Potential distribution of sugar palm in Jepara Regency for soil conservation and climate change mitigation

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Abstract. Agroforestry can be developed for climate change adaptation and mitigation. Farmers in Jepara Regency have long been developing sugar palm agroforestry for starch. Increasing the use of sugar palm and the low knowledge of farmers about the potential of sugar palm plants are a threat to the existence of sugar palm agroforestry. This study aims to inventory the potential distribution of sugar palm with the support of remote sensing and field surveys in Pakis Aji, Bangsri, and Kembang sub-districts which was carried out in August-December 2020. The interpretation results used Landsat 8 imagery and Google Earth images in 1161 sugar palm objects with the largest number in Bangsri District. Remote sensing accuracy testing with the Omission-Commission method obtained a value of 90.8%, which means the accuracy value is very high. The correlation test between the value of vegetation density (NDVI) and the survey results obtained a value of $R^2 = 0.575$ with a significance value of $0.00 < 0.05$. The overall potential of palm plantations is predicted to be 5740 m$^3$ with an area for the development of sugar palm agroforestry of 10,008.9 ha.

1. Introduction

Agroforestry began to be used and developed as an integrated sustainable farming system in recent years because it has brought environmentally friendly agriculture and economic improvement. Agroforestry is the sustainable management of agricultural land that can increase the selling value of agriculture by agricultural crops, trees, forests and/or animals that are interconnected in an environmentally friendly manner with local cultural patterns [1]. The application of agroforestry is one form of disaster mitigation due to climate change. Mitigation in agroforestry plays a role in reducing agricultural applications that contribute greatly to the production of greenhouse gases [2]. Agroforestry provides an increase in carbon stocks in vegetation and soil as a form of mitigation of the global climate that is beneficial for increasing farmers’ production rather than agriculture with slash-and-burn, fallow, and unshaded crops [3].

Sugar palm is a plant from the palm family that is often found in Indonesia and is classified as a multipurpose plant because almost all of its parts can be used to meet human needs [4]. Sugar palm is one of the agroforestry plants that is easy to grow in mixed garden areas or forests in the wild. Farmers in Jepara Regency have been developing sugar palm agroforestry for a long time by using it to extract the starch. However, the increasing use of sugar palms by slashing, as well as the low knowledge of farmers about the potential of sugar palm plants pose a threat to the existence of sugar palm agroforestry. In fact, in addition to acting as a provider of human livelihoods, sugar palm also has conservation value [5]. So, it is necessary to have an inventory of palm plants to find out their potential, in this case through...
remote sensing. Such research has never been carried out in Jepara Regency, especially for sugar palm commodities using remote sensing. Sugar palm-based agroforestry has great potential in the form of increasing business viability for agricultural business actors [6]. This study aims to inventory the potential distribution of sugar palm with the support of remote sensing and field surveys that are used as sugar palm agroforestry development in dealing with climate change issues. So that with the estimation of the potential of palm plants, farmers can find out which locations can be used as food raw materials and as conservation in supporting the sugar palm agroforestry program.

2. Materials and method

2.1. Study site and materials

The research was conducted in a descriptive exploratory manner using a combination method [7], using remote sensing and field surveys. The sampling location was in Jepara Regency in Pakis Aji, Bangsri, and Kembang Districts which was carried out in August-December 2020. The tools used in the implementation of this research both in the field and in the laboratory included a sample point map, Garmin GPS, UTM Geo Map application, Avenza maps, Envi 5.1, Arcgis 10.3, diameter type, meter, stationery, farmer questionnaire, and laptop. The materials used in this study include the latest aerial photo imagery from the Landsat 8 satellite, the Rupa Bumi Indonesia (RBI) map of Jepara Regency imagery, Google Earth, and DEM (Digital Elevation Model).

2.2. Research steps

Google Earth is used as a large resolution image to interpret the distribution of palm trees. Remote sensing interpretation needs to pay attention to several things, such as basic elements (color, shadow, size, shape, texture, pattern); collection of site information, and field investigations; ecological unit classification and validation; and field verification to obtain ecological maps [8]. To obtain strong evidence for the existence of sugar palm, the convergence of evidence is needed, especially for plants from the Arecaceae family which refers to Susanto [9]. So that the distribution of sugar palm can be found for field surveys in estimating its potential.

Testing the accuracy of the model using the Omission - Commission method. The purpose of using the Omission - Commission method is to obtain the accuracy of an object interpreted by an image or aerial photograph by comparing the results of measurements of objects in the field [10]. The formula for the equation for the Omission-Commission method is as follows:

\[
\text{Accuracy} = [1 - \left( \frac{\Delta}{\text{Survey}} \right)] \times 100\%
\]

\[
\Delta = \text{interpretation} - \text{survey}
\]

The use of NDVI from Landsat 8 imagery is used to determine the green level of palm plants. NDVI is obtained by performing a transformation between the near-infrared (NIR) channel and the infrared channel. The NDVI formula can be seen in the following equation:

\[
\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}
\]

Through the use of NDVI, the value of the resulting pixel is then formulated with the regression value of the correlation between the total volume and the NDVI value. So that the estimated value of the potential of the palm plant as a whole is obtained.

Sampling was done by purposive sampling technique or purposive sampling by selecting 20 points by utilizing a combination of the land face between NDVI imagery and slope. This combination is used because wild sugar palm grows on such land characteristics. Sampling in each sample point was carried out by making a grid plot of 25 hectares and for observations, a subplot was made with a size of 200 m x 20 m. The variables observed in this study were the number of sugar palm plants, age of the palm plant, plant height, and plant The regression analysis used to make a production estimation model for
sugar palm plants used two variables, namely the vegetation index and slope as the x (independent) variable while the biomass potential was the y (dependent) variable:

Simple Linear Regression

\[ Y = a + bx + \]

Information:
- \( Y \): dependent variable (volume);
- \( a, b, c, \ldots, n \): regression coefficient;
- \( x \): independent variable (NDVI) [11]

Determination of the estimated value of the potential of sugar palm plants using the results of the regression model formula from the NDVI variable transformation with the plant volume variable survey results. The formula calculation is obtained from the simple linear test results. The production estimation model accuracy-test based on the production effect parameter and the vegetation index value is calculated using the formula used in the proprietary research Susetyo and Setiono [11] which uses a standard error between estimated production and reality production can then be calculated the level of accuracy. The standard error value is better if it is close to 0 so that the level of accuracy is higher if the percentage is close to 100%.

3. Results and discussion

3.1. Determine the distribution of sugar palm

Visual interpretation of the palm plant object resulted in a total of 1,611 sugar palm which was divided into three sub-districts of the research location (Table 1 and Figure 1). The highest population of sugar palm is Bangsri sub-district, with 731 sugar palms, followed by Pakis Aji sub-district with 671 palm trees and Kembang sub-district with the least population of 209 sugar palm plants. Information obtained from the surrounding community when conducting a survey, the majority revealed that the locations that had the highest population of palm sugar in Jepara Regency were Bangsri and Pakis Aji Districts. This assumption is strengthened by the existence of 5 palm flour processing industries in Plajan Village, Pakis Aji District which have been operating for decades.

| No | District   | Number of Trees |
|----|------------|-----------------|
| 1  | Pakis Aji  | 671             |
| 2  | Bangsri    | 731             |
| 3  | Kembang    | 209             |
|    | **Total**  | **1,611**       |

The majority of palm trees are scattered in mixed garden and forest land uses which can be seen from the land use at an altitude of 300-900 meter above sea level. As is known, sugar palm is a non-timber forest plant, the majority of which are found in mixed gardens and forests [12]. However, it is possible that sugar palm can grow in other land uses with varying altitudes according to the map. Aren is a plant that has a high tolerance to its agro-climatic environment and can grow in the lowlands to an altitude of 1400 masl [13]. The irregular distribution pattern of sugar palm based on the results of field observations occurs naturally with the help of palm-eating animals, namely a type of civet (*Paradoxurus hermaphroditus rinjanicus*) [14].
Figure 1. Map of sugar palm distribution in Jepara Regency.

The survey was carried out on a 25 ha grid plot area by carrying out an inventory based on 21 predetermined land face combinations of slope and NDVI value (Figure 2). The sample points are 21 points representing each combination of land faces. The survey is used as an inventory of the number of sugar palm plants and measures the height, diameter, and age of the plants. Determination of the sample point was done by purposive sampling based on a combination of land face and palm distribution maps.

Figure 2. Map of survey point in research location.

The results of the accuracy-test using the Omission-Commission method at each point (Table 2), the greatest accuracy value is 100% and the smallest value is 10%. The overall accuracy of 90.8% is obtained from the average of the overall accuracy value for each point. This shows that the interpretation results can be trusted because they have high accuracy [10]. The difference in the number of palm plant populations in the interpretation results with field surveys is because based on the conditions in the field many of the palm population are still young with plant heights less than 3 meters. So that many sugar palm plants are not visible in the image because they are covered by a larger plant canopy. In addition, there is an illumination effect that causes a dark hue that affects visual interpretation causing a faint plant canopy. Research locations that have an illumination effect are generally located on mountain ridges on steep ravines.
Table 2. Accuration value of omisi-komisi.

| Point | Land Combination | Citra Survey | Accuration (%) |
|-------|------------------|--------------|----------------|
| 0     | C1l1             | 0            | 100            |
| 1     | C1l2             | 0            | 100            |
| 2     | C1l3             | 0            | 100            |
| 3     | C1l4             | 0            | 100            |
| 4     | C1l5             | 0            | 100            |
| 5     | C2l1             | 0            | 100            |
| 6     | C2l2             | 0            | 100            |
| 7     | C2l3             | 8            | 70             |
| 8     | C2l4             | 8            | 90             |
| 9     | C2l5             | 6            | 75             |
| 10    | C3l1             | 0            | 100            |
| 11    | C3l2             | 0            | 100            |
| 12    | C3l4             | 19           | 86             |
| 13    | C3l5             | 14           | 93             |
| 14    | C3l6             | 31           | 97             |
| 15    | C3l7             | 0            | 100            |
| 16    | Pemukiman l1     | 1            | 100            |
| 17    | Pemukiman l3     | 0            | 100            |
| 18    | Sawah l1         | 3            | 100            |
| 19    | Sawah l3         | 1            | 10             |
| 20    | Sawah l4         | 6            | 86             |
|       | **Total**        | **97**       | **120**        | **90.8**      |

Point 7

\[
\text{Accuration} = \left(1 - \frac{8 - 12}{12}\right) \times 100\% = 70\% \ [10]
\]

Overall accuracy =

\[
\left(\frac{100+100+100+100+100+100+100+70+90+75+100+100+86+93+97+100+100+100+100+100+100+100+100+86}{21}\right) \times 100\% = 90.8\%
\]

Referring to the distribution map, the palm trees are in a combination of land faces C2l3, C2l4, C2l5, C3l4, C3l5, C3l6, settlement l1, paddy field l1, and paddy field l4. Inland combinations C2l3 to C3l6, palm sugar is found in mixed plantation land conditions that have medium to dense density on a gentle to the sloping slope. Aren grows naturally without any deliberate cultivation so that it grows naturally in areas that have dense vegetation and have tolerance for high slopes [15]. Whereas in residential areas, sugar palm grows naturally in the yard of the house as forest plant residue due to land-use change from mixed garden/forest. While sugar palm grows in rice fields, it generally grows around irrigation streams.

3.2. Determine the potential for sugar palm

Determination of potential is carried out based on the number of palm trees surveyed, totaling 120. Statistical analysis is needed to determine the relationship between the potential, in this case, the total volume of sugar palm plants with the value of the vegetation index (NDVI). The total volume of the stem of the palm plant is used in calculating the potential because in Jepara Regency, the use of palm sugar is only for the stems for the starch. Based on the results of the model test using a simple linear test, the correlation between plant volume and the NDVI value has a significant impact. The significance value obtained in the ANOVA test is 0.000. Sig. value 0.000 <0.05 so that based on the F test the
correlation between variables is said to be significant (Table 4). Correlation is said to be mutually influential, indicated by the $R^2$ value of 0.575 (Table 3), which means that the plant volume has a significant effect on the NDVI value of 57.5% and the remaining 42.5% of the model is influenced by other variables outside this regression test.

Table 3. Result of regression model.

| Index of Vegetation | R   | $R^2$ | Standard error of estimate |
|---------------------|-----|-------|---------------------------|
| NDVI                | 0.758 | 0.575 | 0.428                     |

Table 4. Result of ANOVA test.

| Model     | Sum of Squares | Df | Mean Square | F   | Sig. |
|-----------|----------------|----|-------------|-----|------|
| Regression| 29.338         | 1  | 29.338      | 159.770 | 0.000 |
| Residual  | 21.668         | 118| 0.184       |       |      |
| Total     | 51.006         | 119|             |       |      |

The potential estimation results were obtained by informing the results of the NDVI value with the total volume of the survey results on 120 sugar palm plants. Determination of the predictive potential value is generated using the formulation of the value of the model regression coefficient. The overall value of the predictive potential for sugar palm plants is 127.69 m$^3$. Meanwhile, the potential for sugar palm plants in the field is 127.67 m$^3$ (Table 5).

Table 5. Potention of sugar palm.

| No | Land Combination | Point | Number of Trees | Vtot (m$^3$) Prediction | Vtot (m$^3$) Survey |
|----|------------------|-------|-----------------|-------------------------|---------------------|
| 1  | C2l3             | T7    | 12              | 11.30                   | 8.406               |
| 2  | C2l4             | T8    | 9               | 9.53                    | 6.53                |
| 3  | C2l5             | T9    | 8               | 7.66                    | 8.38                |
| 4  | C3l4             | T12   | 22              | 26.76                   | 27.1                |
| 5  | C3l5             | T13   | 15              | 20.38                   | 25.43               |
| 6  | C3l6             | T14   | 34              | 35.10                   | 35.44               |
| 7  | Pemukiman l1     | T16   | 1               | 0.98                    | 1.08                |
| 8  | Sawah l1         | T17   | 3               | 3.54                    | 2.36                |
| 9  | Sawah l3         | T18   | 9               | 7.83                    | 7.45                |
| 10 | Sawah l4         | T19   | 7               | 4.60                    | 5.43                |
|    |                  |       | Total           |                         |                     |
|    |                  |       | 120             | 127.69                  | 127.67              |

Table 6. Test of accuracy model.

| Vegetation Index | R   | $R^2$ | Standard error of estimate |
|------------------|-----|-------|---------------------------|
| NDVI             | 0.984 | 0.967 | 2.29                      |

The results of the potential for sugar palm plants, both survey and in the field, need to be tested for accuracy. So that if the data has a small error rate, the model can be used in determining the potential for sugar palm in the entire Jepara district. The accuracy test is carried out by performing a standard error test resulting in a value of 2.29. Standard Error shows that the model has high accuracy. This is because the smaller the standard error value or towards 0, the higher the accuracy rate. The results of
the accuracy can be concluded that the model can be used to estimate the potential of sugar palm in all of Jepara Regency.

The estimation of the potential of sugar palm plants is obtained from the calculation of the total volume of the prediction potential. The potential value is adjusted to the NDVI value ranging from rare, medium, and meeting. Overall, the prediction of sugar palm plants in the Jepara Regency is 5,740 m³. The potential for palm trees is quite large in inland conditions with moderate to dense NDVI values. The majority of NDVI values have land uses in the form of mixed gardens and forests with a total area of 10,008.9 ha. Through the predicted potential value, it can be used as a guide in supporting the development of palm agroforestry. So that the development of palm agroforestry on mixed garden land uses and forests can be a step in maintaining ongoing soil conservation and mitigation in the face of climate change by producing abundant carbon sequestration.

![Figure 3](image.jpg)

**Figure 3.** Map of potential distribution of sugar palm in Jepara Regency.

4. Conclusion
Estimation of the potential of sugar palm plants is the first step for the people of Jepara Regency, especially for farming actors in the application of sugar palm agroforestry. The population of sugar palm in nature is decreasing, while the demand for sugar palm as a food raw material for starch is increasing, which is feared to reduce its function as a conservation plant in supporting climate change mitigation. So that there is a map of the potential distribution of sugar palm, farmers will know the location of the sugar palm population to be used wisely by knowing the existing field conditions. Estimation of the potential of palm plants will support sugar palm agroforestry in sequestering carbon emissions through the total biomass of sugar palms. The research has produced a responsible innovation that is expected to be supported by all parties, especially the people of Jepara Regency in dealing with the issue of climate change through seriousness towards sugar palm agroforestry.

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Acknowledgment

The author would like to thank BAPPEDA Jepara and Sebelas Maret University Surakarta for facilitating the implementation of this research and to all parties involved in this research so that this publication can be carried out well.