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DIAMETER AND VOLUMETRIC COMPUTATION OF PLANTATION SAWLOGS

Mohd-Jamil AW & Nor Marzuina FKN

INTRODUCTION

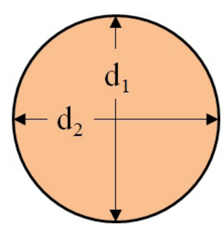
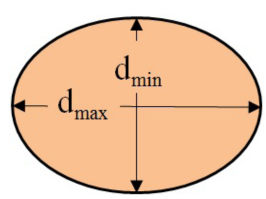
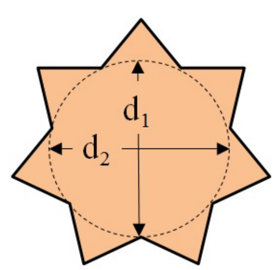
In plantation forestry, accurate analysis of the quantitative parameters is essential to evaluate the productivity and economics of the operations. Scientific knowledge is being applied to enumerate variables that contribute to the efficiency and monetary value of the whole system from cultivation, harvesting, timber processing to product marketing. For instance, in timber processing, the geometrical dimensions of sawlogs of plantation forests are not identical albeit from a single species of the same planting plot (Figure 1). Neglecting the accurate volumetric mass of each log will adversely affect the magnitude of Hoppus volume per waste volume, particularly of the small diameter sizes. Inaccurate geometrical measurements of these logs will eventually end up with wrong information regarding the expected production of the sawing processes. Likewise, the efficiency of a sawmill is assessed based on the ratio of output per input variables, thus highly dependent on the precision of the dimensional measurements of the logs. Besides, processing machines such as band saw have their own functional limitation. For example, the maximum diameter of a log that can be processed by a band saw is restricted to the blade-opening gap. Thus, erroneous geometrical measurement of a log may lead to wasteful cutting or might even causes operational disaster.

Figure 1 Variation of sizes and cross-sectional shapes of *Hopea odorata* logs

It is important to note that in the production of sawn timber the diameter of a sawlog is normally measured excluding the bark. The bark volume differs based on the tree species and age. Besides, the bark of many species has fissures and voids which can lead to incorrect estimation of the timber volume (Anonymous 2020). Nevertheless, since the bark is an important source of energy and has other potential uses, knowing the volume of round log inclusive of bark is useful for the assessments of forest-based energy.

This article is a quick reference for the recommended methods of dimensional measurements of plantation sawlogs. The diameter measurement and volumetric computation of different log profiles are detailed out in Tables 1 and 2 respectively. The formulae recommended for the determination of surface area and volume are based on the principles of geometric forms and supported by research outputs (Tan et al. 2010, Mohd-Jamil et al. 2019). Each formula is complemented with a geometrical diagram. It is important to convert the measurements to a single physical unit (e.g. both diameter and length based on the SI unit meter) before applying the formulae. Examples of major plantation species that include acacia (*Acacia mangium*), teak (*Tectona grandis*), African mahogany (*Khaya ivorensis*), batai (*Paraserianthes falcataria*), sentang (*Azadirachta excelsa*), kelempayan (*Neolamarckia cadamba*), binuang (*Octomeles sumatrana*), rubberwood (*Hevea brasiliensis*), pulai (*Alstonia angustiloba*), merawan siput jantan (*Hopea odorata*), meranti temak nipis (*Shorea roxburghii*) and meranti tembaga (*Shorea leprosula*) are shown with the most probable cross-sectional geometry.

Table 1 Measurement of diameter and cross-sectional area of sawlog

DIAMETER AND CROSS-SECTIONAL AREA			
Cross-sectional geometry	Common species	Diagram (Cross-sectional view)	Diameter measurement and surface area calculation
Round	*Alstonia angustiloba* *Azadirachta excels* *Hopea odorata* *Khaya ivorensis* *Neolamarckia cadamba* *Octomeles sumatrana* *Paraserianthes falcataria* *Shorea roxburghii* *Shorea leprosula*		The diameters are measured at any point through the cross-sectional surface perpendicular to each measurement ($d_1 \perp d_2$). Cross-sectional area, A is calculated using the formula: $A = \frac{\pi}{4} \times d_1 \times d_2$
Elliptical	*Hevea brasiliensis* *Khaya ivorensis*		The diameters are measured using both largest and smallest measurements through the cross-sectional surface (d_{max} and d_{min}). Cross-sectional area, A is calculated using the formula: $A = \frac{\pi}{4} \times d_{max} \times d_{min}$
Fluted	*Acacia mangium* *Tectona grandis*		The diameters are measured based on the most round part of the cross-sectional surface (d_1 and d_2). Cross-sectional area, A is calculated using the formula: $A = \frac{\pi}{4} \times d_1 \times d_2$

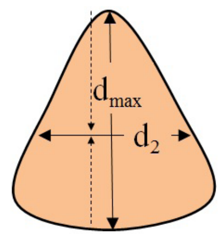
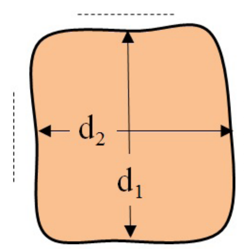
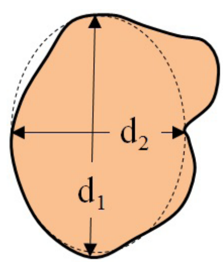
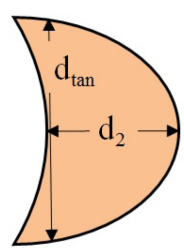
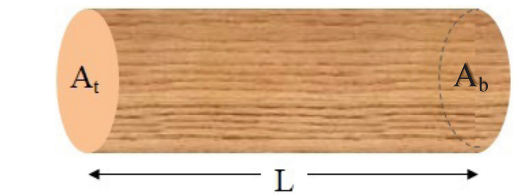
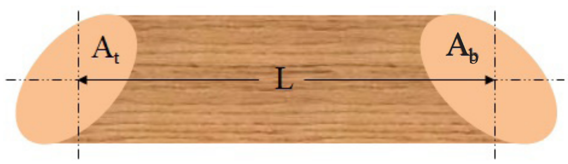
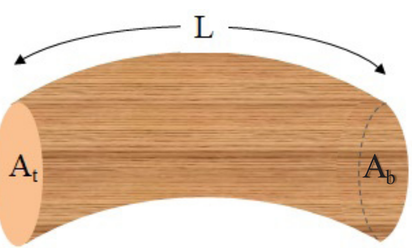
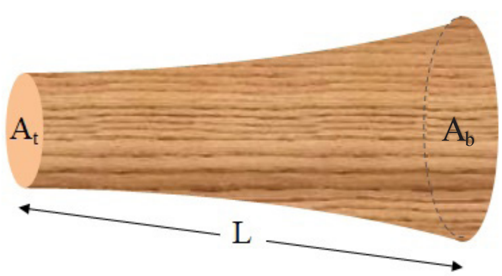
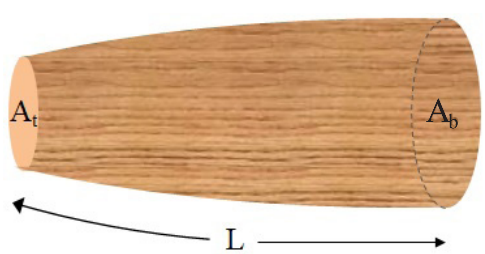
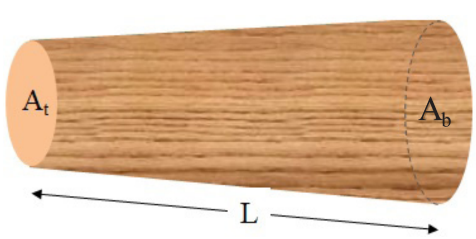
DIAMETER AND CROSS-SECTIONAL AREA			
Cross-sectional geometry	Common species	Diagram (Cross-sectional view)	Diameter measurement and surface area calculation
Triangular	*Hevea brasiliensis* *Khaya ivorensis* *Tectona grandis* *Hopea odorata*		The maximum diameter is measured at the most extended part of the cross-sectional surface (d_{max}). Diameter 2 is measured perpendicular and across the centre of d_{max}. Cross-sectional area, A is calculated using the formula: $A = \frac{\pi}{4} \times d_{max} \times d_2$
Squared/ Rectangular	*Acacia mangium* *Hopea odorata* *Khaya ivorensis*		The diameters are measured based on the quadrilateral edges of the cross-sectional surface (d_1 and d_2). Cross-sectional area, A is calculated using the formula: $A = \frac{\pi}{4} \times d_1 \times d_2$
Unsymmetrical	*Acacia mangium* *Hevea brasiliensis*		The diameters are measured based on the most round part of the cross-sectional surface (d_1 and d_2). Cross-sectional area, A is calculated using the formula: $A = \frac{\pi}{4} \times d_1 \times d_2$
Crescent	*Acacia mangium* *Alstonia angustiloba*		The diameter is measured tangent to the inner curve (d_{tan}). Diameter 2 is measured perpendicular to d_{tan}. Cross-sectional area, A is calculated using the formula: $A = \frac{\pi}{8} \times d_{tan} \times d_2$

Table 2 Volumetric formulae of sawlog

VOLUMETRIC FORMULAE		
Log geometry	Diagram	Formula
Straight		The volume of a straight log is calculated based on the formula: $V = \frac{L}{2}(A_b + A_t)$
Oblique cut		The length of a log with oblique cross-sectional surfaces is measured based on the distance of pith point of each surface. The volume is calculated based on the formula: $V = \frac{L}{2}(A_b + A_t)$
Crooked		The length of a crooked log is measured along the peripheral curve. The volume is calculated based on the formula: $V = \frac{L}{2}(A_b + A_t)$
Frustum of a neiloid		The volume of a neiloid-shaped log is calculated based on the formula: $V = \frac{L}{4}\left(A_b + \sqrt[3]{A_b^2 A_t} + \sqrt[3]{A_b A_t^2} + A_t\right)$
Frustum of a paraboloid		The volume of a paraboloid-shaped log is calculated based on the formula: $V = \frac{L}{2}(A_b + A_t)$
Frustum of a cone		The volume of a conoid-shaped log is calculated based on the formula: $V = \frac{L}{3}\left(A_b + \sqrt{A_b A_t} + A_t\right)$

A_b

A_b = Surface area of the bottom cut; A_t = Surface area of the top cut; L = length of log

SUMMARY

The geometrical dimensions of sawlogs of plantation forest are not identical although they originated from the same planting plot of a single species. Common profiles of the cross-sectional surface of sawlogs are round, elliptical, fluted, triangular, square, unsymmetrical, and crescent. Common geometrical shapes of sawlogs are straight, oblique, crooked, frustum of a neiloid, frustum of a paraboloid, and frustum of a cone. The accurate diameter measurement and volumetric computation of different log profiles are explained herein so that they can be applied for the estimation of material volume of sawlogs for production purposes.

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The measurement of diameter and volumetric computation of plantation sawlogs are essential in assessing the productivity and economics of sawmilling processes. In fact, erroneous geometrical measurement of the logs may lead to wasteful cutting or even operational disaster. This article provides a quick reference for the recommended methods of diameter measurement and volume computation of plantation sawlogs.

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