kaufman, 2012) It utilises input/output methodologies, including both material and economic information. MFA is used to study material, substance or product flows across different industrial sectors or within eco-systems. Because working with an industrial topic, a MFA is an excellent tool to finalise decisions, focused on environmental evaluation. Especially in regions with limited financial and technical resources.

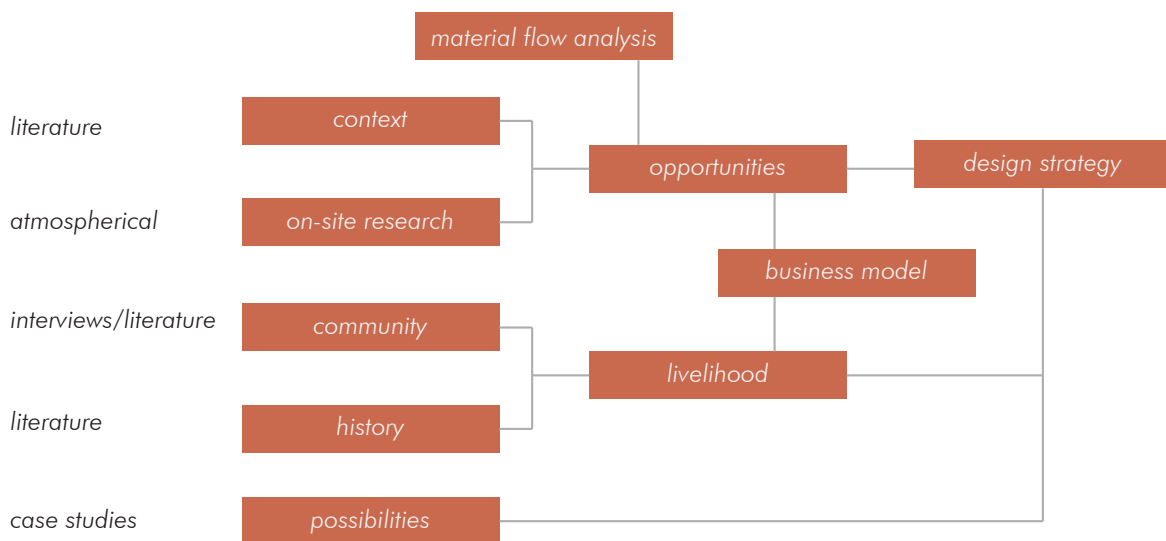


Image 05. Research methodologies used in the research (own image, 2020)



Image 06. Tambok Lorok, fish drying (Putri, 2019)



Image 07. Tambok Lorok, fish boats (Putri, 2019)

02. On-site Observations

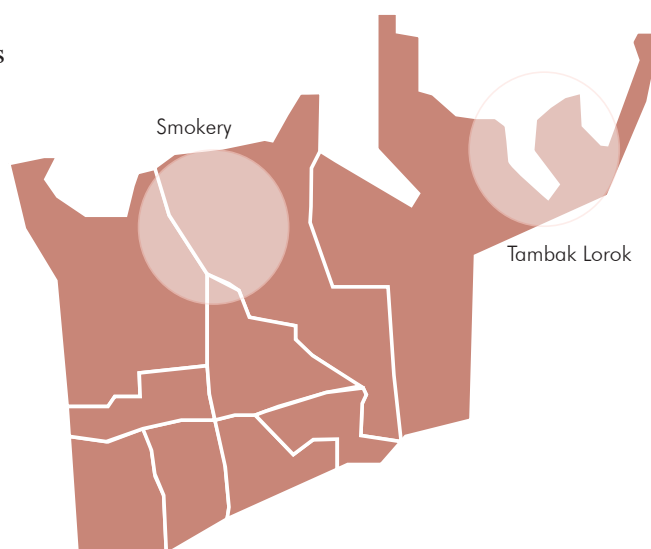


Image 08. location fish industry north coast Semarang (own image, 2020)

02.1 Tambak Lorok

Tambak Lorok is a Fishermen's Village in Semarang, which has existed since 1950 (Firmandhani, 2018). Nowadays, most of the fish that is smoked in the smokery has been wild catch in the Java Sea by the Tambok Lorok Fishermens. As a fishing village in a coastal area, Tambak Lorok has the potential of marine fisheries and ponds, natural scenery of the sea coast, and appreciating fishermen's culture. The settlement's environmental condition is still in the slum category because the status of houses is mostly still unfeasible, and the infrastructure is not adequate. The main economic driving factors in the Tambak Lorok area are marine product trading, aquaculture, and fish processing. The daily activities that are commonly seen in Tambak Lorok area are fisherman's activities, such as drying fish, repairing fish nets, repairings boats, and selling various types of sea catch. In the area fishing, related products play an important role in helping the economy of the Tambak Lorok community.

02.1.1 Overfishing Java Sea

Overfishing is one of the severe threats to the eco-system, not only for the aquatic animals but also for humanity. Every single life form in the ocean has a significant contribution to give to the eco-system. Researcher Dr. Norhidayah Mohd Taufek from the University of Malaya department Biological Sciences describe the threat as "old fish is reducing in the wild because they were caught while still young and those left were not sufficiently mature to produce offspring, hence contribute to the unstable eco-system." (Global Aquaculture Alliance, 2020) Aquaculture or fish farming could prevent this from happening in the first place. Fish will be produced from eggs, hence will not be put on pressure on the old fish. As we are already aware, the human population is growing, so does food demand, particularly protein. Fish could be considered as one of the cheap and healthy sources of protein. Nevertheless, aquaculture is already a big industry concept in Indonesia, and parts outside of the Semarang. "With an anticipated 10 billion people expected to inhabit the planet by 2050, the demand for animal protein will increase by 52 per cent. Sustainable and healthy approaches to feeding the world are more critical than ever before" (Global Aquaculture Alliance, 2020).

02.1.2 Products and process

Fishers using Bamboo Sodo, a specialised fishing technique, depart for the sea at 5 p.m. and return home at 4 a.m. in the following morning. These fishermen are sweeping all kinds of fish and shrimps, large and small, in the shallow part of the sea, which has a depth of 1-2 meters. Fishermen use fish food to attract their catch. Furthermore, the residents of the community are making fishing nets made out of nylon (Kistanto, 2019). The earnings of fishermen can range from 0 rupiahs to 200,000 rupiahs, depending on the catch of the day. While the price is very varied depending on the type and size of fish purchased from fishers, the fishers sell their catch with a profit margin of 1,5%. The fish can be sold immediately in Tambak Lorok. Temporary shelters (TPS) are located behind the market where wet and dry waste is mixed. The wet waste consists of vegetables, leftover fruit, and remaining fish material in the form of fish heads, fish meat flakes, fish stomach contents, fish fins, and fishtails, while the dry waste is made out of bottles, plastic, rubber. The vendors who occupy the stalls in the fish market have to pay a rent of 3500 rupiahs, security charge of 5000 rupiahs, and cleaning-waste charge of 2000 rupiahs a day (Kistanto, 2019).



Image 09. Fish smokery, man carried a bucket full with smoked fish (Ifansasti, 2013)



Image 10. Fish Smokery Bandarharjo, woman cutting the fish (Ifansasti, 2013)

02.2 Fish smokery

The fish-smoking site in Bandarharjo is one of the most important industrial centres. Its existence as a coastal city is essential to support the characteristics of Semarang. The fish-smoking industry, located on the bank of the Semarang River, has existed since 1986 (Hardiman, 2012). Workers keep maintaining the activities of smoking fish regardless of the poor physical condition of the buildings and environmental infrastructure. The changing water levels created these poor conditions. The fish-smoking centre in Bandarharjo is located on a floodplain consisting of muddy grounds. Besides, the geological conditions exhibit that the site is located in a subsidence area. Therefore, the buildings are prone to collapse. To increase the safety of the workers, any building must involve a fundamental construction concept, and an appropriate system of environmental infrastructure both in high tide and flooded areas.

The activities at the fish-smoking centre start at 8 a.m. and last until 6 p.m. If there is an abundant supply of fish, then the smoking activities may last till 10 p.m. 95% of those workers are residents of Bandarharjo. The average daily income ranges from 25000 rupiahs to 50000 rupiahs (Hardiman, 2012). The results of the interview (see appendix VI) also explains that the conditions of the buildings are not a considerable concern for the corporations since they have adapted to the situation. Moreover, the most crucial matter for them is to get a job and wage to remain. The biggest issue for the community would be the pollution created by the fish smokeries. The fish smokeries initially were located in the Bandarhajo's housing area, located next to the Kali Baroe river. The government resettled the smokery more to the western side of the Kali Semarang River because of the excess smoke. Based on a personal experience: *"as I was walking on-site, I noticed a cloud of pollution hanging above the smoked fish industry. Even standing on the ground, you could feel the pollution sticking to the top of your skin. All my senses were signalling me that the environment was unbalanced. I can still remember the smell when I think of the fish smoking huts; it has been branded into my memory."* (see appendix VIII)

02.2.1 products and process

The fish arrives at the industry park in the morning, brought in by scooters or other small bike transport. The amount of the availability of raw materials depends on the natural conditions. There are taken from the fishery market in Tambok Lorok to the industry park in Bandarharjo. The industry park houses around 21 fish smokeries. Every smoker is an individual corporation. One fish smokery can produce around 2,000 kilos/fish a day. One kilo of smoked fish equals 50.000 rupiahs on the market. Smoked fish are immediately distributed on the same day to vendors in the market.

The by-products of the fish-smoking process are acquired from the processing of fish waste and fuel waste. Coconut shells are used as a source of fuel for the fish-smoking process. This process leaves a residue in the form of coconut charcoal. The charcoal is dried and sold to distributors. Other fuel sources consist of corn and rest wood. The charcoal can be sold to restaurants for the use of grilling fish. Meanwhile, the fish bones are prepared into fish flour for fish feed and fishing bait. Furthermore, fish farmers use the fish viscera as fish feed. The leftover fish waste is boiled to receive fish oil. The wastes are partially sold (Hardiman, 2012).

02.3 Conclusion part 1

1. What is the current material flow system of the fish industry?

By applying the method of atmospherical research, the following processes have been determined. Firstly, the fish is caught from the Java Sea. The moment it arrived on the shore, it is directly sold on the market in Tambak Lorok. The fish will then be transported with the use of a motorbike to the smokeries located on the western bank in Bandarharjo. Once it has arrived in the industry park, the processing of smoked fish can start. The workers start the process with cleaning and cutting the fish. When the fish is cut, the usable parts of the fish will be smoked on a stove filled with corn, coconut shells and rest wood. Once the fish is smoked and ready, it will be transported in baskets on motorbikes to markets all over the city.

Fortunately, the current material flow already enhances the circular ecological steps in this strategy. These steps are creating charcoal out of the burned coconut shells to use in restaurants and transforming the viscera fish waste into new fish food. These actions show that the community is already aware of the benefits of a circular industrial system. Nevertheless, this diagram of the system has a few deficiencies. First, the community is still lacking a good source of drinking water. Second, the demand for production of smoked fish will increase overfishing in the ocean. A fish farm can provide a circular system to the already current ecology system. Moreover, the farm can work on an aquacultural design that can provide clean water and air for the community.

2. How can this community profit from a fish farm?

The information for this research was gained by doing on-site interviews with workers in the fishing industry. The outcome of these interviews show the diverse layers and steps that are involved in making products and how the residents collaborate between kampungs. (image 11) This diagram shows the fishing industry's potential to improve. Firstly, smoke is a tremendous problem for the local environment and the communities that live near the industrial area. The research aims to include solutions to these pollution problems, such as creating green parks in public spaces, and air purification filters in the chimneys. The green park can function as a community garden. By growing more food in urban environments, the community can benefit from an increase in locally sourced food, the shortening of the transportation of the production flow, the possibility to reconnect with the natural world, and the improvement of mental health and well-being. Secondly, overfishing of the Java Sea is another unsustainability factor of this area. An increase in demand has also increased the amount of fish that is being fished, to the detriment of the ocean and the eco-systems. Continuing with this practice is under no circumstances sustainable because the fish are harvested at such a rate, the aquatic fauna of the ocean can no longer replenish itself naturally. Aquaculture can provide a sustainable resource for fish production in harmony with farming and fishing. To improve the eco-systems, the transformation of the fish farming community should take place in small steps.

Introducing a more controlled production can help solve the unemployment on the north coast of Semarang. People living in the kampungs on the north coast are all specialised in the fishing industry, but as it is now, there is a severe lack of job opportunities. A fish farm could solve this problem partially. By manufacturing the fish with aquaculture, there is a lesser need for catching wild fish from the ocean, thus resulting in new job opportunities. An integration of this magnitude should consider economic and cultural factors both in Bandarharjo and Tambak Lorok. The residents in Tambak Lorok depend on the facilities of the fishing industry for 70 years in Semarang. Their economy, as well as the economy of neighbouring villages, are dependant on the capacity of the ocean. By transforming the urban layout in a more aquacultural landscape, it will also change the job capacity in the area. To prevent unemployment from shifting from one district to another, the capacity of the production of fish should balance the activities in the community between farming and fishing.

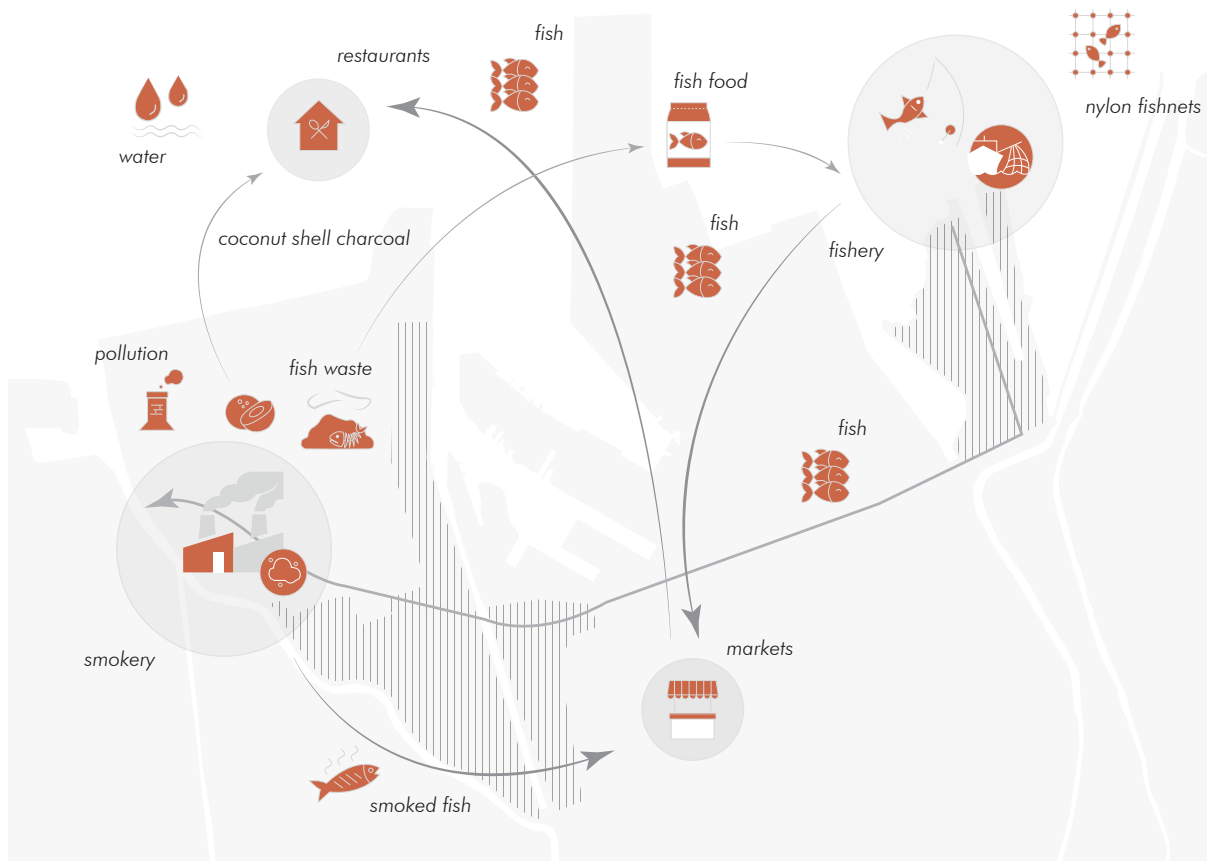


Image 11. Diagram of the current fish industry flow on the north coast of Semarang (own image, 2020)

03. Design Solutions

03.1 Milkfish

The smoked fish production uses a certain kind of fish, locally known as the *chanos chanos* (milkfish). The milkfish lives in the East Asian waters and can be cultured in freshwater, brackish water, and marine waters. (FAO, 2020) The fish only appears in the tropical and subtropical Indian and Pacific oceans where temperatures are higher than 20 degrees Celcius. Milkfish can swim in depth of waters ranging from 1 meter to 30 meters. Their average market size is around 250-500 grams, with a length of 30 cm. (see appendix IV) When the milkfish is farmed, the harvest traject can take about six months.

03.1.1 products and processes

The first stage in aquaculture is the hatchery. Newly hatched milkfish larvae are stocked in circular fibreglass tanks at 24 larvae/L. The fry (fish eggs) is either caught from the wild or obtained from a hatchery. The hatchery is the place where the breeding of fish, hatching of eggs, and rearing of fish through the early life stages happen. This part of the process has to be undertaken indoors to control the climate. In the next stage, once the animals are mature enough, they are transferred to the ponds, where they are grown to harvest size. When the fish are ready for harvest, the fish can then be transported to a processing facility, and sent to food retailers. After harvesting, ice is added to keep the value of the fish high. The specific growth rate of the fish depends on the feed quality, food availability, and the stocking density.

In the hatching phase, larvae get their food by a method called “straining”. After 125 hours the mouths of the larvae are wide enough to begin feeding them with rotifers. Since milkfish are daytime feeders, feeding with artificial food begins soon after sunrise and is terminated at sunset. The menu for the milkfish varies between anything that the environment presents varies between detritus, phytoplankton, zooplankton, filamentous algae, and artificial feed. Plankton and lab-lab are two types of natural food preferred by milkfish. Organic and inorganic fertilisers are applied in the ponds to stimulate the growth of lab-lab and other natural food. (see appendix III) Feeding trays are typically installed in cages and ponds to reduce wastage. The majority of feedstuffs that is used as protein sources are fishmeal, shrimp meal, meat and bone meal, and copra meal. Soybean meal and other pulses are used both as a protein and an energy source. Cereal grains and cereal by-products (rice bran, cornmeal, corn germ meal, corn starch, wheat pollard, wheat flour) are used as energy sources. Other potential protein sources are snail meat, poultry by-products, and feather meal, blood meal, cowpea, feed pea, and leaf meals. The fish needs to be fed three times a day. (FAO, 2020)

03.1.2 design of the ponds

Milkfish are farmed in ponds, cages, and pens, however, the design choice depends on reference, location, and the density of the farm. The process of farming milkfish can be divided into three phases each of which will take up six weeks. Each phase has its own pond of which the dimension is at a ratio of 1:2:4 to 1:3:9 (see appendix I). At lower stocking densities, the growth of the milkfish is faster during the nursery period. For marine ponds, the lower densities (0,5-1 fish/m³) gives the ability of faster growth. When a pond uses extensive support systems, such as aerators and pumps, they are not employed. For both floating or stationary cages, stocking density is maintained at 10-30 fish/m³. Milkfish tend to swim against the current flow of water. When transferring the fish to a bigger pond, the pond is partially drained at the level of low tide. During high tide water is allowed to enter so that the fish will swim towards the water flowing in. A seine or a long net is used to collect the fish near the opening of the pond. Fish are scooped into a counting net and finally transferred into another pond. The same process is used for harvesting the fish. The fish are then scooped into chilling tanks or boxes which contain flaked ice with a ratio 1:1 of fish and ice to decrease the temperature of the fish to 4 degrees in two hours. (FAO, 2020)

When fish do not respond to the currents, fish are harvested as they congregate in deeper regions of the pond by draining the pond and leaving enough water to expose 1/3 of the dorsal portion of the fish. Milkfish producers supply the fish throughout cooperatives, dealers, and brokers. In general, the majority is sold in auction markets. Increasingly, more of the milkfish harvest is processed into value-added forms, such as smoked, dried, marinated, fermented with rice, and canned or bottled forms.



Image 12. Milkfish (SeafoodWatch, 2020)

03.2 Fish Loss & Waste

In the food supply chains, several aspects contribute to waste, loss of food. Firstly, in the harvest phase, there are losses due to spillage, and degradation during handling, icing, packaging, storage and transportation between farm and distribution. Secondly, in the process cycle, losses may occur when crops are sorted out if not suitable to process—lastly, the losses in distribution and consumption in the market system.

In the previous chapter, it became clear that in the fish smokeries, the fish bones are prepared into fish flour for fish feed and fishing bait. Furthermore, fish farmers use the fish viscera as fish feed. The leftover fish waste is boiled to receive fish oil. These are sustainable solutions from fish waste. FAO created a table of the fish waste in different regions. This table summarizes the discarded, lost and wasted at different stages in South and Southeast Asia; fisheries 8%, post-catch 5%, processing 7%, distribution 11%, consumption 2%.

Figure 8. Part of the initial catchings (fish and seafood harvested) discarded, lost and wasted in different regions and at different stages in the FSC

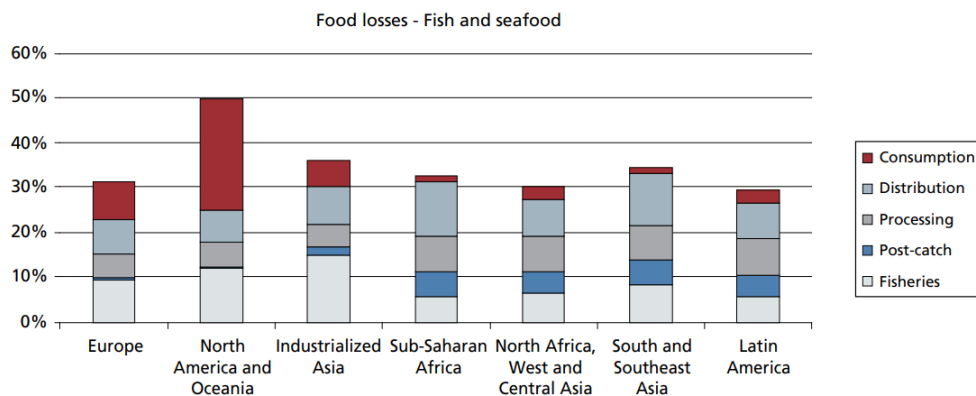


Image 12. Fish Waste (FAO, 2018)

03.2 Aquaponic

Aquaponic is a bio-integrated system that consists of aquaculture and hydroponic sub-systems. With aquaculture, the focus lays on the farming of fish cultures, while hydroponic targets the growth of the plants. Like their fish counterparts, these plants are tailed in buckets. These two components interact through a water pump which cycles between the aquaculture and the hydroponic. This water medium is needed to supply the plants with the fish waste, that consist of nutrients which are needed for their growth. The plants will then release nitrogen, which results in purified water which, eventually, will go back to the aquaculture pond. (see appendix V)

Besides animals and plants, there is a third party which plays a role in aquaponics. The beneficial nitrifying bacteria are microorganisms that make the cycle complete. The plants need nitrogen for growth. Furthermore, ammonia and nitrite, which builds up in the water, are toxic to fish. By providing a more sustainable design solution, aquaponics can offer a combination of nature and fish in an urban layout.

03.3 Case studies

By researching the following case studies about the integration of fish farm systems in a similar built environment, spatial potentials are highlighted. These case studies must be applicable on areas with the small and dense urban layout, such as the kampungs on the north coast of Semarang. Furthermore, the interventions analysed in these case studies must be suitable for central neighbourhoods. A new design proposal should be accessible from every direction and be attractive to the public. The following case studies are selected because they analysed the spatial qualities of program combination or enhanced specific building technologies.

03.3.1 KOI Café / Farming Architects

Coffee shop, Vietnam, 2017, 88 m²



Image 13. Section of the KOI Café designed by the Farming Architects (Archdaily, 2020)

The following project, designed by Farming Architects, is a coffee shop located in Vietnam. It showcases the combination of the quality of spaces, the interaction of visitors, and fish farming. The ponds in the back of the coffee shop are divided into three sections with a waterfall stream. The water feature is not only decorative and symbolic; it also keeps the water fresh for the fish. *“Waste created by the coffee shop is pumped into a tank, where bacteria in the soil converts the ammonia excreted by the fish into nitrates”* (Archdaily, 2020). The trees on the roof can then use the nutrients. Besides trees, vegetables have also been planted in the soil so that café workers can harvest them for use in the recipes. The vegetation helps clean the water, which is then returned to the aquariums. The process of the fish farm is easily visible to the visitors. The visitors of the coffee shop can experience the ponds on several building levels. Even though the coffee shop is located in a compact urban area, with a lack of green public spaces, the architecture introduces a part of nature on a small scale intervention. The facade provides a closed-off connection from its surroundings, meaning the visitor needs to enter the building to experience the farming process. (Dezeen, 2020)

03.3.2 VAC library / Farming Architects

Library, Vietnam, 2018, 55 m²



Image 14. Impression of the VAC library designed by the Farming Architects (Archdaily, 2020)

“Farming Architects aim is not only to produce an effective use of natural resources but also favourite experimentation in using different types of plants and animals in the urban environment.” (Archdaily, 2020) This project reflects the natural spatial qualities of the design. The system is designed with renewable energy in mind (by transferring solar energy). Furthermore, the design reduces the number of pumps by letting the water flow downwards naturally as much as possible. To create a adaptable and flexible structure, the architect uses a design style that derives from the use of wooden frames. The design is more open for the public than the previous case study and will give the community a more in-depth insight into the effective use of waste in aquaponic systems.

03.3.3 Surbana Jurong’s Floating Ponds

Water prize winner WAFX, Surbana Jurong, 2017

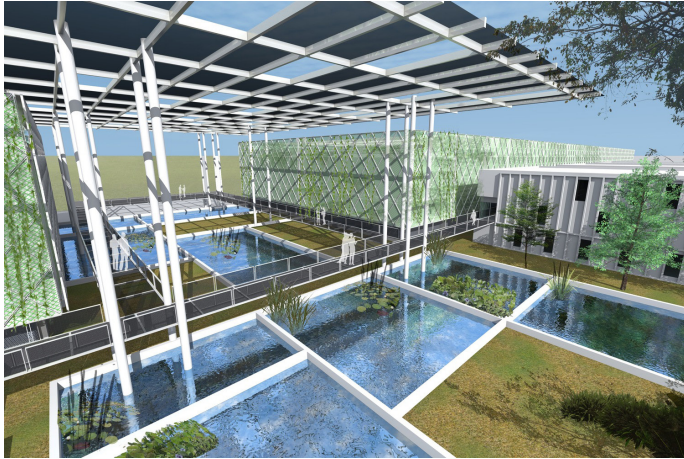


Image 15. impression of the Floating Ponds by Surbana Jurong (Archdaily, 2020)

The following project, Surbana Jurong’s Floating Ponds, is on a larger scale than the previous case studies. In this project, several rearing ponds are integrated into the design. These ponds focus more on the fish food production industry. The concept leads to the creation of a self-sustainable and closed-loop farming eco-system. The system highlights the production of farming and is less accessible to the public.

As showcased by the previous design solutions implementing features such as a market, open spaces, or a restaurant will increase public appeal. These features will increase the design qualities and create more spatial interaction with the community. In order to enhance the farming process of fish, the design has to achieve a balance between farming and the qualities of other programs.

0.3.4 Conclusion part 2

3. What is the flow diagram of a fish farm?

The following flow diagram (image 16) can be indicated for a fish farm production in the area of Bandarharjo. In this diagram, the fish farm introduces a more circular process to the already current fishing industry flow in Semarang. (See appendix VII) This diagram showcase an one-weekcycle. The rate of the losses and waste during the process has been taken into account. New aspects in this diagram, compare to the current situation, that the cycles illustrate to be more sustainable. The coconut shells can be grown in the park, and the organic wastewater can be a fertilizer for the park. Currently, the smokery uses coconut shells as fuel for smoking fish. If the system temporary storage the organic waste on the river banks, the smokery can in a few years use biogas instead. Furthermore, by introducing a park, the system can provide a source of usable clean water for their facilities, and provide clean air. Visible in the diagram that there are several in and output systems, such as the ponds, park, smokery, restaurant, market, and fish food. By creating fish ponds with a hydroponic park, the outputs of the smokery, market and restaurant can be sustainable reused, what profit the system economically and create a better social environment. However, in the system, there are opportunities to improve. The percentage of the fish loss is based off an average fish losses in aquaculture system all around South-East Asia. By creating a fish-friendly design, the percentage can increase and provide more profit. For more in-depth information about the flows see appendix IX and appendix X.

4. What are the architectural and spatial impacts of these technologies?

Fish farm technologies can be used to increase the spatial potentials of a site. In the previous chapter, the fish farming technologies were analysed. These technologies have an impact on the spatial relationships within the urban context. In the following case studies, the research can conclude that ponds provide interaction between visitors and nature. The dimension and weight of the rearing ponds require them to be located frequently on the ground floor. In earlier phases of the farming process, the ponds can be integrated on higher building levels and provide different experiences for the visitors.

As shown by the KOI Café designed by Farming Architects, the implementation of the ponds gives a playful touch in the form of a more interactive swimming track. The hydroponic part of the design should always be above the aquaculture part of the design. The dimension of the ponds can be various but must be between the ratio 1:2:4 or 1:3:9. Research shows that milkfish like to swim against the current flow of water. The natural behaviour of the fish must be taken into account when creating a design intervention.

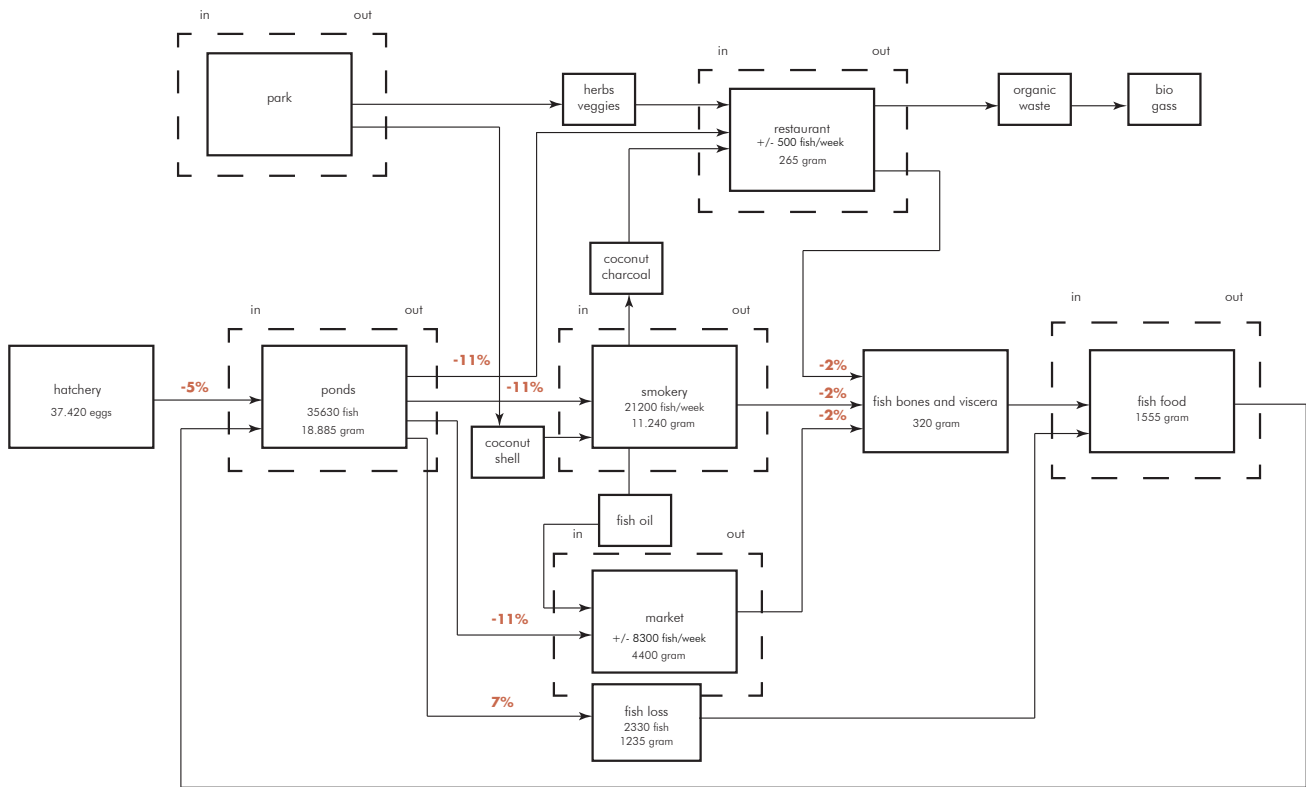


Image 16. diagram fish farm one-week cycle (own image, 2020) For more in depth details of the in and outputs see appendix IX, and for the calculations see appendix II.

FINAL CONCLUSION

Research question

The smoked fish is Semarang best output product on the market. The system is currently ecology provided but not circular. How would the introduction of a fish farm increase the sustainability of the current smoked fish industry in Semarang and provide a closed cycle fish capacity?

The farm can provide a circular water system and an increase of the fish capacity by introducing fish farming to the current fish industry. Nevertheless, some outputs need to be addressed. At the beginning of this paper, the various pain points were listed. Firstly, the lack of clean drinking water. The design of a fish farm can improve the water quality and purify the water, however, the water source must never contain plastic waste or blackwater. The lack of a functional drainage system in the kampung Bandarharjo results in polluted water made out of a combination of plastic waste, greywater, and blackwater. The design needs control of the water source. This can be the collection from rainwater or greywater from controlled facilities. The new design strategy cannot help the drainage problem inside of the kampung. Only if the kampung itself can separate the different water flows than the drainage system can be integrated into the design. At the same time, the intervention of aquaponic can provide purified, clean drinking water that will benefit the community. Secondly, there is a low number of public spaces in the community. Not only will the aquaponics system provide clean drinking water for the community, but it will also increase the value of public areas. One of the design interventions can be a park functioning as a hydroponic, which will decrease the pollution in the air created by the smoked fish industry. Overall, this can make the system more sustainable for the environment.

The material flow analysis provides a clear overview of the system and the levels of intervention opportunities. The design will benefit from additional programs, such as a restaurant and a market. It will increase the experience of the visitors by implementing more public spaces into the design solutions. These design solutions can also provide economic benefits to the community. By placing these diverse economic programs in one location, the economic flow of materials will be more sustainable.

REFERENCES

- Alliance, G. A. (2020, juni 5). Gobal Aquaculture Alliance. Opgehaald van Gobal Aquaculture Alliance: <https://www.aquaculturealliance.org/>
- Amin, C. (2018). *Exploring Typology of Residents Staying in Disaster-Prone Areas: A case study in Tambak Lorok, Semarang, Indonesia*. Semarang: Forum Geografi.
- Firmandhani, S. R. (2018). *Casual Factors in Resilience of Old Tambak Lorok Fishing Port in Semarang*. Semarang: Diponegoro University.
- Hadromi, H. M. (2019). *The Development Strategy of Fish Fumigation Industry as a Driving Force of Culinary Tourism Destination in Bandarharjo, Semarang Indonesia*. Semarang: GeoJournal of Tourism and Geosites.
- Hardiman, G. (2019). *The Improvement of buildings and infrastructure condition to anticipate degradation process of fish-smoking centre in Bandarharjo, Semarang*. Semarang: Diponegoro University.
- Kaufman, S.M. (2012) *Metropolitan Sustainability*, Woodhead, Cambridge pages 721-739
- Kistanto, N. (2019). *Sociocultural System of Tambak Lorok Community, Tanjung Mas, Semarang City*. Semarang: CL-Lamas.
- FAO (2020, Juni 5). *Aquaculture Feed and Fertilizer Resources Information System*. Retrieved from FAO: <http://www.fao.org/fishery/affris/species-profiles/milkfish/milkfish-home/en/>
- Patadjai, R. (2001). *The technology for milkfish hatchery*. Kendari, Indonesia: Halouleo University.
- Purnaweni, H. (2017). *Revitalization of Slum Area in Semarang City with Thematic Village Program*. Semarang: Diponegoro University.
- Purwaningsih, R. (2017). *Product-service system method to measure sustainability level of traditonal smoked fish processing industries*. Semarang, Indonesia: Diponegoro University.
- Sharom, N. K. (2018). *Alternative housing System & Materials Criteria For Land Subsidenfe Area (Case Study: Bandarharjo, Semarang)*. Bandung: Institut Teknologi Bandung.
- Subiyanto, A. (2019). *Cultural Values Dimensions of Tambak Lorok Fisheries Community*. Semarang: CL-Lamas.
- Sullivan, K. M. (2007). *An Economic Analysis of Milkfish Farming in Tanzania: Potential for Economic Development and Policy Issues*. Narragansett: Coastal Resources Center.
- Yulianto, B. K. (2019). *Utilization of Fish Waste Processing as Compost Raw Material in Tambak Lorok Market*. Semarang: Diponegoro University.
- image 01. Beijer C, *Semarang - Semarang Utara - Bandarharjo*. (2020)
- image 02. Beijer C, *People of Bandarharjo perform their daily acitivities in front of their homes photograph* (2019)
- image 03. Beijer C, *People of Bandarharjo utilizing their porch to sell their fish* (2019)
- image 04. Beijer C, *Paint points diagram north coast Semarang* (2020)
- image 05. Beijer C, *Research methodologies used in the research* (2020)
- image 06. Putri W, *Tambok Lorok, fish drying* (2019)
- image 07. Putri W, *Tambok Lorok, fish boats* (2019)
- image 08. Beijer C, *location fish industry north coast Semarang* (2020)
- image 09. Ifansasti U, *Fish smokery, man carried a bucket full with smoked fish* (2013) Retrieved on Getty Images
- image 10. Ifansasti U, *Fish Smokery Bandarharjo, woman cutting the fish* (2020)
- image 11. Beijer C, *Diagram of the current fish industry flow on the north coast of Semarang* (2020)
- image 12. SeafoodWatch, *Milkfish* (2020) Retrieved from <https://www.seafoodwatch.org/seafood-recommendations/groups/milkfish/overview>
- image 13. Archdaily, *Section of the KOI Caf  designed by the Farming Architects* (2020) Retrieved from <https://www.archdaily.com/884951/koi-cafe-farming-architects>
- image 14. Archdaily, *impression of the VAC library designed by the Farming Architects* (2020) Retrieved from <https://www.archdaily.com/908873/vac-library-farming-architects>
- image 15. Archdaily, *impression of the Floating Ponds by Surbana Jurong* (2020) Retrieved from <https://www.archdaily.com/881499/winners-announced-of-inaugural-wafx-prize-for-worlds-most-forward-looking-architectural-concepts/59df9302b22e3805c3000083-winners-announced-of-inaugural-wafx-prize-for-worlds-most-forward-looking-architectural-concepts-image>
- image 16. Beijer C, *diagram fish farm* (2020)
- image 17. Beijer C, *ratio dimensions fish ponds* (2020)
- image 18. Beijer C, *tabel calculation dimensions* (2020)
- image 19. FAO, *Milkfish larvae food table* (2020) Retrieved from <http://www.fao.org/fishery/affris/species-profiles/milkfish/tables/en/>
- image 20. FAO, *Milkfish growth diagram* (2020) <http://www.fao.org/fishery/affris/species-profiles/milkfish/tables/en/>
- image 21. FAO, *Milkfish feed combination* (2020) <http://www.fao.org/fishery/affris/species-profiles/milkfish/tables/en/>
- image 22. Green and Vibrant, *Aquaponic system* (2020) <https://www.greenandvibrant.com/aquaponic-gardening>
- image 23. Beijer C, *fish farm flow diagram* (2020)

APPENDIX I

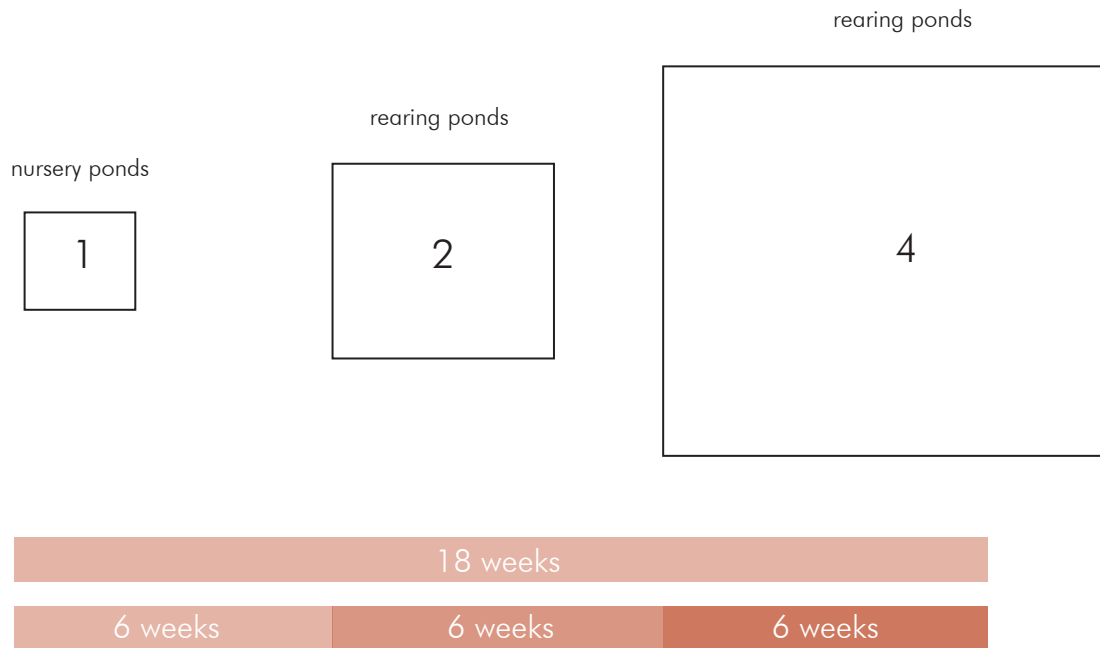


Image 17. ratio dimensions fish ponds (own image, 2020)

APPENDIX II

smokeries +/- 20 * 2000 kilo/week= 40.000 kilo/week
 30 cm milkfish: 531 gram = 0.53 kilo
 $\log(\text{gr}) = -5.3 + 3.24 \log(\text{mm})$ (FAO)

21200 fish/week
 +/- 8300 fish market/week
 +/- 500 fish restaurant/week

30.000 fish * 6 processes = 180.000 fish

180.000 / 20 fish/m³ / 2 meter depth = 4500 m²
 4500 m² - 2250 m² - 1125 m²
 4500 + 2250 + 1125 = 7875 m²

30.000 * 0.53 = 15.900 gram

15.900 * -2% during consumption phase = 320 gram fish waste
 15.900 * +11% during distribution phase = 17.650 gram fish
 17650 * -7% during processing phase = 1235 gram fish losses
 17650 * +7% during ponds phase = 18.885 gram fish = 35630 fishes
 35630 * +5% during hatchery phase = 37420 eggs

Image 18. tabel calculation dimensions (own image, 2020)

APPENDIX III

Table 1. Ontogenetic dietary shifts (% of total food intake by volume) of different life stages/size classes of milkfish, *Chanos chanos*

| Type of food | Life stages/size class | | | | Broodstock |
|---------------------------------------|------------------------|-----------------------------------|---------------------|------------|------------|
| | Fry (1) | Juvenile (2) (natural habitat) | Juvenile (pond) (3) | | |
| | | | Feeding | No feeding | |
| Algae | | 10 | 4 | 22 | present |
| Detritus | | 15 | 15 | 12 | present |
| Diatoms | | 8 | 1 | 0 | present |
| Animal | | <2 | | | |
| Plant | | <2 | | | |
| Resuspended materials | 50 | | | | |
| Plankton | 50 | | | | |
| Zooplankton excretion | 50 | | | | |
| Crustaceans | | | 0 | 1 | present |
| Others (snails, eggs, higher, plants) | | | 1 | 7 | present |
| Supplemental feed | | | 45 | | |
| Sand particles | | 0 | | | present |

*Major composition of food consumed: 50%

Data source: (1) Buri (1980); (2) Kumagai and Bagarinao (1981); (3) Lückst (2004)

Image 19. Milkfish larvae food table (FAO, 2020)

Table 6. Feed formulations (ingredient composition) and proximate composition of commonly used farm-made feed for different life stages of milkfish in modified extensive and semi-intensive farming systems**

| Ingredient/proximate composition (% dry matter) | Life stages/size class | | |
|---|------------------------|--------|--------|
| | Fry/fingerling/grower | Grower | Grower |
| Ingredient composition (%) | | | |
| Fishmeal | | 25 | 4 |
| Rice bran* | 100 | | 42 |
| Biscuits | | 75 | |
| Soybean meal | | | 20 |
| Copra meal | | | 33 |
| Dicalcium phosphate | | | 1 |
| Binder** | | | |
| Proximate composition (%) | | | |
| Dry matter | 9.2 | 8.5 | |
| Crude protein | 13.3 | | 20.7 |
| Crude lipid | 14.1 | | 12 |
| Ash | 10.7 | | 9.7 |
| Crude fibre | 8.5 | | 6.7 |
| NFE | 53.4 | | 50.9 |
| Gross energy (kJ/g feed) | 17.9 | | 18.4 |
| Cost (US\$/kg) | 0.2 | 0.2 | 0.3 |

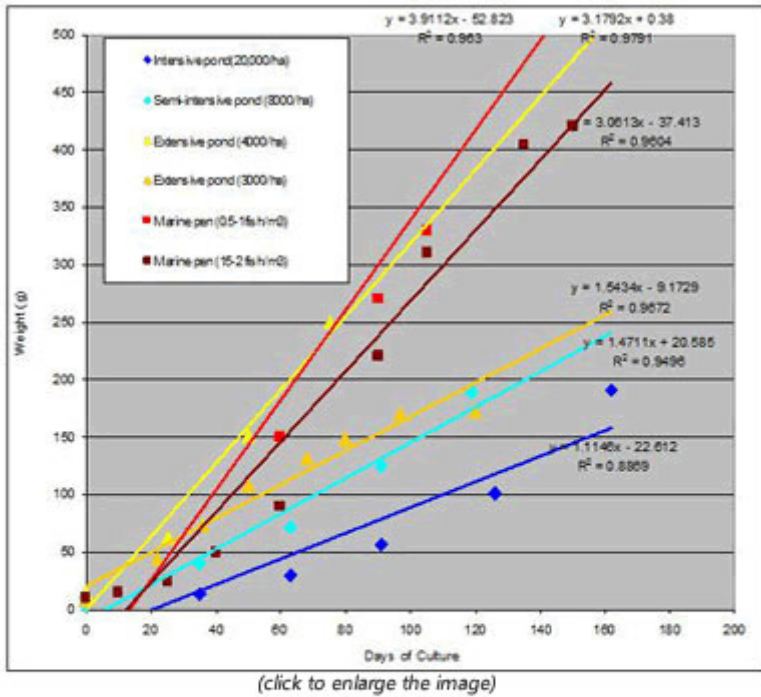
*Rice bran serves as binder in farm-made feeds

**Complete feed is provided for milkfish broodstock

Data source: Sumagaysay et al. (1991)

Image 21. Milkfish feed combination (FAO, 2020)

APPENDIX IV



- I. Intensive pond – 1 000 m²; stocking density, 20 000 fish/ha (Sumagaysay and McGlone, 2003)
- II. Semi-intensive pond (a) – 1 000 m²; stocking density, 8 000 fish/ha (Sumagaysay and McGlone, 2003)
- III. Extensive pond - 500 m²; stocking density, 4 000 fish/ha (Otubusin and Lim, 1985)
- IV. Extensive pond – 1 000 m²; stocking density, 3 000 fish/ha (Sumagaysay et al., 1999)
- V. Marine pen - 0.5-1/m³ (de la Vega, personal communication)
- VI. Marine pen - 1.5-2/m³ (de la Vega, personal communication)

Image 20. Milkfish growth diagram (FAO, 2020)

APPENDIX V

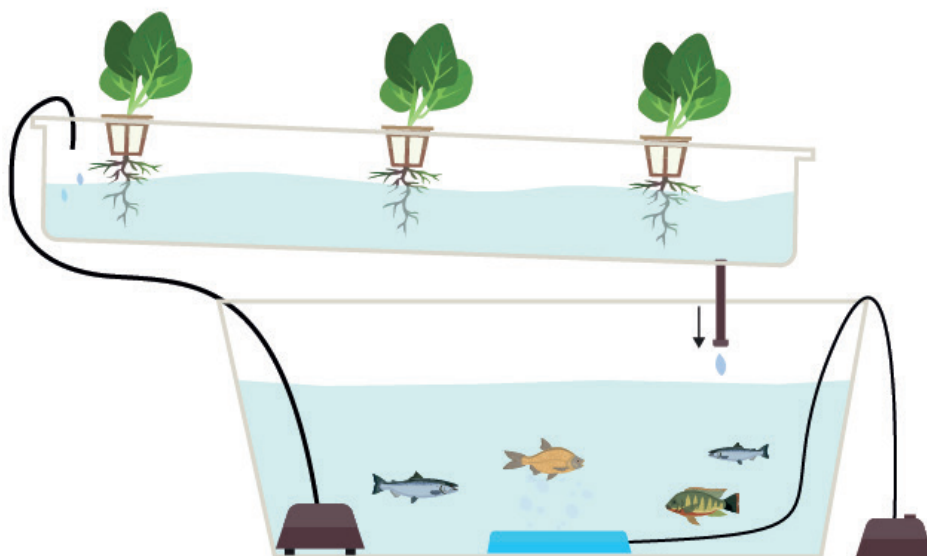


Image 22. Aquaponic system (Green and Vibrant, 2020)



Interview 1: Bandarharjo Residents

Name: Supriyadi

Job: Drinking water refill store in Bandarharjo

1. How long have you lived here?

I have been living here for 25 years since 1995.

2. Why do you choose to live here?

I choose to join my wife as she is from here.

3. What do you do on a daily basis?

I run this store of refilling drinking water from the mountain.

4. What are the activities of the RT/RW community here?

Well each of us have our own jobs during the day: re-selling groceries, factory workers, etc. Afterwards, we just hang out with the neighbors in the evening.

5. Where is the gathering place?

Mainly in our terraces, or probably on the side of the road.

6a. Where do people here obtain clean water access?

Some people took it from the artesis wells. We have several around here. It is used to be for drinking water, but it is no longer drinkable today due to intrusion. Some have access to the PDAM pipes. For the actual drinking water, everyone tends to buy it from the grocery stores. They would come to re-fill their drinking water galloons to re-fill stations like mine, which I obtain from the Ungaran Mountain.

6b. Do you know where the grey water goes?

Yeah just to the sewer on the streets.

7a. Is there flooding issues?

Not lately, the new drainage system seems to be working here.

7b. If so, how did people deal with it?

We just let it in to our houses or move to relatives house outside.

7c. Has the problem been reduced or worsen?

It has been way reduced, since the pumping station at the end of Kali Semarang has now been built. It appears like we have no coastal floodings anymore since 2015.

8. How is the waste management here being dealt?

Well, every two days a guy comes to take up the trashes in front of our houses. But, that's it.

9. What are your hopes in the future for this place?

I just hope the water around here would not be polluted, and that there would be no future problems related with the water access nor flooding.



Interview 2: Bandarharjo Residents

Name: Mukhtarom

Job: Casual worker

1. How long have you lived here?

I have been living here all my life.

2. Why do you choose to live here?

I have all my families here and sufficient source of income around.

3. What do you do on a daily basis?

I go look for money here and there; sometimes by pulling becak rides, construction work, or fishing to the sea.

4. What are the activities of the RT/RW community here?

Pretty much similar to me.

5. Where is the gathering place?

Just in our houses, we take turns. Although we have a bigger gathering place near the fish factory, just for an official and bigger events though.

6a. Where do people here obtain clean water access?

We have a well on a nearby mosque! That's where we get it.

6b. Do you know where the grey water goes?

Well just on the sewage outside?

interviewee have similar answer to first respondent for Q7 and Q8

9. What are your hopes in the future for this place?

I think what the people need here the most are some help with regards to fundings. Especially on the sinking houses that is of 1m height from the ground and have not yet afford to elevate their houses.

APPENDIX VII

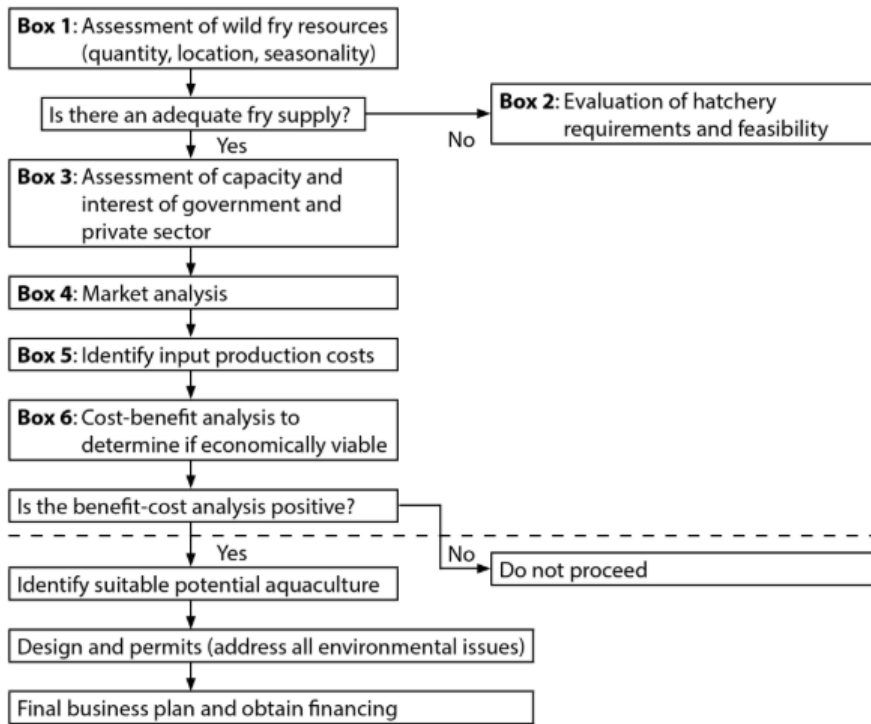


Figure 1. Structure of a feasibility assessment for milkfish aquaculture (FitzGerald 2004).

Image 12. book: The feasibility of milkfish (Chanos chanos) aquaculture in Solomon Islands

APPENDIX VIII

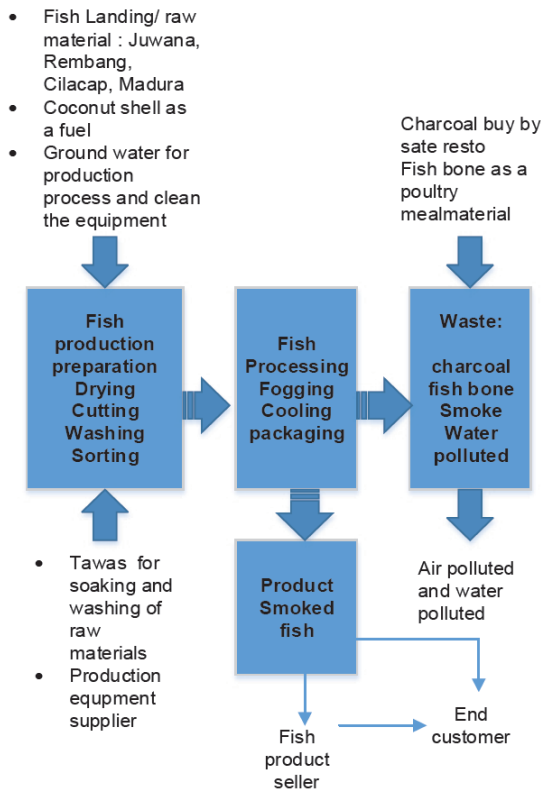
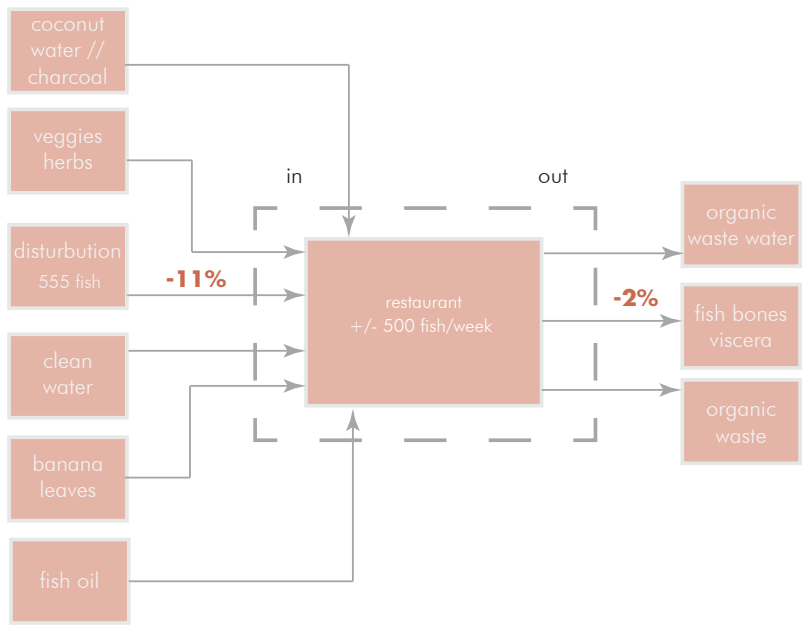
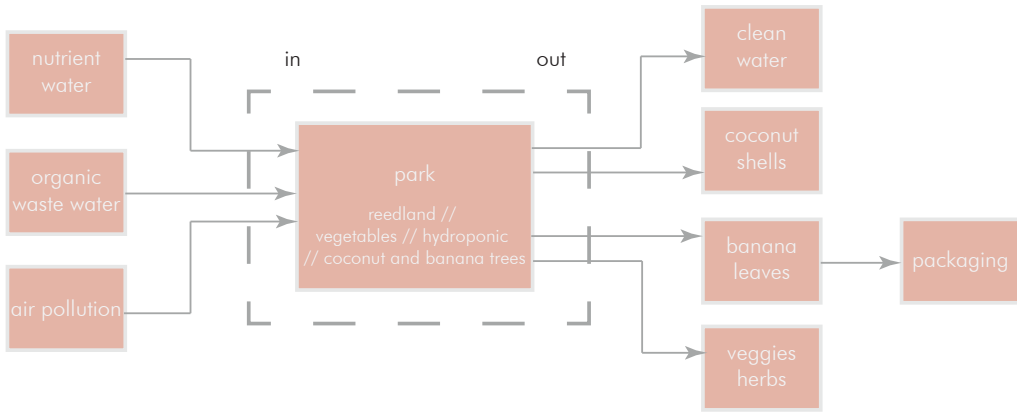
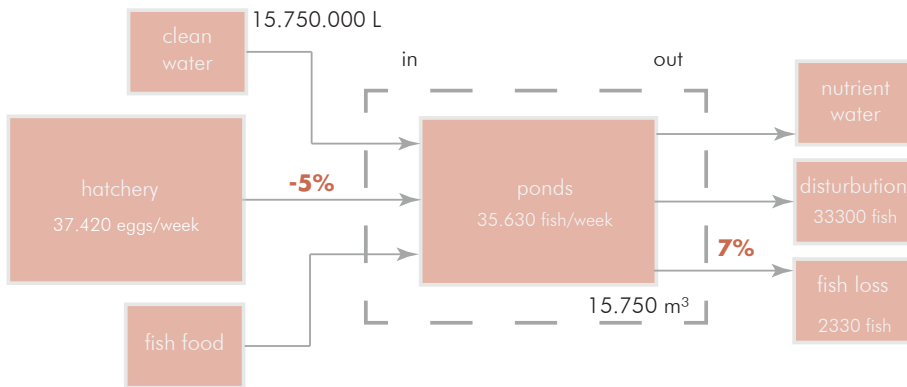
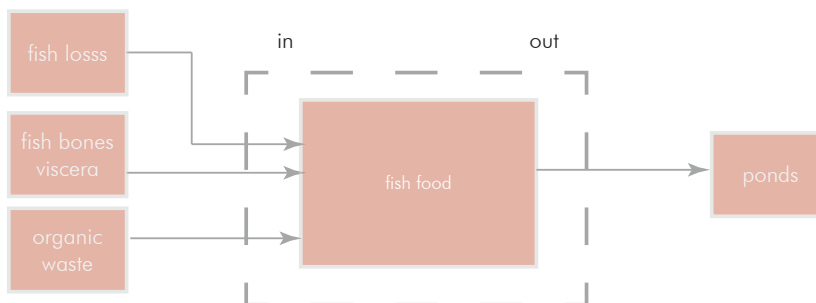
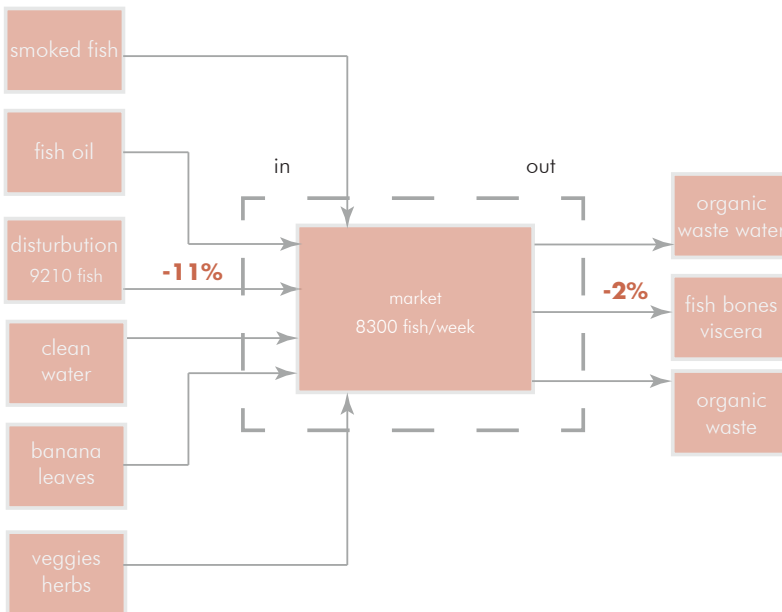
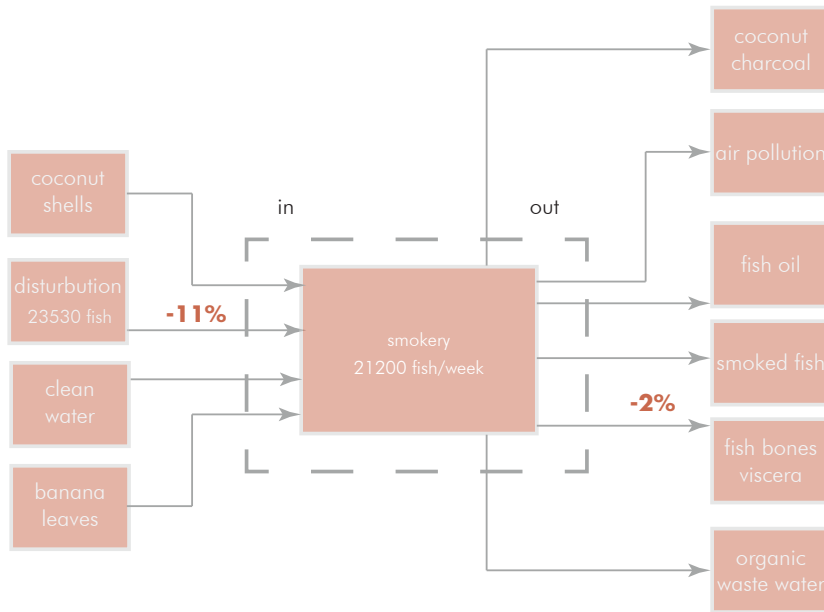


Fig. 1. System map of traditional smoked fish processing industries

Image 12. Fish smokery process (Purwaningsih)

APPENDIX IX





APPENDIX X

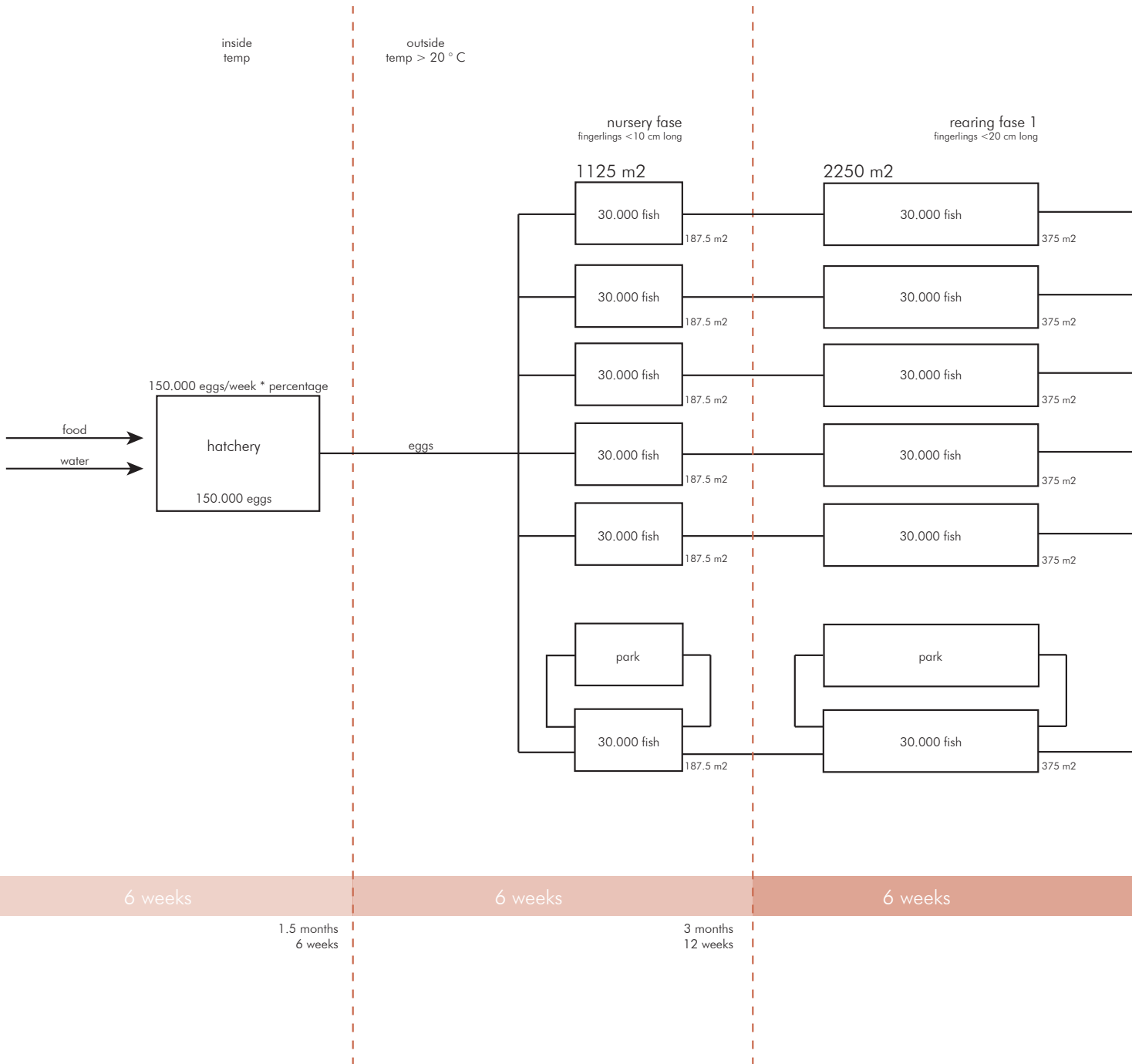


Image 23. fish farm flow diagram

