Root Morphological Analysis of 10 Forest Tree Species in an Effort to Design a Rooter System in the Bukit Barisan Forest

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Abstract: Forests have gave us an education in building a good ecosystem balance. This balance causes flooding during the rainy season. This is contrary to conditions in urban areas which often experience flooding during the rainy season. Therefore, the behavior of forest vegetation in treating nature needs to be studied further, especially tree roots. Roots in trees are a very important foundation for tree growth and development. Not only does it provide mechanical reinforcement to maintain the straight-up structure of a tree, but it is also essential for the absorption of water and minerals. In its growth the roots are the most important part of the tree to be able to maintain its life. Roots have the task of strengthening the establishment of plants, absorbing water and nutrients dissolved in it from the soil, and sometimes as a place to store food. This research can provide information about the root behavior of several forest tree species and the optimization of land use. There were ten types of trees studied, namely Pinus (*P. merkusii*), Eucalyptus (*E. grandis*), Jackfruit (*A. heterophyllus*), Jengkol (*A. pauciflorum*), Rambutan (*N. lappaceum*), Cinnamon (*C. burmannii*), Petai (*P. speciosa*) and Meme (*A. angustiloba*). Parameters observed were root behavior, root shape and root size. The results showed that the root behavior of each tree was different with varying lengths and angles ranging from 10-65o, lateral root lengths ranging from 300-570 cm with root diameters of mature trees 10-28.8 cm, taproot depth as deep as 1.5-2 m.

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1 INTRODUCTION

Roots in trees are a very important foundation for tree growth and development. Not only does it provide mechanical reinforcement to maintain the straight-up structure of a tree, but it is also essential for the absorption of water and minerals. In fact, the health and vigor of the root system strongly underlie the overall health and vigor of the tree, so ideally, silvicultural treatment should be based on balanced root and crown characteristics. The root system is relatively little known because of the unavoidable difficulty of studying roots without at the same time changing their growing conditions. Characteristics of tree roots vary widely between species, individuals within the same species, and even among different roots within an individual tree. Lateral spread of the root system is usually 2 to 5 times the crown radius, becoming greater in poor growing sites and in drier conditions. The extensive lateral development of the tree's root system means that generally the highest concentrations of food-absorbing fine roots are present at some distance from the trunk. This fact has a clear relationship with fertilizer placement (Daniel et al, 1987).

Roots are the lower part of the plant axis and usually develop below the soil surface, although there are also roots that grow outside the soil. A good root system allows plants to get the necessary resources in sufficient quantities. Bahuguna and Bhatia (2010) stated that dry matter from photosynthesis is a source of energy for cell division and enlargement which results in an increase in plant height. Knowledge of root characteristics as influenced by management and growing conditions is very important for optimizing land use (Schroth, 1995).

According to Bahuguna and Bhatia (2010) in a forest ecosystem, trees are vegetation that cannot be separated from the area, trees are the largest carbon sinks and become vegetation that plays a very important role in maintaining ecosystems, maintaining soil fertility, preventing erosion, flooding and contributing the largest oxygen. . To

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maintain the growth and development of the tree, the root is one part of the tree that needs to be considered, including the system, as well as the behavior of the tree's roots. Because the system and how the behavior of the roots on a tree greatly affect its growth and development. The behavior of tree roots needs to be known to study how forests treat nature so that the balance of the ecosystem can be maintained. The shape of the roots of this tree can be imitated to create an optimal water absorption system in order to prevent flooding in the city area.

2 MATERIALS AND METHODS

This research was carried out in the Bukit Barisan National Park (TMBB) forest, precisely in the Sibolangit Village area, Deli Serdang Regency. This forest is located at an altitude of 700-1250 masl with an annual average temperature of 19.60C and humidity in the range of 85% - 89% and with an average humidity of 87%. This research lasted for 3 months starting from April to June 2017.

The tools used in this study were hoe, meter, digital camera, machete, spray and stationery. The research material used was the roots of 10 dominant tree species found growing in this forest area.

The trees studied consisted of 10 different species, the most dominant species appearing in the TNBB forest area which had the largest height and diameter. Furthermore, data for all sample trees were recorded, such as tree height, branch-free height and tree diameter.

Excavations adjacent to tree roots were carried out to examine the behavior of tree roots in forest areas as deep as the roots of the tree to be studied. Damage to the roots should not occur when excavation is carried out to prevent damage to the roots and the tree.

After doing the excavation, the root depth was measured from the soil surface, measured the diameter at the largest root, estimated the average angle between the roots and the soil surface and measured the length of the lateral roots. These measurements were carried out with the aim of knowing the relationship between rooting and tree age in one species and knowing the relationship between root behavior and optimization of land use (Hidayat, 1995).

Observations were made on the behavior of tree roots in penetrating the soil and adapting to the horizon or differences in the soil layers, as well as observing the behavior of roots towards growing places dominated by rocks, to high humidity, to fertile soil, to soils with a high level of drought and to soils with high levels of drought. soil that is difficult for the roots of the tree to penetrate.

Furthermore, observations were made on the shape of the tree roots of each individual to be observed, the shape of the roots on the taproot, lateral roots and adventitious roots. Measurements on the roots of the trees studied included lateral root length and root diameter with a distance of about 30 cm from the base of the tree trunk and observed changes in root colour along with the depth of the soil that had been excavated. Observation activities were carried out using descriptive methods, namely observing directly in the field.

3 RESULTS AND DISCUSSION

The trees studied consisted of 10 different tree species that were dominant in the TNBB forest. The measurement results obtained from the 10 tree species studied in the TNBB Forest are as follows:

Table 1. Characteristics of Trees Researched with Different Types and Ages in TNBB Forests

No	Local Name	Species	Tree Age (Year)*
1	Pinus	*Pinus merkusii*	20
2	Nangka	*Artocarpus heterophyllus*	20
3	Rambutan	*Nephelium lappaceum*	15
4	Petai	*Parkia speciosa*	20
5	Jengkol	*Archidendron pauciflorum*	20
6	Dadap	*Erythrina subumbrans*	25
7	Eucalyptus	*Eucalyptus grandis*	15
8	Alpukat	*Persea Americana*	25
9	Meme	*Alstonia angustiloba*	25
10	Kayu manis	*Cinnamomum burmanni*	15

Note: *The age of the tree is known by receiving information directly from the community at the research site.

The trees studied differ based on the type and age level of the tree. The age of the tree is known by asking directly to the people who are in the research location. Each tree has an age ranging from 15 years to 25 years. The purpose of taking tree age data was to determine the relationship between tree age and root diameter, root depth from the soil surface, estimated total root depth, estimated average angle and lateral root length. Tree age data collection also aims to find out how it relates to root behavior and root forms of the tree. After that, the root behavior and root shape will be known at a certain age class.

Table 2. Characteristics of Tree Roots Researched Based on Tree Diameter, Tree Height and Branch-Free Height

No	Local Name/Species	Tree Diameter (cm)	Tree Height (cm)	Height of Free Branch (m)
1	Pinus (*P. merkusii)*	57.9	25	3
2	Nangka (*A. Heterophyllus)*	41.8	17.5	1.5
3	Rambutan (*N. lappaceum)*	33.1	13.5	4.5
4	Petai (*P. speciosa)*	39	17	5.5
5	Jengkol (*A. pauciflorum)*	28.7	12	2
6	Dadap (*E. subumbrans)*	52	18.5	2
7	Eucalyptus (*E. grandis)*	40.7	18.5	7.5
8	Alpukat (*P. americana)*	45.2	15.2	5
9	Meme (*A. angustiloba)*	44.1	14.5	4.5
10	Kayu manis (*C. burmannii)*	41	16.4	3.5

Tree diameter, tree height and branch-free height were different among the ten tree species studied. Based on field data, the species with the largest diameter is Pinus (*P. merkusii*) and the species with the lowest diameter is Rambutan (*N. lappaceum*). The species with the largest tree height was Pinus (*P. merkusii*) and the species with the lowest tree height was Jengkol (*A. pauciflorum*). The species with the largest free branch height was Eucalyptus (*E. grandis*) and the species with the lowest free branch height was Jackfruit (*A. heterophyllus*).

Measurements of tree diameter, tree height and branch-free height were carried out to determine the relationship with root behavior and root forms. The difference in the size of tree diameter, tree height and branch-free height between the ten tree species caused a comparison between the behavior of the root of one species and the behavior of the root of another species could not be done. The behavior of tree roots and root form will be known based on the class of tree diameter, tree height and branch-free height.

Table 3. Condition of Tree Roots Researched in TNBB Forest

No	Local Name/Species	Root depth from soil surface (cm)	Estimated total depth root (m)	Root diameter (cm) *
1	Pinus (*P. merkusii)*	25	2	22.6
2	Nangka (*A. Heterophyllus)*	35	1.8	21.9
3	Rambutan (*N. lappaceum)*	3	1.5	7.3
4	Petai (*P. speciosa)*	35	2	22.4
5	Jengkol (*A. pauciflorum)*	35	2	14.3
6	Dadap (*E. subumbrans)*	30	1.8	22.6
7	Eucalyptus (*E. grandis)*	25	2	12.4
8	Alpukat (*P. americana)*	30	1.9	28.8
9	Meme (*A. angustiloba)*	25	2	16
10	Kayu manis (*C. burmannii)*	5	1.5	11.3

note: *Measured about 30 cm from the base of the tree trunk

The depth of the roots from the soil surface was measured by measuring precisely from the top soil surface until the topmost roots were visible. Estimates of the total root depth are carried out when the roots have shown a smaller diameter. Root diameter was measured based on a distance of about 30 cm from the base of the tree trunk.

Measurement of root depth from the soil surface is carried out to determine the relationship of roots to the presence of other plants in the vicinity, because the depth of tree roots is related to other plants living in the vicinity. Measurement of the total root depth was carried out to determine the relationship of roots to the conditions of a barren (hardened) or fertile growing place. In fertile soil conditions root growth is shallower than in harder or barren soil conditions. However, there are several types of trees that are unable to penetrate the compacted soil conditions, so that root growth becomes shallow due to direct physical obstacles. Measurement of root diameter was carried out to determine root behavior based on certain root diameter sizes.

Table 4. Characteristics of Tree Roots Under Study Based on Estimated Mean Angle and Lateral Root Length

No	Local Name/Species	Mean of root angle $(^0)$	Length of lateral root (cm)**
1	Pinus (*P. Merkusii*)	30	510
2	Nangka (*A. heterophyllus*)	50	420
3	Rambutan (*N. lappaceum*)	15	65
4	Petai (*P. speciosa*)	35	470
5	Jengkol (*A. pauciflorum*)	30	330
6	Dadap (*E. subumbrans*)	65	570
7	Eucalyptus (*E. grandis*)	40	435
8	Alpukat (*P. americana*)	40	305
9	Meme (*A. angustiloba*)	40	350
10	Kayu manis (*C. burmannii*)	20	310

note: **Measured by adjusting the radius of the crown until the lateral root diameter is + 1 cm

The approximate mean angle is measured from the soil surface to the top root. This measurement is carried out to determine the direction of root growth when it emerges from the base of the stem, which is far below the soil or growing to the side. The lowest angle indicates that the root growth is shallow and the growth is inclined to the side. The highest angle indicates that root growth is deep into the soil.

Lateral root length was measured by adjusting the radius of the tree canopy, then observations were made until the roots began to shrink with a diameter of approximately 1 cm. Measurement of lateral root length aims to determine its relationship with the roots of other plants in the vicinity. The long lateral roots will encounter the roots of other plants in the vicinity, some types of trees interfere with the growth of other tree roots and some species give each other space in carrying out their functions.

1. Pinus (*Pinus merkusii*)

A B C

Figure 1. Trunk (A), Roots (B), Crossed and united roots (C)

2. Nangka (*Artocarpus heterophyllus)*

A B C

Figure 2. Trunk (A), Roots (B), Roots about 30 cm below the soil surface (C)

3. Rambutan (*Nephelium lappaceum)*

A B C

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Figure 3. Trunk (A), Roots (B), Small roots resembling fibrous roots (C)

4. Jengkol (*Archidendron pauciflorum)*

A B C

Figure 4. Trunk (A), Roots (B), There is a bending of the roots towards the top (C)

5. Petai (*Parkia speciosa)*

A B C

Figure 5. Trunk (A), Roots (B), Overlapping roots (C)

6. Dadap (*Erythrina subumbrans)*

A B C

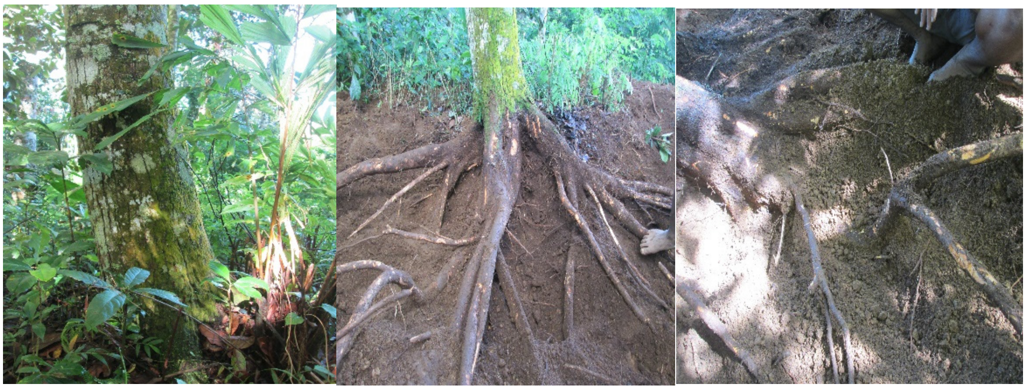
Figure 6. Trunk (A), Roots (B), Roots penetrate the roots of the surrounding trees (C)

7. Eucalyptus (*Eucalyptus grandis)*

A B C

Figure 7. Trunk (A), Roots (B), Roots penetrate the roots of other trees (C)

8. Alpukat (*Persea americana)*



A B C

Fgure 8. Trunk (A), Roots (B), Roots bend upwards when they encounter hard soil in the form of rocks (C)

9. Meme (*Alstonia angustiloba*)

A B C

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Figure 9. Trunk (A), Roots (B), Trees have buttress roots (C)

10. Kayu manis (*Cinnamomum burmanii)*

A B C

Figure 10. Trunk (A), Roots (B), Roots are mostly found on the soil surface (C)

The roots of the trees studied are often found meeting with the roots of other trees in the vicinity in the soil surface. Some of the 10 tree species studied were found to have roots that damage the roots of other trees growing in the vicinity, such as cinnamon (*C. burmanni*) and Rambutan (*N. lappaceum*) roots.

Several tree species that do not show interfering behavior between roots are the roots of the Dadap tree (*E. subumbrans*) crossing with the roots of the

Jackfruit tree (A. heterophyllus) that grow close together, the roots of the Dadap tree (*E. subumbrans*) that penetrate roots of coffee plants, roots of Eucalyptus (*E. grandis*) trees that intersect with one of the local plants in the vicinity, but provide each other with good growth space by providing an opening to penetrate the soil layer to get the nutrients needed.

Some of the trees studied did not have branches around the base of the trunk and some had branches around the base of the trunk. There are several types of trees that do not have branches around the base of the trunk, such as pine trees (*P. merkusii*), eucalyptus (E. grandis), jackfruit (A. heterophyllus), dadap (*E. subumbrans*) and Meme (*A. angustiloba*). Meanwhile, trees with branches close to the base of the trunk are rambutan (*N. lappaceum*), Petai (*P. speciosa*), Jengkol (*A. pauciflorum*), Avocado (*P. americana*) and Cinnamon (*C. burmanii*).

The tree under study had irregularly bent roots and more often straight roots. Trees with irregularly bent roots are rambutan (*N.lappaceum*), Pinus (*P. merkusii*), and Cinnamon (*C. burmanii*), while trees with more straight roots are Eucalyptus (E. grandis), Jackfruit (A. heterophyllus), Dadap (*E. subumbrans*), Meme (*A. angustiloba*), Petai (P. speciosa), Jengkol (A. pauciflorum), and Avocado (*P. americana*).

The behavior of tree roots that grow less than 10 cm above the soil surface is more suitable for land rehabilitation activities on flat (horizontal) land conditions. The behavior of roots growing at a depth of less than 30 cm above the soil surface and penetrating physical barriers far down or to the side is more suitable for land rehabilitation purposes on sloping or rocky land conditions. (Bahuguna and Bhatia 2010) stated that tree roots can function in maintaining cliff stability through two mechanisms, namely, gripping the topsoil (0-5 cm), and reducing the driving force of the soil mass due to the rupture of the soil clod. The role of tree roots in increasing soil shear resistance is determined by tree age, total root length and root diameter. Trees that have intensive roots in the top layer are very effective in helping to reduce the drift of the top layer (Lakitan, 1991).

Hairiah et al., (2007) stated that the most appropriate strategy to increase the stability of cliffs is to increase the diversity of trees planted in a land to increase the network of strong roots in both the top and bottom soil layers. Therefore, for the conservation of landslide-prone cliff areas (steep slopes with a slope of 80% or 40%) it is better to reforest with plants with deep root systems.

The behavior of tree roots found at a depth of more than 30 cm from the soil surface and never turning to the surface is more suitable for agroforestry purposes. (Brunner and Godbold, 2007) stated that the inclusion of forest plants in the agroforestry system has the potential to be able to exploit nutrients that are not reached by seasonal roots, capture nutrients that move down and move laterally in the soil profile, and dissolve nutrients that are not available to plants.

4 CONCLUSIONS

From the 10 types of trees studied in the age range of 15-25 years, the root diameter of mature trees is 10-28.8 cm, depth is 1.5-2 m and the angle of inclination from the ground surface is 10-65o. The length of the lateral roots ranges from 300-570 cm.

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