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Growth-site Quality Assessment of Nypa fruticans using Unmanned Aerial Vehicles Images: A case study in Kubu Raya Regency, West Kalimantan Province

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ABSTRACT

The growth-site quality is one of the essential information needed to support sustainable forest management particularly in forestry planning. This paper describes the development of a site-quality class of Nypa vegetation by considering the biological and physical factors. The main objective of this study is to develop a discriminant model and to find out major factors that may be used to predict the quality of Nypa growth-sites. The model was developed using variables either measured on UAV images or from field measurement, namely soil texture (X1), water salinity (X2), water pH (X3), crown closure (X4) and stand density (N) measured on the UAV image (X5). The study found that the site quality of Nypa could be indicated by the variation of its biomass content. Then, it was concluded that the major factors that affect the site quality are the soil texture (X1), water salinity (X2), and water pH (X3) with 78.3% of overall accuracy.

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1. INTRODUCTION

Nypa is a family of palm that commonly grows in the mangrove ecosystem affected by tidal of sea water [1]. It had been reported that Indonesia has the widest Nypa palm area in the world of about 700 000 ha [2]. Its distribution covers the region of Sumatra, Kalimantan, Java, Sulawesi, Maluku, and Irian Jaya. In Bengkalis, Riau Province, people had been started to utilize the potential of Nypa as a source of natural antioxidants as well as for bioethanol [3] within 26 ha out of 100 ha concession area [4].

From the other economic perspectives, Nypa is one of the forest resources that may give a promising economic value, but its potential is still less utilized and even abandoned. In South Kalimantan Province, the Nypa fruit was utilized as main ingredients of dried-sweets, wet-candy sweets, flours and as a medicinal plant [5-7]. While in Gresik. East Java Province, people utilize the Nypa as a mixed ingredient of syrup for making jam [8]. In Banten and West Java Provinces, people are used to utilizing the leaves of Nypa as raw materials for making medium density fiberboard [9]. In the South Sulawesi, people tapping the “nira (palm wine)” of Nypa for producing traditional drinks and utilize their leaves for traditional roof [10]. Several studies show that Nypa in Riau and Central Java were used as raw material for bioethanol [4, 11-12], while Nypa in East Kalimantan is used as a food resource [13]. All the above show that Nypa may provide a potential economic value and need to be utilized optimally. The lack of public knowledge about the potential, distribution, stand quality and utilization as well as and the processing of Nypa, may threat the existence of Nypa, whether marginalized, abandoned and even considered as a confounding plant.

The sampling error and/or the sampling intensity of terrestrial forest inventory are always facing by cost, time, and human resources problems particularly during measurements and observations [14]. In the context of determining the growth-site quality or stand productivity, field measurement and observation is a crucial activity in forestry planning. Spatial information about site quality, such as distribution, perimeter and area are required in spatial planning, species matching, and yield regulations. Information on the site quality is important in determining the success level of a planting [15]. In general, the better the growth-site quality, the higher the productivity. The previous research states that the success level of a plant growth could be measured by the factors of growth-site [16-17].

The growth-site quality significantly affects the quality of the stand or vegetation as indicated by its timber or biomass stock. In forestry sector, the problems always arise at the beginning of forest planning or forest management, particularly when there is no information regarding the site productivity. Determination of site quality based on productivity becomes difficult to do, particularly when the of supporting data required are not available. Therefore, in this study, the authors explore the existing Nypa stand. The productivity assessment being piloted was to identify the bio-physical variables that were highly related to productivity. Physical variables that may affect productivity include the acidity levels (pH), water salinity [18] and soil texture [19]. While the biological aspects considered were related to the presence of vegetation as well as the variables derived from measuring stand dimensions such as stand density [17, 20], basal area, stand volume, tree diameter [20], and biomass content [21]. The lack of data base on Nypa in Indonesia may encourage forest inventory activities to assess the Nypa site quality that might be used for future works to support a sustainable forest management.

The use of airborne remote sensing in the forestry sector has been started since the early 19th century, and even since the 1990s, the use of satellite remote sensing in Indonesia has increased sharply, especially in the context of land cover and land use. Currently, the advent of very high resolution images recorded using a dynamic remotely operated navigation equipment (drone), also called unmanned aerial vehicle (UAV) technology has provided a new perspective, providing more detailed information due to its high spatial resolution. In this study, the authors reviewed the ability of the 10-cm-resolution UAV image to assess the quality of the growth-site, especially on the Nypa stand. The use of UAV image is one of the alternatives to get more detailed data, more real time, faster and cheaper [22]. Several studies that examined the use of 10-cm-resolution UAV image capability to estimate the timber standing stock can be found in the study [23-24]. Besides, the use of UAV image for developing a biomass estimation model can be found in other study [24]. The assessment of the growth-site quality of teak using a non-metric aerial photo (similar to UAV imageries) also provide a promising result [25].

As mentioned earlier, only few Nypa ecosystems that has gotten an attractive attention, nor even utilized at a large scale. Information on the spatial distribution, extent and productivity as well as the quality of Nypa's growth-site quality is still our common challenge. In the forestry sector, the determination of the growth-site quality of Nypa is something newly done. Although the Nypa existence is always associated with mangrove vegetation which is considered to have more attractive economic value, the research on Nypa ecosystem is still limited. Thus, this study focuses on estimating the quality of Nypa stands with the main objective of establishing growth-site quality as well as to identify the most significant biophysical factors measured in both UAV images and in the field, including soil texture (X1) , Water salinity (X2), water acidity, pH (X3), crown closure on the UAV image (X4) and stand density (N) on the UAV image (X5). Besides, this research would also like to determine the indicator of the Nypa growth-site quality such as basal area, volume, biomass, and stand density which is the most consistent and accurate indicator for assessing the site quality.

2. Research Method

2.1. Date and Time

This study was conducted in March and April 2016, within the concession area of PT Kandelia Alam, Kubu Raya Regency, West Kalimantan Province (Figure 1). Furthermore, the processing, analysis and reporting were carried out from May 2016 until February 2017 at the Remote Sensing Laboratory, Faculty of Forestry, IPB.

2.2. Tools, Software, Hardware, and Data

The main data used in this study was digital image data of UAV having 10-cm-spatial resolution, 8 bits radiometric resolution and RGB spectral resolution. While, the image data processing hardware used was a set of computer unit, with the following software: ArcGis 10.1, Erdas Imagine 9.1, Excel, SPSS 16 (statistical package for service solution), Minitab 17, and Excel Stats. For ground data collection, the tools used were GPS, suunto clinometer, rope, measuring tape, digital scales, compass, plastic bags, oven, salt meter and pH-meter.

To support achieve the study objective, stand variables of the Nypa were measured on sample plot in the field. Those variables include the largest circumference of the Nypa leaf blade at 1.3-m height, the smallest circumference of Nypa leaf at 1.3-m height, dead and alive leaves, the individual diameter of each Nypa, the circumference of the base and the tip of the Nypa stump (leaf blade) at a height of 1.3 m, the length of the leaf stump, the number of leaf stumps, the circumference and the length of the leaf blade sample, the circumference and the length of the bucked leaf blade, the wet- and dry-weight of the sample blade and wet- and dry- weight of sampled leaf blade, relative coordinates of each Nypa clump, species name, number of trees in each observation plot, water pH, water slinity, and soil texture. In UAV imagery, the measured variables were crown cover and stand density.

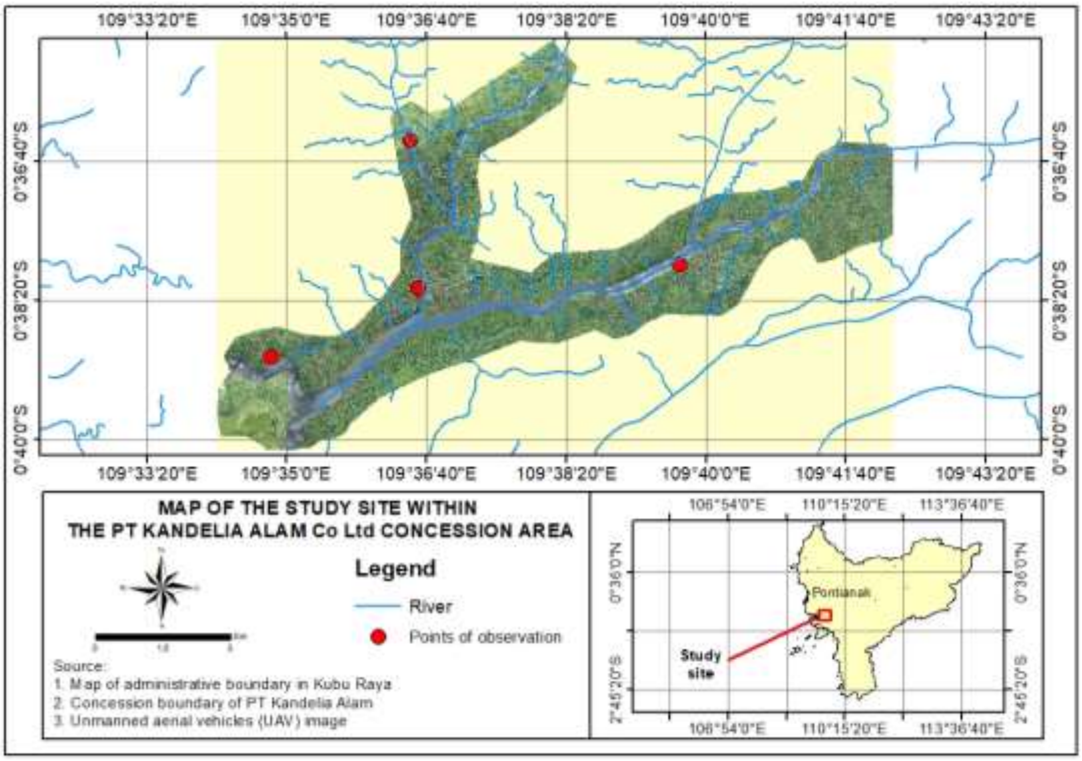

Figure 1. Map of the Study Site within the PT Kandelia Alam Co Ltd Concession Area

2.3. Data Analysis Procedure

2.3.1. Image Processing unmanned aerial vehicle (UAV) images

The image processing included visual interpretation by using the on-screen digitizing to count the individual clump of Nypa within each plot, then used to measure the stand density. The other variable measured was crown closure on the UAV image. The crown closure variable was calculated by a segmentation approach using the best parameter-combination that have been done by the earlier stage of this research.

2.3.2. Data collection

Field sampling technique applied in this study was a purposive sampling technique to represent the variation of the Nypa from downstream to upstream parts of area. This was designed to cover the variation of water salinity, water acidity, soil condition and Nypa productivity. In this study, four clusters with the size of 60 m x 100 m were laid out on the UAV image, in which each cluster was divided into 15 cluster elements with the grid size of 20 m x 20 m. In each of the cluster element (plot), there are four sub-plot having size of 10 m x 10 m (four quadrants); and single sub-plot of 2 m x 2 m at the center of the plot. On each element of the cluster all physical variables and Nypa vegetation were measured. In this 2 m x 2 m sub-plot, the measurement of midrib and leaves of Nypa, water and soil samples were done. The establishment of four-quadrant was aimed to facilitate the calculation of the number of individuals (clumps) Nypa.

2.4. Data Analysis

The indicators for estimating the site quality index are basal area (BA), Nypa volume and biomass of Nypa as follows:

2.4.1. Basal area (BA)

The basal area of the Nypa is expressed as the following formula:

$$BA = \frac{\frac{1}{4}(\pi(d)^2)}{Pe}$$

Notes:
BA = basal area (m2/ha)
π = 3.14
d = the diameter of Nypa clump
Pe = plot extent (Ha)

2.4.2. Nypa volume

The calculation of live and dead volume of leaf blade was obtained using a model that express the relationship between volume of Nypa midrib and the midrib diameter. This equation model was used to calculate the volume of the live and dead per individual Nypa, with the following equation:

Vm = 1.7602 d1.4661

The volume of the live and dead midrib of Nypa were calculated using the following formula:

VLDMN = (Vm. NLNM) + (Vm . NDNM)

Notes:
d = the diameter of Nypa clump (m)
Vm = volume of Nypa midrib (m3)
VLDMN = the volume of the live and dead midrib of Nypa (m3)
NLNM = number of live Nypa midrib
NDNM = number of dead Nypa midrib

The volume of the midrib stump was calculated using the following formula:

$$VS = \frac{G_{SB} + G_{ST}}{400\pi} . \ L_S . \ N_S$$

Notes:
Vs = volume of stump (m3)
π = 3.14
GSB = girth of stump base (meter)
GST = girth of stump top (meter)
LS = length of stump (meter)
NS = number of stump

The total volume of Nypa (VTN) was calculated using the following equation:

$$VTN\ (m3/ha) = \frac{V_{LDMN} + V_S}{\text{Plot extent}}$$

2.4.3. Biomass of Nypa

Leaf biomass (leaf and midrib) was obtained using the following equation:

Vbm (gram) = 292419 dm1.6565

Notes:
d = the diameter of Nypa clump (m)

Vbm = Midrib biomass (leaf and midrib) in gram

Furthermore, the leaf and stem biomass of Nypa was multiplied by the number of live and dead midrib for each clump using the following formula:

$$\text{Vbm (ton)} = \frac{V_{bm}\ (N_{LMN}+N_{DMN})}{1000000}$$

$$\text{Vbm (ton/clumps)} = \frac{V_{bm}\ .\ F_K}{Nc}$$

Notes:
Vbm = Midrib biomass (leaf and midrib) (ton)
NLNM = number of live Nypa midrib
NDNM = number of dead Nypa midrib
Vbm = Midrib biomass (leaf and midrib) (ton/clumps)
CF (Conversion factor) = 0.10937
Nc = number of the Nypa clump per plot

The equation for calculating the biomass per unit area (ton/ha) was as follows:

$$\text{Biomass per plot (ton/ha)} = \frac{V_{bm}\ \text{(ton/clumps)}}{\text{plot extent (Ha)}}$$

Indicators of the growth-site quality examined in this study are basal area (Y1), volume of Nypa (Y2), and Nypa biomass (Y3) per unit area. Furthermore, three and five classes of site quality were developed using the methods of (a) equal intervals, (b) equal frequencies, with the following description, (1) for five classes, the site qualities were categorized into infertile, less fertile, moderately fertile, fertile and extremely fertile, while the three classes, they were classified into less fertile, moderately fertile, and extremely fertile (Tables 1 and 2).

Table 1. Five classes of growth-site quality of Nypa

Notation	Description	Equal interval method	Equal frequency method
		Interval	
I	Infertile	< μ-1.2 SD	< μ-0.84 SD
II	Less fertile	(μ-1.2 SD) – (μ-0.4 SD)	(μ-0.84 SD) – (μ-0.25 SD)
III	moderately fertile	(μ-0.4 SD) – (μ+0.4 SD)	(μ-0.25 SD) – (μ+0.25 SD)
IV	Fertile	(μ+0.4 SD) – (μ+1.2 SD)	(μ+0.25 SD) – (μ+0.84 SD)
V	Extremely fertile	> μ+1.2 SD	> μ+0.84 SD

SD: standard deviation, μ: mean

Table 2. Three classes of growth-site quality of Nypa

Notation	Description	Equal interval method	Equal frequency method
		Interval	
I	Less fertile	< μ-0.67 SD	< μ-0.43 SD
II	Moderately fertile	(μ-0.67 SD) – (μ+0.67 SD)	(μ-0.43 SD) – (μ+0.43 SD)
III	Extremely fertile	> (μ+0.67 SD)	> (μ+0.43 SD)

SD: standard deviation, μ: mean

The discriminant variables of the growth-site quality considered in this study were soil texture (X1), water salinity (X2), water pH (X3), crown closure on UAV image (X4), and the number of trees measured in UAV (N) (X5) imagery. Those variables were calculated based on field measurement results and image interpretation. The soil texture was developed by following the IHMB (periodically performed overall forest inventory) guidelines, while water salinity was measured by salt meter and water pH by pH meters. The percentage of crown closure and the number of trees on the UAV (N) image were obtained by delineating the UAV image and segmentation process.

2.4.4. Data Evaluation

Prior to further discriminant analysis, the collected data was analyzed, then used as the determinant variable in the analysis. The normality test results show the data have normal lines of 55.1% [19], and the normality of 51.67%, concluding that the data were normal. Furthermore, a multicollinearity test to evaluate whether the data can analyze directly or need to be normalized was performed, by evaluating the tolerance and VIF value (variance factor inflation). The evaluation shows that the tolerance value above 0.1 (> 0.1), and or VIF value around 1(less than 10). This means that there is no multicollinearity between independent variables [26 & 27].

2.4.5. Discriminant Function Analysis

In this study, the discriminant analysis used was the forward method. With this forward method, the study will record the variables are entered firstly, secondly, thirdly etc. Then this discriminant method simultaneously identifies the sequence of variables entered.

2.4.6. Accuracy assessment

To evaluate the reliability of the classification the results of discriminant analysis were then evaluated using accuracy analysis. The accuracy measures used was overall accuracy expressed as follows:

$$OA = \frac{\sum_{i=1}^{r} x_{ii}}{N} 100\%$$

Notes:

N = number of pixel used in the sample plot

r = number of column or row of the matrix (number of classes)

∑ii = The diagonal value of the matrix on the row-i and column-i

2.4.7 Map of growth-site quality of Nypa

Based on the discriminant function developed, then the distribution map of the growth-site quality of Nypa was developed using the variables selected. To be mapped, the discriminant variable was prepared for each layer. By using the spatial operation function in ArcGis 10.3, then overlay operation was performed.

3. RESULTS AND ANALYSIS

Based on the correlation analysis between indicators of the site quality, i.e., basal area, stand volume of Nypa and biomass of Nypa with the physical and biological variables such as soil texture, salinity, water pH, crown closure and the number of trees measured on the UAV image, it is known that the Nypa volume has a high correlation with soil texture and water salinity with R2 of 62.1% and 51.0% respectively. Besides, it is also shown that the biomass of Nypa biomass has a close correlation with soil texture and water pH with R2 of 59.4% and 45.4% respectively.

Of the 31 different combinations of variables examined in the process of classifying 3 and 5 classes of site quality, i.e., from using the single variable to full five variables, we can summarize by the best three ranks of each combination as presented in Table 3. From the classification results obtained using (a) equal interval and (b) equal frequency, then we selected 13 the top rank combination that have has a higher accuracy.

From Table 3, among the three growth-site quality indicators of Nypa, the indicator that consistently gives a high quality assessment is the Nypa biomass content. The highest accuracy provided by using the biomass indicator is 78.3%, while the volume is 71.7%, and the basal area is only 65%. Theoretically, the most comprehensive indicator explaining the quality of the environment is the standing biomass, which consider all the biological components both living and dead (necromass and litter) materials. While the volume only considers the volume of standing stands and neglect the necromass and litter. The area of the basal area is simpler than the volume, regardless of the height variation of the stand. The discriminant analysis result shows that the biomass of Nypa could be the best indicator in describing the growth-site quality as shown by its accuracy, larger than the volume and basal area.

For the basal area indicator, the assessment of using only one variable with five and three classes of growth-site quality, the highest accuracy was provided by the water salinity (X2) with an accuracy of 48.3% for 5 classes and 60% for 3 classes (based on equal interval method). For the combination of two variables, the highest accuracy was obtained from the combination of water salinity (X2) and water pH (X3) with 55% accuracy (for 5 classes) and 65% (for 3 classes) with equal frequency method. The use of the combinations with 3, 4 and 5 variables did not give any significant accuracy increase. As shown, the combinations of 3 and 4 variables are giving accuracy that equal to two variables, especially for three classes of site qualities using the equal interval method. With 5 variables, the accuracy of the discriminant even decreased, which may be caused by the data outlier or "data noise". In other words, the basal area indicator is only able to describe 3 growth-site quality with a maximum of 65% accuracy.

Table 3. The best three combination using one to five independent variables to classify three and five growth-site quality with (a) equal intervals and (b) equal frequencies methods

Equal interval method Variable (5 class)	Accuracy (%)	Equal frequency method Variable (5 class)	Accuracy (%)	Equal interval method Variable (3 class)	Accuracy (%)	Equal frequency method Variable (3 class)	Accuracy (%)
Basal area							
X_2	48.3	X_2	35.0	X_2	60.0	X_2	56.7
X_3	45.0	X_3	31.7	X_3	51.7	X_3	55.0
X_5	33.3	X_5	26.7	X_5	50.0	X_5	51.7
X_2X_4	51.7	X_2X_3	55.0	X_2X_5	58.3	X_2X_3	65.0
X_1X_2	48.3	X_1X_3	40.0	X_2X_4	56.7	X_2X_4	61.7
X_2X_3	46.7	X_1X_2	38.3	X_2X_3	51.7	X_2X_5	60.0
$X_1X_2X_3$	60.0	$X_2X_3X_5$	50.0	$X_2X_3X_4$	56.7	$X_2X_3X_5$	65.0
$X_2X_3X_4$	51.7	$X_1X_2X_3$	46.7	$X_2X_4X_5$	56.7	$X_1X_2X_3$	63.3
$X_2X_4X_5$	48.3	$X_2X_3X_4$	46.7	$X_1X_2X_3$	53.3	$X_2X_3X_4$	63.3
$X_1X_2X_3X_4$	56.7	$X_1X_2X_3X_4$	46.7	$X_2X_3X_4X_5$	56.7	$X_2X_3X_4X_5$	65.0
$X_1X_2X_3X_5$	51.7	$X_1X_2X_3X_5$	45.0	$X_1X_2X_3X_4$	53.3	$X_1X_2X_3X_4$	61.7
$X_2X_3X_4X_5$	50.0	$X_2X_3X_4X_5$	43.3	$X_1X_2X_4X_5$	51.7	$X_1X_2X_3X_5$	61.7
$X_1X_2X_3X_4X_5$	58.3	$X_1X_2X_3X_4X_5$	41.7	$X_1X_2X_3X_4X_5$	56.7	$X_1X_2X_3X_4X_5$	61.7
Volume of Nypa							
X_3	30.0	X_2	43.3	X_3	71.7	X_3	66.7
X_1	25.0	X_3	35.0	X_5	53.3	X_4	48.3
X_5	23.3	X_1	31.7	X_4	33.3	X_1	36.7
X_2X_3	50.0	X_2X_4	48.3	X_2X_3	71.7	X_2X_3	71.7
X_3X_5	45.0	X_2X_5	43.3	X_1X_3	61.7	X_3X_4	58.3
X_3X_4	40.0	X_2X_3	41.7	X_3X_4	61.7	X_3X_5	56.7
$X_2X_3X_4$	50.0	$X_1X_2X_3$	55.0	$X_2X_3X_4$	73.3	$X_2X_3X_4$	65.0
$X_1X_3X_4$	46.7	$X_2X_3X_4$	55.0	$X_1X_3X_4$	63.3	$X_3X_4X_5$	60.0
$X_3X_4X_5$	46.7	$X_1X_2X_4$	53.3	$X_1X_2X_3$	61.7	$X_1X_3X_4$	56.7
$X_1X_3X_4X_5$	53.3	$X_1X_2X_3X_4$	56.7	$X_2X_3X_4X_5$	76.7	$X_2X_3X_4X_5$	63.3
$X_2X_3X_4X_5$	53.3	$X_2X_3X_4X_5$	55.0	$X_1X_2X_3X_4$	66.7	$X_1X_2X_3X_4$	61.7
$X_1X_2X_3X_4$	46.7	$X_1X_2X_4X_5$	51.7	$X_1X_3X_4X_5$	65.0	$X_1X_3X_4X_5$	56.7
$X_1X_2X_3X_4X_5$	53.3	$X_1X_2X_3X_4X_5$	56.7	$X_1X_2X_3X_4X_5$	63.3	$X_1X_2X_3X_4X_5$	63.3
Nypa biomass							
X_3	53.3	X_3	38.3	X_5	50.0	X_3	75.0
X_5	53.3	X_2	30.0	X_4	46.7	X_5	58.3
X_2	46.7	X_1	28.3	X_2	38.3	X_2	41.7
X_1X_3	56.7	X_2X_4	40.0	X_2X_5	48.3	X_1X_3	71.7
X_1X_4	56.7	X_3X_5	38.3	X_2X_4	43.3	X_2X_3	70.0
X_1X_2	55.0	X_2X_3	36.7	X_3X_4	41.7	X_3X_5	63.3
$X_1X_2X_3$	61.7	$X_2X_3X_4$	46.7	$X_1X_2X_3$	48.3	$X_1X_2X_3$	78.3
$X_1X_3X_4$	61.7	$X_1X_3X_4$	43.3	$X_1X_2X_5$	46.7	$X_1X_3X_4$	75.0
$X_1X_3X_5$	56.7	$X_2X_4X_5$	40.0	$X_2X_3X_5$	45.0	$X_1X_3X_5$	71.7
$X_1X_2X_3X_5$	63.3	$X_1X_2X_3X_5$	45.0	$X_1X_2X_3X_5$	55.0	$X_1X_2X_3X_4$	78.3
$X_1X_3X_4X_5$	60.0	$X_2X_3X_4X_5$	45.0	$X_1X_2X_3X_4$	50.0	$X_1X_2X_3X_5$	76.7
$X_1X_2X_3X_4$	58.3	$X_1X_2X_3X_4$	43.3	$X_1X_3X_4X_5$	45.0	$X_1X_3X_4X_5$	73.3
$X_1X_2X_3X_4X_5$	60.0	$X_1X_2X_3X_4X_5$	45.0	$X_1X_2X_3X_4X_5$	51.7	$X_1X_2X_3X_4X_5$	78.3

Notes: X_1: soil texture; X_2: water salinity; X_3: water pH; X_4: crown density on UAV image; X_5: the number of trees measured in UAV (N)

When the volume Nypa was applied as a site quality indicator, the classification of the growth-site quality into five (equal frequency) and three classes (equal intervals), the single variable water salinity may give an accuracy of 43.3% and while water pH variable gave 71.7%. With two variables combination, the accuracy of the assessed site quality did not give any improvement at all. It provides accuracy that the same to single variable i.e., 71.7%, using water salinity (X2) and water pH (X3). With three variables, there was a slight increase of 73.3% (3 classes of growth-site quality) derived from a combination of soil texture (X1), water salinity (X2), and water pH (X3) or water salinity (X2), water pH (X3) and crown closure (X4). With a combination of four variables there was a significant increase to 76.7% (three classes of growth-site quality), provided by a combination of water salinity variables (X2), water pH (X3), crown closure (X4) and number of trees measured on the image (X5). With all five variables, the resulting accuracy was decreased sharply to only 63.3%. This behavior is the same as the basal area (see Table 3).

Based on biomass content indicator, the classification into three classes site quality with frequency equal method, single variable of water pH (X3) provides 75.0% overall accuracy. For classifying into five site qualities, the single variable that gives the high accuracy of 53.3% is water pH (X3) or tree density (N) measured on the UAV image (X5). The classification of five growth-site quality using two variables, the highest accuracy is provided by the combination of soil texture (X1) and water pH (X3); or the combination of soil texture (X1) and image density (X4), both combinations have an accuracy of 56.7%. For classifying three classes of site quality, two variables soil texture (X1) and water pH provided accuracy of about 71.7%.

The combination of three variables that covers soil texture (X1), soil salinity (X2) and water pH (X3), was capable to classify three site qualities (equal frequency) providing accuracy of about 78.3%. The increase of the number of variable from using three variables to four or five variables did not increase the classification accuracy.

From the results and discussion mentioned above, the most consistent indicators that provide the highest accuracy are the Nypa biomass. The most accurate numbers and the best combinations of variables were obtained using a combination of three variables with an accuracy of 78.3% (equal frequency). These variables are all ground measured variables, namely soil texture (X1), water salinity (X2), water pH (X3). The combinations using four and even five variables did not provide the increased accuracy, the accuracy is stagnant at 78.3%. The combination with three variables was chosen due to the lesser number of variables applied, while the accuracy are still the same. The addition of variable will cause the addition of cost, both in field data collection and in the data processing. Thus, it is expected to select the most efficient combination. The study noted that of all combinations, with all indicator, the water pH variable (X3) becomes the most frequent variable that presents in the combination. The selected discriminant function is presented in Table 4.

Table 4. Discriminant Function for Classifying the Nypa Site Quality with the Variables of X1, X2 and X3

Nypa site quality class	Discriminant function
Site quality I (less fertile)	$Y = -213.62 + 11.94 X_1 + 14.84 X_2 + 63.51 X_3$
Site quality II (moderately fertile)	$Y = -266.94 + 13.42 X_1 + 18.07 X_2 + 70.84 X_3$
Site quality III (fertile)	$Y = -278.31 + 14.77 X_1 + 13.64 X_2 + 72.06 X_3$

This study also shows the alternative use of other combinations, by combining the field measured and on UAV-image measured variables (model II), providing a comparable accuracy of 75%. Although its accuracy is 3% smaller than the previous one, this function would be more practical since the salinity can be replaced by crown closure measured on the UAV. The variables used are soil texture (X_1), water pH (X_3) and crown closure (X_4) (Table 5).

Table 5. Discriminant function of model II for classifying the three growth-site quality of Nypa using the variables of X1, X3 and X4 with equal frequency

Nypa site quality class	Discriminant function
Site quality I (less fertile)	Y = -209.63 + 12.89 X1 + 63.01 X3 – 0.02 X4
Site quality II (moderately fertile)	Y = -261.84 + 14.66 X1 + 71.21 X3 – 0.13 X4
Site quality III (fertile)	Y = -275.09 + 15.68 X1 + 71.98 X3 – 0.06 X4

From the discriminant model developed above, it is known that the soil texture had been a key variable that affects the variation of Nypa biomass. Soil texture is one of the most decisive factors for stand suitability since it has a close relationship with other soil properties such as water holding capacity, cation exchange capacity, porosity, infiltration rate and water movement and soil aeration [20]. This is inline with the earlier study that identifies the soil texture as one of the independent variables in determining the site quality of Paraserianthes falcataria (L) Nielsen [28]. Water salinity also becomes one of the independent variables in determining the site quality of Nypa. The study of also found that water salinity is one determinant in assessing mangrove vegetation site quality with an accuracy of 66.7% [20]. However, for practical use, the water salinity could be substituted with the crown closure as the function tabulated in Table 5.

Figure 2 shows the distribution of the Nypa site quality, using a Model II with the variables of soil texture (X1), pH (X3) and crown closure (X4). In the map, three site qualities are expressing the biomass contents. The descriptions are as follows: site quality I less fertile, site quality II moderately fertile, and site quality III fertile. Based on the result on the mapping of the growth-site quality of Nypa, the proportion of each site quality could be summarized in Table 6.

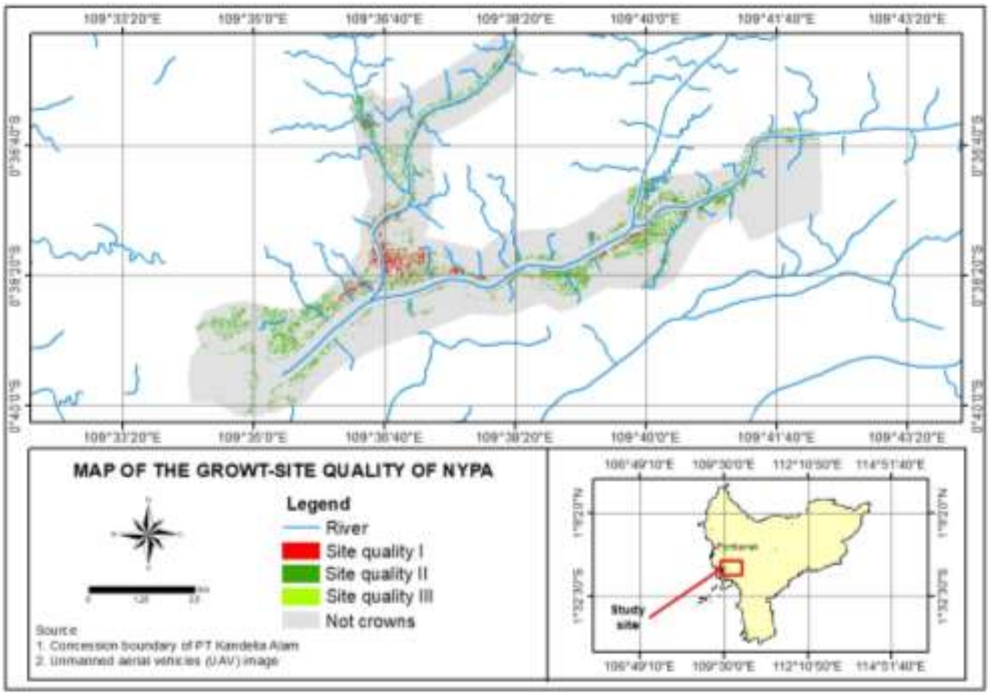

Figure 2. Map of Growth-Site Quality of Nypa

Table 6. the proportion of each site quality maps

Site quality of Nypa	Area (ha)
Site quality I (less fertile)	40.4
Site quality II (moderately fertile)	302
Site quality III (fertile)	10.6
Non Nypa	3734.8
Total	4087.8

4. Conclusion

From the results and discussions described earlier, some conclusions related to the development of discriminant function for assessing the growth-site quality of Nypa are derived. The most consistent and accurate indicator used in describing the site quality of Nypa is the biomass of the Nypa. The site quality of the Nypa could be classified into 3 classes with an accuracy of 78.3% using soil texture (X1), water salinity (X2) and water pH (X3). The use of the combination between ground-based variables (soil texture and water pH) and UAV-image-based variable provided relatively large yields of about 75%.

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