Silvofishery: an aquaculture system harmonized with the environment

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Abstract

Mangrove forests are valuable biologically and economically, but these have been decreasing yearly. It is usually converted into human settlement and for brackishwater aquaculture. To arrest the massive decrease of mangrove forests, reforestation of mangroves has been done but most failed because of conflict among users. To resolve such problems, a system that combines utilization and conservation called silvofisheries has been introduced.

Costs-and-returns of silvofishery ponds per year differ depending on scale and type of species cultured. The following are necessary to maintain the silvofishery pond in good condition: good site and design, suitable vegetation, high economic value of target organisms, good water quality and quantity, and optimal rearing conditions (stocking density, adequate feeding, etc.).

Introduction

The mangrove forest that grows along the coast has a high value both biologically and economically. The mangrove forest has a role as spawning, nursery, and feeding ground for many economically important species of fishes and crustaceans (Matthew & Kaptesky 1988; Saclauso 1989; Caddy & Sharp 1986). Moreover, mangrove forests also function as shields against storms, floods, and erosion (Christensen 1978). The trees can be utilized for charcoal, construction materials and leather dyeing (Saenger *et al.* 1983).

The mangrove area is decreasing yearly. It is usually converted into human settlement and for brackishwater aquaculture. The decrease of mangrove forests has a great influence on the coastal fisheries, causing reduction of catches of fishes (Caddy & Sharp 1986) and shrimps (Clark 1992). Moreover, Kapetsky (1987) pointed out that the production pattern of coastal fisheries might be shifted from production based on detritus feeders to production based on plankton feeders, and noted how large the mangrove area has been degraded.

Reforestation of mangrove has been carried out in some tropical and sub-tropical countries, but these efforts are not always successful because of conflicts of interest in using the area for human settlement, agriculture, aquaculture, or industries. To resolve these problems, a system which attempts to combine utilization and conservation called silvofishery has been introduced.

Silvofishery defined

In the Webster's dictionary, silvoculture is defined as "a phase of forestry that deals with the establishment, development, reproduction, and care of forest trees." According to this concept, the system of unique aquacultural method that allows to rear both aquatic animals and mangrove trees in the same pond is termed silvofishery in Indonesia. This system is also called "tambak tumpangsari" which means brackish pond with multi-crops.

Brief history of the system

It is said that silvofishery was initially developed in Myanmar about 50 years ago by the government in order to make artificial forests with low operation cost. This system allowed the farmers to use the land by contract, obligating them to plant trees. Silvofishery was introduced in Indonesia in 1978 by the Department of Forestry so that the fanner could cultivate fishes and shrimps in addition to trees. The purposes of this system in Indonesia are to minimize planting cost (the farmer does the planting), increase farmer's income, and conserve the mangrove forest (Hartojo 1991). In the 20 years after introduction, several national or local government silvofishery model ponds have been constructed. Some interesting data are described below. In this paper, the author wishes to introduce the two pilot farms at Segara Anakan in Cilacap (West Java, facing the Indian Ocean) and at Cikinon Farm in Karawang (West Java, facing the Java Sea).

Types of system

There are basically two types of silvofishery pond. The first consists of a shallow water area ("caren") which is exposed to the air at low tide, and a deeper area surrounding the "caren" (called "pelataran"). Another type consists of a water area (pond) and a neighboring land area with mangrove trees. The land and water areas are located alternatively.

Design and management

Construction of the pond (Figure 1)

Based on the layout of pond and channel, land is cleared and marked. The pond and channel are formed by cutting and digging. The internal channel ("caren") is usually deeper than the inlet and outlet of water. Pond gate must also be constructed. The "pelataran" is about 1.0 to 1.25 meters in depth. After construction, young mangrove trees like *Rhizophora* are planted on the shallow area ("pelataran") with a distance between plants of about 3.0-4.5 meters by 1.0-1.5 meters. The relative area for the tree ("caren") is usually 80%. Water is introduced to the pond, and seed fish later on. The cost of pond construction was about US$20 in 1981.

Silvofishery ponds in Indonesia's Cilacap project are arranged in series, consisting of two rows. The

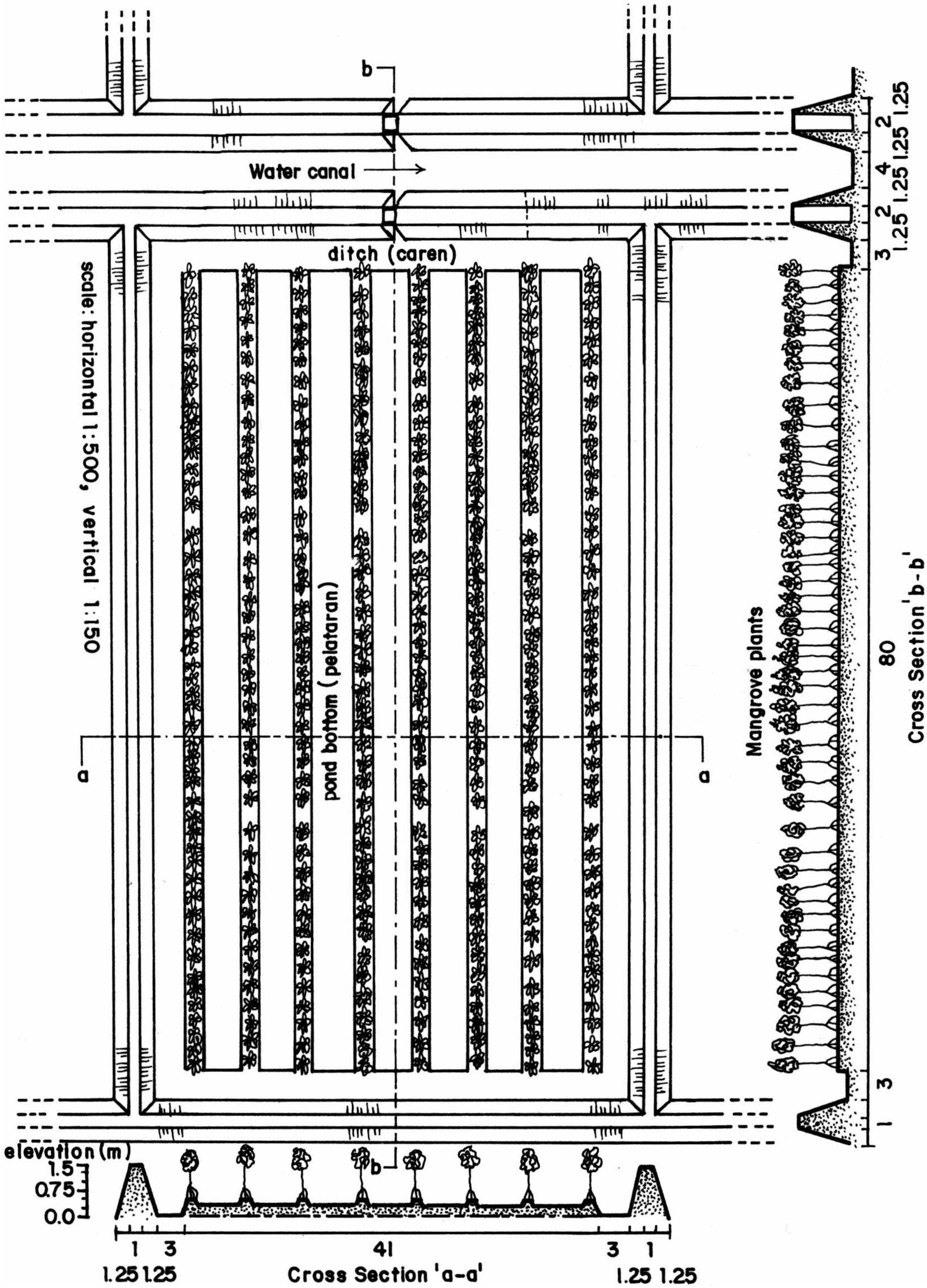

Figure 1. **Layout of one of the "tambak tumpangsari" and its cross-sections** (Takashima *et al.* 1994)

first row has 19 ponds and the other 11. Between the rows is the main water channel which supplies the ponds. The main water channel (for intake and drainage) has the following dimensions: 5.0-6.5 meters in the upper part, 4.0-4.5 m in the bottom, and 1.6-2.0 m depth. The slope of this channel is about 7% to 9%.

The main gate is made of concrete cement. It is 0.85 m in width, 1.9 m in length and 1.9 m in depth. The dike of the water channel is 2 m in width in the upper and 4.5 m in the lower part. The gate for each pond is wood, with or without wings, and is 0.45 m in width and 0.3-0.4 m in depth.

Mangrove vegetation
There is scarce information about suitable species of the mangrove. Usually, *Rhizophora* sp. is selected as in the case of the Cilacap Project.

Main aquatic species for aquaculture
The main species cultured in the pond are: (1) milkfish *Chanos chanos,* (2) tilapia *Oreochromis niloticus,* (3) mullet *Mugil cephalus,* (4) sea bass *Lates* sp., (5) black tiger shrimp *Penaeus monodon,* (6) shrimp *Metapenaeus* sp. and (7) mudcrab *Scylla* spp. Juveniles of black tiger shrimp usually migrate into the pond with incoming tide, but fry of milkfish and tilapia are released artificially. Birds, turtles and snakes are sometimes harvested as by-products.

Environment
In the case of Indonesia's Karawang project, water parameters such as temperature, transparency, salinity, nitrate, nitrite, phosphate, pH, dissolved oxygen (DO), biological oxygen demand (BOD) and total organic matter (TOM) have been analyzed (Table 1). Salinity fluctuated from 0 ppt (at low tide) to around 30 ppt (at high tide), but did not seriously damage the euryhaline species. Other parameters showed slight fluctuation within narrow ranges. Concentration of TOM was higher in the thick mangrove area.

Table 1. **Water quality of silvofisheries pond**

Parameters	Without mangrove	With mangrove cover		
		(40-60%)	(70-80%)	(>80%)
Transparency (cm)	48.0	29.0	44.0	40.0
pH	7.5	7.5	7.5	6.5
Dissolved oxygen (ppm)	7.0	6.5	8.5	5.1
Total organic matter (ppm)	41.0	78.0	39.0	170.0
Ammonia (ppm)	0.270	0.250	<0.001	<0.001
Nitrate (ppm)	<0.001	<0.001	<0.001	<0.004
Nitrite (ppm)	0.027	0.048	0.039	0.061
Phosphate (ppm)	<0.001	<0.001	<0.001	<0.001

Productivity of silvofishery
Production from aquaculture from one site is as follows: milkfish, 467 kg/ha/year; tilapia, 67; shrimp, 150; and crab, 20. This amounts to 703 kg/ha. In another site, milkfish harvest was about 625 kg/ha/

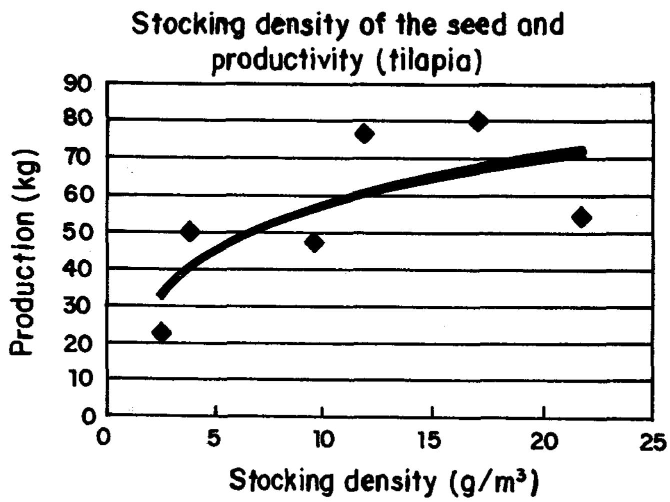

Figure 2. **Production of tilapia at different stocking densities in silvofishery**

year; tilapia, 50; shrimp, 130; and others, 5; or a total harvest of 811 kg/ha. Productivity of fish is relatively low when compared to the intensive system (with artificial feeding). However, the productivity of shrimp seemed high (Table 2).

Total 2. **Total production of wild shrimp in brackish pond with and without mangrove cover** (Karawang project)

	Without mangrove	With mangrove cover 40-60%	70-80%	>80%
Productivity (kg/ha/year)	171	181	355	414

Optimum seed density

There are few data about optimum stocking density of either fish or shrimp. In the case of tilapia, juveniles are released into the pond and reared for several months. Relationship between the stocking density and production was analyzed and is indicated in Figure 2. Production increased with stocking density but reached a plateau after 20 g/m^2

Costs-and-returns

According to Rusdi & Jasin (1994), cost-and-revenue per year of silvofishery differs depending on scale and type of species cultured. The cost-and-revenue of a typical silvofishery pond of size 3-8 ha is indicated in Table 3. This pond contains naturally recruited shrimp juveniles and artificially stocked

Table 3. **Costs-and-returns of silvofishery** (rupiah/ha/year)

Item	Pond covered by dense mangrove trees (> 80%)		Pond covered by sparse mangrove trees (40-60%)	
Farm (area)	6 ha	3 ha	4 ha	8 ha
Operational costs	172,550	609,200	501,000	2,353,700
Variable costs				
Seeds	0	191,400	217,500	360,000
Fertilizer	0	53,000	40,500	50,400
Chemicals	0	29,000	30,000	0
Harvesting	37,500	40,000	25,000	41,300
Fixed costs	1,688,000	295,800	284,000	1,902,000
Gross revenue	360,000	1,235,000	1,128,000	1,385,000
Net revenue	154,000	625,000	529,000	933,000
Total net revenue	924,000	1,875,000	2,116,000	7,464,000

tilapia and milkfish fry. Total net revenue of each farmer varies from 920,000 to 7,500,000 rupiahs in 1994. This income is thought to be reasonable for most farmers until the recent economic crisis.

Problems

The condition of pond and dike always changes because of erosion. The soil in mangrove area is relatively non-compact and has low stability. It is clay sand with high organic matter. Therefore, the dike should have a talus (or slope) of 1:2 or 1:1.25, and the shrinkage factor must be about 40%. To overcome seepage, the soil in the center of the dike has to have low permeability, for example clay. To avoid erosion, it is suggested to grow some grass common in the locality.

Although one of the objectives of silvofishery is to increase income of local peoples, conservation of mangrove must be considered deeply. At the beginning of this system, when mangrove trees are still young, there are less problems. However, when the trees are bigger, fish production decreases because of shading effect and the appearance of fish predators. The ponds in Cilacap project were covered totally with mangrove within 4 years. Therefore, it is recommended to plant gradually. For example, mangrove is planted in 10-15% of the area for every 6 months or one year.

Factors associated with silvofishery

Listed below are the parameters necessary to maintain silvofishery in good condition:

(1) *Selection of the site*
Water quality, type of soil, tidal changes, inlet and outlet of water, species of mangrove trees and surrounding flora, road, worker, market or consumer

(2) *Construction*
Design, supply of the materials, labor, legal permit

(3) *Mangrove vegetation*
Suitable species, quality of young plant, price, supply source, transport

(4) *Selection of fish and/or shellfish*
Adaptability, economic value of target organisms, introduction of the seed, artificial seed production techniques

(5) *Environment check*
Water quantity and quality, stability of water supply, natural fry supply, natural predators (carnivorous animals)

(6) *Observations during rearing*
Growth and survival, stocking density, water quality (daily observation), amount of fertilizer, additional food, fish health, harvesting, sales, visitors, accident record, balance sheet

(7) *Harvesting and marketing*

(8) *Relationship to local community*
Population, number of fanners interested, their ways of work, available services, infrastructure

(9) *Official financial and technical support*

[Literature citations in full may be requested directly from the author.]