Establishment of Growth and Yield Plots of *Dalbergia latifolia* in Java and West Nusa Tenggara, Indonesia

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On behalf of the project team,

Dr. Kusumadewi Sri Yulita
Project Team Leader

ACRONYMS AND ABBREVIATIONS

BKSDA	Conservation of Natural Resources Regional Office (*Balai Konservasi Sumber Daya Alam*)
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CTSP	CITES Tree Species Programme
cm	centimeter
D	*Dalbergia*
dbh	diameter at breast height
GPS	Global Positioning System
ha	hectare
KPH	Forest Management Unit (*Kesatuan Pengelola Hutan*)
m	meter
mm	millimeter
m^3	cubic meter
n.a	not available
NDF	Non-detriment Findings
NTB	West Nusa Tenggara (*Nusa Tenggara Barat*)
UTM	Universal Transverse Mercator

EXECUTIVE SUMMARY

This research established six growth and yield plots in three regions, namely, West Java, Yogyakarta, and West Nusa Tenggara, to estimate the growth and yield of *D. latifolia* (rosewood or *sonokeling*) and to study the effect of rainfall patterns on rosewood growth. Field data collection on growth parameters, such as diameter, was carried out to estimate tree volume and annual growth increment. Unfortunately, due to the Covid-19 pandemic, data collection from the established plots was only conducted in two regions instead of three.

The plots in West Java, Yogyakarta, and West Nusa Tenggara were established based on the different climatic conditions. In West Java, the three plots were established in Cikepuh, Gunung Batu Village, Ciracap Sub-district, Sukabumi Regency, which is geographically located in latitudes 7^{o} 17' 28'' S-7^{o} 17' 55'' S and longitudes 106^{o} 25' 44'' E-106^{o} 25' 33''E in a conservation area with good stand condition. The climatic conditions data showed that West Java has an annual rainfall of 3,000 to 4,000 mm with more than two peaks of rainfall in a year (multiple waves pattern). These conditions are believed to affect the growth of *D. latifolia.* The average diameter of *D. latifolia* from the three plots (West Java 1, 2, 3) in Sukabumi, West Java were 15.1 cm, 16.4 cm, and 39.8 cm, respectively; diameter increments of West Java 1, 2, and 3 were 1.4 cm/year, 1.0 cm/year and 1.4 cm/year, respectively; and standing stock volumes of West Java 1, 2, and 3 were 54 m^3/ha, 92.7 m^3/ha, and 233.7 m^3/ha, respectively. In Yogyakarta, the plots were located in Imogiri in latitudes 7^{o} 55' 8'' S-7^{o} 56' 42'' S and longitudes 110^{o} 23' 33'' E-110^{o} 23' 30'' E. It has an annual rainfall of 1,000 to 2,000 mm with two peaks of rainfall in a year (double waves pattern). The three plots (Yogyakarta 1, 2, 3) in Imogiri, Yogyakarta had an average diameter of 21.6 cm, 18.9 cm, and 20.1 cm, respectively; diameter increment of 1.1 cm/year, 1.2 cm/year and 0.7 cm/year, respectively; and standing stock volumes of 31.3 m^3/ha, 22.5 m^3/ha, and 36 m^3/ha, respectively. In West Nusa Tenggara, three plots were established on the Sumbawa island (West Nusa Tenggara 1, 2 and 3) and one plot in Lombok Barat (West Nusa Tenggara 4), which are geographically located in latitudes 8^{o} 32' 39'' S-8^{o} 28' 42'' S and longitudes 117^{o} 28' 19'' E-116^{o} 3' 13'' E. The annual rainfall was 1,000 to 2,000 mm with only one peak of rainfall in a year (single wave pattern). The average diameters recorded in West Nusa Tenggara 1, 2, 3, and 4 were 33.5 cm, 24.3 cm, 32.7 cm and 25.5 cm, respectively; and the standing stock volumes were 178.8 m^3/ha, 58.5 m^3/ha, 222 m^3/ha and 82.9 m^3/ha, respectively. In this area, the annual diameter data could not be collected. Therefore, the increment information is not available.

Each location has a different environmental condition, and many factors affect the growth of *D. latifolia.* The drier areas are expected to be more suitable habitats which yield a higher quality of rosewood heartwood*.* Furthermore, the easy regeneration capacity of *D. latifolia* also supports the yield of a stand which is affected by the number of individuals in a particular area. *D. latifolia* is relatively easy to be propagated. Hence, it is grown as an inter-cropping species and rarely cultivated in a monoculture system. *D. latifolia* as an inter-cropping species made the management activities of this species less intensive. Furthermore, the annual rainfall and its pattern would affect the diameter increment of *D. latifolia*. In West Java 1 and

3, the annual precipitation of 3,000-4,000 mm had resulted in a higher increment of 1.4 cm/year compared to the diameter increment in Yogyakarta 3 of only 0.7 cm/year, with annual precipitation of 1,000-2,000 mm.

1. INTRODUCTION

Dalbergia latifolia, which is commonly known as *sonokeling* or rosewood, is one of the tree species with high economic wood value. It is commonly used in making musical instruments with a distinctive style of luxurious impression. The distribution of rosewood in Indonesia is spread over several areas, both in state-owned forests and community-owned yards. With these conditions, the real potency of rosewood in Indonesia still needs to be studied. Until now, *D. latifolia* is included in Appendix II of CITES, in which international trade needs to be regulated and controlled to prevent its extinction. Therefore, the Indonesian CTSP project, among others, is to prepare a Non-Detriment Findings (NDF) report on *D. latifolia* to ascertain that the international trade of rosewood will not endanger its natural population.

The establishment of the growth and yield plots is to produce data on diameter, wood volume, and annual diameter increment from each growth and yield plot located in three rainfall regions in West Java, Yogyakarta, and West Nusa Tenggara. The collected data would be used to determine the allowable annual cut used in the preparation of the NDF report. The data collection was quite challenging because not all the rosewood potentials were recorded. They are often found on community land which can be easily traded without official registration.

The increment is one of the most important and basic information in forest management planning (Kainde, 2021). This information is needed in yield regulation, which determines the amount that could be harvested each year, thus enhancing resource preservation and exploitation sustainability (Krisnawati and Wahjono, 2004). Therefore, it is necessary to collect information or data related to its growth to maintain the sustainability of natural rosewood populations.

2. MATERIALS AND METHOD

2.1 Site Selection

The three regions selected for establishing the growth and yield plots were based on differences in climatic conditions, especially rainfall: low (1,000-2,000 mm/year) and high (3,000-4,000 mm/year); and rain pattern which is a single wave (one peak of rainfall in a year, most probably occurring during the months of December-January), double waves (two peaks of rainfall in a year, most probably occurring during the months of November-February), and multiple waves (more than two peaks of rainfall in a year during the months of January-December). In West Java, the three plots were established in Cikepuh, Gunung Batu Village, Ciracap Sub-district, Sukabumi Regency, which is geographically located in latitudes 7^{o} 17' 28'' S-7^{o} 17' 55'' S and longitudes 106^{o} 25' 44'' E-106^{o} 25' 33'' E, in a conservation area with good stand condition. The climatic conditions data showed that West Java has an annual rainfall of 3,000 to 4,000 mm with more than two peaks of rainfall in a year (multiple waves pattern). In Yogyakarta, the plots were located in Imogiri in latitudes 7^{o} 55' 8'' S-7^{o} 56' 42'' S and longitudes 110^{o} 23' 33'' E-110^{o} 23' 30'' E. It has an annual rainfall of 1,000 to 2,000 mm with two peaks

of rainfall in a year (double waves pattern). In West Nusa Tenggara, three plots were established on the Sumbawa island (West Nusa Tenggara 1,2 and 3) and one plot in Lombok Barat (West Nusa Tenggara 4), which are geographically located in latitudes 8° 32' 39'' S-8° 28' 42'' S and longitudes 117° 28' 19'' E-116° 3' 13'' E. The annual rainfall was 1,000 to 2,000 mm with only one peak of rainfall in a year (single wave pattern). In addition, the criteria for selecting the locations of the growth and yield plots were (i) accessibility needs to be easy; (ii) long-term measurements are secured; and (iii) priority to be given to state forests or conservation areas. The distribution of the regions is in **Figure 1**.

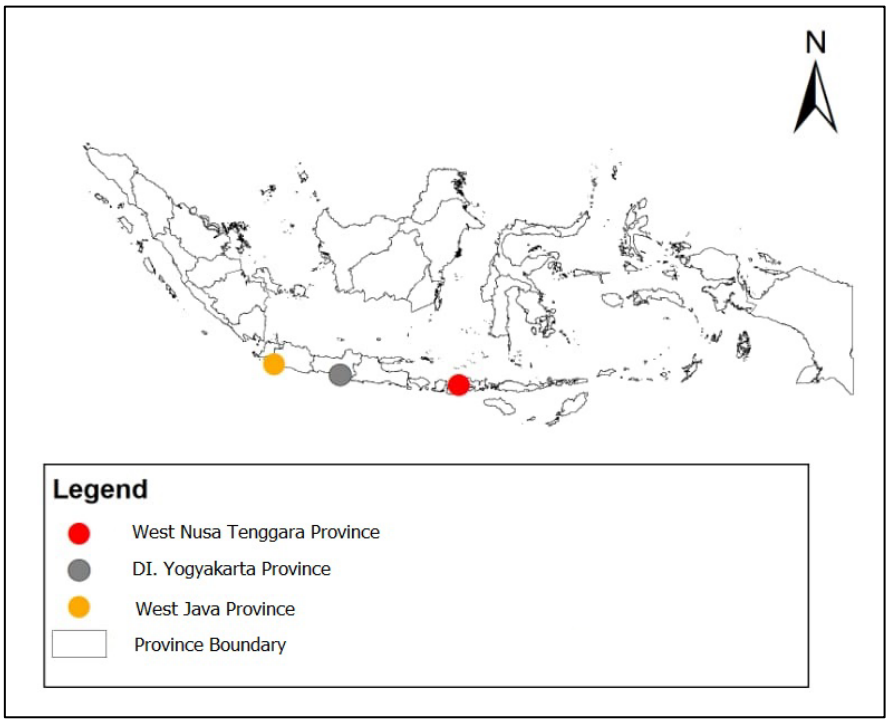

Figure 1. The location of the three regions where the growth and yield plots were established

2.2 Plot Establishment

Pre-survey was conducted through intensive discussion with the regional forestry conservation office to determine the suitable location for establishing the growth and yield plots. This was followed by several field visits and observations of the location suggested by the regional forestry conservation office. During the field visit, the coordinates of the locations were also recorded. The plots were established in suitable areas based on the criteria mentioned in 2.1. In each region, three plots of 20 m x 20 m or 0.04 ha per plot were established which included sub-plots of 10 m x 10 m, 5 m x 5 m and 1 m x 1 m in each plot. All the growth and yield plots were established in accordance with the guidelines in **Appendix 1**.

2.3 Measurement Recorded

All the individual trees with a diameter at breast height (dbh) of 15 cm and above (commercial trees) in the 20 m x 20 m plot were measured. The number of individuals or seedlings (height <150 cm) was recorded in the sub-plot of 1 m x 1 m. In the sub-plot of 5 m x 5 m, saplings with a diameter <10 cm and height >150 cm were recorded. In the sub-plot of 10 m x 10 m, poles with a diameter of 10-20 cm were recorded. The data on rosewood timber volume was computed by converting its diameter to volume using an estimation table of rosewood volume developed by Siswanto and Imanudin (2008).

Measurements to determine annual diameter increments were carried out in West Java and Yogyakarta annually, except for NTB. Other than the diameter, the other data recorded were the number of individual trees at various stages of growth, the tree form, height, and ecological parameters. The measurement would be conducted annually to keep the data updated. On the other hand, the complete data from those plots would form a reliable database for determining the yield of *D. latifolia.* The complete recorded data (the most relevant data) are in **Table 1** and are inseparable from this report.

3. RESULTS AND DISCUSSION

3.1. Diameter and Volume

Annual data on diameter measurements were successfully recorded from the growth and yield plots in West Java and Yogyakarta, as shown in **Table 1**. The plots were established in three locations with varying climatic conditions, namely in Cikepuh, West Java, located in Gunung Batu Village, Ciracap Sub-district, Sukabumi Regency; Imogiri in Yogyakarta; and Sumbawa, Sumbawa Barat, and Lombok Barat in West Nusa Tenggara. The largest average diameter was achieved by *D. latifolia* stand in West Nusa Tenggara 1, 2, 3 and 4 which were 33.5 cm (325 individuals of commercial trees), 24.3 cm (250 individuals of commercial trees), 32.7 cm (575 individuals of commercial trees) and 25.5 cm (400 individuals of commercial trees), respectively; followed by West Java 1, 2 and 3 which were 15.1 cm (425 individuals of commercial trees), 16.4 cm (650 individuals of commercial trees), and 39.8 cm (425 individuals of commercial trees), respectively; and Yogyakarta 1, 2 and 3 which were 21.6 cm (200 individuals of commercial trees), 18.9 cm (100 individuals of commercial trees), and 20.1 cm (200 individuals of commercial trees), respectively. The diameter increments were only recorded in West Java and Yogyakarta. Diameter increments in West Java 1, 2 and 3 were 1.4 cm/year, 1.0 cm/year and 1.4 cm/year, respectively; and diameter increment in Yogyakarta 1, 2 and 3 were 1.1 cm/year, 1.2 cm/year and 0.7 cm/year, respectively. Each of these stands had a different planting year. However, the planting years were just an estimation from the local authorities. Regarding the condition of the stand, some stands are grown in a state-owned forest (West Nusa Tenggara), as well as in a conservation area (West Java and Yogyakarta).

Figure 2. Three growth and yield plots established in Cikepuh Wildlife Sanctuary Sukabumi, Imogiri Nature Reserve Yogyakarta, and Protected Forest in Sumbawa Besar, West Nusa Tenggara

Diameter growth is influenced by several factors, including climatic and edaphic factors. From the diameter data that has been obtained, the volume of a stand can be estimated as in **Table 1**.

Table 1. The average diameter and diameter increment of *Dalbergia latifolia*

Location, City (Province)	Rainfall (mm/year)	Rain pattern	Average diameter (cm) in 2020	Average diameter (cm) in 2021	Diameter increment (cm/year)	Number of commercial trees (diameter >15 cm) per ha	Total standing stock (m^3/ha)
Sukabumi (West Java 1)	3,000- 4,000	Fluctuate[1] (multiple waves)	13.7	15.1	1.4	425	54.0
Sukabumi (West Java 2)	3,000- 4,000	Fluctuate (multiple waves)	15.4	16.4	1.0	650	92.7
Sukabumi (West Java 3)	3,000- 4,000	Fluctuate (multiple waves)	38.4	39.8	1.4	425	233.7
Imogiri (Yogyakarta 1)	1,000 – 2,000	Double[2] (double waves)	20.5	21.6	1.1	200	31.3
Imogiri (Yogyakarta 2)	1,000 – 2,000	Double (double waves)	17.7	18.9	1.2	100	22.5
Imogiri (Yogyakarta 3)	1,000 – 2,000	Double (double waves)	19.4	20.1	0.7	200	36.0
Sumbawa (West Nusa Tenggara 1)	1,000 – 2,000	Single[3] (single wave)	-	33.5	n.a	325	178.8
Sumbawa Barat (West Nusa Tenggara 2)	1,000 – 2,000	Single (single wave)	-	24.3	n.a	250	58.5
Bima (West Nusa Tenggara 3)	1,000 – 2,000	Single (single wave)	-	32.7	n.a	575	222
Lombok Barat (West Nusa Tenggara 4)	1,000 – 2,000	Single (single wave)	-	25.5	n.a	400	82.9

[1] There are more than two peaks of rainfall in a year
[2] There are two peaks of rainfall in a year
[3] There is only one peak of rainfall in a year

3.2. Increment

According to Vanclay (1994), the increment is an increase in the dimensions of one or more trees in a forest stand during a certain time interval or period. The information on the stand increment will determine various management policies, including the length of the cutting cycle, annual cutting allowance, cutting diameter limits, and silvicultural treatments required (Kuswandi and Nugroho, 2019). Therefore, by having adequate knowledge of the rosewood growth and increment, policies related to the management and trade in rosewood can be effectively regulated.

Several field activities, such as field measurement to record annual diameter data in West Nusa Tenggara Province had been delayed due to the high number of Covid-19 cases in Indonesia. Therefore, the data of diameter increment was only recorded from two regions, namely, Yogyakarta (three sites) and West Java (three sites). The difference in the value of the diameter increment from these areas is expected to be due to the influence of climatic conditions. The diameter increments obtained from the three growth and yield plots located in Cikepuh, Gunung Batu Village, Ciracap Sub-district, Sukabumi Regency, namely, West Java 1, 2 and 3 were 1.4 cm per year, 1.0 cm per year, and 1.4 cm per year, respectively; and standing stock volumes of 54 m^3/ha, 92.7 m^3/ha, and 233.7 m^3/ha, respectively. Meanwhile, the diameter increments in the three locations in Imogiri, Yogyakarta, namely, Yogyakarta 1, 2 and 3 were 1.1 cm per year, 1.2 cm per year, and 0.7 cm per year, respectively; and standing stock volumes of 31.3 m^3/ha, 22.5 m^3/ha, and 36 m^3/ha, respectively, as in **Table 1**. The record of standing stock volumes in West Nusa Tenggara 1, 2, 3, and 4 were 178.8 m^3/ha, 58.5 m^3/ha, 222 m^3/ha, and 82.9 m^3/ha, respectively. The diameter increment is influenced by factors such as soil fertility, climate, and water availability (Dina, 2012).

Soekotjo (1976) stated that plant growth is influenced by two main factors, namely internal and external factors, which are also known as genetic (permanent) and environmental (changing) factors, which are effective in influencing the life of a plant community. In addition, Soekotjo (1976) further elaborated on the external factor as follows:

(i) Climatic factors are closely related to the state of the atmosphere that affect a plant's life, including climate, rainfall, and humidity.
(ii) Edaphic factors, those related to the state of the soil.
(iii) Physiographic factors are the conditions that determine the shape and structure of the earth's surface.
(iv) Botanical factors are those related to the influence of the plant’s gene.

Some of the factors above are expected to greatly influence the differences in stand conditions and growth of *D. latifolia* in each of the 10 study locations.

4. CONCLUSION

The increase of rosewood diameter in the Cikepuh Wildlife Sanctuary ranges from 1.0 cm/year to 1.4 cm/year, while those in the Imogiri Nature Reserve range from 0.7 cm/year to 1.2 cm/year (**Table 1**). Meanwhile, the diameter increment of the rosewood in West Nusa Tenggara was not available because it had only been measured once. The population of rosewood in the survey areas in Java and West Nusa Tenggara showed high natural regeneration of rosewood which was considered abundant. Communities will not damage the saplings due to the high value of rosewood and cattle are considered not a threat because the stands are maintained by their owners. However, the long dry season has the potential to reduce the number of rosewood saplings.

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APPENDIX 1.

GUIDELINES FOR ESTABLISHING GROWTH AND YIELD PLOTS OF *Dalbergia latifolia*

1. INTRODUCTION

Since the inclusion of rosewood (*Dalbergia latifolia*) as a threatened tree species (CITES 2017) in Appendix II of CITES in 2016, its price has soared, making it one of the most expensive timbers in Indonesia. This significant price increase has encouraged an increase in logging intensity, which is feared to threaten the species sustainability. Therefore, to ensure its sustainability during the cultivation process, it is necessary to have a mechanism and procedure for its exploitation by paying attention to the information regarding the increment of growth and potential of the wood needed.

Growth and yield plots are areas designated to collect data to estimate the increment of growth regularly and the potential of timber yield from the represented area. This information is used to determine policies and rules for sustainable management of the rosewood forest.

The scope of these guidelines is the procedure for establishing growth and yield plots, measuring the number of individual rosewood trees at various growth stages, and determining the tree diameter and height. The resulting information, among others, will be used as the basis for determining the allowable annual cut in the preparation of a NDF protocol needed in the global trade in rosewood timber.

2. PURPOSE

These guidelines act as a guide for field implementers, researchers, and CTSP project partners in implementing growth and yield plots preparation, establishment and measurement. The growth and yield plots are means to assess the potential and growth of rosewood and the volume of wood that could be harvested.

3. METHOD

Growth and yield plots of rosewood will be established in three regions (province), namely, West Java, Central or East Java, and West Nusa Tenggara, representing areas with high, moderate, and low rainfall. At each location, three growth and yield plots will be established with sizes ranging from 20 m x 20 m (400 m^2) to 50 m x 50 m (2,500 m^2), depending on the density of the rosewood stands in the areas. The design of the plot layout of a 20 m x 20 m growth and yield plot is as in **Figure 1**, for example. The placement of the growth and yield plot should be determined purposively in areas where there are rosewood stands. After

establishing the growth and yield plot, the abundance of standing stock, such as the number of individual trees at various stages of growth, diameter, height and ecological parameters, is measured and recorded at least once a year.

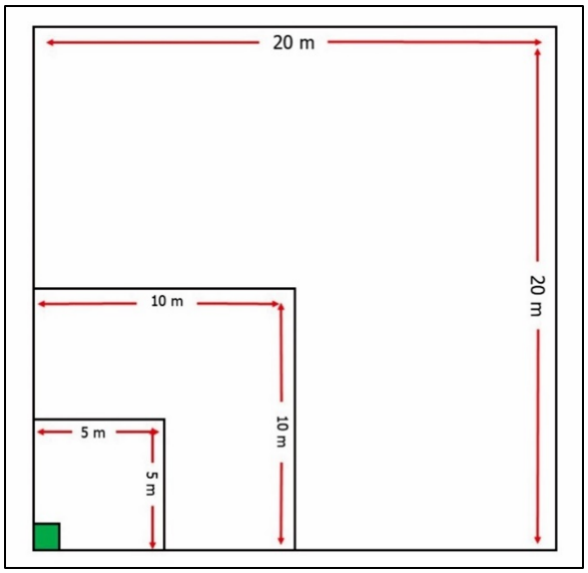

Figure 1. Design of the growth and yield plot. (The green quadrangle (1 m x 1 m) is for measuring the number of seedlings (height below 1.5 m); the 5 m x 5 m quadrangle is for measuring the number of saplings (height above 1.5 m, diameter below 10 cm); the 10 m x 10 m quadrangle is for measuring individuals at pole stage (diameter above 10 cm - 20 cm); the 20 m x 20 m quadrangle is for measuring the tree (diameter above 20 cm)

4. PROCEDURES

The growth and yield plots of rosewood should be established within their distribution areas, either in the community or in natural forests. The stages of activities in the development of the growth and yield plot are described as follows (Curtis and Marshall 2005; Hurst and Allen 2007; Imanudin and Wachjono 2006):

1. Collect information on the distribution of rosewood at the Office of the Forestry Service, BKSDA (Conservation of Natural Resources Regional Office), or KPH (Forest Management Unit) (**Figure 2**). Based on the information collected above, the ideal location is determined for the establishment of the growth and yield plot which should also consider its accessibility and the abundance of trees.

Figure 2. Discussion with local institution

2. Conduct a pre-survey in the area proposed as the location for the growth and yield plot, and determine the position of the permanent plot by sampling (**Figure 3**).
3. Collect information on the planting year from the landowner.
4. Record the history of exploitation of rosewood, such as information on harvesting carried out in the area.

Figure 3. Initial survey, collect and record information from land owner

5. Record the Universal Transverse Mercator (UTM) coordinates of the plot by using GPS and place the position of the plot on a topographic base map of 1:50,000 or higher (**Figure 4**).

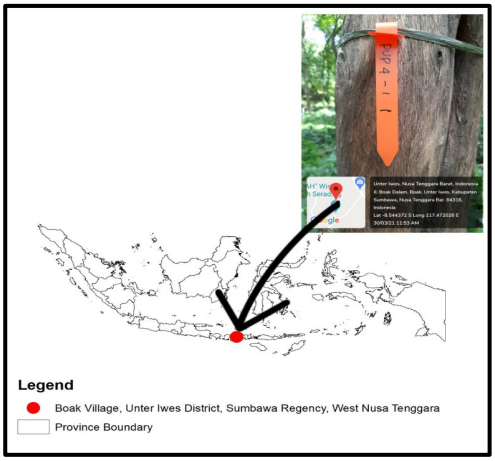

Figure 4. Record coordinates and mark it on the map

6. For ease of finding the plot in the next measurement, the plot position should be referenced to the nearby permanent point, such as river bridges, houses of worship, etc. (**Figure 5**).

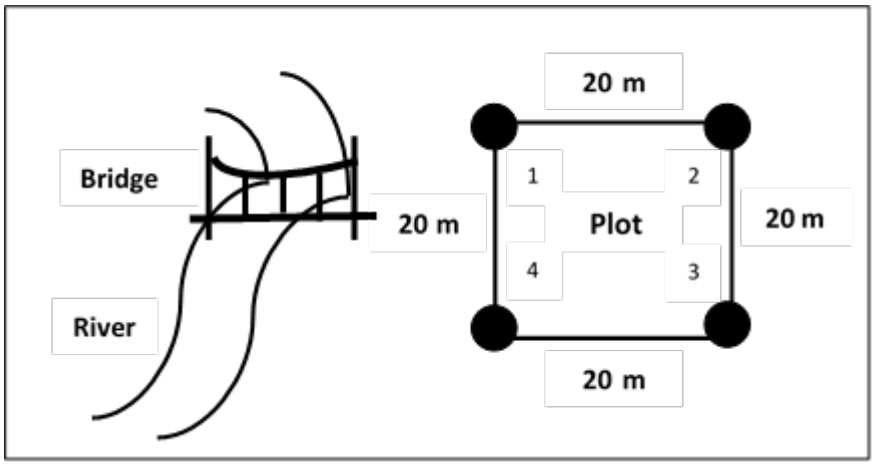

Figure 5. Mark the plot position

7. Carry out measurements and recording of stand abundance (**Figure 6**):
   - Record the number of individuals at the seedling, sapling, pole, and tree stage
   - Measure diameter at breast height (dbh) of 130 cm from the forest floor for individual pole and tree
   - Measure branch-free and the total height of individual poles and trees
   - Record the physical condition of the tree/pole, such as health, straightness, clear bole, etc.

Figure 6. (a) Measurement and recording of standing stock
(b) Growth and yield measurement sheet

8. Number all individual poles and trees and mark with strong and good labels without injuring the plant (**Figure 7**).
9. The data obtained is then used to estimate the potential volume of the tree and its growth.
10. Record ecological parameters such as rainfall, altitude, soil type, and existing plant associations.

Figure 7. Numbering all trees in the growth and yield plot

11. Record measurement data using the attached Growth and Yield Measurement Sheet.
12. Document the activities in establishing the growth and yield plot in the form of digital photos.

Note:
- Seedling stage: height below 1.5 m
- Sapling stage: height above 1.5 m, diameter below 10 cm dbh
- Pole stage: diameter above 10 cm dbh, up to 20 cm dbh
- Commercial tree: diameter above 15 cm dbh

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GROWTH AND YIELD MEASUREMENT SHEET

Location:

- Village: .....
- Sub-District: .....
- City/Regency: .....
- Province: .....

Number of PSP: .....

PSP Size and Area: ..... Number of saplings: .....

Rainfall: ..... Record/measurement date: .....

Altitude: ..... Name of recorder: .....

Soil type: ..... Resource person: .....

Plant associations: ....

Number of seedlings: ....

Tree number	Diameter	Height (clear bole height/total)	Tree physical condition

Tree number	Diameter	Height (clear bole height/total)	Tree physical condition