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Determining Harvest Time of Balangeran Plants (*Shorea balangeran* Korth. Burck) Using Rational Model

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Abstract: ***The balangeran tree (Shorea balangeran Korth. Burck) is a commercial species that grows well in peat swamps. Plant growth can be described through mathematical equations. The research aims to determine the most appropriate harvest time for balangeran plants using rational equations. The model was then tested for validation, accuracy and coefficient of determination. The results of the research show that the diameter growth model for balangeran plants using a rational equation is namely: $y = - 6.94 + 7.26 x / (1+ 0.48 x + (-0.01) x^2)$ with a coefficient of determination of 80%, The equation is valid and quite accurate. Based on this equation, the harvest time for balangeran plants can be determined, namely 29 years, when the average diameter of balangeran plants reaches 30.97 cm.***

Keywords: balangeran, growth, harvest time, rational equation

1.Introduction

A. Background

Based on the results of plant species trials in peat swamp land, the balangeran tree (*Shorea balangeran* Korth. Burck) is a species that has the potential to be planted and used for restoration of degraded peat swamp land (Setyo et.al 2013) and peat swamp scrub areas (Sampang 2015). The survival percentage of balangeran plants in peat swamp land is more than 75%, making it very suitable for use for cultivated plants and restoration activities on degraded peat swamp land (Turjaman et.al 2011).

Balangeran or kahoi (local name) is a species of Dipterocarpaceae family that naturally grows in peat swamp areas (Indriani et.al 2020). Balangeran trees also have excellent economic benefits and ecological value because the wood has a high selling price (Rusmana 2012, Setyo et.al 2012, Wibisono et.al 2005), and has a large role in maintaining the sustainability of peat swamp forest ecosystems (Atmoko 2011, Indriani et.al 2020). This tree also has benefits as a medicinal plant, such as for antibiotics (Wardani et.al 2021) and its bark can inhibit the growth of babesial parasites (Subeki at.al 2005).

Several agencies and community members have planted balangeran on a trial scale, research scale, and as an arboretum plant. The Plantation and Forestry Service of Pulang Pisau Regency in Central Kalimantan Province has been building urban forests using balangeran plants since 2009. Efforts to plant balangeran like this need to be supported, because apart from conserving critical plants, they can also improve the quality of natural resources and peatland ecosystems, as well as bringing financial benefits at the time of harvest.

Efforts to predict the yield of balangeran plants can be done by creating plant growth equations (Brown 1997, Burckhart 2003, Grant et.al 1997, Hauhs et.al 2003, Radonsa et.al 2003, Wahydi 2013). Plant growth equation models can use rational equation approaches, exponential equations, polynomial equations, logistic equations, and others. By forming this growth equation model, stakeholders can predict the yield of balangeran plants at a certain time and can plan balangeran wood harvesting at the right time.

B. Research Objectives

The aim of this research is to determine the harvest time of balangeran plants using rational growth equations. This research is useful for predicting the results of balangeran plants at a certain time so that stakeholders can prepare good balangeran cultivation plans, including planning the right time to harvest balangeran plants.

2.Research Methods

A. Place and Time

Research was carried out at several balangeran planting sites, namely in the urban forest of Pulang Pisau Regency, in the Banjarbaru Forestry Research Institute and in balangeran gardens owned by the community. All balangeran plant samples were taken in peat swamp areas with a peat depth of 1-3 m and a distance from the river of 1-3 km. Samples of balangeran plants were taken from plants with age classes of 1, 2, 3, 4, 6, 7, 12 and 16 years. The research was conducted from June to September 2024.

B. Research Stages

The data collection procedure to determine growth and create a growth equation model for balangeran plants were:

1) Determine the plant population which is divided into several age classes of balangeran plants, namely 1 year,

2 years, 3 years, 4 years, 6 years, 7 years, 12 years and 16 years.
2) Each plant population is determined to consist of 150 plant samples whose diameter at breast height (dbh) and plant height will be measured. Plant samples were determined systematically with random starts
3) Carry out data processing and analysis to determine plant growth and mean annual increment.
4) Modeling the diameter growth of balangeran plants using a rational growth equation model
5) Carrying out validation, accuracy and coefficient of determination tests on the model created.

C. Rational Growth Model

The growth pattern of balangeran plants is formed based on the increment and time functions through a rational function model (Wahyudi, 2013) with the equation:

$$y = \frac{a + b\,x}{1 + c\,x + d\,x2}$$

where:

y : final diameter
x : time of year
a,b,c,d : constant

D. Validation and Accuracy of Models

A good growth model to describe plant diameter growth is an equation model that describes actual conditions in the field. To determine the validation of the plant growth model, the Chi Square test can be carried out as follows (Sudjana 1988, Wahyudi 2013):

$$\chi^2 = \sum_{i=1}^{n} \frac{(O_i - E_i)^2}{E_i}$$

where:

Oi : actual data (observed) the i
Ei : expected data/modeling results (expected) the i
n : number of data pairs

If the calculated χ^2 value $\geq \chi^2$table $_{(db\text{-}1;\ 0.05)}$, then accept H1 (different data)
If the value of χ^2count$<\chi^2$table $_{(db\text{-}1;\ 0.05)}$, then accept H0 (homogeneous data)

Meanwhile, the level of accuracy of the research model is calculated based on the Mean Absolute Percentage Error (MAPE) with the following equation (Wahyudi, 2013):

$$y = 100\% - \left[1/n \sum_{i=1}^{n} \frac{|O_i - E_i|}{E_i} x\ 100\%\right]$$

Accuracy criteria:

y> 80% : very accurate
y = 75% - 79.99%: accurate
y = 60% - 74.99%: quite accurate
y< 60% : inaccurate.

3.Results and Discussion

A. Measurement Results

The results of measuring the diameter and height of balangeran plants (Shorea balangeran Korth. Burck) from the field are as presented in Table 1, which shows that balangeran plants aged 1, 2, 3, 4, 6,7, 12 and 16 have diameters of 0.41cm; 1.51cm; 6.38cm; 7.86cm; 10.24cm; 11.97cm; 11.76 cm and 19.03 cm respectively. At the same age, balangeran plants have an average height of 0.56 m; 1.17m; 5.24m; 6.5m; 10.29m; 10.57 m, 9.34 m and 13.78 m.

Table 1: Recapitulation of data from measurements of diameter and height of balangeran plants planted in peat swamp land

No	Plant age (year)	Average	
		Diameter (cm)	Height (m)
1	1	0.41	0.56
2	2	1.51	1.17
3	3	6.38	5.24
4	4	7.86	6.50
5	6	10.24	10.29
6	7	11.97	10.57
7	12	11.76	9.34
8	16	19.03	13.78

Source: Data processed, 2024

Based on Table 1, it can be seen that the growth of balangeran plants in peat swamp land in Pulang Pisau Regency always increases over time. In plants aged 12 years, balangeran plants showed less good performance compared to younger plants, namely 6 and 7 years. This is because the 12-year-old plants found in Tumbang Nusa Village are often submerged in water, while the 7 year old balangeran plants found in the Urban Forest of the Pulang Pisau Plantation and Forestry Service always receive care by making mound, namely elongated mounds of soil so that the plants do not flooded when it rains. The balangeran plants in this study were planted with a spacing of 4x4 m or at high density. Plants with high densities tend to produce slower growth when the tree canopies begin to touch, due to greater competition for growing space (Ramadhan et.al 2023, Patabang et.al 2011). To overcome this, plants should be thinned regularly. Density is a function of diameter. The closer the plants are, the slower the tree diameter growth will tend to be (Wahyudi and Panjaitan 2011, Wahyudi and Pamoengkas 2013).

Figure 1. The 7 year old Balangeran plants in the urban forest of Pulang Pisau Regency

Plants planted with close spacing create limited growing space to develop well. Competition for growing places in a limited environment will cause the root zone in the soil to become limited and competition for the canopy to obtain optimal sunlight will also be difficult to obtain. In order to obtain good plant growth, the tree crowns must not be overlapping and this sign is also a correction to the planting distance that has been made previously (DNPI 2012, Hilwan et.al 2013, Lansberg 1986, Nyland 1996). Plants planted with wider spacing get a wider root zone and more light, which has a direct impact on their growth rate. The diameter growth of balangeran plants at the research location increases with increasing plant age as seen in Table 2, which shows that the average growth in diameter of balangeran has increased from year to year, where the largest average is achieved when the plants are 16 years old, which is equal to 19.03 cm, while the rise shows no consistent trend. Based on the standard deviation value, it can be seen that the diameter growth of balangeran has a high level of diversity, namely when the plant is 16 years old and the lowest level of diversity is when the plant is 1 year old. The value of diversity increases with increasing age.

Table 2: Calculation results of the Mean Annual Increment of Balangeran diameter

Age Plant	Diameter			MAI (cm/tahun)	SD
	Max	Min	Average		
1	0.70	0.10	0.41	0.41	0.12
2	2.30	0.80	1.51	0.76	0.35
3	10.80	2.50	6.38	2.13	1.65
4	15.00	4.00	7.86	1.96	2.09
6	15.30	6.30	10.24	1.71	1.87
7	20.70	7.74	11.97	1.71	2.46
12	26.69	6.53	11.76	0.98	3.47
16	26.97	13.54	19.03	1.19	3.58

Source: Data processed, 2024

Table 2 shows that the largest mean annual increment (MAI) was found in 3 year old plants, namely 2.13 cm year^{-1}. However, from the age of 1to 16 years, the incremental growth in diameter at age 1 is the smallest compared to the others. This is thought to be because the plants are still adapting to the new environment even though the habitat is the same. Plant growth tends to form a sigmoid (Burckhart 2003, Hauhs et.al 2003, Wahyudi 2012), that is, it grows slowly at first, then quickly and then slows down again closer to the plant cycle. The research on red meranti showed that the growth in plant diameter was initially small, then gradually increased in size (Grant et.al 1997, Setyo et.al 2012). At this stage of growth, balangeran plants still require silvicultural treatment in the form of intensive plant maintenance, such as replanting, drying, mulching and loosening. The growth of balangeran plants is also assisted by the presence of mycorrhiza with species of *Scleroderma columnare* (Laura et.al 2023) and *Scleroderma* spp. (Turjaman et.al 2011). The presence of mycorrhiza can also inhibit the presence of plant disease (Rahmanto, 2012, Triwibowo et.al 2014).

B. Growth Equation Model

The growth and yield of forest stands in quantitative terms can be described through a plant growth model that forms a multiple regression equation (Hauhs et.al 2003). Tree growth is not actually linear, but forms a parabolic sigmoid pattern which is described through multiple regression equations (Bettinger et.al 2009, Burckhart 2003, Hauhs et.al 2003, Wahyudi 2012). This equation is usually formed based on a function of time based on the condition and size of the diameter, height or volume of the tree. Based on this model, stand conditions can be projected at each age, thereby enabling managers to obtain the information needed to make management decisions, including those related to determining cutting cycles based on sustainability. The results of modeling the diameter growth equation of balangeran plants using the following rational equation:

$$y = \frac{-6.94 + 7.26\,x}{1 + 0.48\,x + (-0.01)\,x^2}$$

Where,
y : final diameter (cm)
x : time (year)
a, b, c, d : constant.

C. Test the Growth Equation Model

The rational growth model for balangeran plant diameter was carried out with validation tests, accuracy tests and coefficient of determination values. The validation test was carried out by comparing the projected plant diameter results from modeling (expected) with actual plant diameter data from measurements in the field (observed) (Sudjana 1988). The results of this test will determine whether the two data are homogeneous (valid) or heterogeneous (different). Based on the results of the validation test, the calculated Chi square (χ^2) value was:

2.48, which is smaller than the Chi square (χ^2) value of table $_{(7,0.95)}$: 14.07 (accept H0) so that the rational equation model is valid. A valid model can be used to predict the achievement of results based on the desired time.

Mean absolute percentage error (MAPE) is a model error indicator that determines the level of accuracy of a model. Based on the results of the MAPE analysis of the balangeran plant diameter growth equation model, a model accuracy value of 75.45% was obtained so that the model is accurate so it can be used. This model has a coefficient of determination of 80% so that plant age can determine the diameter of balangeran plants growing in peat swamp land.

D. Harvest Time for Balangeran Plants

The harvest time for balangeran plants is determined based on the average diameter achieved. The quality of the results is determined by the level of data distribution which forms a bell-like curve (Burckhart 2003, Wahyudi 2013). Based on the balangeran plant diameter growth equation model which is valid, accurate and has a high coefficient of determination (80%), a table of the attainment of balangeran plant diameter at a certain age can be prepared (Table 3).

Balangeran plants grow in swamp, peat and heath land (Balitan 2012, Indriani et.al 2019, Mc Kinnon et.al 2000, Wahyudi 2012). This plant is able to grow in flooded and dry areas (Atmoko 2011, Indriani et.al 2020, Wibsonono et.al 2005). Based on survey results in the Tumbang Nusa and Jabiren areas, Pulang Pisau Regency, people produce and trade balangeran wood with a diameter of 20 cm to 30 cm. This wood can be used for foundations, bridges and various other uses that require high strength and durability of wood. Based on Table 3, the harvest time for balangeran plants when they reach a diameter of 30.97 cm is 29 years. If stakeholders want balangeran wood with a diameter of 25 cm, then a good harvest time is at the age of 25 years, because at that time the average diameter of balangeran plants has reached 25.56 cm.

Table 3: Prediction of the attainment of balangeran plant diameter results at a certain age using a rational equation model

Year	D (cm)		Year	D (cm)		Year	D (cm)
2	2,91		12	14,70		22	22,44
3	5,46		13	15,39		23	23,41
4	7,28		14	16,09		24	24,45
5	8,69		15	16,80		25	25,56
6	9,84		16	17,52		26	26,76
7	10,82		17	18,26		27	28,05
8	11,70		18	19,02		28	29,45
9	12,51		19	19,82		**29**	**30,97**
10	13,26		20	20,65		30	32,63
11	13,99		21	21,52		31	34,47

Source: Data processed, 2024

Table 3 can be used by stakeholders to predict the diameter of balangeran plants at a certain age. This achieved plant diameter can be converted into volume using the volume table of balangeran plant or using the results of measuring the free height of plant branches. Furthermore, the volume of wood obtained can be converted into financial value per m^3 of logs for economic analysis of balangeran plant cultivation in peat swamp land.

This table is only used for balangeran plants planted on peat land with a thickness of no more than 3 meters, especially in the Pulang Pisau Regency area, Central Kalimantan Province, Indonesia. If the table will be used in other regions, it is recommended to revalidate it.

4.Conclusions

A. Conclusion

The average growth in diameter of balangeran plants (*Shorea balangeran* Korth. Burck) at the ages of 1, 2, 3, 4, 6, 7, 12 and 16 years is 0.41cm, 1.51 cm, 6.38 cm, 7.86 cm, 10.24 cm, 11.97 cm, 11.76 cm and 19.03 cm respectively with the highest MAI at the age of 3 years, namely 2.13 cm/year.

A valid rational equation model to describe the diameter growth of balangeran plants, with an accuracy of 75.45 % and a coefficient of determination of 80 %, namely:

$$y = \frac{-6.94 + 7.26\,x}{1 + 0.48\,x + (-0.01)\,x^2}$$

This model predicts the harvest time for balangeran plants at the age of 29 years, namely when the average plant diameter reaches 30.97 cm.

B. Suggestions

1. It is necessary to carry out further research on the similarities in plant growth in different site conditions
2. Further research needs to be carried out regarding the financial feasibility of cultivating balangeran plants

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