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Stand Structure and Composition and Model for Estimating Stand Volume Potential at the Citragaluh Sustainable Community Forest Management Unit, Subang Regency, West Java

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Abstract

In general, community forest management is still limited to the management of individual farmers so that it affects diversity, especially in the form of stands. This study aimed to explore the stand structure and composition characteristics and develop a model for estimating the potential stand volume at the Citragaluh community forest management unit with 55 observation plots based on a combination of slope and density classes. The data taken includes slope; plant species; plant coordinates; planting pattern and spacing; tree diameter, tree height, and canopy density. The results of plot observations showed that the cropping pattern of Citragaluh Community Forest Management Unit (CFMU) consisted of monoculture (10.9%), mixed stands (20%), agroforestry (29%), dry fields (27.27%), wet fields (9%), bamboo stands (1.8%) and built-up area (1.8%). The trees species found were Jeungjing, Mahogany, Teak, Tisuk, Sobsi, Akasia, and Puspa. Based on the results of stratification, diameter distribution, and stand volume, mixed gardens were the best cropping pattern. This research proves the role of community forest as a transition between plantation forest and natural forest based on the stand form and composition. The stand volume potential estimator model chosen was linear with the equation $Y = 0.074X_1 + 2.924 X_2 - 1.679$ where X_1 = slope and X_2 = Normalized Difference Vegetation Index (NDVI). The values of R_2 models are 51.3%. The average potential for the Citragaluh is 119,835 m^3/ha, which tends to be higher than other community forest studies.

Keywords: *community forest, agroforestry, stand structure, stand composition, stand volume potential*

1. Introduction

The community forest is a forest that is outside the state forest area and the land is owned by the general public so that the form of management is unique compared to other forest types. Community forest management is generally still on a traditional individual per family-scale with limited knowledge and experience of farmers [1]. This form of management affects diversity, especially in the form of land stands such as patterns and spacing. The planting pattern of the community forest is influenced by the needs and habits of the landowner, as well as the biophysical condition of the land [2][3]. The needs and habits of the landowner can be seen when viewed from the land owner's profession. Landowners who work as farmers tend to have agroforestry planting patterns, while landowners with other professions have monoculture or polyculture cropping patterns [2].

Land biophysical factors in the form of land contours, climate, season, and soil conditions and types are also one of the considerations for farmers in choosing cropping patterns. Land with steep slopes will have a high potential for erosion and runoff so that it can experience critical conditions. Therefore, land with steep slopes will generally be dominated by perennial/forestry species with denser spacing than those with low slopes. The closer the spacing, the higher the canopy cover density, where the denser the canopy cover, the higher the vegetation index value [5]. Consideration of these two factors is important for farmers in determining the shape of the pattern and spacing to avoid failure [4].

In addition to affecting the shape of the stand, the planting pattern and spacing of community forests also affect the amount and type of product produced. The main product of

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community forest is wood, but other products can also be produced, especially on land with agroforestry patterns. Community forests can be an alternative source in increasing national log production. Based on data from the Ministry of Environment and Forestry, the total production of logs in 2019 from natural forests and plantations was 6.77 million m^3 and 36.23 million m^3, respectively. This number has decreased from 2018 which was 8.60 million m^3 of 40.14 million m^3 for natural forests and industrial forests [6]. The level of wood production in community forests can be determined by estimating the potential stand volume. Until now, it is still difficult to get the right form for estimating the potential stand volume in community forests, so involving geographic information systems (GIS) and remote sensing is expected to produce a good model.

The Citragaluh Sustainable Community Forest Management Unit (CFMU) is one of the certified community forests, located in four villages namely Cimeuhmal, Rancamanggung, Gandasoli, and Cibuluh. The Citragaluh CFMU has a total area of 3906 land units with a total land area of 516.38 hectares. Although it has been in the form of a management unit, the management of the Citragaluh CFMU is still traditional in which each member is individual, so it does not have a clear plan and does not fully guarantee sustainability in terms of farmers' income and the existence of community forests [1]. This study aims to explore the structural characteristics of the stand composition on the land and determine a model for estimating the potential for stand volume on the Citragaluh CFMU land.

2. Methodology

The research was carried out in March – April 2021, which was located at Citragaluh CFMU, Tanjungsiang District, Subang Regency. The boundary of the research coordinates is between 107° 47' – 107° 50' east longitude and 6° 41' – 6° 45' south latitude. The area of the CFMU Citragaluh based on the certification is 516.38 ha, but in this study, the area used is 1724,797 ha as shown in Figure 1 below.

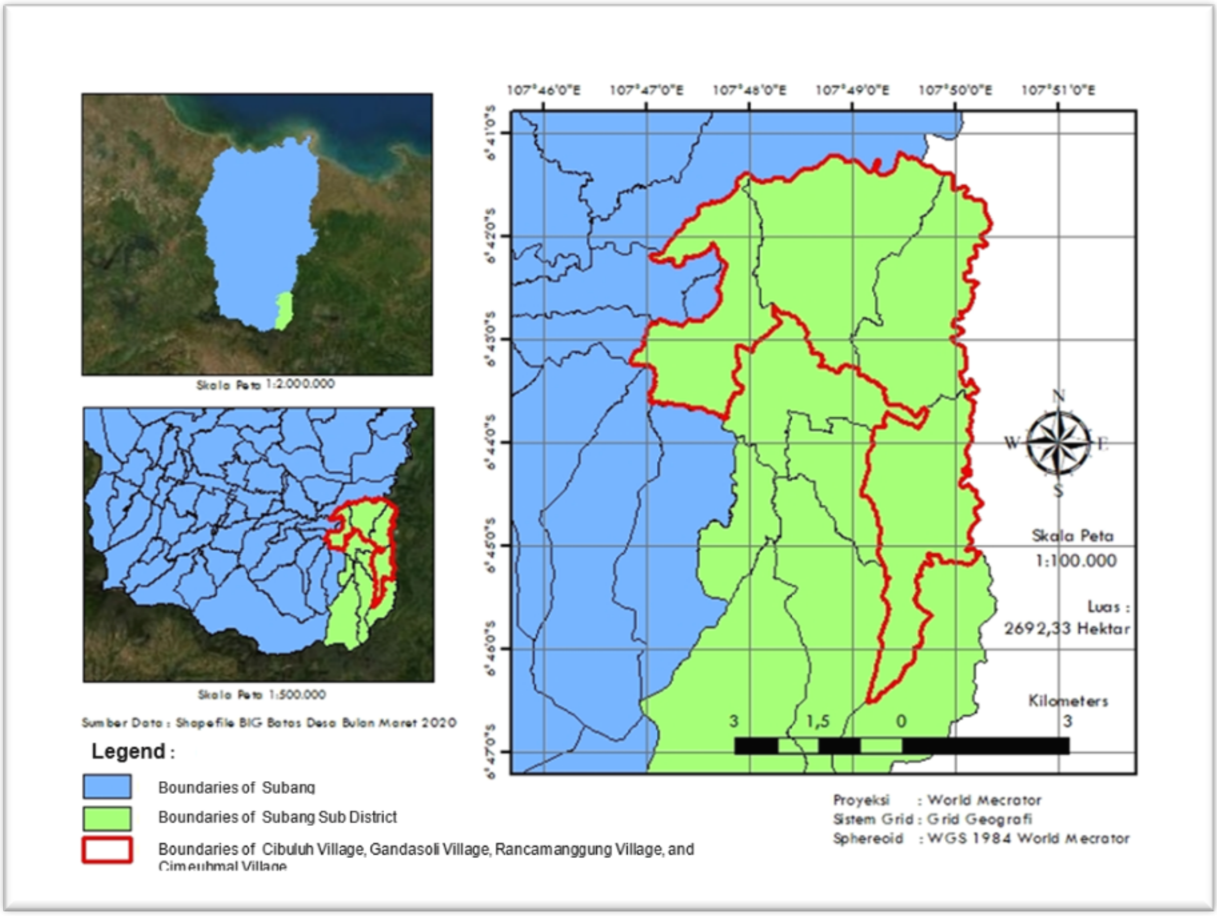

Figure 1. Map of Research Locations (Boundary of the four villages)

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The data used in this study were the Citragaluh CFMU certification documents in the form of images of land cover maps of the four villages in 2016; shapefile map of the boundaries of the four villages sourced from the Geospatial Information Agency (BIG) web-based on data in March 2020; Digital Elevation Model (DEM) data for the Subang Regency area from the National DEM/DEMNAS; and a panchromatic SPOT 6 satellite image dated June 1, 2020, sourced from the Lembaga Antariksa dan Penerbangan Nasional (LAPAN). The data retrieval stages were carried out entirely with the ArcGIS 10.8 application. The creation of the Area of Interest (AOI) is carried out by georeferencing and digitizing the certification document of the mixed plantation land cover map image. The slope map is made from DEM data based on the Regulation of the Minister of Forestry of the Republic of Indonesia No. P.32/Menhut-II/2009 concerning Procedures for Compiling Technical Plans for Forest and Watershed Land Rehabilitation [7] with classifications as shown in Table 1 below.

Table 1. Slope class classification

Class	Slope percentage range	Explanations
1	0 – 8%	Flat
2	8 – 15%	Sloping
3	15 – 25%	A bit steep
4	25 – 40%	Steep
5	> 40%	Very steep

The vegetation density class map is made based on the Normalized Difference Vegetation Index (NDVI) value, with the following formula.

$$NDVI = \frac{Near\ Infra\ Red\ Band - Red\ Band}{Near\ Infra\ Red\ Band + Red\ Band}$$

The results of the calculation of the NDVI value will vary in the range of values from -1 to 1. This study uses a range of NDVI values between 0.3-0.7 or more to distinguish tree-vegetated areas in community forests [8]. The interval of the density class NDVI value is determined based on the desired number of classes using the following formula [9].

$$Interval\ Class = \frac{highest\ NDVI\ value - lowest\ NDVI\ value}{total\ desired\ class}$$

This study has divided the vegetation density class into five classes as shown in Table 2 below.

Table 2. Vegetation density class classification

Class	NDVI value range	Explanations
1	(-0,187 - 0,3)	No vegetation
2	(0,3 - 0,402)	Very sparse vegetation
3	(0,402 - 0,504)	Sparse vegetation
4	(0,504 - 0,606)	Medium/enough vegetation
5	(0,606 - 0,708)	Dense vegetation
6	(0,708 - 0,810)	Very dense vegetation

The results of overlaying the slope map and vegetation density map are then intersected to produce 27 classes of overlay of slope and density. This study used stratified random sampling based on the combination of slope and density classes which had 55 samples of square plots measuring 20x20 meters square (0.04 ha). The number of plot allocations per combination of slope and density is determined based on the results of the calculation of the proportion of the area. Data were taken during field observations in the form of the plant species (either forestry or agriculture); the number of plants; planting pattern and spacing; tree diameter at breast height/DBH; total tree height; branch-free tree height; canopy width radius; tree coordinates; and the slope of the land.

2.1 Analysis of Structural Characteristics and Stand Composition

The existing/actual condition of the stand characteristics composition structure was analyzed using diameter distribution diagrams and tables. The type of stand structure can be identified using a diameter distribution diagram. If the shape of the diagram resembles an inverted 'J', it describes a forest that is not the same age/similar to a natural forest; Otherwise, if the shape resembles the form of a bell/normal distribution, it describes a forest of the same age/similar to a plantation forest [10]. The form of the stand structure can also affect the sustainability of its management, where the stand structure of a good community forest is similar to the concept of a normal forest [1]. In addition, the shape of the stand structure will also be visualized with a vertical profile diagram (3D model) and a horizontal stand (tree canopy diagram) using the SExi-FS. The tree canopy diagram was analyzed using the Tree Cramming method, which is measuring the percentage of canopy cover by moving and closing the positions of the tree

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canopy sizes so that they become one group [11]. The results of the 3D model of the stand will be able to know the stratification, while the results of the canopy profile diagram can know the percentage of the canopy cover area. The stratum division is grouped into five based on natural forest, namely stratum A (>30m), stratum B (20-30m), stratum C (4-20m), stratum D (1-4m), and stratum E (0-1m) [12]. To determine the composition of stands, they are divided into monoculture forests, mixed forests, natural forests and non-forests such as gardens, agroforestry and others.

2.2 Statistical Analysis of Stand Volume Potential Estimator Model

The stages of building a stand volume potential model consist of calculating the volume of each plot, testing correlations between variables, testing the validity of the combined vegetation density and slope class mapping, determining the basic shape of the model, testing classical assumptions, testing verification and model validation, selecting the best model, and volume prediction map creation based on the model. The calculation of the total volume in each plot with the following formula.

$$V_i = \frac{1}{4}\ x\ \pi\ x\ DBH^2\ x\ Tbc\ x\ f \qquad V_{teg} = \sum_{i=1}^{n} V_i$$

Explanations :

V_i = tree volume (m^3)

V_{teg} = total volume in each plot (m^3/plot)

π = 3,14

DBH = diameter at breast height (m)

Tbc = branch-free tree height (m)

f = tree form factor (f = 0,7)

The correlation testing between variables is carried out to determine the relationship between two or more variables, with the Pearson correlation formula as follows [13].

$$r = \frac{n\sum X_iY_i - (\sum X_i)(\sum Y_i)}{\sqrt{\{n\sum X_i^2 - (\sum X_i)^2\}\{n\sum Y_i^2 - (\sum Y_i)^2\}}}$$

Explanations :

r = coefficient correlation

n = number of sample

X_i = first variable value

Y_i = second variable value

The results of the correlation coefficient test will produce a value between -1 to 1 with the confidence level used in the study is 95%. The form of interpretation of the value of the relationship between variables can be seen in full in Table 3 below [14].

Table 3. Interpretation of correlation level

Coefficient range	Correlations
0,00 – 0,199	Very low
0,20 – 0,399	Low
0,40 – 0,599	Medium/enough
0,60 – 0,799	Strong
0,80 – 1,00	Very strong

Testing the validity of the combined density and slope class mapping is carried out by checking the field conditions (ground check) from the observations based on the combined slope and density map. Testing the accuracy of the two variables was carried out using the confusion matrix, Overall Accuracy (OA) calculations, Kappa value and its interpretation in Table 4 as follows.

$$Kappa = \frac{N\ \sum_i^r X_{ii} - \sum_i^r X_{i+} X_{+1}}{N^2 - \sum_i^r X_{i+} X_{+1}}\ x\ 100\%$$

$$OA = \frac{\sum_i^r X_{ii}}{N}\ x\ 100\%$$

Explanations:

X_{ii} = diagonal value from row i and column i

X_{i+} = total column pixel i

X_{+i} = total row pixel i

N = total sample plot

Table 4. Interpretation of correlation level

Kappa value	Correlations	Reliability percentage
0 – 0,2	None	0 – 4%
0,20 – 0,39	Minimum	4 – 15%
0,40 – 0,59	Low	15 – 35%
0,60 – 0,80	Medium/enough	35 – 63%
0,80 – 0,90	Strong	64 – 81%
> 0,90	Very strong	82 – 100%

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The modeling uses two scenarios, namely a model with one estimator variable, namely the NDVI (X) value; and a model with two estimating variables, namely slope (X1) and NDVI value (X_2) to estimate the potential stand volume (Y). The form of the basic equation used is as follows.

1) Linear regression formula ($Y = \alpha + \beta_1 X$)
2) Logarithm formula ($Y = \alpha + \beta_1 LnX$)
3) Invers formula ($Y = \alpha + \frac{\beta_1}{X}$)
4) Quadratic regression formula ($Y = \alpha + \beta_1 X + \beta_2 X^2$)
5) Cubic regression formula ($Y = \alpha + \beta_1 X + \beta_2 X^2 + \beta_3 X^3$)

Explanations:
Y = Stand volume potential
α = intercept
βn = n regression coefficient
X_1 = Slope variable
X_2 = NDVI variable

Before making the model, the data must meet the classical assumptions, namely normality, multicollinearity, heteroscedasticity, and autocorrelation tests [16]. This study was not conducted autocorrelation test because the data is not in the form of time series. All classical assumption tests were performed with the IBM SPSS 25.

The model verification and validation testing is carried out using several criteria such as coefficient of determination, adjusted coefficient of determination, Root Mean Square Error (RMSE), error (e), aggregate deviation (AD), mean deviation (MD), and Chi square test. The calculation of the coefficient of determination (R2) aims to determine the effect of the level of accuracy and the closeness of the relationship between variables in the regression model, while the corrected coefficient of determination (adjusted R2) is a modification of the corrected coefficient of determination which shows the effect of the number of estimators/predictors on model predictions [17]. The formula for calculating R2 and adjusted R2 is as follows.

$$R^2 = \frac{SSR}{SST} = \frac{SST - SSE}{SST} = 1 - \frac{SSE}{SST} = 1 - \left\{\frac{\sum(y_i - \hat{y}_i)^2}{\sum(y_i - \bar{y})^2}\right\}$$

$$\bar{R}^2 = \frac{(1 - R^2)(n-1)}{n - k - 1}$$

Explanations:
R_2 = coefficient of determination
SSR = Sum of Squared Regression
SST = Sum of Squared Total
SSE = Sum of Squared Error
y_i = observed value
$\hat{y}_1$ = predicted value
$\bar{y}$ = mean value
$\bar{R}^2$ = adjusted coefficient of determination
n = number of observations
k = total parameter used in model

The calculation of RMSE (Root Mean Square Error) is carried out to determine the level of error / error that occurs in the calculation results of the model when compared to the actual value [18]. The formula for calculating RMSE is as follows.

$$RMSE = \sqrt{\frac{\sum\left(\frac{E-O}{O}\right)^2}{n}}\ x\ 100\%$$

Explanations:
RMSE = Root Mean Square Error
E = expected value
O = observed value
n = total sample plot

The calculation of error (e) is carried out to determine the level of error in the study that can be caused by errors in measurement or technical errors/human error [18]. The formula for calculating the error is as follows.

$$e = \sum\left\{\frac{\left(\frac{E-O}{O}\right)}{n}\right\} x\ 100$$

Explanations:
e = error
E = expected value
O = observed value
n = total sample plot

The calculation of the aggregate deviation (AD) is the ratio of the difference between the number of actual values and the total estimated values of the model with the total estimated values of the model, with a range of values between -1 to +1[18]. The formula for calculating SA is as follows.

$$AD = \left(\frac{\sum E - \sum O}{\sum E}\right)$$

Explanations:
AD = aggregate deviation
E = expected value
O = observed value

The calculation of the mean deviation (MD) is the absolute sum of the ratio of the difference between the estimated value and the actual value with the estimated value, which is divided by the total estimated value [18]. The formula for calculating SR is as follows.

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$$MD = \left(\frac{\sum \left| \frac{E - O}{E} \right|}{n} \right) x\ 100\%$$

Explanations:
MD = mean deviation
E = expected value
O = observed value

The calculation of the mean deviation (MD) is the absolute sum of the ratio of the difference between the estimated value and the actual value with the estimated value, which is divided by the total estimated value [18]. The formula for calculating SR is as follows.

$$X^2{}_{cal} = \sum \frac{(O - E)^2}{E}$$

Explanations:
X^2_{cal} = calculated X value Chi Square
O = observed (actual volume value/Va)
E = expected (model volume value/Vm)

Hypotheses in the significant test:
H0: Vm = Va; the model volume value is similar to the actual volume value
H1: Vm ≠ Va; the model volume value is not similar to the actual volume value.

The best model is selected based on the ranking score of each criterion based on the test results of each model. The higher the score value, the lower the ranking. The criteria that will be used in selecting the best model are as follows.

1) Has a high R2 value and a high R2 adjustment.
2) Has a low RMSE value.
3) Meet the real difference test / Chi Square.
4) Has a bias value closest to zero.
5) Has a MD value below 10%.
6) Has an AD value in the range of -1 to +1.

The distribution map of the potential standing volume of Citragaluh CFMU was made based on the selected model equation with ArcGIS 10.7.

3. Results and Discussion

3.1 Characteristics of Structure and Composition of Stands

The characteristics of the structure and composition of stands at Citragaluh CFMU are quite diverse, including monoculture, polyculture, and agroforestry. Monoculture is a homogeneous cropping pattern that only grows one type of forest plant species; while polyculture or mixed stands is a heterogeneous cropping pattern that grows more than one species with forestry plant types. Agroforestry is the most homogeneous cropping pattern among the three because there is a combination of two or more types of crops between forestry, plantation, and agriculture in one area. The agroforestry found on the Citragaluh CFMU land is in the form of complex agroforestry with a combination of the three types of forestry, agricultural, and plantation crops that resemble natural forest ecosystems. The agroforestry complex is divided into two based on the location, namely the yard and the agroforest.

The type of yard is located near a residential area with three phases of form, the first form is garden, then the second form is a mixed garden, and the last form is talun garden. In the first phase, the dominant annual crops are planted by farmers after land clearing or the beginning of planting; in the mixed garden phase, farmers begin to plant various types of trees side by side with annual crops; the final phase of the talun garden has tree species that have dominated and growth large in size so that there are almost no annual plants. The second type is agroforest, located far from the owner's house and does not produce seasonal food crops. Seasonal food crops are only planted at the beginning of land clearing and will be replaced directly by planting various types of trees. Another form of cropping pattern found is a field of annual crops, with a few trees planted in the form of a line as a land boundary fence.

Based on the results of field observations, the stand compostion at Citragaluh CFMU can be identified into four types, namely monoculture patterns, polyculture patterns (mixed stands), agroforestry patterns, and other patterns. In the monoculture cropping pattern, 6 plots (10.9%) were found with two types of plants; mixed stands pattern was found in 11 plots (20%) with four dominant plant species; two forms of agroforestry patterns were found in 16 plots (29%) based on their location; other patterns were found as many as 22 plots (40%) which were dominated by dry fields. The overall stand composition of Citragaluh CFMU.can be seen in Table 5 below.

Each cropping pattern will be represented by one sample plot for visualization of the 3D stand model and tree canopy profile diagram as shown in Table 6. In the monoculture pattern, the spacing used is 2x2 m2 so that the stands are very close together; the mixed stand pattern varies quite a bit between 2x2 m and 3x3 m; the agroforestry pattern (mixed garden, talun garden, and agroforest) do not have regular spacing; and the form of dry fields of 2x2 m or 3x3 m between fence trees. The pattern and spacing also affect the stand volume. The denser the stand, the volume will also increase. Based on the results of data processing, the highest volume value was obtained with an average of 3,959 m3/plots, followed by talun gardens of 3,453 m3/plots, then mixed stands of 1,743 m3/plots, mixed gardens of 1,262 m3/

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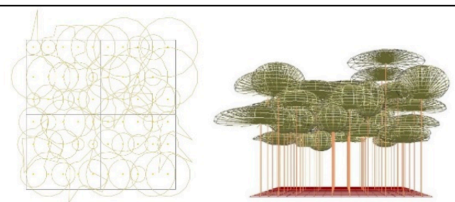
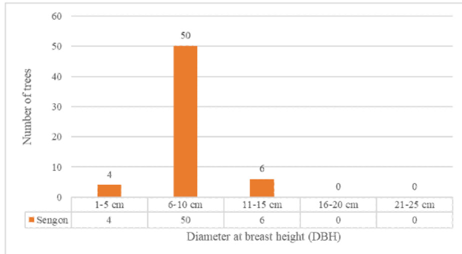
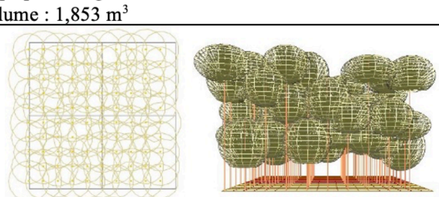
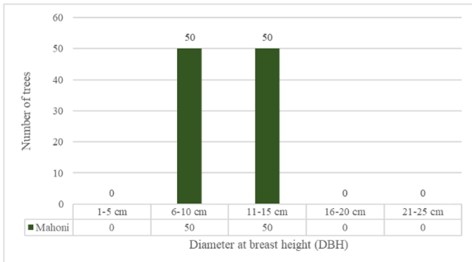
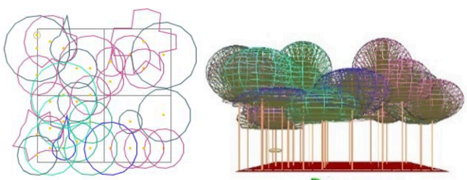
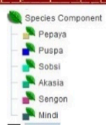
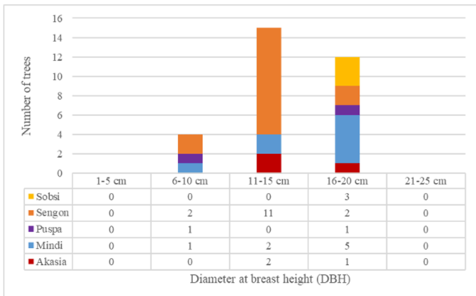
plots, dry fields of 0.347 m3/plots, and agroforests of 0.087 m3/plots. The volume in the agroforest is the lowest because there is only one plot. The distribution of volume values for each cropping pattern can be seen in Table 7 below.

Table 5. Stand Composition of CFMU Citragaluh's cropping pattern

Stand characteristics		Plot number	∑ Plot	Rasio (%)
Monoculture	Sengon	6	2	3.63
	Mahoni	54	4	7.27
Mixed Tree Stand	Sengon Dominant	29	3	5.45
	Mahoni Dominant	48	5	9.09
	Tisuk Dominant	25	1	1.81
	Sobsi Dominant	40	2	3.63
Agroforestry	Mixed garden	20	11	20
	Talun garden	10	4	7.27
	Agroforest	12	1	1.81
Others	Dry fields	32	15	27.27
	Rice fields	-	5	9.09
	Bamboo stand	-	1	1.81
	Building area	-	1	1.81

Table 6. The form of visualization of the structure and composition of stands per cropping pattern

Stand characteristics	Canopy diagram/ Canopy Stratification / Explanations/ Species components	Diameter distribution graph
Sengon Monoculture	 Species count : 1 Strata count : 1 (Stratum C) Canopy cover percentage: 100% Slope percentage : 7% Volume : 1,853 m^3	
Mahoni Monoculture	 Species count : 1 Strata count : 1 (Stratum C) Canopy cover percentage : 100% Slope percentage : 28% Volume : 5,203 m^3	
Mixed Tree Stand Sengon Dominant	 Species count : 6 Strata count : 1 (Stratum C) Canopy cover percentage : 11% Slope percentage : 96% Volume : 2,088 m^3 	

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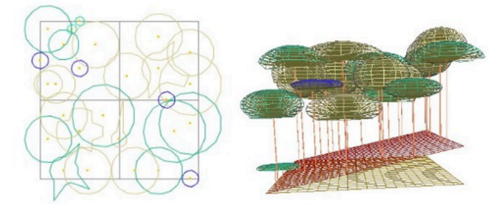
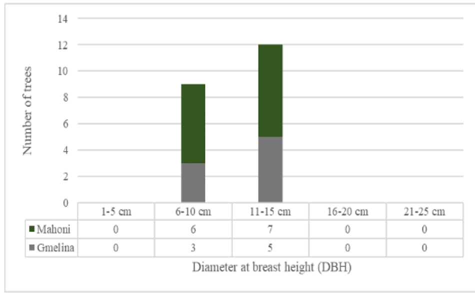
<table>
<tr><td>Mixed Tree Stand Mahoni Dominant</td><td>
Species count : 4
Strata count : 1 (Stratum C)
Canopy cover percentage : 20%
Slope percentage : 96%
Volume : 1,099 m^3

</td><td>
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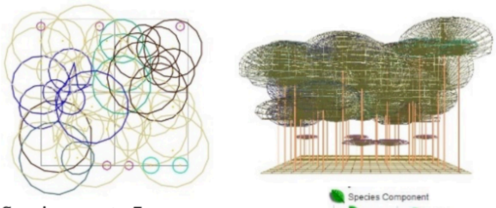
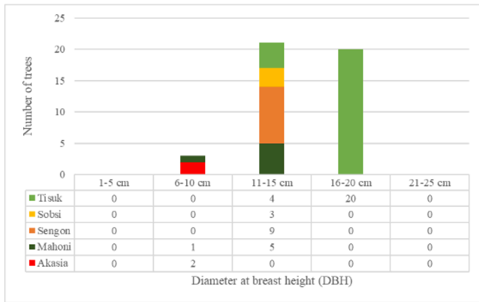
<tr><td>Mixed Tree Stand Tisuk Dominant</td><td>
Species count : 7
Strata count : 1 (Stratum C)
Canopy cover percentage : 100%
Slope percentage : 5%
Volume : 3,239 m^3

</td><td>
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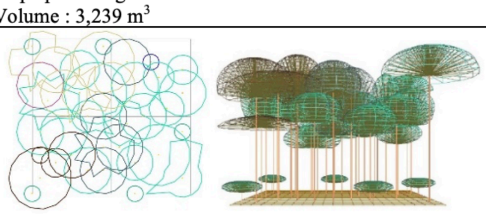
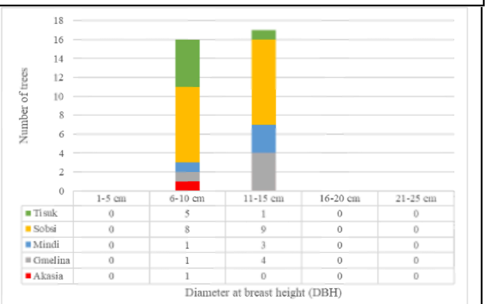
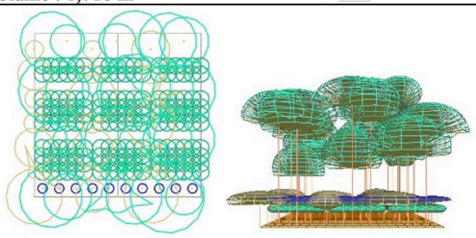
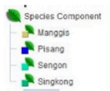
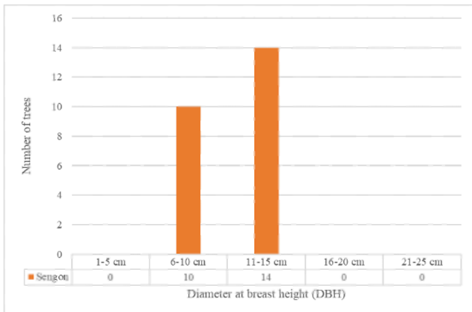
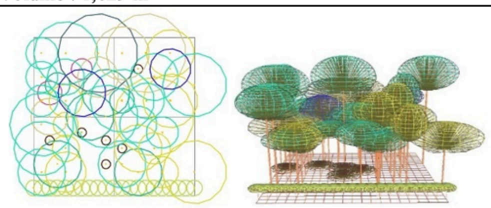
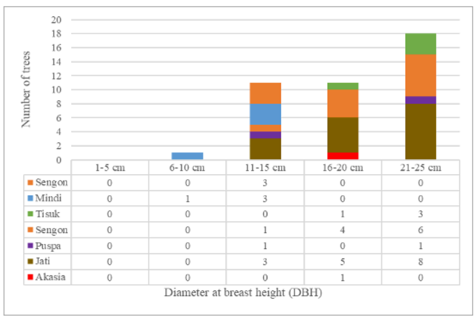
<tr><td>Mixed Tree Stand Sobsi Dominant</td><td>
Species count : 7
Strata count : 1 (Stratum C)
Canopy cover percentage : 96%
Slope percentage : 5%
Volume : 1,718 m^3

</td><td>
</td></tr>
<tr><td>Mixed Garden</td><td>
Species count : 4
Strata count : 2 (Stratum C, D)
Canopy cover percentage : 96%
Slope percentage : 7%
Volume : 1,029 m^3

</td><td>
</td></tr>
<tr><td>Talun Garden</td><td>
Species count : 9
Strata count : 2 (Stratum C, D)
Canopy cover percentage: 94%
Slope percentage : 60%
Volume : 5,046 m^3

</td><td>
</td></tr>
</table>

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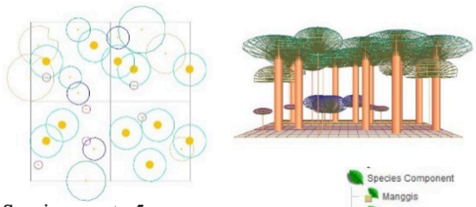
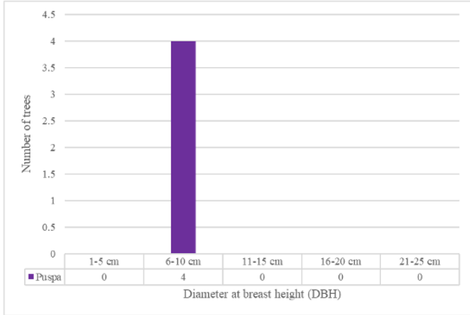
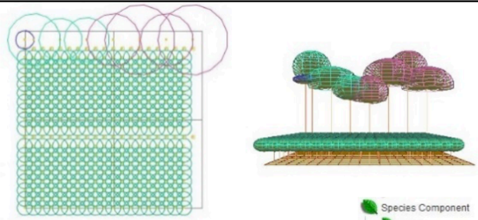
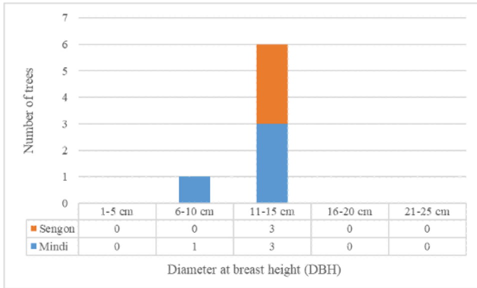
Agroforest	  Species count : 5 Strata count : 2 (Stratum C, D) Canopy cover percentage: 54% Slope percentage : 80% Volume : 0,087 m^3	
Dry Fields	  Species count : 5 Strata count : 3 (Stratum C, D, E) Canopy cover percentage : 25% Slope percentage : 80% Volume : 0,087 m^3	

Table 7. The form of visualization of the structure and composition of stands per cropping pattern

Cropping pattern	Volume (m^3)		
	Min	Max	Mean
Monoculture	1.854	5.203	3.959
Mixed tree stand	0.769	4.039	1.743
Mixed garden	0.075	3.404	1.262
Talun garden	1.682	5.046	3.453
Dry fields	0.000	1.002	0.347
Agroforest	-	0.087	-

The number of plant species depends on the type of cropping pattern, which is a commercial type. The types of forestry plants found were jeunjing/sengon (*Falcataria moluccana*), mahoni (*Swietenia mahagoni*), tisuk (*Hibiscus macrophyllus*), sobsi (*Maesopsis eminii*), ki maung (*Bischofia javanica*), mindi (*Melia azedarach*), white teak (*Gmelina arborea*), and Teak (*Tectona grandis*). Types of plantation crops found were mangosteen (*Garcinia mangostana*), coffee (*Cofea arabica*), sugar palm (*Arenga pinnata*), banana (*Musa paradisiaca*), coconut (*Cocos nucifera*), and hanjuang (*Cordyline fruticosa*). The dominant types of crops are cassava (*Manihot esculenta*), aromatic ginger (*Kaempferia galanga*), ginger (*Zingiber officinale*), taro (*Colocasia esculenta*), and long beans (*Vigna unguiculata*). The more types of plants that make up a stand, the more the number of strata.

Monoculture patterns and mixed stands, only had one stratum, namely stratum C; agroforestry pattern has two strata, namely stratum C and D; and the form of the field has three strata, namely stratum C, D, and E. The field has small annual plants so that it can have more strata. In addition to stratification, Citragaluh CFMU stands shape can also be identified through the distribution of tree diameters. Overall, the shape of the diameter distribution graph for each cropping pattern is similar to a bell/normal distribution curve. This shows that the shape of the stands at Citragaluh CFMU tends to resemble a plantation forest where the planting is carried out simultaneously (for a lifetime), but with quite varied types of plants. Based on the results of data processing, the average tree height was 10,455 m and the dominant diameter was 11-15 cm. The diameter size tends to be small and based on the tree's survival level, the size is still at the pole level. The shape of the diameter distribution graph for each cropping pattern can be seen in Table 6.

3.2 Statistical Analysis for Estimating Stand Volume Potential Model

The results of the calculation of the plot volume for each form of cropping pattern can be seen in full in Table 7 and the sampling error value is 0.013. Based on the results of the correlation test of all variables, a moderate relationship (r = 0.636) was obtained between the percentage of canopy cover and NDVI so that it could be used in the ground check (ground-truth). The relationship between NDVI and volume is also moderate (r = 0.438), but the relationship between

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slope and volume is low (r = 0.388) so two scenarios were carried out in constructing the model. Based on the results of the Ground check, the Kappa and OA values for the slope are 0.502 and 0.672, respectively; while the vegetation density is 0.454 and 0.654. Kappa values in vegetation density tend to be low because many plots have high NDVI values but in actual conditions do not have appropriate canopy cover. Based on the Kappa value, the reliability level of slope and NDVI data is 15 – 35%. The slope, NDVI, and volume data were then tested for classical assumptions and divided into training data and validation data with a proportion of 80:20. The form of the model that was successfully raised can be seen in full in Table 8 below.

Models number one to six are the first scenario models (using only the NDVI variable), while models number seven and number eight (using the NDVI variable and slope variable). The results of the validation and verification tests of the model can be seen in Table 9, Table 10, Table 11, and the best model selection can be seen in Table 12.

Table 8. Model form and estimator equation

Model form	No.	Model equations
Linear	1	$Y = 3{,}106\,X - 1{,}5173$
Logarithmic	2	$Y = 1{,}863\,\text{Ln}\,(X) + 1{,}403$
Invers	3	$Y = 2{,}281 - 1{,}025/X$
Quadratic	4	$Y = 7{,}444\,X^2 - 6{,}731\,X + 1{,}504$
Cubic	5	$Y = 16{,}405\,X^3 - 24{,}622\,X^2 + 13{,}328\,X - 2{,}455$
	6	$Y = 5{,}817\,X^3 - 3{,}642\,X^2 + 0{,}219$
Multi-linear	7	$Y = 0{,}074X_1 + 2{,}924\,X_2 - 1.679$
Multi-Quadratic	8	$Y = -0{,}042{X_1}^2 + 6{,}641{X_2}^2 + 0{,}388X_1X_2 + 0{,}145X_1 - 7{,}45X_2 + 1{,}515$

Table 9. R^2, Adjusted R^2, and RMSE value from training model

No. Model	R^2	*Adjusted* R^2	RMSE
1	0,299	0,282	0,763
2	0,273	0,255	0,748
3	0,240	0,222	0,733
4	0,333	0,317	0,794
5	0,337	0,321	0,795
6	0,335	0,319	0,794
7	0,323	0,290	0,841
8	0,406	0,377	0,790

Table 10. R^2, Adjusted R^2, and RMSE value from testing model

No. Model	R^2	*Adjusted* R^2	RMSE
1	0,320	0,245	0,696
2	0,300	0,222	0,676
3	0,266	0,184	0,657
4	0,327	0,252	0,752
5	0,317	0,241	0,762
6	0,323	0,248	0,756
7	0,513	0,391	0,644
8	0,285	0,106	0,731

Table 11. error, AD, MD, dan Chi-Square value

No. Model	e	AD	MD (%)	*Chi Square*
1	0,199	-0,067	45,9	13,609
2	0,190	-0,073	47,6	14,042
3	0,179	-0,076	49,2	14,836
4	0,206	-0,056	46,9	14,646
5	0,208	-0,042	46,8	14,827
6	0,205	-0,052	47,1	14,825
7	0,199	-0,037	40,9	13,277
8	0.182	-0.080	51,2	14,093

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Table 12. Best model selection based on rankings

No. Model		1	2	3	4	5	6	7	8
Training phase	R^2	6	7	8	4	2	3	5	1
	Adjusted R^2	6	7	8	4	2	3	5	1
	RMSE	3	2	1	5	7	6	8	4
Testing phase	R^2	4	6	7	2	5	3	1	8
	Adjusted R^2	4	6	7	2	5	3	1	8
	RMSE	4	3	2	6	7	8	1	5
Model Validation	e	4	3	1	7	8	6	5	2
	SA	5	6	7	4	2	3	1	8
	SR	2	6	7	4	3	5	1	8
Total		38	46	48	38	41	40	28	45
Ranking		3	7	8	2	5	4	1	6

All models have met the requirements of the Chi-Squared test criteria where the value of Xcount < Xtable (18.307) at a 95% confidence level. Based on Table 12, the best model has the lowest total score, namely linear two variables with the equation $Y = 0.074X_1 + 2.924\ X2 - 1.679$. This model describes a positive relationship between volume and slope and NDVI, where the effect of NDVI is greater than slope. The values of R_2, Adjusted R_2, RMSE, models are 51.3%, 39.1%, and 0.644, respectively. This study also shows that variations in the level of land slope and variations in NDVI values can explain the volume variation of 51.3% and the remaining 48.7% can be explained by other factors. The graphic form of the two-variable linear model equation can be seen in Figure 2 below.

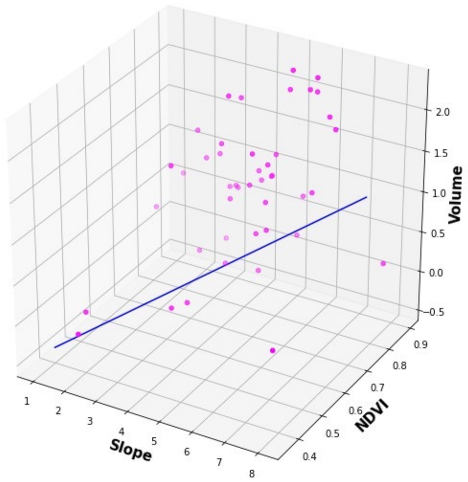

Figure 2. Graph of a 2-variable linear model (multi-linear)

The R_2 value of the linear model of these two variables has a considerable difference between the training and validation stages when compared to the R_2 value of other models. This can be caused by the lack of data making up the model so that the R_2 value of the model that appears is not optimal. However, when compared with the results of other community forest stand volume studies, the R_2 value of the linear model of the two variables is still lower and no one has used the slope of the land variable in constructing the model [19]. The results of the selected model mapping resulted in a volume value range of 1,983 x 10-5 m^3/ha to 2192,825 m^3/ha, with an average stand volume potential of 119,835 m^3/ha. Due to the shape of the volume graph being indicated to be positively skewed, the mapping of the potential volume distribution of the stands is divided into four classes based on quartiles so that the proportion of potential volumes could be known. Quartile 1 has a value range of 1,983 x 10-5 m^3/ha to 25,976 m^3/ha with an area of 302,409 ha (20.61%); Quartile 2 has a range of values from 25.976 m^3/ha to 68.795 m3/ha with an area of 422.784 ha (28.82%); Quartile 3 has a range of values from 68.795 m^3/ha to 168.388 m^3/ha with an area percentage of 394.989 ha (26.92%); Quartile 4 has a value range of 168,388 m^3/ha to 2192,848 m^3/ha with a percentage of 346,578 ha (23.62%) of area.

Based on this division, it can be seen that the second quartile has the largest proportion with a volume potential range of 25.976 m^3/ha to 68.795 m^3/ha. If these results are compared with other community forest studies, the quartile range and the

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average potential volume of this study have similar results to the average potential volume of around 40-80 m^3/ha [19][20]. When compared with natural forest and plantation forest, the average yield potential of this study is close to plantation forest and much higher than natural forest [21][22]. Based on the results of this study, it can be seen that the stand structure of Citragaluh CFMU resembles a plantation forest of the same age through the graph of its diameter distribution; with a stand composition resembling a natural forest through its mixed cropping pattern of varying plant types with more than one canopy stratification. The more strata of the canopy of a stand, the better the performance of the plant in increasing water and soil conservation. Strata A to D can slow down the kinetic energy of rainwater by interception and stem flow, while strata E can reduce the surface runoff [23]. In addition, the shape of the structure and composition of the stand also greatly affects the volume of the stand, where the observed volume value tends to be small due to the cropping pattern being dominated by the form of fields that only have a few trees. This shows that community forests with mixed cropping patterns can act as a transition between plantation forests and natural forests.

4. Conclusion

The stand structure at Citragaluh CFMU has the characteristics of an age-old plantation based on its diameter distribution and the characteristics of a natural forest based on its stratification and composition of plant species. Planting pattern affects the amount of stratification and composition of plant species, while spacing affects tree size. The average tree size at Citragaluh CFMU is 11 m for tree height and 11-15 cm for diameter. The best model for estimating the potential stand volume at Citragaluh CFMU is a linear model of two estimating variables, namely slope (X_1) and NDVI (X_2), having the equation $Y = 0.074X_1 + 2.924 X_2 – 1.679$ with a value of R_2 is 51.3%.

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