Study of the weather parameters effect on the maduris salt production

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Abstract. The most widely used salt production technique is the process of evaporating seawater into salt by utilizing sunlight. This study conducted to measure the weather parameter and salt production during the salt season in 2019. The method used to measure the rate of evaporation was with an impermeable pan to prevent leakage of water samples. The results show that the evaporation rate of freshwater (0°Be) is greater than saltwater (20°Be) and the evaporation in July (0.62 cm/day) is smaller than October (1 cm/day). The correlation coefficient during July until October 2019 for air temperature (r) = 0.964, humidity (r) = -0.985, wind speed (r) = 0.622, and sunshine duration (r) = 0.987. The total salt production was from July until October 2019 reached 37395 kg on a demonstration plot area of 0.43 hectares. It is estimated the total of production per hectare will reach 87 tons /season. And for 2020 based on in-situ data it is estimated that production will decrease which is salt production will begin in July 2020, unlike 2019 which began in June, this is due to the influence of changes from the West wind (Asian monsoon) to East wind (Australian monsoon).

1. Introduction
Salt is one of the strategic commodities because it is needed by many people [1]. The salt production process can be carried out using various techniques, including the production of sea water salt, brackish water salt production, and mining in salt hills. In Indonesia, the salt production technique that is widely used is the seawater salt production technique which relies on sunlight for the evaporation process of sea water into salt. The quality of salt is determined to be influenced by 3 important factors, namely the quality of seawater raw materials, the quality of the pond or crystallization table and the weather.

Currently, salt production in the community is generally still traditional in nature, so it has a very high dependency the weather [2], [3] According to KP3K, technically the weather conditions required for salt production are: (1) high evaporation/evaporation (average> 650 mm/year); (2) Wind speed and direction above 5 m/sec; (3) The air temperature is greater than 32°C; (4) 100% solar irradiation; (5) Air humidity less than 50% H; (6) Low rainfall (between 1,000-1,300 mm/year or below 100 mm/month); and (7) Long dry, long dry without intermittent rainy days at least 140 days.

Weather conditions are one of the determinants of the success of salt production targets [4]. High wind speeds and evaporation rates, as well as low rainfall support to the traditional of salt production. The target of salt production is often not achieved due to several reasons, one of which is the delay in starting and ending the salt production period. Therefore, it is necessary to plan the time of salt production by considering wind speed and direction, evaporation rate, and rainfall as parameters for optimization of traditional salt production.
Zuhud [5] has studied the effect of evaporation rate and rainfall on salt production in the salt land of PT. GARAM. The method used is the Penman for evaporation rate, Multiple Linear Regression as an analysis between weather parameters and salt production, and temporal analysis to see the effect of timeseries on weather factors. It is known that the correlation results and the coefficient of determination of the rate of evaporation and rainfall on salt production are very low. However, through a temporal analysis from 2008-2012, there is a relationship between weather factors and salt production. Referring to Zuhud in optimizing salt production, it is necessary to consider the weather aspect to assess other meteorological parameters such as air temperature, humidity, wind speed and duration of exposure that affect evaporation and later correlated with the amount of salt production in the crystallization table.

As is well known, the process of making salt depends on the rate of evaporation of the brine. Based on the statements of Dama-Fakir and Toerien; Hernanto and Kwartatmono; Moinier; Kartikasari, that climatic factors that need to be considered at the time of salt production to increase the rate of evaporation include:

- Temperature can heat the water molecules needed for evaporation.
- Air humidity which can increase the rate of evaporation. If the humidity is high, the evaporation rate will be low because the saturation of the air will be achieved more quickly.
- Solar radiation can increase heat energy for evaporation.
- Wind can function to replace saturated air with unsaturated air to support evaporation.

To determine the effect and correlation of the weather parameters mentioned above, this study will measure the weather in-situ data and the production volume data generated from the crystallization table during the salt season.

2. Material and methods

Figure 1 shows a demonstration plot of 0.43 Ha used in this study to measure salt production which will be associated with weather parameters to determine the correlation.

![Figure 1. Research site to calculate salt production using the maduris method.](image)

2.1. Data Collection

In this study, we measured weather parameters such as air temperature, humidity, wind speed and sunshine duration from October 2018 to October 2019. Weather conditions are an important factor of high or low evaporation rate which will ultimately have an impact on the success of salt production. Therefore, observations of weather data such as air temperature, humidity, wind speed and sunshine are also needed in planning salt production time.

Evaporation is the process of exchanging water molecules into water vapor in the atmosphere. In this study, the measurement method using the impermeable evaporation pan so there is no leakage of water samples. This method aims to determine the total of daily evaporation by measuring changes in water level in the pan every day. The evaporation data will be correlated with meteorological data such as temperature, humidity, wind speed and the length of sun exposure within a certain period of time during the salt production.
In this study, used the evaporation pan, timer, ruler, stationery, baometer instruments and automatic weather station (AWS) equipment as shown in Figure 2. As for the work procedure that must measure the rate of evaporation, the first is to prepare 4 evaporation pans filled with 4 types of water samples (0°Be freshwater, 3°Be seawater, 10°Be seawater and 20°Be seawater) with a height of 8cm per pan. Furthermore, the four pans are placed in an open area with the four containers not far from each other and take measurements of the water level at 16.00 per day and changes in the value of salt concentration (°Be). Finally, calculate the depreciation of the water level in the pain where this value is the rate of evaporation that occurs in the four different water samples.

Table 1. The Weather parameter data for the period October 2018-October 2019.

| No | Period | Temp °C | RH % | Wind m/s | Sunshine Hour/day |
|----|--------|---------|------|----------|------------------|
| 1  | Oct-18 | 29.67   | 71.14 | 2.73     | 10.36            |
| 2  | Nov-18 | 29.40   | 78.17 | 2.28     | 7.18             |
| 3  | Dec-18 | 28.26   | 83.30 | 2.03     | 4.66             |
| 4  | Jan-19 | 27.59   | 85.93 | 2.72     | 3.98             |
| 5  | Feb-19 | 27.60   | 86.64 | 1.39     | 5.26             |
| 6  | Mar-19 | 27.71   | 85.10 | 2.03     | 5.12             |
| 7  | Apr-19 | 28.61   | 83.97 | 2.03     | 7.03             |
| 8  | May-19 | 28.89   | 77.61 | 3.10     | 9.46             |
| 9  | Jun-19 | 28.14   | 74.93 | 3.23     | 9.57             |
| 10 | Jul-19 | 27.42   | 73.19 | 3.68     | 9.71             |
| 11 | Aug-19 | 27.50   | 71.74 | 4.19     | 9.79             |
| 12 | Sep-19 | 28.11   | 70.93 | 4.07     | 10.15            |
| 13 | Oct-19 | 29.08   | 68.88 | 4.13     | 10.40            |

Figure 2. Evaporation pan and automatic weather station instruments.

Table 2. Evaporation rate (cm/day).

| No | Period | Evap I Be 0° | Evap II Be 3° | Evap III Be 10° | Evap IV Be 20° |
|----|--------|--------------|---------------|-----------------|----------------|
| 1  | Jul-19 | 0.62         | 0.52          | 0.4             | 0.32           |
| 2  | Aug-19 | 0.72         | 0.64          | 0.58            | 0.36           |
| 3  | Sep-19 | 0.86         | 0.78          | 0.68            | 0.48           |
| 4  | Oct-19 | 1            | 0.84          | 0.72            | 0.5            |

2.2. Correlation analysis

Correlation analysis is a statistical method used to measure the magnitude of the linear relationship between two or more variables. The population correlation value (ρ) ranges from the interval -1≤ρ≤1. If the correlation is positive, then the relationship between the two variables is unidirectional. Conversely, if the correlation is negative, then the relationship between the two variables is opposite [6]. Correlation coefficient is a statistical measure of the covariance or association between two
variables. The magnitude of the correlation coefficient ranges from +1 to -1. Correlation coefficient indicates the strength (strength) of the linear relationship and the direction of the relationship between two random variables. If the correlation coefficient is positive, then the two variables have a unidirectional relationship. This means that if the value of variable X is high, then the value of variable Y will be high too. Conversely, if the correlation coefficient is negative, then the two variables have an inverse relationship. This means that if the value of variable X is high, then the value of variable Y will be low and vice versa. To make it easier to interpret the strength of the relationship between the two variables, the author provides the following criteria [7]:
0: There is no correlation between the two variables
> 0 - 0.25: The correlation is very weak
> 0.25 - 0.5: Fair correlation
> 0.5 - 0.75: Strong correlation
> 0.75 - 0.99: The correlation is very strong
1: Perfect correlation

The equation used in determining the correlation value is:

$$r = \frac{n\Sigma xy - (\Sigma x)(\Sigma y)}{\sqrt{(n\Sigma x^2 - (\Sigma x)^2)(n\Sigma y^2 - (\Sigma y)^2)}}$$

3. Result and discussion
3.1 Correlation of the weather parameters with the evaporation rate

Baumeter (Be) is a unit level of salt concentration in solution or what is commonly known as salinity level. In units of salinity 30-45 ‰ or 3-4.5 ° Be, which means that in 1000gr of water there are 30-45 grams of salt. In this study, it was found that the rate of evaporation in samples consisting of water samples with salt concentrations of 0°Be, 3°Be, 10°Be and 20°Be showed that the salt content in water affects the evaporation rate where the higher the salt content in a solution, the lower the evaporation rate and vice versa. This difference in evaporation rate is due to differences in the increase in density of water [8].

![Figure 3. Diagram of evaporation rate (cm/day).](image)

Manan and Suhardianto [9] stated that evaporation is the process of changing molecules in a liquid state (for example water) spontaneously into gas (for example water vapor). This process is the opposite of condensation. Generally, evaporation can be seen from the gradual disappearance of the liquid when it is exposed to a gas of significant volume. In this study, the evaporation measurement method used is pan evaporation, which is tightly porous so that there is no leakage of sample water. Through this method, we will find out the amount of evaporation that occurs on a day by measuring changes in the height of water in the pan every day and the samples used are 4 water samples that have different concentrations (Be) or salt levels in seawater. Based on the results of in-situ observations as shown in figure 3, it was found that the evaporation rate from July to October 2019 increased for all samples, from sample 1 (concentration 0°Be) to sample 4 (concentration 20°Be). However, the
difference in the evaporation rate of the 4 samples is different which in sample 1 (concentration 0°Be) has the highest evaporation rate in the range of 0.62 cm to 1 cm per day while the lowest evaporation rate is in sample 4 (concentration 20°Be) in the range of 0.32 cm to 0.5 cm per day.

Table 3. The correlation calculation between the air temperature and evaporation rate.

| No | Period | Temp °C | Evap cm/day | X² | Y² | XY |
|----|--------|---------|-------------|----|----|----|
| 1  | Jul-19 | 27.42   | 0.62        | 751.644 | 0.384 | 16.998 |
| 2  | Aug-19 | 27.50   | 0.72        | 756.427 | 0.518 | 19.802 |
| 3  | Sep-19 | 28.11   | 0.86        | 790.172 | 0.740 | 24.175 |
| 4  | Oct-19 | 29.08   | 1           | 845.356 | 1.000 | 29.075 |
|    |        |         |             | 112.10 | 3.2  | 3143.599 | 2.642 | 90.050 |

where (r) = 0.964

As shown in table 3 data, it shows that the correlation coefficient value is r = 0.964, indicating that evaporation has a strong positive correlation to air temperature. This correlation value applies to all samples, both fresh water (0°Be) to salt water (20°Be) because it has the same pattern with increasing evaporation followed by an increase in air temperature.

Table 4. The correlation calculation between the humidity and evaporation rate.

| No | Period | RH % | Evap cm/day | X² | Y² | XY |
|----|--------|------|-------------|----|----|----|
| 1  | Jul-19 | 73.19 | 0.62        | 5357.796 | 0.384 | 45.380 |
| 2  | Aug-19 | 71.74 | 0.72        | 5146.905 | 0.518 | 51.654 |
| 3  | Sep-19 | 70.93 | 0.86        | 5031.538 | 0.740 | 61.003 |
| 4  | Oct-19 | 68.88 | 1           | 4743.766 | 1.000 | 68.875 |
|    |        |       |             | 284.74 | 3.2  | 20279.504 | 2.642 | 226.912 |

where (r) = -0.985

As shown in table 4 data, it shows that The calculation of the correlation between the variable air humidity and the evaporation rate is in table 4, where the correlation coefficient value of r = -0.985 indicates that the increase in the evaporation rate is inversely proportional or has a strong negative correlation with air humidity.

Table 5. The correlation calculation between wind speed and evaporation rate.

| No | Period | Wind m/s | Evap cm/day | X² | Y² | XY |
|----|--------|----------|-------------|----|----|----|
| 1  | Jul-19 | 3.68     | 0.62        | 13.523 | 0.384 | 2.280 |
| 2  | Aug-19 | 4.19     | 0.72        | 17.586 | 0.518 | 3.019 |
| 3  | Sep-19 | 4.07     | 0.86        | 16.538 | 0.740 | 3.497 |
| 4  | Oct-19 | 4.13     | 1           | 17.016 | 1.000 | 4.125 |
|    |        |          |             | 16.06 | 3.2  | 64.663 | 2.642 | 12.922 |

where (r) = 0.622

The results of the correlation calculation between the variable wind speed and the evaporation rate, the correlation coefficient value is r = 0.622 shows that the increase of evaporation rate is positively correlated with wind speed, but not so strong when compared with temperature and humidity variables.

The evaporation rate pattern with the sunshine duration shows that the increase in the rate of evaporation has a positive correlation with the sunshine duration where the correlation coefficient value is r = 0.987 which means that it has a very strong correlation. The evaporation process requires energy from solar radiation where a large amount of latent heat is transferred from the earth’s surface to the atmosphere. The rate of evaporation depends on three factors: deficit in water vapor pressure,
temperature and air movement. Evaporation increases if the saturated water vapor pressure at the water surface becomes greater than the actual water vapor pressure of the air above it or if the vapor pressure deficit becomes larger. Thus evaporation occurs faster in dry air than humid air. Wind movement and turbulence will replace air near the surface of the water with drier air and increase evaporation [10].

Table 6. The correlation calculation between sunshine duration and evaporation rate.

| No | Period | Sunshine Hour | Evap cm/day | $X^2$ | $Y^2$ | $XY$ |
|----|--------|---------------|-------------|-------|-------|-------|
| 1  | Jul-19 | 9.71          | 0.62        | 94.278| 0.384 | 6.020 |
| 2  | Aug-19 | 9.79          | 0.72        | 95.787| 0.518 | 7.047 |
| 3  | Sep-19 | 10.15         | 0.86        | 103.023| 0.740 | 8.729 |
| 4  | Oct-19 | 10.4          | 1           | 108.160| 1.000 | 10.400|

where ($r$) = 0.987

As can be seen from the correlation data above, the factors of air temperature, humidity and sunshine are the dominant factors where the rate of evaporation is linearly correlated with them. This is different in the wind speed factor where there is relatively little increase during the salt season, but the wind speed in the salt season has increased the speed when compared to the rain season.

3.2 Characteristic of the weather parameters with the maduris salt production

In this study, several weather variables such as air temperature, humidity (RH), wind and sunshine that are considered to have an effect on salt production include determining the production period. There is something interesting if you observe the AWS data for the period October 2018 to August 2020 as shown in Figure 4 which the average air temperature value in June to July (2019 and 2020) always decreases compared to the air temperature in May and again increases in August even though that month has entered dry season.

This phenomenon occurs due to the influence of the Australian Winter. The Australian winter is expected to last from June to the peak of the dry season in September. when winter on the Australian continent which is under high air pressure causes the formation of anticyclones in areas and air masses that are cold and dry. Meanwhile, the Asian region occurs in the summer and there are low pressure areas that form cyclones. The flow of air masses in Indonesian territory is dominated by east winds where the air masses originate from the Australian continent. This is due to the pattern of relatively high air pressure in Australia and low in Asia which causes the movement of air masses from Australia bringing cold and dry air to Asia via Indonesia [11].

![Figure 4. Diagram of weather parameter (air temperature, humidity/RH, wind speed and sunshine) for the period 2018-2020 with the maximum limit value (75%) of humidity in the salt season.](image-url)
However, if we look at the humidity data for the months of June to October in 2019, the humidity value decreased below the 75% limit, meanwhile when compared to the activities of farmers in the ponds, it was in the same month that they began produce to salt in the pond. It is the same as in 2020, which the humidity below 75% occurs in July, the farmers activities have started preparing for salt production in July 2020 too. This is an empirical fact which there is a similar pattern of salt farmers starting their production in humidity conditions with a value below 75%.

So if we look at Figure 4 that the time for salt production to begin in June, while in 2020 salt production is postponed in July, so it is possible that this year the amount of salt production will decrease due to weather factors that hit Indonesia. This is also in accordance with the BMKG's statement in 2020 that the prediction of the dry season this year will be delay in several region of Indonesia until early July with a peak in mid-August, this is influenced by the transition from the West wind (Asian monsoon) to the East wind (Australian monsoon) ) [12].

Figure 5. Harvesting activities on the maduric method.

The process of changing water (liquid phase) to vapor (gas phase) requires energy in the form of latent heat for evaporation. The latent heat for evaporation comes from radiation from the sun and soil. Solar radiation is the main source of heat and affects the amount of evaporation above the earth's surface, which depends on latitude and seasonality [13].

Salt production in Indonesia generally uses the evaporation method and executed during the dry season on pond and seawater as a source of raw materials, either directly from the sea or from rivers or brackish water estuaries. In general, salt production starts from water storage ponds (Bozem), ponds and crystallization tables. In this study, the measurement of Madura salt production was conducted by calculating the salt production in the crystallization table over the land area as shown in Figure 5.

Figure 6. Diagram of salt production in the demonstration plot (kg).

The formation of salt crystals in ponds is greatly influenced by weather factors. Based on in-situ weather data, during July to October 2019 the air temperature ranges from 27.42-29.08°C, humidity 68.88-73.19%, wind speed 3.68-4.19 m/s and sunshine 9.71-10.40 hour/day which is associated with
salt production data for 0.43 ha of ponds produce 37,395 kg or if it was estimated that the total of production per hectare could receive 87 tons/season. As shown in Figure 6 with details in July was 2385 kg, August was 6525 kg, September was 12546 kg and October was 15939 kg so this data showed that salt production on the crystallization table is strongly influenced by weather conditions which the peak of salt production occurs in October with the driest weather conditions with the lowest humidity.

In conclusion, if we refer to the results of in-situ data between weather parameters and salt production in the 2019 demonstration plot, that the salt production process using evaporation techniques has a very high dependence the climate or weather so that weather conditions must fulfilled because otherwise salt cannot be produced.

4. Conclusion
In the salt season, the weather parameter is an important factor in the evaporation of sea water into salt. The average humidity parameter with a value below 75% becomes an indicator to determine the salt season where the results obtained indicate that the lower the humidity will increase salt production.

5. References
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