AQUADAPT:

Nature-based solutions in Thailand

Evaluation under the IDRC-funded project "Knowledge brokering for nature-based solutions (NbS) in aquaculture transformation in Asia-Pacific: Support to the Aquaculture Innovation and Investment Hub (AIIH)".

IDRC · CRDI
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The project evaluated the effectiveness of various types of nature-based solution (NbS) in Thailand that contribute to climate change resilience by enabling off-grid farm operations and reducing reliance on costly fossil fuels. Aquaculture enterprises were assessed for this project based on the NbS they utilised and the potential benefits they offer in mitigating climate change impacts and enhancing production systems in Thailand.

Three enterprises / innovations were selected and they are described in Showcase 1, 2, and 3, below.

Nature-based solutions

The current development of traditional aquaculture requires adaptation to environmental changes and efficient resource utilization to achieve long-term sustainability. **Nature-based solutions (NbS)** can help address these challenges for example, improving ventilation systems in aquaculture ponds through renewable energy sources can enhance energy efficiency and reduce reliance on environmentally harmful energy supplies. By developing technologies that utilize low-cost and environmentally friendly energy, we not only lower long-term costs but also enable aquaculture systems to grow without negatively impacting the environment.

Another crucial factor in enhancing sustainability in aquaculture is the use of alternative protein sources. By incorporating plant-based or natural waste materials as food sources. The insect protein or plant proteins with high nutritional value can reduce dependency on animal protein. This shift not only lessens the environmental issues associated with sourcing raw materials from aquatic animals but also lowers production costs and promotes the sustainable use of natural resources.

Preventing diseases in aquatic animals is essential for the sustainability of aquaculture. Utilizing nano-bubble technology, which releases tiny bubbles into the water, offers numerous benefits. These bubbles increase oxygen levels in the water and lower the risk of disease outbreaks among aquatic animals. Improved oxygen distribution fosters healthier animals that are more resistant to illness. This technology is also environmentally friendly, as it can decrease the need for chemicals in water treatment.

Additionally, zero-feed aquaculture presents another sustainable approach by allowing natural systems to provide food for aquatic animals. By utilizing aquatic plants and resources from the ecosystem, aquatic animals can obtain the nutrients they need without relying on human-produced food sources. This method reduces food costs, minimizes human dependence on food production, maintains balance within the aquatic ecosystem, and lowers pollution from excessive food use.

To make aquaculture in Thailand more resilience, it is essential to address the challenges posed by climate change and unsustainable resource use, especially in the inland and coastal aquaculture sectors. This can be achieved through the integration of technology and natural approaches that enhance aquaculture efficiency while reducing environmental impact. Ultimately, these strategies can help lower costs and maintain ecological balance, making aquaculture sustainable in both economic and environmental terms over the long term.

In this progress report, Thailand has undertaken detailed assessments of three showcase technologies that are considered innovative NbS for sustainable aquaculture production. These are detailed below:

Showcase 1:

Solar Power Use on a Striped Snakehead (*Channa striata)* Rearing Farm

General Information about the Farm

The details of Siriwan Farm, a striped snakehead rearing farm located in Samko District, Ang Thong Province, are summarized in **Table 1**.

Table 1: General information on Siriwan Farm, a striped snake-head rearing farm.

Name	Siriwan Farm
Location	Samko District, Ang Thong Province
Farm owner	Ms. Siriwan Meesanga
Farm area	0.48 ha (3 rai)
Productivity	53-62 ton/ha/cycle (51-60 ton/farm/year) 8.5-10 ton/rai/cycle

Farming practices

This is a commercial snakehead farm consisting of a 1-rai earthen pond divided into three sections, each 2 meters deep, with a water level of approximately 1 to 1.5 meters. The farm releases 15,000 to 18,000 snakehead larvae (3-4 inches in size) per rai. These fish are fed a commercial diet designed for carnivorous fish with a protein content of 40%. The farming period lasts between 5.5 to 6 months, allowing for two production cycles annually, with each fish sold weighing between 0.7 to 0.8 kilograms. The feed conversion ratio is approximately 1.3 to 1.4, and the survival rate of the fish is around 80%. Water in the ponds is changed every 10 to 15 days, and sediment, leftover food, and fish waste are removed from the bottom of the pond daily.

Problems Leading to the Adoption of Innovation

The rising cost of energy (electricity) prompted the farm to seek ways to reduce its energy expenditures.

Innovation Models Implemented

- Solar Power System. The farm has installed a solar power system to facilitate water pumping in and out of the ponds. This system comprises 14 Monocrystalline Silicon solar panels (with a total power generation of 8.05 kWp; each panel rated at 575W) along with a control cabinet and an inverter to convert direct current (DC) to alternating current (AC). This system operates as an On-Grid setup connected to the Provincial Electricity Authority's power transmission line, but it does not utilize battery storage (**Figure 1**).
  The solar panels primarily use groundwater for pumping, requiring about 6 hours to change the water in the ponds and approximately 3 to 4 days to replenish it. The water pump operates from 08:00 to 15:00, aligning with daylight hours.

- Solar Power Aerator. The farm employs a 4-blade solar power aerator turbine (350 Wp), which operates solely during the day when sunlight is available. This system is not connected to the power grid and does not include battery storage. Each pond contains one set (**Figure 2**).

Figure 1. Solar power system (solar panel 8.05 kWp) for water pumping.

Figure 2. A Four-blade solar power aerator turbine (350 Wp) installed in each fish rearing pond.

Size of Investment

The cost for installing the solar power system completed with all necessary equipment is approximately 150,000 baht (not including installation fees).

The 4-blade solar power aerator turbine is priced at 20,000 baht per set, total 60,000 baht for all three ponds.

Empirical Impact (as shown in **Table 2)**

Table 2. Empirical data on the improvement of using solar power system in a striped snake-head rearing farm in Samko District, Ang Thong Province.

Parameter concerned	Comparison		
	before	after	% change
Productivity (ton/ha/cycle)	43.8-50.0	53.1-62.5	21.4 - 25%
(ton/farm/year; 1 year 2 production cycles)	42-48	51-60	
Energy efficiency Electricity consumption (kWh/year)	108,000	77,700	- 28.1%
Diesel fuel (litter/year)	400	-	- 100 %
Electricity consumption per 1 kg (kWh/kg)	2.40	1.39	-42 %
Energy cost Electricity (Baht/farm/year)	540,000	388,500	- 28.1%
Fuel (Baht/farm/year)	12,000	-	- 100 %
Production cost Total cost (Baht/kg)	60	53	- 11.7%
Energy cost (Baht/kg)	12	7	- 41.7%
CO_2 emission from Total energy usage ($kgCO_2eq$ /farm/year)	61,288.8	44,009.28	- 28.2%
Electricity usage ($kgCO_2eq$ /farm/year)	61,171.2	44,009.28	
Fuel usage ($kgCO_2eq$ /farm/year)	117.6	-	
1 kg of striped snake-head production ($kgCO_2eq$/kg)	1.36	0.79	- 41.7%

Emission factor electricity=0.5664 $kgCO_2eq$/kWh; Emission factor Diesel=0.3522 $kgCO_2eq$/kg

- **Farm productivity.** The use of solar energy has enhanced fish farming practices by enabling frequent water exchanges, which improves the overall water quality in the ponds. As a result, there has been a reduction in disease prevalence, a decreased reliance on drugs and chemicals, and lower fish mortality rates, all of which contribute to better fish growth. Consequently, farm productivity has increased by 21.4% to 25%.
- **Energy efficiency**. Using of solar power has also decreased energy costs for fish farming from 540,000 baht per farm per year (for 108,000 kWh at a rate of 5 baht per kWh) to 388,500 baht per year (for 77,700 kWh). This marks an increase in energy efficiency of 28.1%. The electricity consumption per 1 kg was reduced from 2.4 kWh/kg to 1.39 kWh/kg, indicating an energy efficiency improving of 42%. Additionally, fuel consumption for water pumping decreased by about 12,000 baht annually, marking a 100% increase in fuel efficiency.
- **Production cost.** The production cost for fish dropped from 60 baht per kilogram to 53 baht per kilogram, reflecting a decline of 11.7%. Furthermore, the energy cost associated with producing 1 kilogram of fish decreased from 12 baht to 7 baht, a reduction of 41.7%.
- **Environmental impacts**. The environmental impacts were also notable, with carbon dioxide emissions from combined energy usage (electricity and diesel) dropping from 61,288.8 $kgCO_2eq$ per farm per year to 44,009.28 $kgCO_2eq$ per farm per year, a reduction of 28.2%.

For fish production specifically, carbon dioxide emissions per kilogram decease from 1.36 kg CO_2eq/kg to 0.79 kg CO_2eq/kg, reflecting a reduction of 41.7% after the implementation of the solar power system.

Showcase 2:

Utilizing a smart aerator control system with IOT for super intensive white shrimp (*Penaeus vannamei*) farming

General Information about the Farm

The details of Lamphu Farm, a super intensive white shrimp rearing farm located in Mueang District, Chumphon Province, are summarized in **Table 3**.

Table 3. General information about Lamphu Farm, a super intensive white shrimp rearing farm located in Mueang District, Chumphon Province.

Name	Lamphu Farm
Location	Mueang District, Chumphon Province
Farm owner	Mr. Alongkorn Sanglapho
Farm area	38.4 ha (240 rai) with 60 rearing ponds (only 17 rearing pond (14.4 ha) is using the smart aerator control)
Productivity	31.25 ton/ha/cycle (1200 ton/farm/year) 5 ton/rai/cycle

Farming practices

At Lamphu Farm, white shrimp are raised in both earthen ponds with a stocking density of 750,000-937,500 pls/ha (120,000-150,000 pls/rai) and in ponds with PE liners covering 0.4 ha (2.5 rai), shrimp are stocked at a super intensive density of 1,250,000-2,750,000 pls/ha (200,000-440,000 pls/rai). The ponds are prepared by disinfecting and eliminating disease vectors before farming begins. During the farming period, microorganisms are utilized to control water quality. Propeller aerators and underwater oxygen diffusor, are installed to ensure sufficient oxygen for the shrimp and to maintain the ecological balance of the water.

Water exchange, along with appropriate use of microorganisms and chemical disinfectants, helps prevent and minimize the risk of disease. Additionally, probiotics are incorporated into the shrimp's feed. Farming management focuses on appropriate feeding levels to avoid overly rapid growth. The shrimp farming cycle lasts about 100-120 days, with a feed conversion ratio between 1.3 and 1.6. Regular health checks, supported by laboratory results, are emphasized to ensure the shrimp are healthy and ready for high-quality harvesting. Harvesting occurs in 2-3 rounds depending on production volume of each production cycle, averaging about 31.25 tons/ha (5 tons/rai).

Problems Leading to the Adoption of Innovation

Recently, super intensive shrimp farming in Thailand encounters significant challenges due to fluctuating weather conditions, particularly with water quality control, which can become difficult during extreme weather and the summer months. Additionally, traditional way of oxygen management which relies on workers' experience, may not be effective, leading to energy waste and potential errors in farming management. These errors can cause shrimp to experience stress from poor water conditions, particularly when oxygen levels are inadequate, resulting in decreased food intake, heightened illness risk, and increased mortality rates. Farmers may be forced to harvest shrimp at suboptimal times for selling, leading to higher costs and energy waste.

Innovation Models Implemented

The "Smart Aerator Control" system has been developed to maintain the level of dissolved oxygen (DO) in the water and enhance energy efficiency in high-density white shrimp farming. This system employs:

- Optical Oxygen Sensors. These measure dissolved oxygen levels in the water using light, which allows for low maintenance and resistance to harsh aquatic environments, including saltwater and freshwater, as well as temperature variations.
- Temperature Sensors. Thermocouples convert temperature into electrical currents.
- pH Sensors. These measure electrical potential differences associated with the acidity or alkalinity of the solution.

A total of 14 "Smart Aerator Control" units have been installed across 14 shrimp ponds, with an additional 3 units moved around to use in the neighboring ponds, making a total of 17 ponds equipped. In each pond, data from the sensors are transmitted via IoT devices to a central control platform. This platform analyzes and manages the dissolved oxygen level, maintaining it within the ideal range of 4.5-5.8 mg/l for optimal shrimp growth. The system controls the operation of the water turbine aerator and the automatic underwater air pipe oxygen supply system, increasing oxygen levels when they fall below the preset value and decreasing them when sufficient oxygen is available (**Figure 3).**

Figure 3. Smart aerator control installed in a super intensive white shrimp farm with a real-time display screen.

The system features a real-time display screen that shows water quality information and the operational status of the equipment. Users receive alerts via a mobile application if oxygen levels drop critically low, allowing for immediate adjustments to the system settings to enhance farm management efficiency and safety. This innovative system enables farmers to accurately manage pond oxygen levels, reduce aerator operating hours, and minimize unnecessary energy consumption. This leads to improved energy efficiency, consistent water quality, and lower electricity costs associated with shrimp farming.

Size of Investment

The "Smart Aerator Control" system includes sensors for measuring dissolved oxygen, temperature, and pH, along with the complete set of necessary equipment. Each set is priced at 86,000 baht, resulting in a total cost of approximately 1,204,000 baht for all 14 sets.

Empirical Impacts (as shown in **Table 4)**

- **Farm productivity.** The implementation of the "Smart Aerator Control" system in super intensive white shrimp farming significantly improves energy management. It allows for better control of oxygen levels and maintains the farming environment within optimal conditions for consistent shrimp growth. This system increases the carrying capacity for white shrimp farming by approximately 33.3%, boosting annual farm productivity from about 337.5 tons to 450.0 tons.
- **Energy efficiency**. The "Smart Aerator Control" system also reduces energy costs in shrimp farming. Previously, the electricity cost for producing 1 kg of shrimp was 21 baht (5 kWh), but after adoption of the system, this cost dropped to 17 baht (4 kWh), representing a 20% improvement in energy efficiency. While the total energy cost for the farm increases from 7,104,375 baht/year to 7,578,000 baht/year (a rise of 6.7%), it is offset by a production increase of approximately 33.3%.
- **Production cost.** The overall production cost of white shrimp has decreased from 160 baht/kg to 156 baht/kg (a reduction of 2.5%). This decrease is primarily attributed to the lack of innovation in some ponds and overall farm practices. In ponds utilizing the innovation, the energy cost for producing white shrimp is reduced from 21 baht to 17 baht/kg (a 20% reduction).
- **Environmental impacts**. In terms of environmental impact, carbon dioxide emissions related to electricity use on the farm increased from 955,800 kg CO_2eq/farm/year to 1,019,520 kg CO_2eq/farm/year (an increase of 6.7%). However, when calculating emissions per production unit, carbon dioxide emissions from electricity used to produce 1 kg of white shrimp decreased from 2.83 kg CO_2eq/kg/cycle to 2.27 CO_2eq/kg/cycle (a reduction of 20%).

Table 4. Empirical Data on Using a Smart Aerator Control System with IoT for High-Density White Shrimp Farming at Lamphu Farm, Mueang District, Chumphon Province.

Parameter concerned	Comparison		
	before	after	% change
Productivity (ton/ha/cycle)	23.7	31.25	33.3%
(ton/farm/year; one year 2-3 production cycles)	337.5	450	
Energy efficiency Total Electricity consumption (kWh/year)	1,687,500	1,800,000	6.7%
Electricity consumption per 1 kg (kWh/kg)	5	4	-20.0%
Energy cost Electricity (Baht/farm/year)	7,104,375	7,578,000	6.7%
Production cost Total cost (Baht/kg)	160	156	- 2.5%
Energy cost (Baht/kg)	21	17	- 20.0%
CO_2 emission from Total energy usage ($kgCO_2eq$ /farm/year)	955,800	1,019,520	6.7 %
1 kg of striped snake-head production $kgCO_2eq$/kg)	2.83	2.27	- 20.0 %

Emission factor electricity=0.5664 $kgCO_2eq$/kWh

Showcase 3:

Using Solar Cells combined with Smart Aerator Control System for Raising White Shrimp (*Penaeus vannamei*)

General Information about the Farm

The following details summarize a closed intensive system for white shrimp farming located in Tha Chang District, Surat Thani Province, as outlined in **Table 5**.

Table 5. General information about Kokhet Farm, a closed intensive system for white shrimp rearing farm located in Tha Chang District, Surat Thani Province.

Name	Kokhet Farm
Location	Tha Chang District, Surat Thani Province.
Farm owner	Mr. Pisit Nuannun
Farm area	27.2 ha (170 rai) with 12 rearing ponds (7.7 ha eq 48 rai)
Productivity	28.13 ton/ha/cycle (496 ton/farm/year)
	4.5 ton/rai/cycle

Farming practices

The farm consists of 12 earthen ponds covering 0.64 ha (4 rai) each, lining with PE along the pond dyke. The shrimp are stocked at density of 1,375,000 to 1,562,500 pls/ha (220,000 to 250,000 pls/rai). During the farming period, microorganisms are employed to help maintaining water quality. A turbine aerator is installed to ensure the shrimp receive sufficient oxygen. Water change and waste management occur in the center of the pond, with water stored in a separate 0.8 ha (5 rai) sludge dumping pond. The shrimp are raised for approximately four months. Farming management focuses on efficient feeding, with a feed conversion ratio ranging from 1.2 - 1.7, influenced by shrimp species, farming duration, weather conditions, and seasonality. Harvesting occurs two to three times based on production volume, and the water removed during harvesting is treated and reused in subsequent farming cycles.

Problems Leading to the Adoption of Innovation

The closed intensive system for white shrimp farming consumes a considerable amount of energy. Rising energy prices, combined with inefficient energy usage and poor farm management, lead to energy waste and higher operational costs. This situation increases the risk of business losses, especially during times of low shrimp prices.

Innovation Models Implemented

To address these challenges and improve energy efficiency, the farmer implemented two innovative systems.

- On-Grid 50.4 kWp Solar Power System. This system is designed to meet the energy demands of the high-density shrimp farm. It connects to the main power supply without the need for batteries. During the day, electricity generated from the solar panels is used, thereby reducing electricity bills and peak demand charges (09:00 - 18:00). The produced electricity is converted from direct current (DC) to alternating current (AC) via an on-grid inverter, allowing immediate use on the farm. This system also gathers real-time data on electricity production and monitors the solar panels for damage or malfunctions, ensuring timely maintenance.
- Smart Aerator Control System. This system is engineered to maintain the dissolved oxygen (DO) levels while enhancing energy efficiency in the high-density shrimp farm. It includes 12 sets of sensors that monitor oxygen, temperature, and pH levels in the pond. This data is transmitted in real-time via an IoT system to a central control platform, which analyzes the information to regulate the turbine aerator and the automatic underwater air pipe supply system. The aerator operates only when necessary, ensuring that the oxygen level is maintained at an ideal 5 mg/L for shrimp growth. Additionally, it features a real-time water quality display and a notification system through a mobile application, allowing for immediate adjustments if abnormal conditions are detected.
- Efficient Use of the Solar Power System with Smart Aerator Control
    - Daytime (09:00-18:00) During peak electricity usage hours when rates are high, the solar cell system provides power to the aerator and other farm equipment. This coordinated operation reduces overall electricity demand and significantly lowers electricity bills.
    - Peak Evening Hours (18:00-22:00) In the absence of sunlight, the Smart Aerator Control system uses sensors to monitor oxygen levels in real-time, ensuring that the aerator operates only as needed to minimize energy consumption.
    - Off-Peak Hours (22:00-09:00) and holiday (00:00-24:00) When electricity rates are lower, the Smart Aerator Control system efficiently regulates aerator operation,

activating it only when necessary to maintain optimal water quality and oxygen levels.

The integration of these two systems allows for effective management of white shrimp farms, promoting energy savings, cost reductions, and enhanced safety for sustainable aquaculture practices (**Figure 4**).

Figure 4. Using solar power system with a smart aerator control system in a closed intensive system for white shrimp farming at Kokhet Farm in Tha Chang District, Surat Thani Province.

Size of Investment

At Ko Khet Farm, a large solar cell system with a capacity of 50.4 kWp was installed, costing 2,000,000 baht. Additionally, 12 sets of smart aerator control systems, each costing 80,000 baht, brought the total investment for the farm to 2,960,000 baht.

Empirical Impacts (as shown in Table 6)

- **Farm productivity.** The integration of solar power system with a smart aerator control system significantly improved energy management in a closed intensive system for white shrimp farming. It enhanced oxygen control and created an optimal environment for shrimp growth. As a result, the carrying capacity of the shrimp farm increased by approximately 28.6%, raising year-round productivity of shrimp from about 336 to 432 ton/farm/year.
- **Energy efficiency**. Utilizing both systems together led to energy cost savings for shrimp farming. Before implementing the systems, the energy cost was 25.68 baht/kg of shrimp (6.1 kWh). After using the innovations, the energy cost decreased to 19.91 baht/kg (4.73 kWh), marking a 22.46% improvement in energy efficiency. Overall, the farm's annual energy cost decreased slightly from 8,628,816 baht to 8,602,546 baht, which is a 0.3% reduction. This small decrease in costs was offset by the increase in production of approximately 28.6%.
- **Production cost.** The overall production cost for white shrimp decrease from 126.68 baht/kg to 121.02 baht/kg, resulting in a reduction of 4.55%. Moreover, the energy cost per kilogram of white shrimp production dropped from 25.68 baht to 19.91 baht, a reduction of 22.46%.
- **Environmental impacts**. The farm also managed to reduce its environmental impact, specifically decreasing carbon dioxide emissions associated with electricity use. Annual CO2

emissions were lowered from 1,160,893 kg CO2eq to 1,157,359 kg CO2eq, a decrease of 0.3%. Calculated per production unit, the carbon dioxide emissions related to producing 1 kilogram of white shrimp decreased from 3.46 kg CO2eq per cycle to 2.68 kg CO2eq per cycle, reflecting a 22.46% reduction.

Table 6. Empirical Data on using solar power system with a smart aerator control system in a closed intensive system for white shrimp farming at Kokhet Farm in Tha Chang District, Surat Thani Province.

Parameter concerned	Comparison		
	before	**after**	**% change**
Productivity (ton/ha/cycle)	21.9	28.13	28.6.%
(ton/farm/year; one year 2-3 production cycles)	336	432	
Energy efficiency Total Electricity consumption (kWh/year)	2,049,600	2,043,360	-0.3%
Electricity consumption per 1 kg (kWh/kg)	6.1	4.73	-22.46%
Energy cost Electricity (Baht/farm/year)	8,628,816	8,602,546	-0.3%
Production cost Total cost (Baht/kg)	126.68	121.02	- 4.55%
Energy cost (Baht/kg)	25.68	19.91	- 22.46%
CO_2 emission from Total energy usage ($kgCO_2eq$ /farm/year)	1,160,893	1,157,359	0.3 %
1 kg of striped snake-head production $kgCO_2eq/kg$)	3.46	2.68	- 22.46 %

Emission factor electricity=0.5664 $kgCO_2eq/kWh$