ASIN CENTER

Accelerating Salt Research & INnovation Center

Project 1: Development of Sustainable and Climate-Resilient Salterns: Best Practices, Standardization, Site Mapping and Pilot Establishment of Saltern Technology

Project Duration:	November 16, 2023 - November 15, 2025
Project Leader:	Nathaniel R. Alibuyog
Implementing Agency:	Mariano Marcos State University
Funding Agency:	DOST-PCIEERD

PROJECT PROFILE

Title:	Project 1: Development of Sustainable and Climate-Resilient Salterns: Best Practices, Standardization, Site Mapping, and Pilot Establishment of Saltern Technology
	Nathaniel R. Alibuyog Vice President for Research, Extension, and Innovation Mariano Marcos State University City of Batac, 2906 Ilocos Norte
Project Duration:	2 years
Actual Duration	November 16, 2023 – November 15, 2025
Implementing Agency:	Mariano Marcos State University
Collaborating Agencies:	Pangasinan State University (Project 2-Lead) President Ramon Magsaysay State University (Project 3) Don Mariano Marcos Memorial State University (Project 4)
	Philippine Council for Industry, Energy, and Emerging Technology Research and Development (PCIEERD)
	Ilocos Norte, Ilocos Sur, La Union, Pangasinan Bulacan, Zambales Occidental Mindoro Negros Occidental, Guimaras, Iloilo Misamis Oriental
Year 1 Proposed Budget	Php 17,226,796.40
First Release	Php 13,984,046.40
Total Release	Php 13,984,046.40

1. INTRODUCTION

Salt is a basic commodity and an essential food and ingredient for many items used in the household, food processing, water treatment, feeds, and a fertilizer for the coconut industry. It is reported that salt has over 14,000 uses. Salt is almost present in every food item and processed food product such as canned goods, meats, baked goods, noodles, and snack foods. It is also an important raw material for the production of many high value products and chemicals, making it a key product for agro-industrial development and chemical industry development (Philippine Salt Industry Roadmap).

Despite the increasing demand for salt, the production of salt in the Philippines declined over the years. The decline of salt production was attributed to several factors which include (1) lack of identified areas for salt production, approved by concerned agencies; (2) lack of new investment in new salt farms, due to risk and lack financing; (3) inability to adapt to the increasing climate variability; and (4) lack of development of new technologies for improving salt production quantity and quality. These problems were explicit identified in the Philippine Salt Industry Roadmap (2022). As a result, the Philippine government is importing about 550,000 MT of salt annually from Australia to augment the local salt produced which is estimated at 123,000 MT annually during an El Niño year and about 36,000 MT during La Niña year. In effect, the country is estimated to be importing about 93% of its salt requirement. Because of this, congressmen passed the House Resolution 1032 and 1046 in 2020 which calls for broader and stronger support among the various government agencies including DA, BFAR, DOST, DENR, DTI, CDA.

As pointed out in the Philippine Salt Industry Roadmap, there is a need to modernize the salt industry by infusing new technologies and innovations to increase the production capacity and efficiency of existing farms and to develop new salt production farms specifically along the coast of Type 1 climate provinces.

In response to this call, this project is proposed to develop a sustainable and climate-resilient saltern technology that will provide more economic opportunities for communities, increase salt production farms to meet future project demands and at the same time preserve the environment and support climate change adaptation strategies.

Meanwhile, salterns are facilities that produce salt by evaporating seawater or brine. Currently, salterns vary in size, design, and production methods. This makes it difficult to compare the productivity and efficiency levels of different salterns. Among the common problems encountered by traditional saltern farms include low purity of salt produce which ranges from 78-90%, increased cost of rice bran which is as fuel, and erratic weather patterns which affects the production cycle of salt farmers. PhilAsin (2021) added the decline of salt production in the Philippines is brought about by several factors which include (1) the inability of salt farmers to adapt to increasing climate variability; (2) lack of development of new technologies for improving salt production both in quantity and quality; and (3) lack of support facilities and materials to maintain and continuously strengthen existing and newly developed salt farms. This include crystallizer materials, heavy equipment, salt storage facilities to protect salt production from abrupt change in weather, and absence of production manual and skills training for salt farm workers. Also, some salt farms were not properly sited and/or designed hence many of the salt farms are flooded during heavy rainfall.

Apparently, the lack of standardization in salterns and absence skills training of workers has contributed to inconsistent quality levels and increase production cost per kg of salt produce. Therefore, there is a need to document the best practices and standardize salterns.

Standardization will involve identifying the optimal size, design, and production methods for salterns. Guidelines for the construction and operation of salterns must also be developed. The standardization of salterns will ensure consistent quality, increase productivity level, and reduce cost of production.

Moreover, the production of salt requires a specific set of conditions, and not all regions are suitable for this purpose. The production of salt requires specific environmental conditions, access to seawater or brine, access to infrastructure and the availability of labor. Therefore, not all regions are suitable for the production of salt. Construction of salterns in unsuitable regions will result in low productivity levels, low quality and high operational costs. Meanwhile, existing productive areas of salt farms had shrank due to conversion of salt farms into real estate development such as the case of Paranaque and Cavite. In 2018, it was reported that the construction of the Bulacan Aerostropolis led to the reclamation of fish ponds, mangrove areas and salt farms, leaving the Bulacan salt production to nearly zero (PhilAsin, 2021). Therefore, mapping the potential sites for new salterns is vital to ensure that new salterns are constructed in suitable regions for higher productivity, quality levels and lower operational costs.

2. REVIEWS OF LITERATURE

The Philippine Salt Industry

The start of the Philippine local salt industry can be traced to pre-Spanish colonial period. The province of Pangasinan, was named after “panag-asinan”, which means “land of salt” or the “place where salt is made.” Salt making know-how was already practiced even before the arrival of the Spanish colonizers. The same techniques using salt ponds and salt beds were found in Java and neighboring countries, where it spread to areas surrounding Manila Bay including Bulacan, Cavite and Paranaque. The Commonwealth Act No.141 Public Land Act of 1936 formalized the leasing out of public lands and foreshore areas into fishponds and salt farms. Several fishpond lease agreements were issued by the Department of Agriculture and Natural Resources, and the salt industry boomed as new fishponds and salt farms were constructed in Pangasinan, Bulacan, Mindoro Occidental, Cavite, Paranaque, Negros, Cebu and other provinces from the 1950s onwards. Salt producing areas in the Philippines, reached an estimated peak of 5,000 hectares nationally, producing an estimated 240,000 metric tons annually. This boom in growth supported a growing population and the development of the salt industry in the 1960s and 1970s.

Large scale salt producers (400 hectares or larger) such as Salt Industries of the Philippines in Mindoro and Pacific Farms in Bolinao, Pangasinan were constructed during this period. Several hundred medium (50 to 399 hectares) and small scale producers (less than 50 hectares) were established as demand grew.

In the 1980s, the urbanization of Paranaque and Cavite led to the conversion of salt farms in these areas into real estate developments. While the productive areas of salt farms shrank, the country did not invest in or construct new areas for salt making. As the population increased, the demand for salt increased, which only led to more dependence on imported salt. At this time, salt from India was seen as a viable source to make up for the increased volume of demand. The salt was bagged at the destination ports, making it easy to distribute to dealers and viajeros upon arrival. Ports of Manila, Batangas, and San Fernando La Union provided entry into Luzon. Ports of Cebu, Iloilo City, Davao, General Santos City, Zamboanga City provided direct entry points of imported salt from India. Unfortunately, increasing costs of inter-island shipping made the transport of salt from Luzon more and more expensive than importing salt from India and bringing it to Visayas and Mindanao. By the late 1990s, salt from Luzon could not be shipped competitively to Visayas and Mindanao markets, leaving the field exclusively to imported salt.

In December 1995, the RA 8172 "An Act for Salt Iodization Nationwide" was passed into law by President Fidel V. Ramos. This law required all salt for human and animal consumption to be iodized. Several small to medium salt farmers were not able to adapt to this change in the salt industry. While the RA 8172 ASIN Law focused purely on salt iodization and regulation, the local salt production industry was neglected. There was no department under the national government which could organize or guide the industry. The DOH was focused primarily on salt iodization, while the Department of Agriculture did not include salt in its plans, programs and roadmap for its food security and crop development programs, even if most salt farms were also utilized as fish ponds.

In 1996, the GATT-WTO panel of the Philippine government agreed to lower the tariffs for imported salt steadily to 1%, from as much as 50% in the 1980s. This ensured that imported salt would become lower in landed cost. However, promised farm-to-market support by the national government did not include the salt industry. No industry roadmap or master plan was prepared to support the onslaught of imported salt, the lowering of tariffs or the regulatory impact of the RA 8172 ASIN law.

In 1997, importation from Australia increased due to innovations in logistics. Australia salt arrives in break bulk form. It is unloaded in bulk form and discharged at the pier. Improved cleanliness and quality in bulk handling at the pier and salt warehouses, and grinding of the salt enabled this salt to displace the Indian salt within just 3 to 4 years.
By 2001, most imported salt was coming from Australia, mainly from Dampier Salt, Cargill Salt, and Shark Bay salt.

In the 1998-2001 period, the salt industry was greatly affected by the 3-year prolonged La Nina period, following the severe 1997-1998 El Nino. La Nina periods bring tremendous amounts of rainfall during the dry season, making brine evaporation and salt crystallization very difficult. Many salt farms lost money, particularly in Bulacan. They resorted mostly to bangus and tilapia cultivation, and avoided salt production. This deemphasis on salt production led to poor maintenance of salt crystallizer ponds, salt warehouses and stoppage of small boats used for transporting salt around the Manila Bay areas of Paombong, Hagonoy, Navotas and Malabon. As time went on, less and less investment.

In 2018, the construction of the Bulacan Aerotropolis by San Miguel Corporation led to its reclamation of fishponds, mangrove areas and salt farms. This reduced the Bulacan salt production further, perhaps to nearly zero.

As can be seen from these events, various factors caused the decline of the salt industry in the Philippines.

Major Salt Producing Provinces in the Philippines

The major salt-producing provinces in the Philippines are:

- Pangasinan - located in the Ilocos Region, Pangasinan is known for its salt beds, which produce large quantities of sea salt of about 230,000 metric tons per year

- Iloilo - located in the Western Visayas region, Iloilo is known for its traditional salt-making methods, which involve using bamboo poles to channel seawater into shallow ponds for evaporation. The current production is about 50,000 metric tons per year
- Cebu - located in the Central Visayas region, Cebu is known for its natural salt pans, which are formed by seawater that has been trapped by natural rock formations. The estimated production is about 25,000 metric tons per year
- Negros Occidental - located in the Western Visayas region, Negros Occidental is known for its modern salt farms, which use advanced technologies to increase salt production. They have an estimated production capacity of about 15000 metric tons per year
- Bohol - located in the Central Visayas region, Bohol is known for its artisanal salt production, which involves using wooden troughs and bamboo baskets to harvest salt from evaporating seawater. The estimated production rate is about 5,000 metric tons per year
- Zambales – located in central Luzon has a production capacity of about 10,000 meteric tons per year
- Batangas – located in Region 4A has a production capacity of about 5,000 tones per year
- Samar – production capacity of 2,500 metric tons per year

Moreover, data obtained from BFAR shows the number of farmers engaged in salt farming across various provinces in the country. It shows that the majority of the salt farmers are classified as small (<3 ha). There are 69 and 7 farms that are classified as medium size farms (3 to 50 ha) and large farms which have 50 ha or larger.

PROVINCE	NUMBER FARMS				TOTAL
	Large (>=50 ha)	Medium (3- 50 ha)	Small (<3ha)	Subsistence	
Antique			10	15	25
Batangas			1		1
Bulacan		7	2		9
Catanduanes				1	1
Cavite			3		3
Guimaras			86	2	88
Ilocos Norte		1	57	23	81
Ilocos Sur			43	56	99
Iloilo		1	52	1	54
La Union			2		2
Misamis Oriental		2	46	10	58
Negros Occidental		1	260	8	269
Negros Oriental			1		1
Occidental Mindoro	6	16	16		38
Pangasinan	1	41	300		342
Quezon			1		1
Zambales			3		3
Zamboanga			4		4
Total	**7**	**69**	**887**	**116**	**1079**

Potential Sites for Solar Salt Production

Climate is one of the environment considerations use in identifying the suitability for salt production. As such, salt production is viable in Type I climatic areas of the Philippines. Based on the report of the Philippine Salt Industry Roadmap (2022), the following provinces as suitable for salt production with their estimated length of coastline.

PROVINCE	COASTLINE (km)
Ilocos Norte	150.18
Ilocos Sur	157.63
La Union	114.70
Pangasinan	285.66
Zambales	110.00
Bataan	188.66
Mindoro Occidental	300.00
Palawan	1354.10
Antique	155.00
Marinduque	161.00

Current Situation of Solar Salt farms in the Philippines

In 1990, Occidental Mindoro, played a significant role in the country's salt production, supplying 60,000 MT out of the total demand of 338,000 MT, meeting 85% of the national requirement. However, by 2018, the local salt industry could only fulfill 20% of the country's salt demand, with the remaining 80% being imported (DOST, 2017). This decline in local salt production can be attributed to various factors, including climate change-induced erratic weather patterns, production losses, poor logistics, poor production and organizational management, water pollution, limited research and development activities, and the absence of supportive policies for the salt industry (TAMACO, 2019 as cited in Muyot et al, 2022).

Solar salt farms is still the most common method of producing salt in the Philippines. This method harnesses the power of the sun to produce salt through the natural evaporation of seawater. As to type of salt beds, Muyot et al (2022) reported that majority (94.2%) of their respondents in Occidental Mindoro used Vigan clay to line their crystallizing ponds. None of the respondents used high density polyethylene (HDPE) geomembranes. In contrast, in Misamis Oriental, Delos Reyes et al (2021) reported that 47% of the salt produces use black polyethylene plastic while 17% and 36% use brick tile and transparent polyethylene plastic, respectively.

Meanwhile, Delos Reyes et al (2021) reported that majority (62%) of salt produces in Misamis Oriental are female and the average age was 45 years but the highest proportion (21%) of them are 51 to 55 years old. This profile suggests the needs to further improve the current technology to attract younger generation to engage in the business.
Additionally, the study of Muyot et al (2022) reported that the absence of facilities to ascertain product quality, limited research on salt production, limited post production technology, logistic and marketing, lack of capitalization, and limited post-harvest facility constitute the major challenges of the salt industry.

Lack of research on salt production and lack of capitalization force the farmers to stick to their age-old traditional salt farming methods. For instance, salt farmers use twigs to determine the concentration of the pond, i.e., if the twig floats, it means the brine is in the right concentration to be transferred to the concentration pond.

The above-mentioned current condition of the solar salt farm in the in the Philippine necessitates scientific intervention to further improve the productivity and efficiency of salt farms.

Available Saltern Technologies

A saltern is an area or installation for making salt. Salterns usually begin with seawater as the initial source of brine but may also use natural saltwater springs and streams. The water is evaporated, usually over a series of ponds, to the point where sodium chloride and other salts precipitates out of the saturated brine, allowing pure salts to be harvested. Today, there are several innovations to optimized the operation and productivity of salt farms. Among these are discussed below.

Traditional Saltern Method. The salt production process in traditional method consist of evaporation, precipitation, and crystallization. The evaporation process spends 7-10 days. After that, the evaporated seawater is transferred into the salt table for precipitation process. This process take 10-15 days, then the precipitated seawater flowed into the salt table for crystallization process. The crystallization process will take 4-10 days relying on the weather. Traditional method have relatively low in terms of productivity and quality. The productivity of land used to salt production is 60 ton/ha/year. The quality of salt production contains sodium chloride (NaCl) and other impurities, i.e. magnesium, calcium, etc.

Geomembrane technology. This method produce salt by coating the base of pond with geomembrane plastic, The main characteristics of geomembrane as a liner in salt ponds are economic value, durability, and resistance to degradation by biological, chemical and ultra violet (UV). The benefits of salt production through geomembrane technology are the productivity of salt increased, the evaporation process is shorter, turnaround time is improved, the harvest and the quality of salt is improved and the long lifetime of geomembrane will reduce the preparation works (Suhendra, 2016).

Filtering-threaded technology (TUF) is the modified technology of salt production integrating geomembrane technology through the serial plots. The main principle of TUF is the evaporation process of seawater flowed through the serial plots in the salt tables. In addition, natural materials are added as filters to purify seawater (Susanto et al, 2015). The advantages of implementing TUF are the productivity could attain 80 ton/ha/cycle (Bramawanto et al, 2015), the color of salt product is white and pure, the purity of salt (NaCl) and price are higher than traditional process products (Susanto et al, 2015).

Prism greenhouse is a method to produce salt by using greenhouse model formed a prism structure. The principle of this method is integrating geomembrane and filtering-threaded technology. The prism greenhouse method is an integration of pre-existing salt producing technologies included geomembrane [6] dan filtering-threaded technology [7]. The process of salt production using the prism greenhouse method is (1) banker I, as a reservoir pond, to collect seawater with concentration of 7-8 oBe (oBaume); (2) filtering-threaded pond, as a evaporation pond, to evaporate seawater until reach concentration of 20- 22 oBe; (3) banker II, as a precipitation pond, to precipitate seawater with concentration 25-27 oBe; and (4) prism greenhouse, as a crystallization pond, to crystallize seawater. The process of salt producing technology in the prism greenhouse method is shown below.

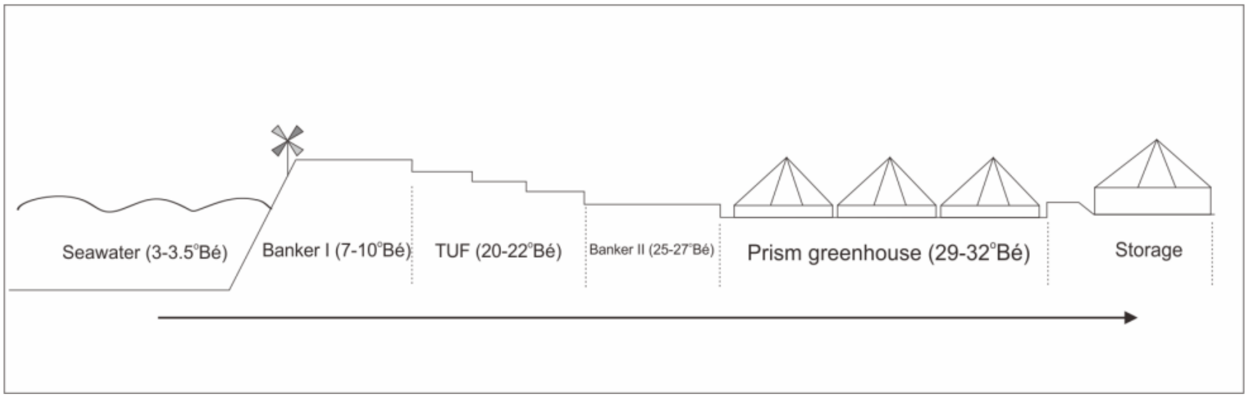


Figure 1. The salt producing technology in the prism greenhouse method

Accordingly, the purity of salt (NaCl) produced by using prism greenhouse method is 95%, which is higher than traditional method which is usually 85%. The increase in purity is attributed to the presence of filters located on the filtering- threaded pond.

Geomembrane Filter Thread Technique (GFTT). GFTT is a form of applying two technologies simultaneously, thread filter technology and geomembrane. GFTT is the modified technology of salt production integrating geomembrane technology through the serial plots. The main principle of FTT is the evaporation process of seawater flowed through the serial plots in the salt tables. In addition, natural materials are added as filters to purify seawater (Susanto et al.,2015). The advantages of implementing FTT are the productivity could attain 80 ton/ha/cycle, the color of salt product is white and pure, the purity of salt (NaCl)and price are higher than traditional process products (Bramawanto et al.,2016). Geomembrane is a layer of HDPE sheet that is spread on salt land and serves as a waterproof barrier between the soil and other parts (Guntur et al.,2018;Abdelaal et al.,2019).

The structure and com-position of the FTT salt pond are shown in the Figure below. It can be seen in the figure that the FTT salt pond is com-posed of 3 main components, namely two reservoirs, two condensers, and three crystallizers. Equipped with brine channels (pre-crystallizers) and bunds.

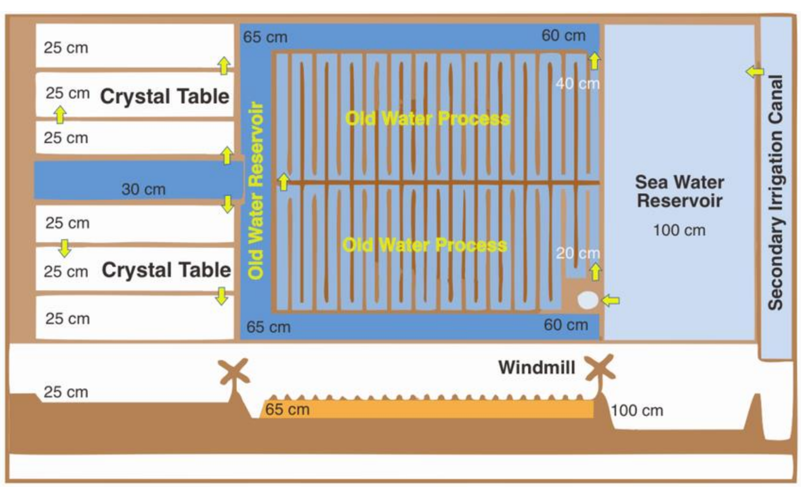


Figure 2. Design of Salt Pond Thread Technology

The functions of each pool are as follows:

- Reservoir ponds or also called reservoirs, dams, and bozeem serve as a starting place to accommodate seawater with a concentration of 1-5°Be and deposit organic material.
- Condenser ponds are plots (pools) where the aging process of seawater with the evaporation of sunlight. In the FTT system, the purification pool is made in a series of plots (threads) such as channels of uniform size with a width of not more than 3 m. In this purification pond, the aging of seawater from a concentration of 5 to a density of 25°Be occurs. Old water (brine) with a concentration of 25°Be is the raw material for salt to flow into the crystal table (crystallizers)
- The brine channel (pre-crystalized) is a small channel and a map to accommodate 25°Be density brine that is ready to be crystallized.
- Crystallization tables (crystallizers) are plots where the crystallization of brine into salt crystals occurs. In the GFTT salt ponds, there are small elongated plots connected to each other in a series, better known as screw pools. This land modification is what distinguishes GFTT salt ponds from traditional salt ponds. The principle of the GFTT system for pond management is focused on modifying pond land and controlling seawater quality to become old water with a viscosity of 25°Be. The production process will be faster and last for 13-15 day

Current Processes of Solar Salt Farms

In the Philippines, Solar Salt farms are commonly used to produce salts. Generally, the salt production is being carried through the capturing of salt water in a pan type structure where the sun evaporates most of the water. The salt production process involves (1) stabilization to remove large particles in sea water and as a reservoir of feed, (ii) evaporation, (iii) concentration, (iv) crystallization, and (v) harvesting of salt products.

Based on the current salt farm technology advocated by the Department of Agriculture, the production ponds are normally prepared by putting up dikes and levelling of the ponds by the use of shovel and rake in an area of 22 ft x 18 ft (most of the producers size of salt bed). This includes the removal of unwanted soil or dirt in the pond or banigan. Seawater will be filled to pond or “paalatan” with 10 inches seawater level to ponds by using water pump and flexible hose. Water from the “paalatan” slowly releases water vapor into the “baingan” or salt ponds. After 3-4 days that pond expose to high solar temperature, concentrated seawater will be transferred through water outlet to another evaporation pond for the crystallization period. Harvesting takes place when concentrated sea water measures 1 inch into the pond or baingan, and harvesting is done by collecting salt granules through food grade stainless shovel or food grade stainless steel rake every day depends on the weather. Collected salt is placed in rattan woven basket for transferring to the holding area using food grade stainless steel wheel-barrow.

Other method that is currently advocated is the production in pond using High Density Polyethylene (HDPE) and Geomembrane as pond liner. In this method, construction of evaporating basins on a leveled -flat even surface without large sand granules sandy beach, the rectangular HDPE plastic-platform that will be used is collapsible. The production process of solar sea salt is carried by collecting sea-water/brine using water pump and flexible hose and filtered using fine mesh (food grade filter bag) into the HDPE platform. Daily monitoring of the water salinity can eb done using refractometer. It should be pointed out that traditional salt farmers use twig to measure the salinity level.

Proposed Interventions

Based on the foregoing discussions, it is evident that the decline of the salt production in the Philippines is brought about several factors which include: (i) lack of identified areas for salt production; (ii) lack of new investment in new salt farms due to risk and lack of financing; (iii) inability to adapt to the increasing climate variability; (iv) lack of development of new technologies for improving salt production quantity and quality; (vi) lack of support facilities and materials to maintain and continuously strengthen existing and newly developed salt farms; and (iv) absence of production manual and skills training for salt farm workers. On the other hand, the review of literature also shows that there existing technologies and practices that could be adapted to increase the productivity of existing salt farms.

To address some of the identified problems, the project shall conduct a comprehensive study to identify potential suitable areas for salt production. The assessment will consider factors such as soil quality, climate conditions, and proximity to coastal areas. It will assess the current practices of salt farmers to identify gaps and solutions to improve the quality and quantity of salt production. It study will focus on improving the current design of saltern to optimize the operation including the use of sensors to automate salinity measurements. Conduct of skills training shall also be conducted to capacitate salt farmers to adopt to new technologies.

The proposed new saltern design will consider the existing design of IDTI and existing designs of Geomembrane Filter Thread Technique (GFTT) but additional modification will be done based on the results of the survey to other salt farms in the country.

3. PROJECT OBJECTIVES

Generally, the project aims to document the best practices, improve, and standardize solar salt farms, and identify potential saltern sites in the Philippines to serve as a basis for scaling up salt production and revitalizing the salt-making industry towards a sustainable and inclusive economic growth.

Specifically, it aims to:

a. document and assess the scientific and engineering principles of saltern design and operation, including, the optimization of salt production and the reduction of environmental impacts;

b. evaluate the salt production process, including flooding, evaporation, crystallization, harvesting, warehousing, and iodizing, to identify areas for improvement and innovation;

c. develop standard solar salt farm based on the best practices for saltern design, operation, and management;

d. develop an integrated sensors to monitor salinity and manage the flow of brine brine solution in solar salt evaporation pond;

e. identify potential saltern sites in the Philippines, with the greatest potential for sustainable salt production considering environmental and social criteria; and

f. design a pilot saltern plant based on the developed standard technology and practices to showcase salt farming industry in the Philippines which operates in an environmentally sustainable and socially responsible manner, while also ensuring the long-term viability of the industry

4. SCIENTIFIC BASIS/THEORETICAL FRAMEWORK

The project is guided with the IPOO framework where the documentation and assessment of best practices of the salt farming industry is vital input to the development design standard for saltern. This will involve the evaluation of existing saltern production processes to come with menu of best practices that could be considered as baseline information in the development of design standards.

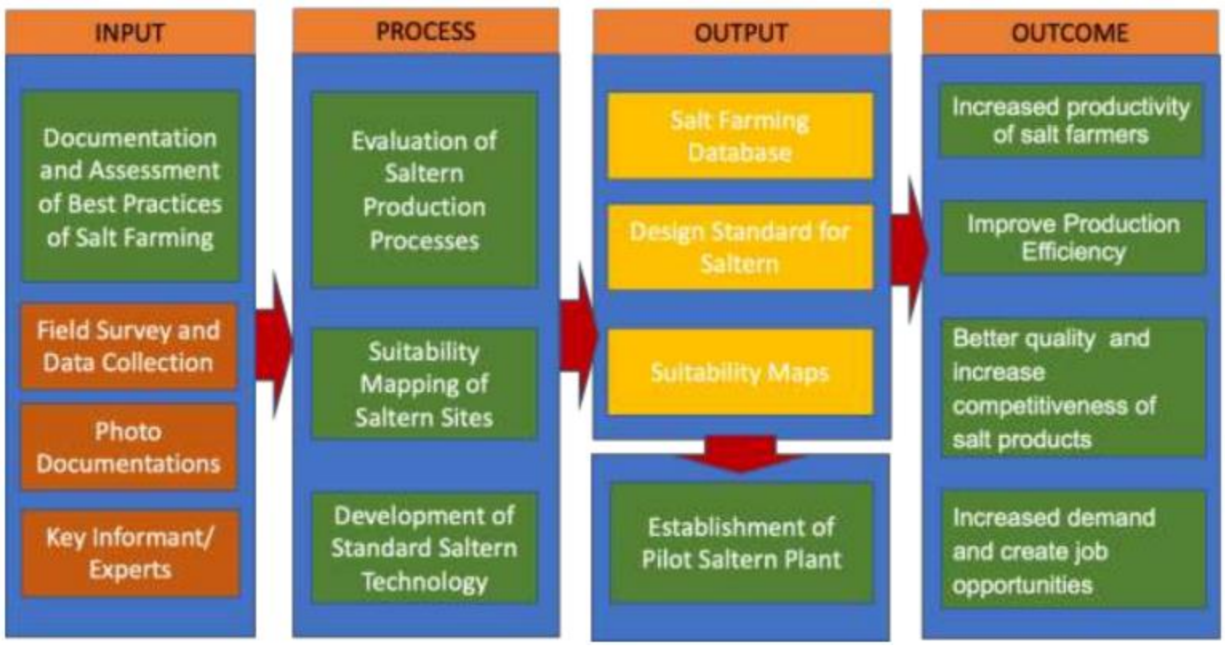


Figure 3. IPOO framework of the project

5. METHODOLOGY

5.1 Documentation and Assessment of Best Practices of Salt Farming

The documentation of best practices of salt farming will be subdivided into two components namely, (1) documentation and assessment of scientific and engineering principles of saltern technology, and (2) documentation and evaluation of the different salt production processes.

To document and assess the scientific and engineering principles of saltern technology, a review of literature on saltern design and operation will be done. Likewise, a field survey will be conducted in major salt producing areas in the Philippines which include the Pangasinan, Ilocos Norte and Ilocos Sur (Region 1), Zambales and Bulacan (Region 3), Occidental Mindoro (4B), Guimaras, Iloilo and Negros Occidental (Region 6), and Misamis Oriental (Region 10). It should be emphasized that the documentation and assessment will not only limited in areas with Type 1 climate but also in other areas that has major producers of salts. Through this, good practices of salt farmers across different climatic types will be captured and compared.

The survey shall include documentation and assessment of existing salterns to document their design and operation, production processes, including identification of areas for improvement and innovation.
The production processes may include flooding, evaporation, crystallization, harvesting, warehousing, and iodizing technologies that the owners and operators are using in producing salt.

Specifically, the following will be undertaken:

a. Identify salterns to survey

A representative sample of salterns in different regions of the Philippines will be identified from each of the major salt provinces in the Philippines. As much as possible, all the saltern farms available per region will we be surveyed to get represented samples for large, medium, and small saltern farms. Each site will be visited once for the characterization. The sample shall include both traditional and modern salterns, and those that are located in areas vulnerable to climate change. The Table below shows the number of salt farmers in the target provinces based on the master list of salt farmers from BFAR. Using the Slovin's formula at 5% margin of error, the minimum number of representatives respondents would be 7, 59, and 274 for the large, medium and small categories, respectively. This would respondents would be proportionately taken from each of the provinces.

REGION	PROVINCE	Large (>=50 ha)	Medium (3-50 ha)	Small (<3 ha)	TOTAL
Region 1	Ilocos Norte		1	57	58
	Ilocos Sur			43	43
	La Union			2	2
	Pangasinan	1	41	300	342
Region 3	Bulacan		7	2	9
	Zambales			3	3
Region 4B	Occidental Mindoro	6	16	16	38
Region 6	Negros Occidental		1	260	261
	Guimaras			86	86
	Iloilo		1	52	53
Region 10	Misamis Oriental		2	46	48
TOTAL		**7**	**69**	**867**	**943**
Number of Samples at 5% margin of error		**7**	**59**	**274**	**339**

The survey instrument that will be used will include questions related to the design and operation of the saltern, as well as the identification of areas for improvement and innovation. The survey will be pre-tested with a small sample of saltern owners and operators to ensure clarity and completeness.

b. **Conduct field visits**

Field visits to the selected salterns were done in coordination with the LGU and a letter of consent from owners or operators was obtained beforehand. During the visits, the general layout and design were be noted. Photographs and measurements were taken to document the design and operation of the saltern. Salinity, pH, TDS, and temperature of ponds were measured using salinity meter and pH/TDS/TDS/DO meter, respectively. At least five measurements were done per pond in order to have an average representation of the quality of the brine solution being used. The owners or operators will be interviewed using the survey instrument as guide to gain insights to their best practices, innovations, climate change adaptation strategies as well as the saltern's strengths and weaknesses. The field visit will be done at least twice per season (early, mid/later period) to document the practices and how the salt production of the salt farmers varies across the seasons.

c. **Development of recommendations**

Develop recommendations for improving and innovating saltern design and operation based on the data collected. These recommendations should be practical, cost-effective, and feasible, taking into consideration the local context, available resources, and potential environmental impacts.

The findings of the field surveys to saltern owners and operators, government agencies, and other stakeholders through workshops, conferences, and other outreach activities. This will help promote the adoption of best practices and innovations in saltern design and operation. It will also highlight the gender role in salt industry.

d. **Capacity building Activities**

Capacity building activities will also be taken to improve the skills and knowledge of salt farmers. The training will include salt production and maintenance of salterns, post production and handling of salt produce. Similar training will also be undertaken to students to create their awareness on salt production technology. Training on the identification of suitable sites, design, construction, and operation of saltern using HDPE or materials will also be conducted. This training will be conducted to LGUs, BFAR, and interested salt farmers/producers/adopters.

For the project staff, training on GIS mapping and conducting field survey will also be conducted prior to the conduct of field survey to the different salt-producing provinces.

5.2 Evaluation of Saltern Production Processes

All the collected data will be compiled and organized in a clear and concise manner. The data will be analyzed to identify patterns, similarities, and differences across the salterns surveyed in terms of principles, engineering designs, and scale of production.

Menu of best practices for saltern design, operation and management will be developed which can serve as the basis for the development of new saltern standards. The data shall also be used to develop policy recommendations to improve production, reduce environmental impact, and ensure the long-term viability of the industry.

5.3 Develop Standard Saltern Technology

Based on the results of the documentation of best practices of saltern technology, a standard saltern technology will be developed. This is crucial for maintaining consistency and quality, improving efficiency, promoting innovation, and ensuring compliance with regulatory requirement. It will also consider existing innovations such as those developed by IDTI and in other countries.

Specifically, the standard saltern technology will include:

a. Standard criteria for site selection

Based on the best practices gathered, a standard criterion for site selection will be developed based on the following factors namely soil type, climate, water source, and topography. A rating scale for these factors will be determined based on the results of the survey. The rating will be further validated by a selected group of salt farmers and/or operators. An analytical hierarchy process (AHP) will be used to further validate the rating scale that will be assigned to the factors of identifying suitable sites for saltern production.

b. Design optimization

Saltern design will be optimized to ensure maximum efficiency and productivity. This will involve analyzing factors such as pond size, shape, depth, and layout to maximize the use of space and minimize energy waste.

A standard design for small scale (<3 ha), medium (3 to <50 ha), and large (>50ha) saltern will be developed to ensure that it will cater to different scales of salt farmers. This will be done by aggregating the different data that will be obtained from the documentation survey results (Study 1) before subjecting them into design optimization. Both simulation and optimization of the production process will be done to come up with the optimal design standard for saltern.

c. Process standardization

Another area that will also be standardized is the production process. This involves developing a standard operating procedure that outlines the steps required for salt production, including flooding, evaporation, crystallization, harvesting, warehousing, and iodizing.

d. Quality Control and Testing

Quality control and testing procedures will also be developed to ensure that the salt production will meet industry standards. This will include a set standard for purity, iodine content, and other quality indicators. To determine the current quality of salt produce, samples will be taken and subjected for laboratory analyses. Moisture of salt produce will be determine using a moisture analyzer while the organic composition of salt to determine its purity will be determined using a Fourier transform infrared spectroscope.

The standard design criteria for saltern technology will be packaged as a blue book. This will be endorsed for approval by the Regional Development Council for wider adoption and implementation of the standards.

5.4 Develop an Integrated sensors to automate Solar Salt Evaporation Pond

The salinity level of existing solar salt evaporation ponds are manually monitored using twigs or floater method. This process will be improved by integrating salinity sensors, temperature sensors, and flow sensors. The readily available sensors will be used but it will be customized to be easily integrated in to the solar salt evaporation pond.

Specifically, the salinity and temperature sensors (at least two sensors per pond) will be installed at strategic location within the brine solutions considering water flow patterns, distribution of salinity levels, and accessibility for maintenance. The sensors will be connected to a data acquisition system or a centralized control system through wireless communication protocols (Figure 4). Similarly, the flow sensors will be installed at the inlet and outlet of the concentration ponds. Once the required salinity level at the concentration pond is attain, the flow sensors at the outlet is open to allow the flow of brine to the crystallizing pond while the flow sensor the inlet will allow the entry of new brine solutions to the pond. The flow sensors will also be used to measure the amount of brine solution entering and leaving the pond.

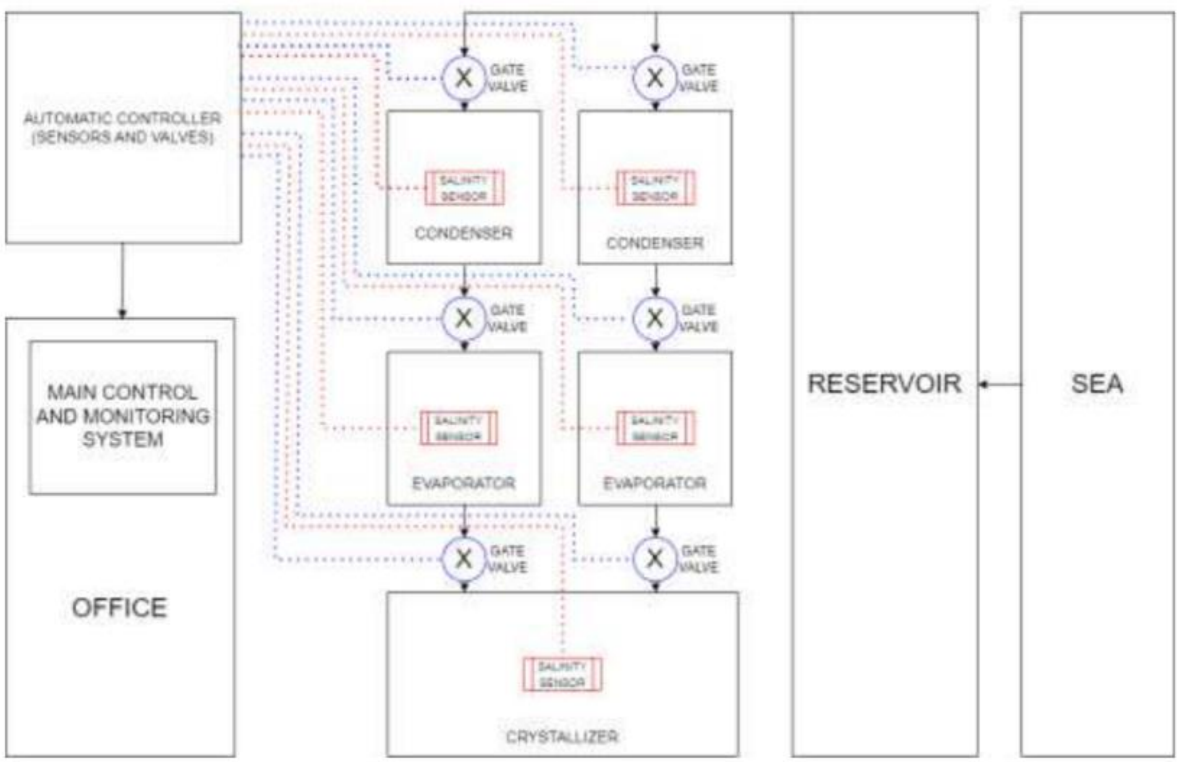


Figure 4. Schematic diagram showing the integration of sensors to salterns

5.5 Identify Potentials Sites for Saltern Technology

Identification of potentials sites for saltern technology in Region 1 will be done. The methodology that will be developed in this project will be used to identify suitable areas in other regions which could be done by other agencies such the Bureau of Fisheries and Aquatic Resources (BFAR).

Figure 5 shows the operational framework of the identification of potential saltern sites. Generally, it involves the collection and preparation of thematic maps which will be obtained from various sources. The data will be processed to come with different maps layers which will serve as the criteria for the site selection of saltern. The weights of each factor will be determined and optimized using the Analytical Hierarchy Process (AHP). Using the optimized weights, the different factors will be combined using map overlay. Calibration and Validation of the output maps will be done. The final output is the saltern suitability map which will be prepared at the provincial and municipal level.

The detailed procedure of each step is discussed below.

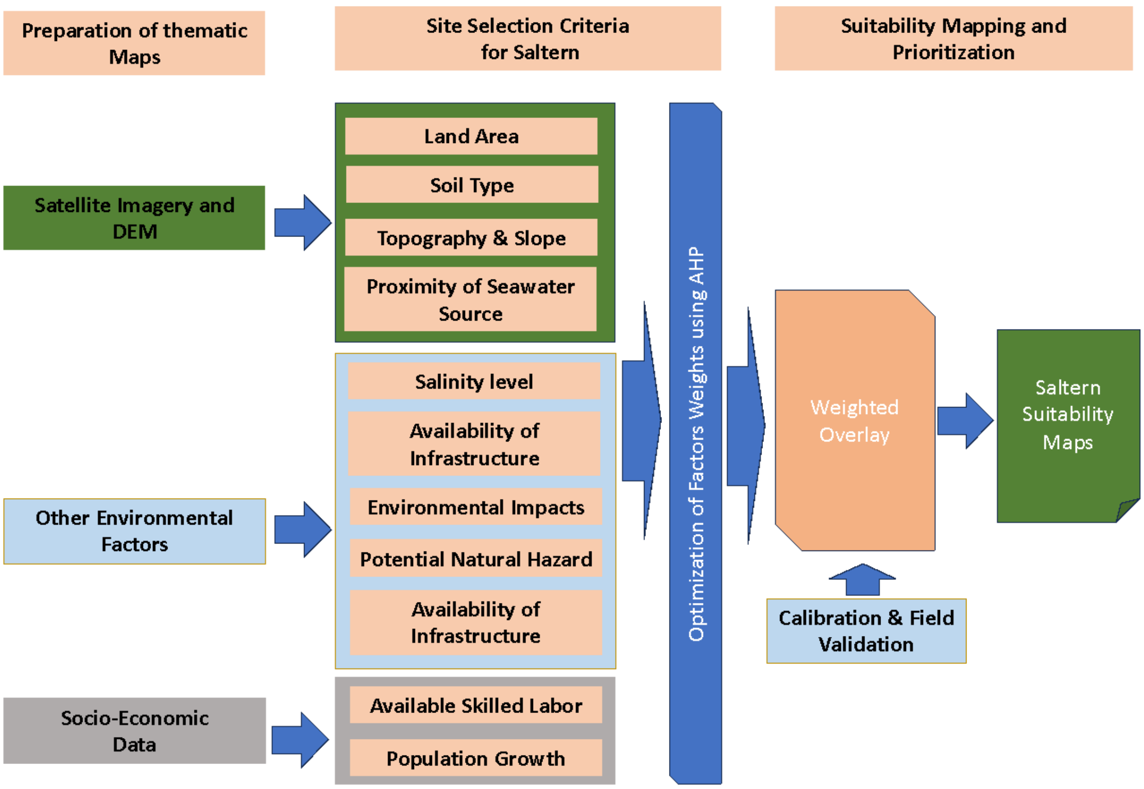


Figure 5. Operational framework for the identification of potential saltern sites

a. Preparation of thematic maps and other data

Data on information on the coastline, topography, climate, soil composition, and water availability will be collected. Up-to-date and reliable data will be obtained from satellite imagery, topographic maps, and environmental reports from different government agencies (NAMRIA, PAGASA, PhilSA), non-governmental organizations and private companies. These data were the most important factors for saltern operation and environmental sustainability.

The accuracy and quality of the data will be verified. This will be done by cross-checking the data with other sources or comparing it to field measurements. It is important to ensure that the data is reliable and accurate, as errors in the data can lead to incorrect site selection and subsequent environmental and economic impacts.

Collected data will be organized into a format that could be readily imported in GIS environment. This will involve converting the data into a standardized format, such as a spreadsheet or a GIS database. It is important to ensure that the data is organized in a way that allows for efficient and effective analysis.

b. Defining criteria for site selection

Defining the criteria for site selection is very important. The criteria will be based on the factors that are most important for saltern operation, such as proximity to the coastline, availability of water, soil composition, accessibility, etc. Key stakeholders involved in the site selection process, such as the project team, management, experts, local community, and regulatory agencies will be identified. It is important to involve these stakeholders in the site selection process to ensure that their perspectives and concerns will be considered. The criteria will be developed in consultation with experts in the field of salt production and environmental sustainability. The initial factors and steps in defining criteria will include the following:

Salinity level. Identification of the salinity level requirement will be done. The salinity level requirement of the saltern will be determined. This is critical because the salinity requirement varies depending on the type of salt to be produced. For example, if the saltern will produce table salt, then the salinity requirement will be higher compared to the production of other types of salt.

Land Area. The land area required for the saltern will be determined and considered. This will depend on the expected production capacity and production process. Factors such as pond size, evaporation rate, and drying time will determine the land area required.

Soil type. The type of soil on the potential site will be considered and evaluated. Salterns require a specific type of soil that is not too permeable, but still allows for adequate drainage. The soil should also be free from contaminants and pollutants that can affect the quality of the salt that will be produced.

Availability and Quality of seawater source. Availability and quality of seawater sources will be assessed. Saltern will require a reliable source of seawater for the production of salt. The potential site should be located close to a large body of seawater or have access to a seawater source that can be easily transported to the site. Also, the water quality will be assessed in terms of salinity and heavy of metals contents.

Climate. The climatic type defines the seasonal weather condition of a particular area. Basically, areas that have distinct wet and dry seasons are the most suitable area. Hence, the climatic type will be considered as one of the factors.

Availability of infrastructure. Availability of infrastructure will be considered. The potential site should have access to infrastructure such as roads, electricity, water, and telecommunications. The site should also be accessible for transportation of raw materials, equipment, and finished products.

Environmental impact. Salterns have the potential to impact the surrounding environment, including wildlife, water quality, and air quality. The potential site will be evaluated for potential environmental impacts, and steps will be taken to mitigate these risks.

Potential for natural hazards. The potential site will be evaluated for potential natural hazards such as flooding, storms, or earthquakes. The site will also have adequate drainage and be situated in an area that is not prone to saltwater intrusion.

Availability of skilled labor. The potential site will be located in an area that has a pool of skilled labor or a training center for local people to develop the necessary skills.

Potential for growth. The potential for growth in the area will be evaluated. Factors such as population growth, economic growth, and access to markets will be taken into consideration.

c. Analytical Hierarchical Process (AHP)

Analytical Hierarchical Process (AHP) will be used to evaluate and prioritize different criteria in a systematic and structured manner. AHP will be used to determine the most suitable site based on a set of criteria.

The AHP method will involve breaking down the decision-making process into a hierarchy of criteria, sub-criteria, and alternatives. The hierarchy will be constructed by identifying the main decision criteria, such as environmental impact, cost, or accessibility, and then breaking each criterion down into sub-criteria, such as air quality, water quality, or noise pollution. Each sub-criterion is then further broken down into alternatives or options that can be evaluated and compared.

The AHP method will involve comparing each alternative against each sub-criterion using a pair-wise comparison matrix. This matrix will be used to assign numerical values to each sub-criterion. The values then will be weighted based on their relative importance to each other, and the results will be used to calculate an overall score for each alternative.

The AHP method will provide a structured and systematic approach to evaluate multiple criteria and alternatives, allowing to make more informed and objective decisions.

d. Suitability Mapping of Saltern Sites

Once the criteria will be defined and data are collected, each criterion will be weighed based on their relative importance to the saltern's success. This will involve assigning a numerical value or percentage to each criterion to reflect its relative importance. The rating will also be based on the developed standard for saltern technology.

Using the weighted overlay in GIS, the different factors will be combined to come up with suitable sites for establishing salterns in the country. The suitability map will be further classified in terms of degree of suitability and size of saltern plant. The map will be color-coded to show the degree of suitability.

e. Field validation

The suitability map that will be developed will be further validated through field visits. This will involve physically visiting and geolocating the areas identified on the map using handheld GPS to assess their suitability for saltern operation. The present land use of the area will be mapped using drone. The drone shots will be stitched together to have the present vegetation which will further classified into land uses. The drone shots may also be used to generate the detailed topography which will be used for further analysis.

During the field visits, data will be collected on the factors that were not included in the GIS analysis, such as local regulations, land ownership, and social considerations. The gathered data will be used to further refine and adjust the suitability map. The final suitability map will be presented at the provincial level which will be distributed to concerned provinces. The map could be the basis for investment planning for the LGU.

f. Site selection and prioritization

Potential sites for new salterns will be selected and prioritized based on the results of the GIS analysis and field verification. The sites will be ranked based on their suitability for saltern operation and the availability of resources required for construction and operation.

5.6 Designed of Pilot Saltern Plant

To demonstrate the applicability of the developed suitability map and standard saltern technology, a design of a pilot saltern plant will be developed. The design will be presented to the LGU and BFAR for possible funding for implementation. As such, the saltern plant will serve as a showcase of the optimized salt production technology, which operates in an environmentally sustainable and socially responsible manner. It will also be used as a research facility to further enhance and optimize the production process of the salt industry as well as a learning facility to capacity salt farmers to improve their production process.

The demo saltern plant will be designed based on the salterns that will be developed from this project. In addition, new materials (i.e., HDPE, Vigan Clay) as lining will be explored and tested to further improve the capacity and efficiency of saltern. It is proposed that the demo plant will be installed in Colobong Salt Farm in Dasol, Pangasinan.

In addition, flow and salinity sensors will be integrated to automate the flow and monitoring of salinity of brine solution in the ponds. The salinity sensors will be placed at the concentration ponds which will be used to continuously monitoring the salinity level of the pond. Once the concentration has reached the required salinity level, a flow sensor is activated to automatically open the gate to allow transfer of brine solution to the crystallization pond. Once the brine solution is transferred, the system will close the outlet gate and open the inlet gate to allow refilling of new brine solution to the concentration pond.

Overall, the inclusion of the sensor will automate the salt production process and thereby assures a continuous production of salt especially during the summer season. It will also reduce cost of operation and increase capacity of salter farms.

Table 1 shows the differentiation between the traditional and proposed saltern plant

Parameter	Traditional	Proposed Saltern
NaCl purity	78-90%	95-97%
Stability of Salinity Level	Not stable since based on traditional knowledge, i.e., use of twig	Salinity sensor which provides real time salinity level, Cost P1200/unit
Production level	45 MT per season/ha	Optimum, as the size of the evaporation pond, concentration pond and crystallization will be optimally designed 50 MT/season/ha (10% increased from traditional)
Additional Investment		Php 100,000 for the cost of sensors and use of HDPE lining
Opportunity Cost		Additional labor in monitoring the ponds in traditional method = P7000/season (10% of total labor cost of traditional). This represent the savings from labor cost of manually monitoring salinity level of the ponds.
Initial investment for 1 ha salt farm	P305,000	P412,000
Total Expenses	P116,250	P109,250
Revenue	P157,500	P186,725
Net Profit	P41,250	P77,475
Return on Investment	13.52%	18.80%

6 RESULTS

6.1 Documentation and Assessment of Best Practices of Salt Farming

The project team conducted numerous site visits to salt-producing towns in the province of Pangasinan to evaluate and document salt farming practices, methods, and equipment. A field visit at Pasuquin, Ilocos Norte was also conducted to document their salt farming practices and get more information for the completion of the survey instrument that is now being used at Pangasinan.

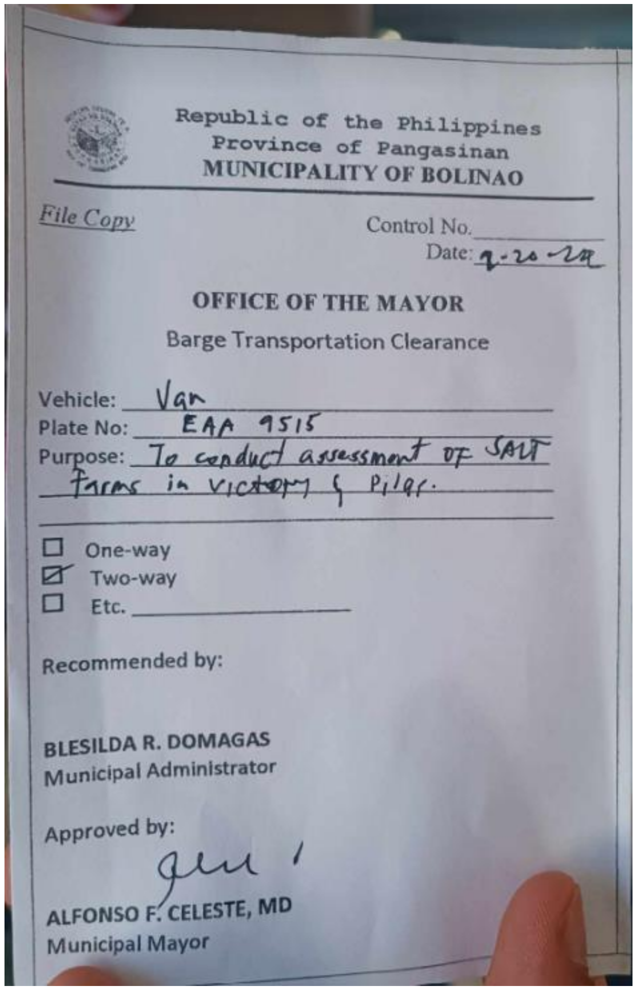
To date, the team has already conducted the documentation and assessment of best practices of salt farming at the following towns in Pangasinan:

a. Dasol
b. Infanta
c. Mangaldan

d. San Fabian
e. Alaminos
f. Anda
g. Bani
h. Bolinao
i. Agno

Additionally, an inventory of salt makers from the different municipalities particularly in the province of Pangasinan was gathered. From the salt-producing municipalities, a complete list of salt makers was obtained.

Figure 6. MMSU ASIN Project Staff meeting


Republic of the Philippines
Province of Pangasinan
MUNICIPALITY OF BOLINAO

File Copy

Control No.________
Date: 9-20-22

OFFICE OF THE MAYOR

Barge Transportation Clearance

Vehicle: Van
Plate No: EAA 9515
Purpose: To conduct assessment of SALT farms in victory & Pilar.

- [ ] One-way
- [x] Two-way
- [ ] Etc. ________

Recommended by:

BLESILDA R. DOMAGAS
Municipal Administrator

Approved by:

ALFONSO F. CELESTE, MD
Municipal Mayor

Figure 7. Permit to conduct assessment of salt makers at Brgy. Victory and Pilar, Bolinao, Pangasinan

Figure 8. Documentation of Salt Farmers Using the Modern Cooking Method at Pasquin, Ilocos Norte Processing Imported Australian Salts

Figure 9. Documentation of Areas Utilized for the Production of salt Using the Traditional Cooking Method at Pasquin, Ilocos Norte

Figure 10. Documentation of Salt Farms at Bolinao, Pangasinan

Figure 11. Assessment of Salt Makers using Saltern (Barara)

Figure 12. Assessment of Salt Makers using Saltern (Barara)

Figure 13. Harvesting the salt using "panulong"

Figure 14. Assessment of Salt Makers using HDPE

Figure 15. Documentation of Storage Area/ Facility

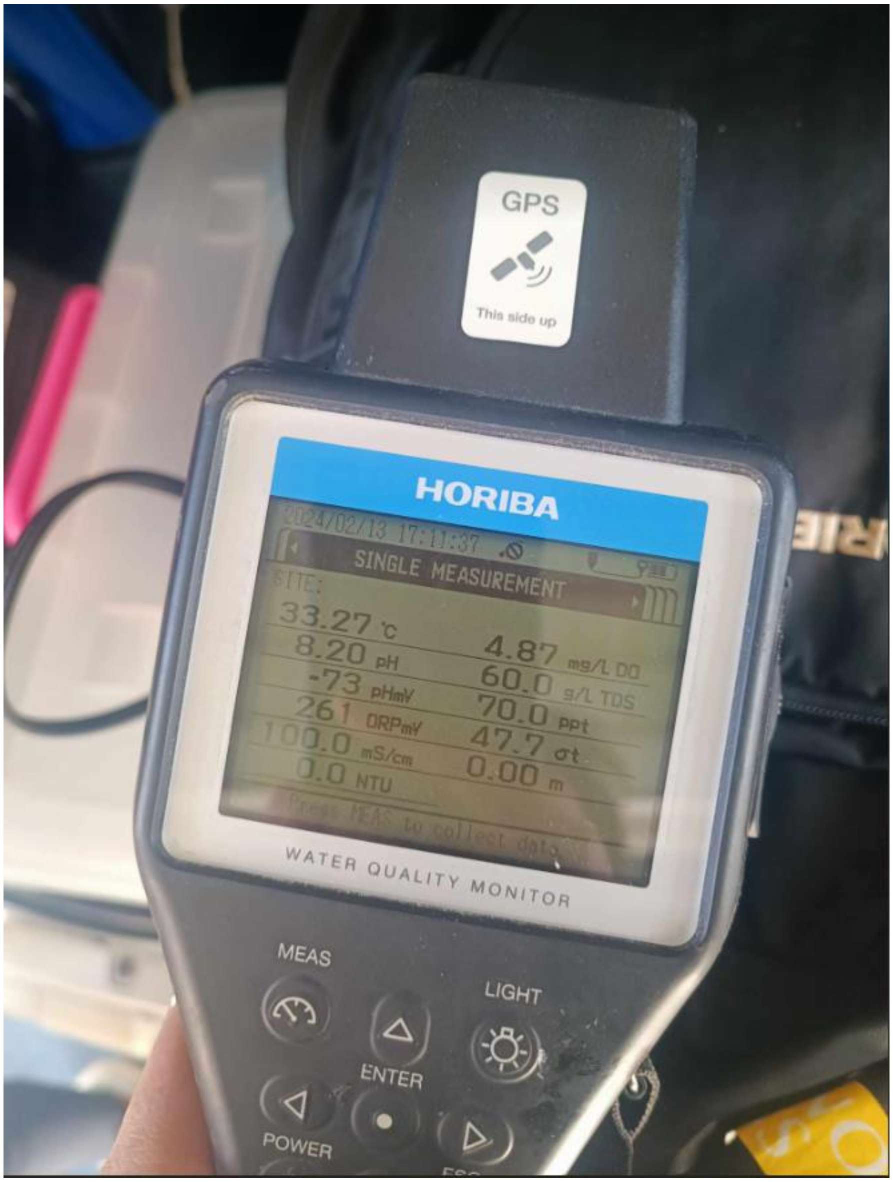


Figure 16. Measuring Salinity of Water within the Study Area

- RESULT AND FINDINGS

Based on the initial result of the survey, there are three methods of salt production, namely; Saltern, Cooking Method, and use of HDPE".

- OUTPUTS (6Ps)

	EXPECTED OUTPUTS	**ACTUAL OUTPUTS**
Publications	Papers for Presentation to National/International Symposiums/Conferences At least two (2) research publications in peer-reviewed journals, (2) IEC materials	
Patents/IP	At least one (1) Utility Model to be submitted/acquired after the project	
Products	Menu of best practices on Saltern Municipal and Provincial Suitability map of Saltern Farms Design of saltern farms	
People Services	At least 20 salt farmers/producers/adopters trained on salt production and handling At least 5MS students engaged in the project At least 50 students, 20 LGU staff trained in GIS suitability mapping, saltern design and establishment At least 5 personnel employed with the project researchers	Hired 6 full-time researchers for the project
Places and Partnerships	MOU with 2 National Agencies MOU with 3 PGLU MOU with 5 LGUs MOU with 2 HEIs	MOA has been utilized instead of MOU MOA drafting is under review by the ff partner agencies:

		DA-BFAR RO1 Region 1 -PGU Ilocos Norte -PGU Ilocos Sur -PGU La Union -PGU Pangasinan *Salt producing areas of Pangasinan* -LGU Bani -LGU Anda -LGU Dasol -LGU Infanta -LGU Alaminos City -LGU Bolinao -LGU San Fabian -LGU Mangaldan Region 3 -PGU Bulacan -PGU Zambales Region 4B -Occidental Mindoro Region 6 -Negros Occidental -Guimaras -Iloilo Region 10 -Misamis Oriental
Policy	At least 1 policy recommendation on the best practices for salt production developed to be submitted to BFAR and RDC One (1) policy recommendation to the RDC for the adoption suitability maps	

- OUTCOMES
- POTENTIAL IMPACTS (2Is)

LITERATURE CITED

Bartolome, G.C., J. Magpantay, J.A. Delos Reyes, A.T. Lat, T.J.L Reodica, C.J.B. Manalo. 2010. GIS

Mapping of Salt Farms and Salt Supply Chain Actors in the Visayas and Mindanao, Philippines. IOP

Conference Series: Earth and Environmental Science.

Bramawanto R, Sagala S L, Suheimi I R, and Prihatno. 2015. Structure and Composition of Salt Pond

Using Filtering Threaded Technology to Increasing Salt Production. J Segara 11:1-11.2015.

Guntur, G., A. A. Jaziri, A. A. Prihanto, D. M. Arisandi, A. Kurniawan. 2017. Development of salt pro-
duction technology using the prism greenhouse method. The 4th International Seminar on Sustaina-
ble Urban Development IOP Publishing IOP Conf. Series: Earth and Environmental Science 106

(2017) 012082.
Hilda Austria, DOST-ITDI technologies boost salt-making in Pangasinan town (2021) [Online],
Available:
https://www.pna.gov.ph/articles/1142947?fbclid=IwAR0vjUrSc6ytu0CC2xs36s0R1DOh
jDkl9dQjk3q4qbBkSsqBp2pWiItEhY, [Accessed: June 8, 2021]
PhilASIN, Salt Industry Roadmap, 2022

S&T Media Service, DOST-ITDI addressing iodized salt woes (2022) [Online], Available:

https://businessmirror.com.ph/2022/11/06/dost-itdi-addressing-iodized-salt-woes, [Accessed: November 6, 2022]

Sumada, K., R Dewati, Suprihatin. 2018. Improvement of seawater salt quality by hydro[1]extraction and re-crystallization. Journal of Physics. Conference Series. 6 p.
Suhendra A. 2016.

Increasing The Productivity of Salt Trought HDPE Geomembrane Indonesia Case History in Salt Evaporation Pond. EJGE 11:4272-4280.
Susanto H, Rokhati N, Gunawan W Santoso. 2015. Development of Traditional Salt Production

Process for Improving Product Quality dan Quality in Jepara District, Central Java, Indonesia. Proceeding Environmental Science. 23:175-178.

Muyot, N.B. and C. B. Asuncion. 2022. Constraints and Challenges of Salt Farming in Occidental Mindoro, Philippine. Journal of Multidisciplinary Studies, Vol.2, Issue.6, June 2022, pg. 1-9. ISSN: 0976-7797.

Salt Production – A Reference book for industry. 2009.

I. APPENDICES

II. PROBLEMS

a. **Coordination with LGUs** - Coordination with numerous LGUs is becoming a challenge. Some local governments have out-of-date databases of contact information of individuals who must be contacted to enable various field activities.

b. **Procurement** - Procured items, such as research equipment and materials, under the capital outlay are yet to be completed, which has had an impact on several project activities.

III. RAW DATA

IV. ATTACHMENTS

i. DOST Form No. 8 Semi-Annual Financial Report
ii. DOST Form No. 11 List of Personnel Involved
iii. DOST Form No. 12 List of Equipment Purchased (include the PAR)