SITE SUITABILITY ANALYSIS OF SALT FARMS IN PANGASINAN USING GEOSPATIAL DATA AND ANALYTIC HIERARCHY PROCESS

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ABSTRACT:

The Philippines has imported 93% (550,000 MT) of its annual salt requirement in 2020. Such heavy reliance on salt importation may be attributed to the two decades of neglect and steady downward production trend of the local salt industry. There is a need to increase local salt production because Filipinos consume salt on a daily basis for over 14,000 uses, ranging from being a household commodity to being utilized for agricultural and industrial processes. It is therefore imperative to increase the number of areas allocated for local salt production. In this study, a suitability analysis for solar salt farm operations in Pangasinan was conducted using geospatial data and Analytic Hierarchy Process (AHP). Physical land variables (slope, land cover, distance from coastline, distance from river, and soil texture) and meteorological factors (temperature, humidity, rainfall, wind speed) were considered to assess the suitability of an area for salt production. Results showed that meteorological factors (62.5%) outweigh the physical land variables (37.5%) by a 25% margin, suggesting the heavy influence of climate on salt production. 4629.88 km^2 (or 86.6% of the total land area of Pangasinan) was identified to be suitable for salt production with 496.01 km^2 (9.5%) being moderately suitable and 3800.87 km^2 (77.1%) being rated as low. The moderately suitable areas were validated using existing salt farm locations in two sites, Dasol and Alaminos City, and showed 62.13% and 28.06% overlapping areas, respectively. The main explanation for these relatively low percentage figures is the gaps in the output suitability map due to the slope and soil datasets. The concentration of the moderately suitable areas is situated along coastal municipalities of Pangasinan including Bolinao, Dasol, Alaminos City, Sual, Agno, Labrador, Infanta, San Fabian, Anda, and Bani. The findings of this study can help policymakers, relevant government agencies and stakeholders in the planning process of revitalizing the salt industry by expanding existing salt farms or constructing new ones in Pangasinan.

1. INTRODUCTION

1.1. Background of the Study

Salt is a resource that is widely consumed by both humans and animals alike and has over 14,000 uses, varying from agricultural to industrial purposes (Khonghun, 2021). It has an increasing demand both locally and internationally and can already be considered a necessity (Delos Santos, 2016). Currently, the Philippines is experiencing a shortage in its local production and relies heavily on importation resulting in the rapid increase of its market price (Cariaso, 2022).

In 2021, the Philippines imported 550,000 metric tons (MT) of salt from China and Australia which represented 93% of the annual salt requirement of the country. The remaining 7% of the said requirement came from local production (Rodriguez, 2022). From being able to locally produce 85% of the annual total salt requirement in 1990 (Acedo & Hontucan, 2017) to only being able to produce 7% in 2021 (Khonghun, 2021) is very alarming. This huge disproportion between the imported and locally produced salt is ironic since the Philippines is an agricultural country and can be easily self-reliant even by utilizing only 1/6th of its entire shoreline or 6,000 kilometers (Tarriela, 2022).

The utilization of Remote Sensing (RS) and Geographic Information Systems (GIS) have played vital roles in modern agriculture. The application of these technologies improved traditional agricultural practices and proved to be beneficial in the revitalization of the salt industry. Thus, the application of RS and GIS is very promising and may be the key to achieving national salt self-sufficiency.

Establishing more salt farms throughout the country can address this problem which will have a direct impact on the local production of salt and can aid in addressing the shortage. This study aims to locate the most suitable areas for salt farm operations in Pangasinan using geospatial data and Analytic Hierarchy Process (AHP). As of this writing, there are no established methodology yet in locating suitable areas for salt farm operations in the Philippines using geospatial data, while there are little to no local studies about salt farms.

2. METHODOLOGY

A site suitability analysis was performed using GIS via the MCDM tool, the Analytic Hierarchy Process (AHP), to determine the most suitable areas for sustainable salt farming in Pangasinan. These two methods have been proven to be effective and accurate in performing land suitability analysis since both quantitative and qualitative data are considered (Efe et. al, 2015). Shown in *Fig. 1* is the workflow of the study.

2.1. Study Area

Pangasinan was chosen to be the study area since it is one of the provinces with the most salt farms (approximately 800 ha) and has rich and major fishing areas and excellent salt beds (Nutrition Center of the Philippines, 2010). Also, the coastal communities of the province formerly relied on salt farming as

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their livelihood, giving the province a high potential for salt production. The extent of the study area can be seen in *Fig. 2*.

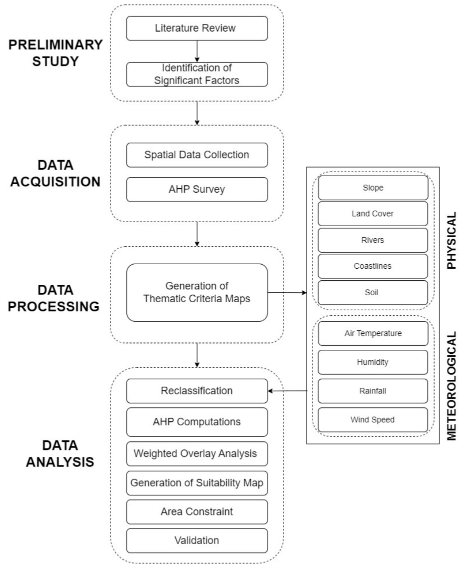

Figure 1. Workflow of the study

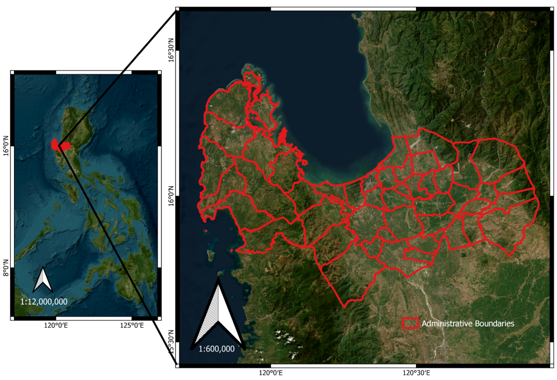

Figure 2. Geographic Location of the Study Area

2.2. Methods

The workflow of the data processing and analysis phase is shown in *Fig. 3*.

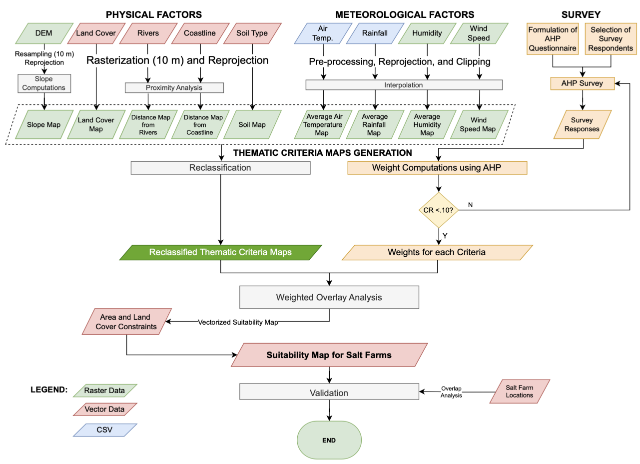

Figure 3. Datasets, tools, and methods used to determine suitable areas for salt farms

2.3. Data Processing and Analysis

The required geospatial data were collected from various sources including the National Mapping and Resource Information Authority (NAMRIA), Bureau of Soils and Water Management (BSWM), Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS), Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), Department of Science and Technology - Advanced Science and Technology Institute (DOST-ASTI), and Global Wind Atlas (GWA), as shown in *Table 1*. The said data were used to generate thematic and reclassified criteria maps for each significant factor.

Data	Type	Derived Data	Source	Period
Administrative Boundary	Vector	Study Area Boundary	DIVA-GIS	N/A
	Vector	Distance from Coastline		N/A
DEM	Raster	Slope	NAMRIA	2021
2020 Land Cover Map	Vector	Land Cover		2020
	Vector	Distance from Rivers		2020
Soil Type	Vector	Soil Texture	BSWM	2013
Precipitation	Raster	Average Rainfall	CHIRPS	Dec 2016 - May 2021
Air Temp	CSV	Average Air Temperature	PAGASA DOST-ASTI	
Humidity	CSV	Average Relative Humidity		
Wind Speed	Raster	Wind Speed	GWA	2008 - 2017

Table 1. Data types and sources

The generated thematic criteria maps were reclassified for the weighted overlay analysis using the *Reclassify by Table* function in *QGIS*. The classes, suitability, and reclassification ratings, and area constraints are based on previous studies (Achmadi, 2013; Kurniawan, 2019; Malawani et al., 2021; Nahar & Taryono, 2019) and are listed in *Table 2*. High suitability values were reclassified with a value of 4, moderate suitability with 3, low suitability with 2, and not suitable with 1.

Variable (Class) (Reclassification Rating)		High Suitability (4)	Moderate Suitability (3)	Low Suitability (2)	Not Suitable (1)
Physical Factors	Slope (%)	0 - <2	2 - <3	3 - <4	≥ 4
	Land Cover	Salt ponds, Moor, Grove/Shrubs	Rice Field, Crops, Mixed Gardens	Swamp, Aquaculture Farm	Settlement, Mangroves, Forest, Others
	Distance from Coastline (m)	100 - <1,000	1,000 - <2,000	2,000 - <4,000	≥4,000
	Distance from River (m)	<500	500 - <1,000	1,000 - <2,000	≥ 2,000
	Soil Texture	Sandy Clay Loam/Clay	Sandy Clay	Dusty/Loamy	Dust, Sand, Silt
Meteorological Factors	Air Temperature (°C)	>32	28.5-<32	25-<28.4	<25
	Relative Humidity (%)	<45-59	60-75	75-90	>90
	Rainfall (mm/month)	<10	10-100	100-200	>200
	Wind Speed (m/s)	>5.7	4.1-5.7	2.4-4.0	<2.4
Constraint		Class		Remarks	Reference(s)
Area (ha)		< 3 3 - < 50 50 - < 1000		Small Scale Medium Scale Large Scale	Philippine Fisheries Code of 1998

Table 2. Factors that determine the suitability of an area for salt production according to class and area constraints

2.4. Selection of AHP Respondents

This study conducted a survey with respondents from the Philippine National Fisheries Research and Development Institute (NFRDI), which is the primary research arm of the Philippine Department of Agriculture (DA). Most of the respondents are science research specialists and staff who documented and identified existing salt farms, and personally interviewed salt farmers and salt farm operators in Pangasinan. A total of 18 respondents participated in the survey.

2.5. Suitable Areas for Salt Farms

The output suitability map was vectorized and geometry attributes were added to the identified moderately suitable polygons to determine their areas. These areas were then filtered through the attribute table, wherein polygons with less than 3 ha (or 30,000 m^2) for all suitability ratings were removed. These filtered areas were used as the inputs for the land cover constraints.

2.6. Land Cover Constraints

Built-up Areas, Mangroves, Open Forest, and Closed Forests were considered not suitable for salt production. Such land cover classes were reclassified as not suitable and were exported separately from the land cover dataset. These land cover constraints were then applied to the filtered suitability map output. The input layer was the filtered moderately suitable areas with area constraints and the overlay layer was the not suitable land covers.

2.7. Validation

The filtered suitable areas with land cover constraints and the existing salt farm polygons of Dasol and Alaminos were used in the overlap analysis for validation. The overlap analysis computes the total area (in m^2) and percentage overlapped by the input layer to the overlay layer.

2.8. Local Moran's I

Spatial autocorrelation analysis was done using the vector file of the final suitability map output (with area and land cover constraints) as the input layer and suitability values as the burn value. The classes for spatial clusters and outliers determine the consistency or similarity of suitability values in an area. These spatial clusters and outliers are the expected output of the clustering analysis.

2.9. Hotspot Analysis (Getis-Ord Gi* Statistic)

This analysis used the vector file of the final suitability map output (with area and land cover constraints) and the suitability values as the burn value to determine particular areas with cold and hot spots. The output map was rasterized with a spatial resolution of 10 m for further analysis. The generated z-scores were used to determine areas with statistically significant hot and cold spots.

3. RESULTS AND DISCUSSION

3.1. Factors Affecting Suitability of an Area for Salt Production

Based on existing literature and interviews with experts, slope, land cover, distance from the coastline, distance from the river, and soil texture, were the physical land variables that have a significant effect on the suitability of an area for salt production (Achmadi, 2013; Chun et al., 2008; Enriquez, 2022; Giap et al., 2005; Hanafiah, 2007; Kurniawan et al., 2021; Kurniawan et al., 2019; Nachshon et al., 2019; Nahar & Taryono, 2019). For meteorological factors, air temperature, humidity, rainfall, and wind speed were the most significant variables (Enriquez, 2022; Lwanyaga, 2013; Dong et al., 2021; Kurniawan et al., 2021; Kurniawan et al., 2019; Ruskowitz et al., 2014; Malawani et al., 2021; Cororaton et al., 2015; Kasedde et al., 2014). Moreover, meteorological factors were more significant than the physical land variables with the combined weight of the former (62.5%) outweighing the latter (37.5%). This suggests the significant influence of the climate on salt production.

3.2. AHP Results

The relative importance of every factor showed variations for each respondent. *Table 3* shows the percentage of the respondents who chose a specific criterion as the most significant parameter to consider in salt production via solar evaporation. Such decisions reflect each respondent's knowledge and understanding of salt production in the Philippines.

Criterion	Percent of Sample (n = 18)
Rainfall	55.6%
Air Temperature	27.8%
Distance from Coastline	5.6%
Distance from River	5.6%
Land Cover	5.6%
Slope	0%
Soil Type	0%
Humidity	0%
Wind Speed	0%

Table 3. Most important factor for each respondent

Ideally, CR values must be less than 10% for good consistency of results (Saaty, 1987); however, some respondents failed to meet the given threshold. Twelve (12) respondents had a CR of less than 10%, while the remaining six (6) had a CR ranging from 10 to 42%. According to BPMSG (2013), having consistency ratios of less than 10% is recommended but not required. Values greater than 10% can still be acceptable depending on the nature of the study and the required accuracy. Therefore, the six responses that did not meet the given threshold were still considered since the consolidated CR value still satisfied the 10% threshold with a resulting overall consistency ratio (CR) of 1.9%. This indicates that the responses from the interviewed experts were consistent enough and were acceptable for pairwise comparisons.

The results of the AHP showed that air temperature was the most important criterion, with a weightage of 22.1%. It was also determined that the summation of the meteorological factors is equal to 62.5% while the total for the physical land variables is 37.5%. The ranking and individual weights of all nine factors are shown in *Table 4*.

Criterion	Weight	Ranking
Air Temperature	22.1%	1
Rainfall	16.1%	2
Humidity	13.7%	3
Distance from Coastline	12.3%	4
Wind Speed	10.6%	5

Distance from River	8.6%	6
Land Cover	6.5%	7
Soil Texture	6.4%	8
Slope	3.7%	9
TOTAL	100.0%	

Table 4. Criteria weights from the AHP survey and their corresponding ranks

3.3. Summary of the Suitability of Individual Factors

Shown in *Fig. 4* is the summary of the suitability distributions for all the factors. The resulting suitability distribution for each factor varied significantly. Hence, each factor was analyzed individually with their corresponding effects on the suitability of an area for salt production based on existing literature, interviews with experts, and results of the AHP survey.

Most physical land variables ranked lower than the meteorological factors, except for the distance from the coastline factor (ranked 4) which ranked higher than wind speed (ranked 5). The garnered overall weight of all the physical land variables is 37.5%. This indicates that the natural physical state of an area contributes less to its suitability for salt production, as compared to meteorological factors. This is possibly because the measures that can be applied to decrease or negate the effects of a physical factor on the suitability of an area for salt production are more feasible and economically viable as compared to the number of resources required to address the limitations caused by meteorological factors.

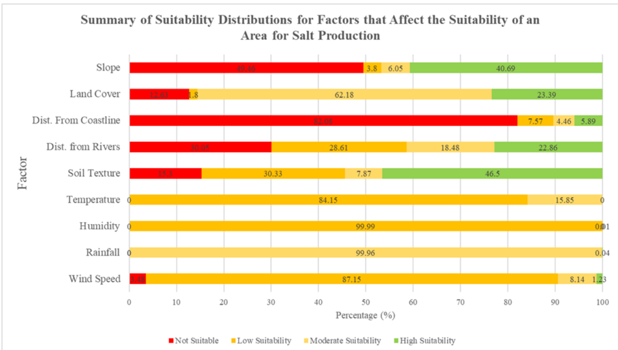

Figure 4. Summary of suitability distributions of all factors

The combined weight of all the meteorological factors is 62.5%. It outweighed the total of all the physical land variables (37.5%) by a margin of 25%. As previously mentioned, there are simple solutions that can address the negative effects of a physical factor on the suitability of an area for salt production and they are more feasible and manageable. However, it is more complex in the case of meteorological factors since they are natural occurrences that cannot be controlled or predicted and the possible interventions that can be made to address them are very expensive, such as having automated roofs that can open or close if there is sunlight or rainfall, respectively. This is not economically viable considering that salt farms require a huge amount of land area to operate and having to construct roofs over them is extremely expensive. Given that the method of salt production is via solar evaporation, which is heavily dependent on the climate of a region, it can be said that Pangasinan is already a suitable region for salt production based on the meteorological factors alone. This claim is also supported by the results of the individually reclassified suitability maps of the meteorological factors and their overall suitability.

3.4. Suitability Map

Fig. 5 shows the generated salt farm suitability map of Pangasinan. The yellow areas are identified to be moderately suitable, while the orange areas are rated with low suitability. There were no identified areas for the not suitable and highly suitable categories due to the heavy influence of meteorological factors. Shown in *Table 5* is the distribution of suitability ratings.

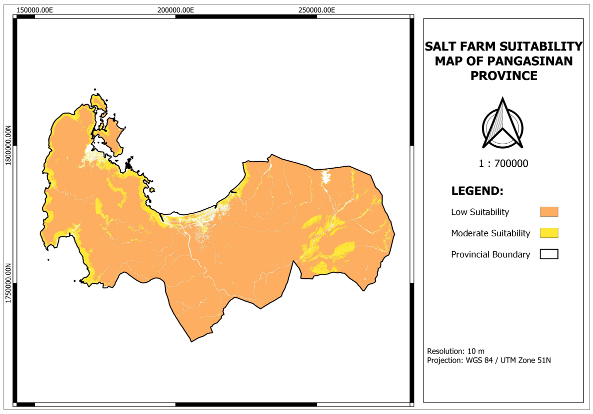

Figure 5. Salt farm suitability map of Pangasinan

Suitability Rating	Percentage (%)	Area (km^2)
Low Suitability	89.43	4451.36
Moderate Suitability	10.57	526.26
TOTAL	100	4977.62

Table 5. Salt farm suitability rating distribution in Pangasinan.

3.5. Area and Land Cover Constraints

This study focused on the identified moderately suitable areas being the more viable areas for salt production. All areas under 3 ha (30,000 m^2) were removed from the identified moderately suitable areas since this study only considered areas that are suitable for medium (3 to 50 ha.) and large-scale (50 to 500 ha.) salt farming operations.

All the identified factors that affect the suitability of an area for salt production considered in this study were treated as a system of factors and not as individual layers, so an area can still be identified as suitable even if it is not suitable based on another factor. However, this is not the case for the land cover factor since it is mandated by law that certain land cover types such as Mangrove Forests cannot be converted to salt farms (Philippine Fisheries Code of 1998). Thus, identified suitable areas that have built-up, mangrove, or forest land covers were removed. Shown in *Fig. 6* is the final suitability map output that was subjected to area and land cover constraints and its distribution is shown in *Table 6*.

Suitability Rating	Percentage (%)	Area (km^2)
Not Suitable	13.36	658.20
Low Suitability	77.13	3800.87
Moderate Suitability	9.51	469.01
TOTAL	100	4928.08

Table 6. Suitability distribution based on the final suitability map before and after constraints

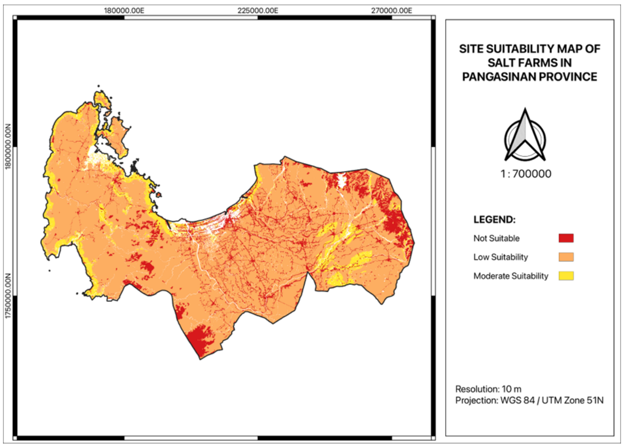

Figure 6. Final suitability map output with area and land cover constraints

The land cover distribution of the identified moderately suitable areas is shown in *Table 7*. It can be seen that most of the identified suitable areas (80%) are annual croplands and brush/shrubs, which are land covers that are rated to be moderately and highly suitable for salt production (Achmadi, 2013), respectively. This indicates that these areas are highly feasible and economically viable to be converted to salt farms.

Class	Percentage (%)	Area (km^2)
Annual Crop	43.72	206.96
Brush/Shrubs	36.30	171.84
Fishpond	8.18	38.74
Grassland	4.03	19.09
Open/Barren	1.81	9
Perennial Crop	5.86	27.73
TOTAL	100	473.36

Table 7. Land cover distribution of moderately suitable areas with land cover constraints

3.6. Validation of Suitability Map

The vector files containing the salt farm polygons of Dasol and Alaminos were overlapped with the output suitability map to determine the total area and percentage of overlap. The total area of all salt farms located in Dasol is 7,831,420.62 m^2. Results from the overlap analysis show that 4,865,280.68 m^2 of the total land area of existing salt farms in Dasol falls within the moderately suitable rated areas. Meanwhile, for the municipality of Alaminos, approximately at least 772,954.2 m^2 of the total land area of existing salt farms falls within the moderately suitable areas. The overlap percentage is relatively smaller than that of Dasol since the provided salt farm vector files for the municipality of Alaminos had no established Coordinate Reference System (CRS) and had an incorrect scale and the researchers had to manually assign a CRS and rescale the vector files before the overlap analysis. As a result, the given vector of existing salt farms was off by a large margin and did not precisely overlay with the fishponds/salt farms in Google Earth satellite image as seen in *Fig. 7*.

In summary, validation results show a 62.13% and 28.06% overlap percentage for Dasol and Alaminos City, respectively. The resulting overlap percentage for both samples is believed to be much higher if not for the gaps in the output suitability map (as seen in *Fig. 8)*. Some areas were not covered due to the gaps in the slope dataset and lack of soil data. Nonetheless, there is considerable agreement between the location of the suitable areas and the existing salt farms in Alaminos.

3.7. Clustering Analysis

Performing spatial analysis further identifies specific areas that are most suitable for salt production. The moderately suitable areas that resulted from the weighted overlay analysis need to be spatially verified to determine if the suitability values are consistently high throughout the area. Thus, the need for spatial autocorrelation analysis. This further validates the feasibility and suitability of an area for establishing new salt farms or expanding existing ones. Local Moran's I and Hotspot Analysis were utilized to determine if there is a spatial correlation between the suitability values of the output suitability map. The suitability values were used as the burn value or spatial unit for both analyses.

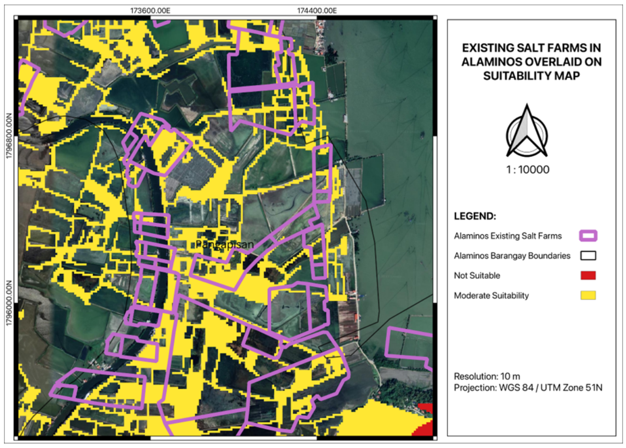

Figure 7. Existing salt farms in Alaminos overlaid on suitability map

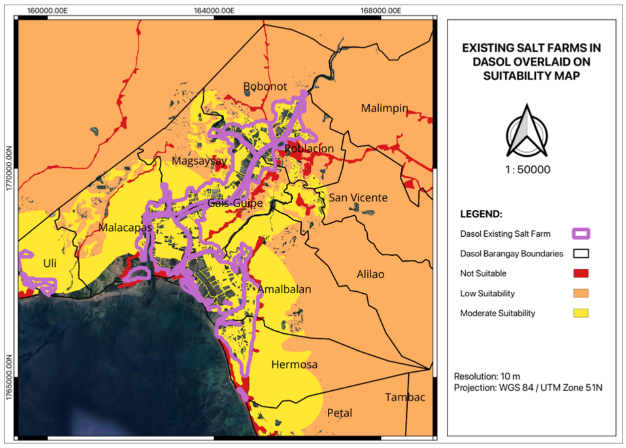

Figure 8. Gaps on existing salt farms in Dasol, Pangasinan

Local Moran's I: The output suitability map of Pangasinan was tested for its spatial correlation between its suitability values, as shown in *Fig. 9*. Given the z-score of 35.761993, there is a less than 1% likelihood that these spatially clustered suitability patterns could result from random chances.

Areas within the high-high cluster are the most suitable for salt production and have the most potential for establishing new salt farms. Meanwhile, areas within the high-low and low-high outliers can also be feasible for salt farm operations meaning smaller salt farms may be established but only to a limited extent due to inconsistencies of suitability values for that specific area. Lastly, low-low clusters were not considered in this analysis since these areas have consistently low suitability values. Shown in *Table 8* are the distribution of the other clusters and outliers.

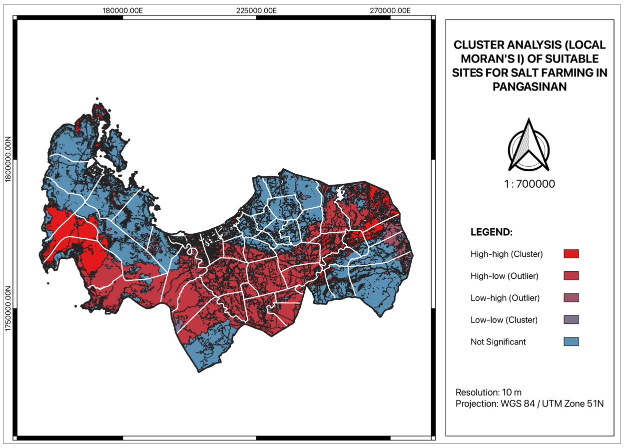

Figure 9. Cluster analysis of suitable sites for salt farming in Pangasinan

Cluster/Outlier	Area (km^2)	Percentage (%)
Low-low cluster	181.03	3.68
Low-high outlier	167.9	3.41
High-low outlier	1648.87	33.49
High-high cluster	539.42	10.95
Not Significant	2386.85	48.47
TOTAL	4924.06	100

Table 8. Areas of corresponding clusters and outliers

Hotspot Analysis (Getis-Ord Gi* Statistic): The intensity or robustness of the suitability values are considered for this analysis. This was used as a supporting spatial autocorrelation analysis to prove that the moderately suitable areas generated in the suitability map output are indeed suitable for salt production.

Fig. 10 shows the province's corresponding hot and cold spots at different z-scores. The Gi* statistic calculated for each cold or hot spot feature at different confidence levels in the dataset represents a z-score. A higher z-score indicates a more robust or intense clustering of high suitability values, referred to as a hotspot. Positive z-score results in hot spots and are the most suitable sites for establishing salt farms and have the most potential in expanding existing salt farms due to a continuous and intense clustering of high suitability values. Conversely, for statistically significant negative z-scores, a smaller (negative) z-score signifies a more pronounced clustering of low suitability values, known as a cold spot. Given this, areas with cold spots are less practical for establishing medium and large-scale salt farms.

Moreover, *Table 9* shows the statistically significant cold and hot spots at varying confidence levels. Based on the results, only 2158.18 km^2 (or 41.51% of the total land area of Pangasinan) were identified as statistically significant cold or hot spots. The remaining 3041.49% km^2 (or 58.49%) were statistically insignificant, therefore, having neither cold nor hot spots. It indicates that there is a combination of high and low suitability values that made that particular area classified as not significant.

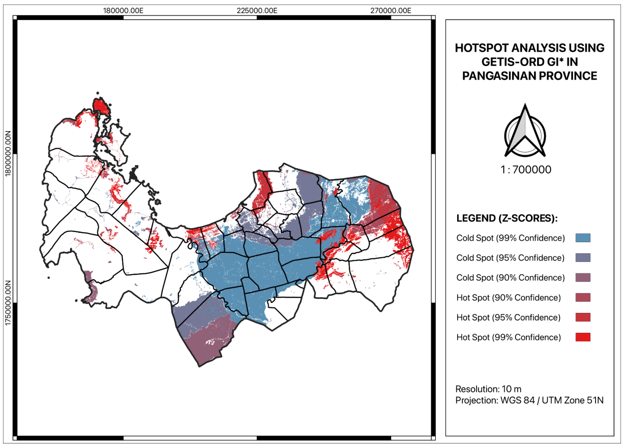

Figure 10. Hotspot analysis (Getis-Ord Gi* statistic) showing cold and hot spots at varying confidence levels

Hot/Cold Spot (Confidence Level)	Z-score	Area (km^2)	Percentage (%)
Cold Spot (99% Confidence)	-3	1001.3	46.4
Cold Spot (95% Confidence)	-2	451.86	20.94
Cold Spot (90% Confidence)	-1	202.89	9.4
Hot Spot (90% Confidence)	1	126.12	5.84
Hot Spot (95% Confidence)	2	126.56	5.86
Hot Spot (99% Confidence)	3	249.45	11.56
TOTAL		2158.18	100

Table 9. Areas of corresponding cold and hot spots at varying confidence intervals

3.8. Municipalities with the Most Suitable Areas for Salt Farming

Shown in *Table 10* are the top 10 municipalities for the coastal and landlocked municipalities. The listed top 10 areas for both coastal and landlocked municipalities were also identified as high-high clustering and hot spot areas for the Local Moran's I and Hotspot Analysis, respectively. This means that the list of the most suitable coastal and landlocked municipalities shown below has a consistent and robust clustering of high suitability values, making the municipality suitable for establishing new salt farms and expanding existing ones. There is ample opportunity for revitalizing the salt-producing sector in Pangasinan given that the total area of the top 10 most suitable coastal municipalities for salt farm operations is 27,549.70 ha and 15,590.87 ha for the landlocked municipalities.

Coastal			Landlocked	
Municipality	Suitable Area (ha.)		Municipality	Suitable Area (ha.)
Bolinao	4,692.94		Balungao	2,965.79
Dasol	4,377.46		Umingan	2,874.19
Alaminos City	3,551.46		Asingan	2,033.38
Sual	3,250.47		Mabini	1,712.25
Agno	3,198.27		Rosales	1,578.70
Labrador	2,101.37		Santa Maria	1,424.05
Infanta	1,863.90		Tayug	1,132.55
San Fabian	1,675.91		San Nicolas	843.47
Anda	1,491.40		Natividad	535.58
Bani	1,346.52		San Quintin	490.91
TOTAL	27,549.71		TOTAL	15,590.87

Table 10. Top coastal and landlocked municipalities in terms of suitable areas for salt production

3.9. Zonal Statistics of Sample Salt Farms for Each Factor

Sample salt farms from Dasol and Alaminos were used as the samples for the zonal statistics for each factor. The existing salt farms with the largest areas in Dasol and Alaminos were used as the samples for the zonal statistics. The area of the sampled salt farm from Dasol is 151.22 ha, while 23.61 ha for the Alaminos sample. Shown in *Fig. 11* are the sample salt farm locations for Dasol and Alaminos.

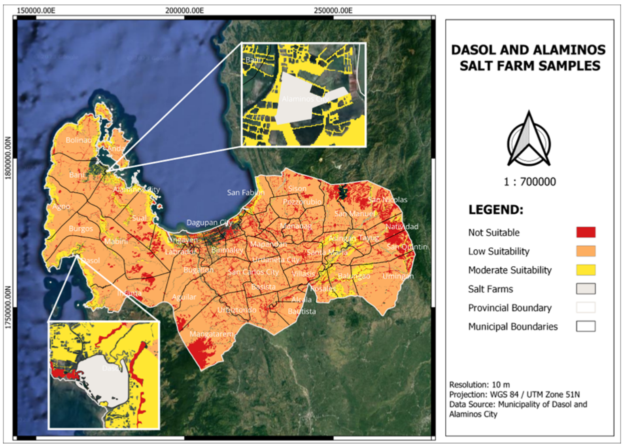

Figure 11. Dasol and Alaminos salt farm samples

The calculated statistics were the median and the majority (or mode). The former was used for the factors with continuous values including slope, distance from the coastline, distance from the river, temperature, humidity, rainfall, and wind speed, while the latter was used for factors with discrete values which were the land cover and soil texture factors. The median was chosen over the mean for the factors with continuous values since it is a more robust statistic because outliers on a dataset have little effect on the computed value. On the other hand, the majority statistic was used for the discrete values since the researchers wanted to determine the most dominant pixel value (which corresponds to a specific classification for both land cover and soil texture) in the sample salt farms. Shown in *Table 11* are the median and majority values for the factors for both Dasol and Alaminos sample salt farms with their corresponding suitability rating (1 for not suitable, 2 for low suitability, 3 for moderately suitable, and 4 for highly suitable).

Variable/Factor		Dasol		Alaminos	
		Median	Majority	Median	Majority
1	Temperature (°C)	28.05 (2)	-	28.04 (2)	-
2	Rainfall (mm/month)	37.84 (3)	-	45.45 (3)	-
3	Humidity (%)	82.02 (2)	-	83.22 (2)	-
4	Distance from Coastline (m)	554.62 (4)	-	737.46 (4)	-
5	Wind Speed (m/s)	3.42 (2)	-	2.97 (2)	-
6	Distance from River (m)	240.00 (4)	-	368.78 (4)	-
7	Land Cover	-	5 (Fishpond) (4)	-	5 (Fishpond) (4)
8	Soil Texture	-	4 (Hydrosol) (4)	-	1 (Clay Loam) (4)
9	Slope (%)	1.58 (4)	-	1 (4)	-

Table 11. Zonal statistics for Dasol and Alaminos salt farm samples

It can be observed that although the samples were rated as highly suitable (score=4) in terms of all the physical land variables, they only overlapped on the moderately suitable areas (score=3) in the final suitability map output. This is because the suitability ratings of the meteorological factors, which only had low and moderate suitability ratings, strongly influenced the overall suitability of the area. This further reinforces the results of the AHP survey wherein the combined weight of the meteorological factors (62.5%) outweighs the physical land variables (37.5%) by a margin of 25%.

4. CONCLUSION

Slope, land cover, distance from the coastline, distance from the river, and soil texture, were the physical land variables that affect the suitability of an area for salt production while air temperature, humidity, rainfall, and wind speed were the meteorological factors. The suitability ratings with their corresponding threshold values for each significant factor were also determined based on existing literature.

Meteorological factors were more significant than the physical ones. The reason behind this is that the solutions to overcome the unfavorable effects of a physical factor on the suitability of an area for salt production are more feasible and manageable. However, this is not the case for the meteorological factors. They are more complex since they are natural occurrences that cannot be controlled or predicted and the required resources to address them can be very costly. Therefore, the meteorological factors garnered a stronger weightage and heavily influenced the overall suitability of an area for salt farm operations.

A total land area of 49,744.82 ha was identified to be suitable for salt production based on the output suitability map. These areas are distributed throughout the coastal and landlocked municipalities of Pangasinan. The top 10 municipalities that had the largest areas suitable for salt farming were: Bolinao, Dasol, Alaminos City, Sual, Agno, Labrador, Infanta, San Fabian, Anda, and Bani for the coastal municipalities, while Balungao, Umingan, Asingan, Mabini, Rosales, Santa Maria, Tayug, San Nicolas, Natividad, and San Quintin for the landlocked municipalities (ranked according to land area, largest to smallest). The landlocked municipalities are subject to further ground validation if there are available sources of salt water within their areas.

Lastly, these findings can help address the problem regarding the lack of identified suitable areas for salt farming. One of the short-term objectives stated in the roadmap for the Philippine salt industry was the identification and fast-track approval of areas suitable for salt production (Khonghun, 2021). The implementing agencies, such as the Department of Agriculture - Bureau of Fisheries and Aquatic Resources (DA-BFAR) and Department of Environment and Natural Resources (DENR), can utilize the results of the study for the planning stage in the establishment of new salt farms and approval of foreshore leases in the coastal areas that were identified to be suitable for salt farm operations. Furthermore, relevant stakeholders of salt production can also use the results of this study in deciding which areas to develop for local salt production.

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