THE FORECASTING ANALYSIS OF SEA SALT PRODUCTION BASED ON RAINFALL VARIABILITY IN THE CIREBON DISTRICT

ANALISIS PERAMALAN PRODUKSI GARAM LAUT BERDASARKAN VARIABILITAS CURAH HUJAN DI KABUPATEN CIREBON

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ABSTRACT

Salt production in Indonesia is generally carried out during the dry season, where the amount of yield is influenced by rainfall in the season. As for agricultural purposes, predictions of precipitation from various national/international meteorological and climatological agencies are expected to estimate the amount of sea salt harvested. This study aims to ascertain the possibility of using rain data to predict salt harvest and the urgency of rain monitoring in specific locations, such as salt pans in Cirebon. Prediction of salt production used multiple linear regression on data of sea salt production, rainfall, and rainy days for eleven years in Cirebon. The analysis results show that the precipitation and rainy days influence salt harvest inversely. The number of rainy days is more influential than rainfall on salt production. Data on rainfall and the number of rainy days is only feasible to predict the fluctuations of salt yields in Cirebon. However, they cannot accurately indicate the number of *harvests. The predictions in this research still use rainfall reanalysis data. Thus, to determine a more accurate forecast of sea salt harvest, monitoring instruments are needed at specific locations of salt ponds to measure rainfall over a long period. Accurate yield forecasts for optimizing natural sea salt production leave a minimal ecological footprint that supports sustainable living.*

Keywords: *salt, rain, regression, prediction, sustainable living.*

ABSTRAK

Produksi garam di Indonesia pada umumnya dilakukan pada musim kemarau, dimana besarnya produksi dipengaruhi oleh curah hujan pada musim tersebut. Sebagaimana untuk keperluan pertanian, prediksi curah hujan dari berbagai badan meteorologi dan klimatologi nasional/internasional diharapkan dapat memperkirakan jumlah garam laut yang akan dipanen. Kajian ini bertujuan untuk memastikan kemungkinan penggunaan data hujan untuk memprediksi panen garam dan urgensi pemantauan hujan di lokasi tertentu, seperti tambak garam di Cirebon. Prediksi produksi garam menggunakan regresi linier berganda pada data produksi garam laut, curah hujan, dan hari hujan selama sebelas tahun di Cirebon. Hasil analisis menunjukkan bahwa pengaruh curah hujan dan hari hujan terhadap hasil panen garam berbanding terbalik. Jumlah hari hujan lebih berpengaruh dibandingkan curah hujan terhadap produksi garam. Data curah hujan dan jumlah hari hujan hanya layak untuk memprediksi fluktuasi hasil garam di Cirebon. Namun, kedua varibel tersebut tidak dapat menunjukkan jumlah yang akan dipanen dengan akurat. Prediksi dalam penelitian ini masih menggunakan data curah hujan reanalisis. Dengan demikian untuk menentukan prakiraan panen garam laut yang lebih akurat, diperlukan alat pemantauan pada lokasi tambak garam tertentu untuk mengukur curah hujan dalam jangka waktu *yang lama. Prakiraan hasil panen yang akurat untuk optimalisasi produksi garam laut alami meninggalkan jejak ekologis yang minim sehingga turut mendukung hidup berkelanjutan.*

Kata Kunci: *garam, hujan, regresi, prediksi, hidup berkelanjutan.*

INTRODUCTION

The demand for salt in Indonesia has reached 4.5 million tons, consisting of 3.7 million tons for industrial use and 0.8 million tons for consumption (Lokadata, 2020; Kemenperin, 2022). As raw and auxiliary materials, this need continues to increase along with population growth and salt-using industries (Iswanto & Purmalino 2019). On the other side, Indonesia's average sea salt harvest is only around 1.7 million tons/year. Salt yields are only able to meet domestic food salt needs (Rusdi, 2018). Meanwhile, to meet the total demand for salt, the government imports it (Simamora et al., 2021).

Ideally, the planned amount of salt imports should consider the current year's salt harvest (Kurniawan & Bramawanto, 2018). However, uncertainty over the achievement of the salt production target is still relatively high. Therefore, we need a scientific approach that can accurately estimate salt harvest. The prognosis of the salt balance can be estimated more accurately with predictions of domestic salt production and "as necessary" import plans. So that the national salt needs can be met and the year-end stock is not in a state of deficit or excessive surplus. Thus, salt stocks can guarantee the sustainability of industries that use salt as raw materials from salt scarcity resulting from a stock deficit and prevent farmers from losses due to falling prices triggered by excessive surplus salt stocks. The bullwhip effect can be avoided (Novianti et al., 2022).

The weather data has been widely used to estimate the yield of various agricultural products and adaptive strategies to changing rain patterns due to climate change. For example, Antony (2021) predicts the harvest of food commodities in South India, especially rice, using rainfall data as one of the predictors. Kumi et al. (2023) also studied the impact of rainfall onset date on crop yield in Ghana. Changes in rainfall patterns due to climate change led researchers to observe adaptive rice crop management strategies carried out by farmers in Indonesia (Matsuura & Sakagami, 2022). The study conducted by Ruminta and Nurmala (2017) also succeeded in making accurate and potential rainfall simulations and predictions to predict rainfall and crop production in West Java.

A study has shown an interaction between El Niño Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD) to the dry season's length, affecting salt production. Strong or extreme El Niño and positive IOD phases simultaneously result in longer drought conditions, thereby increasing salt harvest, as happened in 1982, 1997, and 2015. On the other hand, La Niña and negative IOD phases that occur simultaneously can increase rainfall. Rain throughout the dry season can cause salt harvest failure in all salt centers, as happened in 1998, 2010, and 2016 (Bramawanto & Abida, 2017). Suppose at one time there is El Niño & positive IOD occurs simultaneously. In that case, vigilance is needed when it becomes La Niña and the negative IOD phase drastically the following year, impacting salt harvest failures like 2009-2010 and 2015-2016. Thus, it is increasingly evident that climate-weather factors significantly affect salt production. Historical data on climate variability, especially rainfall (precipitation) and salt production on a national scale, have the potential to be used to predict salt production in the future.

Studying rainfall in Indonesian regions that are generated by climate variability, such as ENSO and IOD, has its challenges. Various non-linear processes such as non-linear ocean advection, non-linear atmosphere-ocean interactions, state-dependent stochastic noise, tropical wave instability, and biophysical processes lead to El Niño and La Niña spatial and temporal asymmetries (An et al., 2020). Approaches using the Global Climate Model (GCM) and the Regional Climate Model (RCM) can be applied to developing climate change scenarios and anticipating ENSO irregularities due to complex ocean-atmosphere interactions (Endris et al., 2018).

Cirebon Regency was recorded as the largest producer of people's salt in 2015, reaching 435,439 tons, outperforming Sampang Regency in East Java Province, Pati Regency in Central Java Province, and Indramayu Regency in West Java (Katadata, 2016). However, this achievement did not continue in the following years, as seen from the decreasing salt production in Cirebon Regency.

Like other salt ponds in Indonesia, Cirebon salt ponds produce salt only during the dry season (Helmi & Sasaoka, 2018). Several studies show that rainfall in the dry season affects the amount of sea salt production. The wet-dry season often causes a decrease in salt harvests and even triggers salt harvest failure. Wet-dry seasons in 2010 and 2016 have proven to cause salt harvest failure in Indonesia (Bramawanto & Abida, 2017). Prediction of dry season conditions should be used to increase salt pans productivity. When the prediction results show that there is a tendency for a dry season that lasts a long time, farmers can make good use of these conditions. Farmers can also set strategies when predictions show a trend for a wet-dry season, if the state permits, by optimizing production at the peak of the dry season.

Predictions of precipitation for agricultural purposes are expected to estimate the amount of sea salt harvested. Accurate sea salt harvest estimates can be counted as domestic supply in the national salt balance, mainly to meet consumption salt needs, and the rest is expected to complement industrial needs. Variations in rainfall influenced by various combinations of ENSO and IOD events result in fluctuations in salt yields in Indonesia (Bramawanto & Abida, 2017). Several studies have also shown that rain plays a role in determining the amount of salt harvested in Rembang (Bramawanto et al., 2019) and Nusa Tenggara (Bramawanto et al., 2022). This study aims to ascertain the possibility of using rain data to predict salt production and the urgency of monitoring rain in specific locations, such as salt pans in Cirebon. Sea salt production optimization can refer to an accurate harvest forecast using reliable meteorological data regarding rain characteristics in the dry season, utilizing renewable energy from sunlight, and other factors that affect salt production. Natural sea salt production in Indonesia leaves minimal ecological footprints. It indirectly supports sustainable living by reducing the use of fossil fuels, reducing the greenhouse gas effect, and simultaneously reducing pressure on the environment.

METHODS

This study examines the salt harvest in the Cirebon district. From the approximately 69,8 km long coastline of Cirebon District, more than 80% of the shoreline is salt pans. Salt pans in Cirebon obtain raw materials from seawater in the Java Sea. The Cirebon coast, on the north coast of Java, is vulnerable to climate change, as represented by rainfall, temperature, and wind speed changes (Mulyasari et al., 2019).

Sumber: *Google, n.d. (Google Earth Pro 7.3.6)*

Figure 1. Salt Pans in Cirebon

Data on sea salt yield (*Y, tons*) was collected from the Ministry of Marine Affairs and Fisheries (KKP). In contrast, climate data, in this case, it is rain (*X, mm*) has been downloaded from Copernicus Climate Data storage and Meteorology (Anonim, 2023a), Climatology, and Geophysical Agency (BMKG) through the site of BMKG (Anonim, 2023b). Rainfall data is processed by filtering precipitation data during the salt production period (May-November) to obtain monthly rainfall accumulation (X_1, *mm*) data and rainy days (X_2, *day*) during the dry season. Researchers have collected data on salt harvest, rainfall and the number of rainy days in Cirebon for eleven years (2011-2021).

Researchers used Microsoft Excel to statistically analyze correlation, multiple linear regression and root mean square error. A correlation analysis was carried out to observe the relationship between variables that are thought to influence sea salt yields in Cirebon. This research only takes two rain-related variables: rainfall and the number of rainy days. The strength of the relationship between variables is calculated using the following formula.

$$r = \frac{n \sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i}{\sqrt{n \sum_{i=1}^{n} X_i^2 - \left(\sum_{i=1}^{n} X_i \right)^2} \sqrt{n \sum_{i}^{n} Y_i^2 - \left(\sum_{i=1}^{n} Y_i \right)^2}} \quad (1)$$

n = amount of data

The correlation coefficient *r* can be positive (+) or negative (-) between -1 and 1. The two variables' relationship is stronger if *r* is close to -1 or 1. If the value is close to 0, the relationship between the two variables worsens. The positive and negative signs on the correlation coefficient indicate the direction of the relationship. A positive correlation coefficient indicates the relationship is directly proportional and vice versa. While the correlation coefficient is negative, meaning the connection is inversely proportional. The strength of the relationship between the independent variable and the dependent variable can be interpreted using the de Vaus Version Correlation Coefficient Interpretation Table as follows:

Table 1. de Vaus Version Correlation Coefficient Interpretation

Coefficient	Correlation Strength
0,00	No correlation
0,01 – 0,09	Non-significant correlation
0,10 – 0,29	Weak correlation
0,30 – 0,49	Moderate correlation

Coefficient	Correlation Strength
0,50 – 0,69	Strong correlation
0,70 – 0,89	Very strong correlation
>0,90	Almost perfect correlation

Sumber: *de Vaus in Zuzana et al., 2019*

The correlation of each variable can be strengthened by looking at the significance of the two independent variables when combined. Multiple linear regression determines if each independent variable predicts the dependent variable significantly. Multiple linear regression analyzes 11-year data of sea salt harvest (dependent variable), rainfall, and number of rainy days (independent variable) in Cirebon with confidence level determined at 95% (alpha 0,05). Multiple linear regression analysis is calculated using the following formula.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n + e \qquad (2)$$

Here, *Y* stands for the dependent variable, X_1, X_2, ..., X_n for the number of independent variables, and *e* for the "noise" variable, a randomly generated variable with a mean of zero and an unknown standard deviation. Additionally, we are unaware of what the coefficients β_1, β_2, ..., β_n are worth. The point estimator of independent variables is the β coefficient.

One of the statistical regression outputs is the coefficient of determination (R^2), which shows the magnitude of the rainfall contribution and the number of rainy days affecting salt yields simultaneously. It is necessary to carry out an F test by presenting its significance value to ensure an effect of rainfall and the number of rainy days simultaneously on salt yields. When the analysis results on the F test were insignificant, the coefficient of determination is not feasible to be used to predict the contribution of rainfall and the number of rainy days to crop yields. The study used a 95% confidence level or an alpha of 0,05, so the significance value must be smaller than the alpha value.

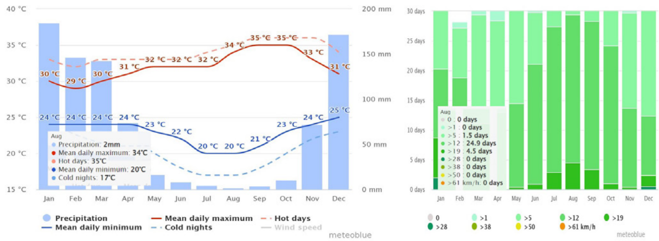
Root Mean Square Error (RMSE) is the magnitude of the error rate of the prediction results, where the smaller (closer to 0) the RMSE value, the more accurate the prediction results will be. The RMSE value can be calculated by the following equation (Frost, n.d.)

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{\left(Y_i' - Y_i\right)^2}{n}} \tag{3}$$

RESULTS

1. Climate-weather in Cirebon

Climate-weather information for salt production is utilized differently than for agricultural (food crop) purposes (Bramawanto & Abida, 2017). Farmers are more aware of drought and extreme rain in food crop farming, while salt farmers are more aware of rain that falls in the dry season when sea salt production is in progress. The drier salt pans in an area become a potential condition for increasing salt harvests. Dry conditions are characterized by low rainfall, low relative humidity, and vast differences between day and night temperatures and are supported by high wind speeds (Tavakol et al., 2020). The weather model simulation results generated by Meteoblue based on temperature and rainfall data for the last 30 years show that the driest conditions in Cirebon occur in August (Figure 2).



Sumber: *Anonim, n.d. (meteoblue.com)*

Figure 2. Monthly Average Precipitation, Temperature, and Wind Speed in Cirebon

The average rainfall in the driest month is only about 2 mm. The average maximum temperature of the day each month for Cirebon (solid red line) is around 34 degrees Celsius. Likewise, the average minimum temperature (solid blue line) is about 20 degrees Celsius. The hottest days and coldest nights on average each month for the past 30 years (dashed red and blue lines) are around 35 and 17 degrees Celsius, respectively. The dominant wind speed in August is 12 – 19 km/hour for 24,9 days. A study that fulfills the history and projections of drought in Cirebon shows that, in the future, drought periods are expected to shift as drought severity increases (Pratiwi et al., 2018).

2. Cirebon's Contribution to National Sea Salt Production

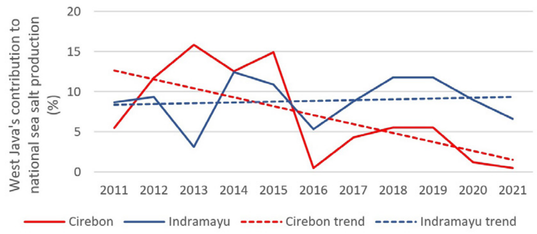
Cirebon Regency is one of the largest salt centers in Indonesia. Cirebon is the second largest salt contributor in West Java after Indramayu and ranks seventh in Indonesia (Table 2). However, salt yields in Cirebon have yet to be optimized, considering that the largest salt fields in Indonesia are Cirebon (3,8 thousand ha) above Sampang (3 thousand ha), Pati (2,8 thousand ha), and Indramayu (2,7 thousand ha). The potential of a large land area should be optimized to support the fulfillment of domestic salt demand.

Table 2. The 10 Largest Salt-Producing Districts in Indonesia

No	District	Sea Salt Harvest (,000 tons)							
		2015	2016	2017	2018	2019	2020	2021	Average
1	Pati	381,70	6,25	115,95	257,79	353,34	191,28	131,57	205,41
2	Sampang	398,98	7,01	110,34	312,06	353,55	119,01	122,35	203,33
3	Indramayu	317,12	6,26	97,82	319,94	300,31	102,63	72,11	173,74
4	Sumenep	236,12	10,17	126,66	199,07	175,43	176,71	113,63	148,26
5	Bima	152,44	7,22	80,47	263,24	187,63	97,21	97,98	126,60
6	Rembang	218,49	1,73	76,49	184,91	169,63	109,49	103,59	123,39
7	Cirebon	434,44	0,59	47,89	149,80	155,71	13,47	5,37	115,47
8	Pamekasan	123,53	10,51	40,61	134,60	104,73	60,67	47,38	74,58
9	Demak	130,12	4,76	40,30	101,32	114,38	20,07	29,57	62,90
10	Jeneponto	40,27	3,15	5,66	65,02	56,97	31,62	3,79	29,50

Sumber: *KKP, 2022*

Cirebon's contribution to the national sea salt has decreased significantly yearly, from around 12,5% in 2011 to only around 2% in 2021 (Figure 3). As a comparison, Indramayu, which is in the same coastal area as Cirebon, has a relatively stable contribution to national sea salt production and has even tended to increase, moving from 8,5% to 9% in the last decade.



Sumber: *KKP, 2022*

Figure 3. West Java's (Cirebon & Indramayu) Contribution to National Sea Salt Production

3. Compiled Dataset

Researchers have collected and compiled data from various sources in Table 3 below. The data table contains information on the last 11 years (2011 to 2021) of rainfall, the number of rainy days during the dry season, and the sea salt harvest in Cirebon. Statistics Indonesia (Badan Pusat Statistik-BPS) has verified sea salt harvest data by calculating the salt weight loss.

Rainfall data and the number of rainy days are the accumulated values of precipitation and rainy days from May to November each year in Cirebon. The data were taken during this period considering that salt farmers in Cirebon usually prepare their ponds in May during the regular dry season and end their production in mid-November. The period of salt production at certain abnormal times can go forward or backward. At the same time, the yield data is the yearly accumulated harvest, calculated at the end of the sea salt production season.

Table 3. Sea Salt Production and Rainfall Data in Cirebon

Year	Rainfall During Dry Season in Cirebon Salt Pans (mm)	Rainy Days During Dry Season in Cirebon Salt Pans (Days)	Cirebon Sea Salt Harvest (,000 ton)
2011	377	31	89
2012	263	11	290
2013	641	41	184
2014	303	19	314
2015	109	9	435
2016	860	34	1
2017	522	37	48
2018	182	29	150
2019	101	16	157
2020	385	47	13
2021	576	56	5

Sumber: *Hersbach et al., n.d. (ERA5 ECMWF); BMKG, n.d. (Data online Pusat Database BMKG); KKP, 2022*

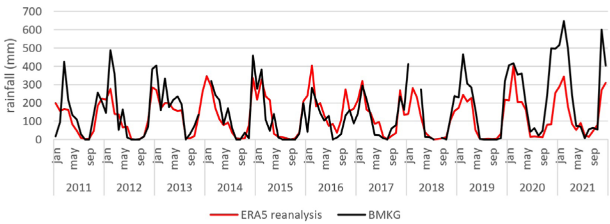
The highest dry season rainfall occurred in 2016, about 860 mm, with a total of 34 rainy days, which was also the year with the highest rainfall intensity in the dry season compared to other years, namely 4,02 mm/day (Table 4). The power of rainfall in 2016 impacted salt harvest failure in Cirebon. The lowest rainfall intensity occurred in 2019 (0,47 mm/day), followed by 2015 (0,51 mm/day). Even though there was a super El Niño in 2015, it turned out that the rainfall intensity was slightly higher than in 2019. However, this slight difference is not directly proportional to the sea salt harvest produced in Cirebon. The comparison of salt production in 2015 and 2019 is 345,000 tons compared to 147,000 tons. Several factors are thought to be the cause of the decline in salt production in Cirebon Regency, including the Covid-19 pandemic (Romdhon, 2022), weather and climate (Putri et al., 2019), low salt prices (Izan, 2020) and reduced land (Adriyani et al., 2020).

Table 4. Annual Variability Rainfall Intensity During Sea Salt Production

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Rainfall Intensity (mm/day)	1.76	1.23	2.99	1.41	0.51	4.02	2.44	0.85	0.47	1.80	2.69

Sumber: *Hersbach et al., n.d. (ERA5 ECMWF)*

The rainfall data used in this research results from a fifth-generation analysis conducted by the European Center for Medium-Range Weather Forecasts (ECMWF). The selection of this data was taken with the consideration of rainfall data, with the closest point obtained from the BMKG being in Kertajati, which is 40-60 km from the salt ponds in the Cirebon district. In addition, there are some incomplete data. Meanwhile, data comparison between rainfall from ERA5 and BMKG shows relatively similar results, especially during the dry season in May-October (Figure 3). The data differ more in the rainy season months, especially December-February.



Sumber: *Hersbach et al., n. (ERA5 ECMWF) & BMKG, n.d. (Online Data of BMKG Database Center)*

Figure 4. Rainfall Data from the ERA5 ECMWF Reanalysis Compared with Rainfall Data from BMKG Observations

There are other alternatives to obtain rain data, which can be downloaded from the results of satellite measurements from the Tropical Rainfall Measuring Mission (TRMM). TRMM is a collaborative project between the United States and Japan to monitor tropical and sub-tropic precipitation. However, in this study, the rainfall from TRMM in the Cirebon district is still being compared with other rainfall data and will be discussed in another article.

The findings of the correlation study reveal that the BMKG and TRMM rainfall patterns in Kalimantan are more similar as the cumulative number increases, with the yearly cumulative showing the highest correlation value (0,661–0,909). In particular, as a replacement for difficult-to-measure specific region data, TRMM rainfall data is considered capable and viable as a fill-in for the missing BMKG rainfall data (Setiyawan et al., 2022).

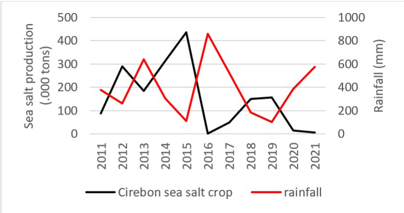
DISCUSSION

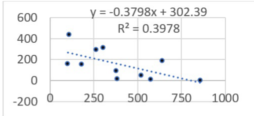
1. Correlation Analysis

The results of the correlation analysis showed that rainfall and rainy days each influenced Cirebon sea salt production with a negative correlation (Figure 4). It means that the increase in rainfall and the number of rainy days separately affect the decrease in sea salt yields. And conversely, low precipitation and a few rainy days can increase salt yields in Cirebon. The negative correlation between the number of rainy days and salt yield was stronger, with a value of -0,81755, than the correlation between rainfall and salt yield, with a value of -0,63075. Based on the de Vaus version correlation coefficient interpretation, interpretation of the strength of the relationship between variables shows that rainfall has a strong relationship with harvest yields, and rainy days have a powerful connection with sea salt yields.

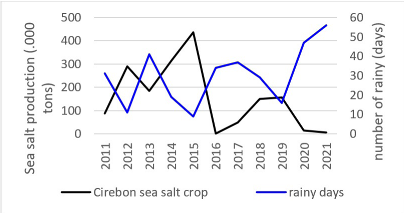
The decline in salt production in 2016, 2020, and 2021 is closely related to the effects of wet drought due to La Niña events in those years. Simultaneous La Niña and negative IOD triggered the 2016 wet-dry season. In 2020 and 2021, the wet-dry season will be caused by a series of multi-year La Niña (also called triple dip La Niña) in 2020-2022, accompanied by a negative IOD. Historical data shows that multi-year La Niña, as happened in the periods 1973–

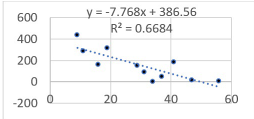
1975, 1998–2000, and 2020-2022, had an impact on a drastic decline in sea salt harvests on Madura Island, although not to the point of causing sea salt crop failure (Bramawanto & Suaydhi, 2023).





	rainfall	sea salt harvest
rainfall	1	
sea salt harvest	-0.63075	1





	rainy days	sea salt harvest
rainy days	1	
sea salt harvest	-0.81755	1

Figure 5. Partial Correlation of Rainfall and Number of Rainy Days to Salt Yields in Cirebon

In the last eleven years, the highest salt harvest only occurred in 2015 and set a record for the most increased salt production at the district level. However, there are indications of other factors, such as non-technical factors, which have more influence on sea salt yields in Cirebon. This condition can be seen from the harvest, which did not increase significantly even though rainfall and rainy days were low in 2018 and 2019. As a comparison, the location of the salt center closest to Cirebon, namely Indramayu, experienced a significant sea salt harvest increase in 2018 and 2019 (Figure 5). Dry conditions occurred in 2018 and 2019, optimally utilized by salt farmers in Indramayu, shown by production results similar to 2014-2015. Further research is needed to study the anomaly that has affected the low salt yields in Cirebon in the last 5-6 years.

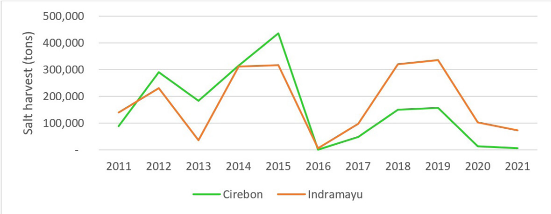


Figure 6. Comparison of Sea Salt Yields in Cirebon and Indramayu

2. Multiple Linear Regression Analysis

The multiple linear regression analysis results (Table 5) show that about 68% of salt production in Cirebon is determined by rainfall (X_1) and rainy days (X_2) during the dry season, and other variables determine the remaining 32%. The significance value of f is 0,0102 (below the alpha value of 0,05), meaning that the combination of variations in rainfall and the number of rainy days significantly determines the gain of salt production.

Table 5. Multiple Linear Regression Analysis for Rain-based Sea Salt Harvest in Cirebon

Regression Statistics	
Multiple R	0,825925
R Square	0,682153
Adjusted R Square	0,602691
Standard Error	90288,14
Observations	11

ANOVA

	df	SS	MS	F	Significance F
Regression	2	1,4E+11	7E+10	8,584668	0,010206409
Residual	8	6,52E+10	8,15E+09		
Total	10	2,05E+11			

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	393909,6	64275,18	6,128488	0,000281	245690,7886	542128,4284
Rainfall	-94,5048	160,559	-0,5886	0,57237	-464,754438	275,7448966
Rainy days	-6777,47	2533,61	-2,67503	0,028142	-12619,98983	-934,9583271

Partially, the effect of the number of rainy days on salt yields looks more significant than the effect of rainfall on salt harvests, indicated by the p-value of the number of rainy days (0,028), which is lower than alpha (0,05). This analysis produced a formula that can be used to estimate the salt harvest (Y') as follows.

$$Y' = 393.909{,}6 - (94{,}5 \times X_1) - (6.777{,}5 \times X_2) + e \quad (4)$$

The results of the predictions can only predict the ups and downs (fluctuations) of sea salt yields in Cirebon and illustrate that if rainfall (X_1) and the number of rainy days (X_2) increase, the sea salt harvest (Y') will decrease and vice versa, indicated by the negative value of the coefficient for rainfall and the number of rainy days. In comparison between the actual value (blue line) and the predicted results (red line) using the formula from multiple linear regression (4), the error value of the model is relatively high (Table 6 and Figure 6), so the prediction accuracy is still low. Using rainfall reanalysis data as a predictor can also result in low prediction accuracy. The anomaly of Cirebon sea salt production in the last five years, which has continued to experience a significant decline compared to the harvest of Indramayu sea salt in a coastal area, is also thought to have affected the low accuracy. However, in general, the resulting fluctuation pattern is similar, so it is still feasible to be used to predict sea salt yields. The accuracy of the method can be improved by increasing the number of input data variables or by adding other variables that have the potential to affect salt yields. Other climatological variables that can be added include air temperature, relative humidity, wind speed, and evaporation rate. Technical variables such as land productivity (tons/ha) and farmer productivity (tons/person) can also be added if the data is available.

Table 6. Comparison of Actual Values to Predicted Results

Year	Sea Salt Harvest (Y)	Prediction (Y')	Errors (Y-Y')	RMSE
2011	88.600,0	146.182,6	57.582,6	
2012	289.581,0	294.474,4	4.893,4	
2013	184.046,0	55.479,4	128.566,6	
2014	314.480,0	236.535,5	77.944,5	
2015	435.439,0	322.603,0	112.836,0	
2016	591,7	82.169,7	81.578,0	76.998,0
2017	47.885,1	93.807,2	45.922,1	
2018	149.802,8	180.178,6	30.375,7	
2019	157.059,4	275.966,3	118.906,9	
2020	13.472,9	38.982,8	25.509,8	
2021	5.368,6	40.052,8	45.421,4	

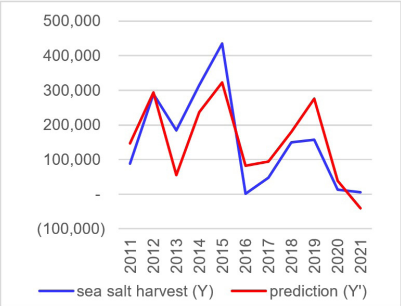


Figure 7. Comparison of Actual Values to Predicted Results

Data and information from weather stations around the salt ponds still need to be improved. BMKG's weather monitoring equipment is usually installed around airports, ports, plantations, and rice fields. The need for fast, accurate, and up-to-date data and information related to changes in the microclimate in the salt pond environment, such as temperature, humidity, air pressure, and rainfall, is also essential during salt production (Amin et al., 2021). Therefore, it is necessary to install weather monitoring devices in the salt pond environment to obtain accurate and real-time weather information.

The availability of weather information through the tools installed around the salt ponds can also explain salt farmers' habits and experience in predicting the weather for salt production purposes (Kuncoro et al., 2021; Widyanto et al., 2022). Even if we rely only on classical predictions, the weather is not erratic, and the season has changed its rhythm lately; of course, it will confuse salt farmers in managing their ponds (Trikobery et al., 2017; Widyanto et al., 2022). Due to this disorder, the habits and experiences of salt farmers based on local wisdom could be more helpful. Therefore, the presence of information technology coupled with local wisdom will help determine the right time to start and harvest salt commodities at a time like this so farmers can still optimize their production.

CONCLUSION

Data on rainfall and the number of rainy days is only feasible to predict the fluctuations of salt yields in Cirebon. However, they cannot accurately indicate the number of harvests. Predictions in this study still use rainfall reanalysis data. This data must be validated with observed rainfall data at specific salt pond locations. Thus, a weather monitoring device is needed at specific salt pond locations to determine a more accurate forecast of sea salt production to measure rainfall over a long period. Further predictions can also be developed by applying deep learning/machine learning methods, especially when the correlation between variables tends to be non-linear. In further research, technical and non-technical factors influencing sea salt yields in Cirebon can be included to accurately calculate sea salt harvest predictions.

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