Nativa, Sinop, v. 12, n. 1, p. 179-183, 2024.
Pesquisas Agrárias e Ambientais
DOI: https://doi.org/10.31413/nativa.v12i1.16910
ISSN: 2318-7670

Natural durability of *Acacia mangium* wood

Thomas Tetteh OLAGA *[1], Kwaku ANTWI [1], Francis Kofi BIH [1],
Mark Bright DONKOR [1]

[1] Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Mampong, Ghana.
*E-mail: thomas.olaga@yahoo.com

Submitted on: 12/28/2023; Accepted on: 03/08/2024; Published on: 03/18/2024.

ABSTRACT: Expanding the base of wood resources, adoption, and effective use of wood species depend primarily on the knowledge of the properties of the wood and the source from which the wood was obtained. The *Acacia mangium* wood, whose natural durability was determined to establish its practical uses, was extracted from Ada Technical Institute's compound in the Ada East District of the Greater Accra Region of Ghana. The study adopted an experimental research design. The natural durability test was done using the accelerated laboratory method based on standard. Seventy-two (72) samples were taken from the six billets (base, middle, and top). The analyses were carried out within each section, established from portions of the trees close to the pith or cascade. The resistance values indicated that the wood studied has a high resistance to rot. In this way, this wood can be used for various uses that require high resistance to interference, such as using parts in direct contact with the ground.

Keywords: serviceable life; decay resistance; Xylophagous fungus.

Durabilidade natural da madeira de *Acacia mangium*

RESUMO: A expansão da base de recursos madeireiros, a adoção e o uso eficaz de espécies madeireiras dependem principalmente do conhecimento das propriedades da madeira e da fonte de onde a madeira foi obtida. As madeiras de *Acacia mangium* Willd, cuja durabilidade natural foi determinada para estabelecer seus usos práticos, foram avaliadas pelo Instituto Técnico Ada, no Distrito Leste de Ada, da Região da Grande Accra, em Gana. O estudo adotou um desenho de pesquisa experimental. O teste de durabilidade natural foi realizado utilizando o método laboratorial acelerado baseado em norma. Setenta e duas (72) amostras foram retiradas dos seis toras (base, meio e topo). As análises foram realizadas dentro de cadaa seção, sendo estabelecidos a partir de porções das árvores próximas à medula ou a casca. Os valores de resistência indicaram que a madeira estudada alta resistência ao apodrecimento. Desta forma, essa madeira pode ser utilizadas para diversos usos que exijam uma elevada resistência a deterioração, como o uso de peças em contato direto com solo.

Palavras-chave: vida útil; resistência a deterioração; fungo xilófago.

1. INTRODUCTION

The low supply of the most well-known forest wood and the high demand for timber for construction and furniture production informed the investigation into lesser–known species of wood, which may have more or similar commercial value compared to the known species and also be fast-growing tree species.

Examining the properties of these less utilized wood species will help us determine their uses. The effective utilization of less used species is expected to sustain forest trees and reduce negative ecological impacts such as reduction in biodiversity and desertification (COLEMAN, 1998). These lesser-used wood species can be used as alternatives to the well-known species.

Acacia mangium plays a significant role in this development, especially in Indonesia and Malaysia, due to its versatility and ability to recapture grasslands dominated by the noxious weed *Imperata cylindrica* (AWANG; TAYLOR, 1993). *A. mangium* is one of the most widely used fast-growing tree species in plantation forestry programs throughout Asia and the Pacific (KRISNAWATI et al., 2011). *A. mangium* can grow to a height of 30 m and a diameter of a breast height of 60cm; the trunk is often straight, to over half the total tree height "*Acacia mangium* is a fast-growing tree for tropical plantation" (HEGDE et al., 2013).

Duke (1983) stated that *A. Mangium* is a fast-growing species, attaining 15 m height and 40 cm DBH in 3 years. They have achieved 23 m tall in 9 years. The complex, light-brown wood is dense, with narrow strips of sapwood and a straight, close grain. A. *Mangium* has variations in its growth from one plantation site to the other (HEGDE et al., 2013).

In Indonesia, the pressure on natural forest ecosystems inevitably resulted in fast-growing plantation trees, such as *A. mangium*, being used as a substitute to sustain the commercial supply of tree products. Among the properties of Indonesia *Acacia mangium* are rapid growth, good wood quality**,** and tolerance of a wide range of soils and environments.

According to Marsoem; Irawati (2016), variations in the structure of acacia wood significantly impact the quality and utility of solid wood products. They have also stated that other countries have recognized the different properties and anatomical characteristics of Acacia wood. Therefore, differences in countries might be expected to be closely related to differences in the properties of acacia wood.

Ghana has many hardwood species doted around a few of its forest regions. Ghana can boast of about 680 different species of trees in its forest reserves (RAFAEL et al., 2020). About 420 species have met the economic value due to their timber size. In Ghana, one of the trees that has the potential to be the best hardwood species, but which should be paid more attention to, is the *Acacia mangium* tree. This tree is found in most of the regions in the country. Because of its fast-growing and shaded nature, it is used in many homes as shade trees. It is also being planted and harvested for firewood and charcoal burning, and its high calorific values are between 4,800 and 4,900 kcal/kg (RAFAEL et al., 2020).

Although some research on the properties of *Acacia mangium* has been conducted, the studies cited above show that more needs to be known about the species' natural durability in Ghana. The species' natural durability must be considered because the chemicals used to treat wood to prolong its serviceable life are toxic to the environment and threaten human and aquatic life.

This called for a search for natural durability wood, including *A. mangium*, for construction and manufacturing since this wood property does not need harmful chemicals to treat timber and its products. Natural durability is "the inherent resistance of wood to attack by wood-destroying organisms." Heartwood has a higher natural durability property compared to sapwood.

Apart from prolonging the life span of the wood, its natural durability reduces the cost of replacement-infested in-service lumber and eliminates the cost of chemical treatment. Wood decay occurs both below and above ground level. Below-ground level decay is high due to the nature of the soil and other microorganisms.

Laboratory tests were conducted on the specimen, and the density/mass loss method was used to evaluate the various portions of the wood. That is the bottom, middle, and top of the wood portions close to the back and the pith.

Therefore, in this study, the researcher would like to determine the natural durability properties of *Acacia mangium* from Ghana in the Ada coastal savanna agroecological zone.

2. MATERIAL AND METHODS

2.1. Study area

Acacia mangium Willd. trees were extracted from the Ada East District of the Greater Accra Region, Ghana's coastal savanna agroecological zone. They were harvested from an approximately ten (10) year old plantation on the compound of Ada Technical Institute in Ada East District of the Greater Region of Ghana. The plantation is about 20 km from the estuary and 9 km from the river Volta at Adonorkopey. The mean minimum temperature of the area is approximately 22–24°C, and the mean maximum temperature is roughly 30–33 °C (Ghana District Archived, 2017) Ada East. The *A. Mangium* was harvested from a thick clay soil land. The harvest was done in July, the end of the significant rainy season.

2.2. Tools and equipment for laboratory work

The facilities for preparing the materials and laboratory works include a chain saw machine (Dolmar CT), circular saw, dimension saw, band saw, radial arm saw, surfacing machine, thicknesser, Laboratory oven, digital veneer calliper, gauge, electronic balance, desiccator, and measuring tape.

The Dolmar chain saw machine filled the tree and converted it to size. The circular saw, dimension saw, band saw, radial arm saw, surfacing machine, thicknesser, and measuring tape were used to prepare the specimen to the required dimensions. The laboratory oven dried the wood species, and a digital veneer caliper and measuring tape were used to estimate the sample pieces to determine their volume. The electronic balance weighed the sample species.

2.3. Sampling and sample preparation

Three samples (Billets) of each tree were collected, constituting six (6) billets samples. The specimens for the experiment were prepared with machines in the Wood Construction Technology workshop at Ada Technical Institute. The natural durability properties tests were conducted at the Pathology Laboratory at the Forestry Research Institute of Ghana (FORIG).

Each tree was first marked according to the breast height diameter (DBH). Then, it was divided into three parts: 30%, 60%, and 90% of the bole length. These parts were classified as the Base (B), Middle (M), and Top (T) parts, respectively. The bole length was taken from 30cm above ground level to 30cm top diameter. The diameter of the trees harvested was 48cm and 40cm at breast height. The clear bole of each tree felled had lengths of 485cm and 420cm. One 75cm thick disk (billet) was collected from each part of the tree log at the mid-long position of the three divisions of the Base, Middle, and Top portions, as presented in Figure 1A. According to the Standard Test Methods for Small Clear Specimens of Timber, the billets were prepared and used as specimens to determine the natural durability property variations within and among the selected trees (ASTM D-143, 2022).

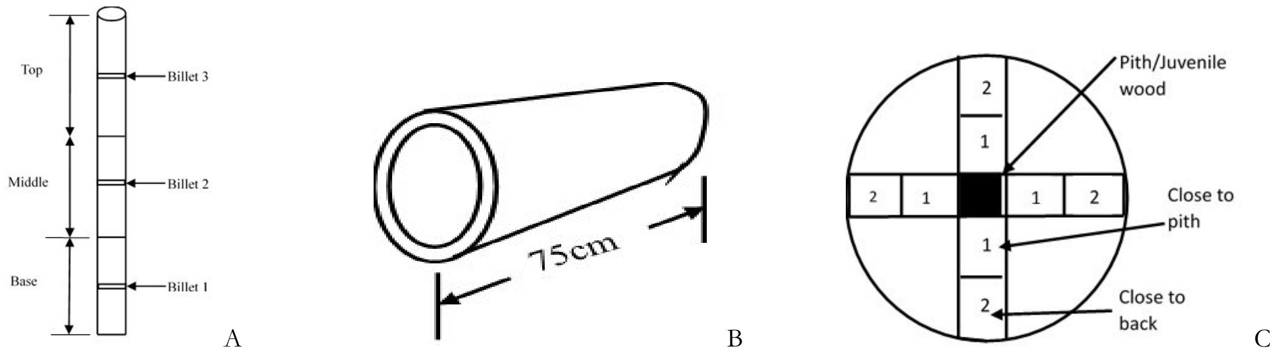


Figure 1 shows details of the whole length of the tree and how the divisions were done (A); the billet is to be cut to the standard test specimen (B); and the end section of a billet is marked out (C).
Figura 1. Detalhes de todo o comprimento da árvore e como foram feitas as divisões (A); o tarugo deve ser cortado no corpo de prova padrão (B); marcando a seção final de um tarugo (C).

The billet of each selected portion/part was divided into four (*i.e.*, North, South, East, and West) and sawn into two (2) planks (1-2) from the pith portion of the tree to the bark portion of the tree (radial direction) to represent pieces close to the pith, and close to the periphery as shown in Figure 1B above and Figure 1C below. *A. mangium* tree has very thin sapwood, which could not be used as a test specimen. Marking and sawing were carefully done to eliminate the juvenile wood portion of each billet.

Three (3) disk samples were collected from each part of the tree to give six (6) billets as tested samples. Eight (8) pieces of wood planks were sawn from each billet, making it a sum of Forty-eight (48) pieces. Each piece was given a unique code for easy identification. Seventy-two (72) specimens used for the experiment were obtained by cutting the selected defect-free wood strips into cubes measured 1.4cm x 1.4cm x 1.4cm, with 12 replicates cut from each of the three (3) tangential sections of the trees at the Timber Mechanic and Engineering Laboratory at Forestry Research Institute of Ghana (FORIG).

2.4. Methods

The test specimens were conditioned before and after fungal attack in an air-forced at 50 ± 1 ⁰C, weighed, sterilized, and submitted to a colonized environment for fungal attack in a controlled environment at 27 ± 1 ⁰C and 70 ± 4 relative humidity (RH). Subsequently, the specimens were oven-dried at 103±2 ⁰C for 24 hours.

The specimens were then cooled to room temperature in a desiccator for each timber species, and the weight of each specimen per species was taken to represent the initial dry weight. A decay chamber was prepared for each of the seventy-two (72) *Acacia mangium* wood cubes using French square bottles, which were three-quarters filled with moistened sieved garden/agricultural soil at a pH of 6.2 and a holding capacity of 39%. The specimens were immersed in distilled water overnight and placed in French square bottles on top of the soil (Figure 2).

Figure 2. The specimens were placed in an autoclave on top of the soil in the French square bottles.
Figura 2. Os corpos de prova foram colocados em autoclave sobre o solo nos frascos quadrados franceses.

The bottles were tightly closed with their plastic screw lids and sterilized in an autoclave at a temperature of 121 ⁰C with a pressure of 15 psi for 20 minutes. After cooling, actively growing mycelium discs of *Coriolopsis polyzoan* of diameter 10 mm were introduced on each of the wooden strips in the fungi-growing incubator at a temperature and relative humidity of 25 °C and 70 %, respectively, for four (4) weeks for complete fungal colonization. Afterward, the oven-dried sterilized specimens of the *A. mangium* were gently placed on the mycelial mat that had formed on the *T. scleroxylon* strips in the French square bottles under sterile conditions. The set-ups were then incubated for 16 weeks at a temperature and relative humidity of 25 °C and 70 %, respectively, to allow the *C. polyzona* to feed on the *A. mangium* specimen.

At the end of the period, the specimens were removed from the bottles, cleaned by gently removing any adhering mycelium, and then oven-dried for 24 hours at 103 ± 2 °C until a constant mass was recorded. The percentage mass loss caused by the action of the decaying fungus was determined (Equation 1).

$$W = \frac{IM - FM}{IM} X100 \quad (1)$$

where w = weight loss (%), IM = initial oven-dry mass of specimen, and FM = final oven-dry mass of specimen.

The wood's natural durability class (Table 1) was based on the mass loss classification adopted from the ASTM D 2017 (2014).

Table 1. Decay resistance classification for percentage weight loss.
Tabela 1. Classificação de resistência ao apodrecimento para perda percentual de peso.

Nº	Weight Loss (%)	Decay Resistance Class
1	0-10	Highly resistant
2	11-24	Resistant
3	25-44	Moderately resistant
4	45 and above	Susceptible

2.5. Methods of statistical analysis

The data from the tests conducted on the natural durability of the wood sampled specimen was analyzed statistically (descriptive and inferential). This is to assess the significant difference within each division of the trees (Base, Middle, and Top) and the variations of the tested durability at the portions of the tree close to the pith and the periphery at the axial locations of the *A. mangium*. Descriptive and inferential analyses were derived using IBM Statistical Package for Social Scientists (SPSS) version 25. One-way Analysis of Variance (ANOVA) was used to describe the relationships between the analytical values. Tukey tests were used to analyze the homogeneity of means further and establish the significant differences between means. Also, welch ANOVA was used where the means violated the homogeneity assumption. All the variations were tested at 95% confidence levels and a P value of 0.05.

3. RESULTS

Table 2 shows the interaction between the axial and the radial position of the wood under study. The radial position near the pith recorded values less than those near the back about the axial sections. This means the axial sections close to the pith are more durable.

Table 3 reported the decay resistance class of *A. mangium* in this study and *A. mangium* and other species of the same genus from Malaysia. The studies were based on accelerated laboratory tests. The specimens were exposed to the fungi for Ten (10) weeks, except the specimens of this study, which were exposed to the fungi for sixteen (16) weeks. Even though the specimens were exposed to different types of fungus, there are similarities in the results, except for Trametes versicolor fungus, which recorded figures at variance from the others.

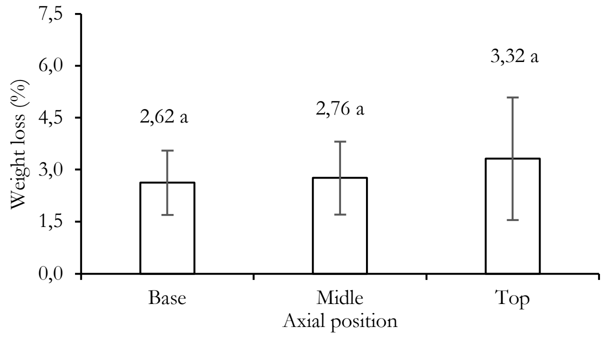
The result of the natural durability of the axial sections presented in Figure 3 shows that the base recorded lower mean and standard deviation values of 2.62% weight loss and 0.93, respectively. The middle section recorded a mean value of 2.76%. The Top section scored 3.319% as the highest mean weight loss and 1.768 standard deviation. Further multiple comparisons of the means do not show any statistical difference among the axial sections.

The means with the same letter are not significantly different at the p-value of 0.05 based on Tukey's test.

The radial portion of the tree close to the pith recorded a mean weight loss of 2.51% and 1.06 standard deviation. The portion close to the back had a mean weight loss of 3.290% and a 1.128 standard deviation, indicating that the portion close to the pith is more resistant to decay, as shown in Figure 4.

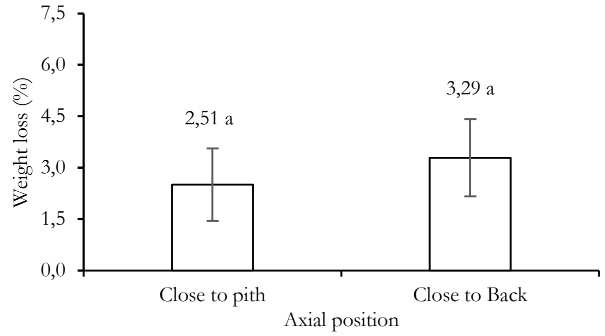
Table 2. Interaction between axial and radial position.
Tabela 2. Interação entre posição axial e radial.

Axial Position	Radial Position	
	Close to pith	Close to back
Base	2.25 ± 0.95	2.49 ± 0.68
Middle	2.50 ± 0.49	3.02 ± 0.80
Top	2.28 ± 0.83	4.07 ± 0.85



The means with the same letter are not significant (p > 0.05).

Figure 3. Decay resistance variation for different axial positions of the *Acacia mangium* wood.
Figura 3. Variação da resistência ao apodrecimento para diferentes posições axiais da madeira de *Acacia mangium*.



The means with the same letter are insignificant (p > 0.05).

Figure 4. Decay resistance variation for different radial positions of the *Acacia mangium* wood.
Figura 4. Variação da resistência ao apodrecimento para diferentes posições radiais da madeira de *Acacia mangium*.

Table 3. Average decay resistance of the *Acacia mangium* wood in different studies.
Tabela 3. Resistência média ao apodrecimento da madeira de *Acacia mangium* em diferentes estudos.

Species	Fungi and weight loss (%)				Country	Source
	Coriolopsis polyzoan	*Trametes versicolor*	*Schizophyllus Cmmune*	*Rigidoporus microporus*		
Acacia mangium	2.9 (class I)	-	-	-	Ghana	This study
Acacia mangium	-	11.2 (class II)	1.8 (class I)	5.6 (class I)	Malaysia	Jusoh et al., 2014
Acacia Hybrid	-	10.2 (class II)	1.5 (class I)	3.4 (class I)	Malaysia	Jusoh et al., 2014
Acacia uriculiformis	-	7.2 (class I)	1.4 (class I)	8.9 (class I)	Malaysia	Jusoh et al., 2014

All the studies were based on accelerated laboratory tests in which the specimens were exposed to the fungi for Ten (10) weeks, except the specimens of this study, which were exposed to the fungi for sixteen (16) weeks.

4. DISCUSSION

According to Viitanen (2014), wood's natural durability determines its ability to resist fungi and termites' attack and prevent decay. In construction and engineering applications, wood with high natural durability will withstand attack from fungi and termites and perform its function in service by carrying specified design loads.

The Interaction between axial and radial positions shows that all the radial sections close to the pith of the three axial sections are more resistant to decay than those close to the back.

Average of decay resistance of the *Acacia mangium* wood in different studies based on accelerated laboratory tests in which the specimens were exposed to the fungi for Ten (10) weeks, except for the specimens of this study, which were exposed to the fungi for sixteen (16) weeks (Table 3). This suggested that the effect of the species, section, portion, and their interaction on the mass loss of the timber can be affected by the action of the fungi exposed to it. All the species under the various fungi can be classified as decay resistance class I, except Malaysia *Acacia mangium* and *Acacia* hybrid *and Trametes versicolor fungus, which* recorded decay resistance class II.

The *A. Mangium* studied's top section of the axial position is less resistant to decay, with an average mean value of 3.32%, while the middle section recorded a mean value of 2.760%. The base recorded the highest resistance mean value of 2.621%, as in Figure 3. These results show that the section from which specimens were taken affects the durability of the wood against decay.

Even though the mean result indicated that the base is more resistant, followed by the middle and the top, the Tukey multiple comparison tests reported no significant difference among the three sections at a P value of 0.05.

The radial portion close to the pith is more resistant than the portion close to the back, with mean values of 2.509% and 3.290%, respectively, as shown in Figure 4. This could be due to the high concentration of extractive close to the pith. The ANOVA result indicates that there is no statistical difference in the two radial sections of the study. Nault 1988 confirms this result by stating that 'some extractives involved in the natural durability increased from the pith to the outer heartwood.'

Based on the total mean average value of 2.9%, the *A. mangium* under study could be classified as highly resistant to decay (Class I) according to ASTM D 2017 (2014), wood durability classification cited by Mensah et al. (2022) as reported in Table 3.

5. CONCLUSIONS

This study on the determination of and natural durability properties of *Acacia mangium* will reduce the reliance on traditional wood species by wood users and exporters of wood products, threatening the survival of the nation's valuable wood stocks.

As its hypothesis, the study proposed no variations in natural durability properties within the sections and among the trees of the *A. mangium*, but the result showed a mixed trend. The findings also recognized the wood as a first-class decay-resistant material per the rating standard by ASTM D2017-05 (2005).

The knowledge of the high-quality natural durability property of the wood will motivate its plantation (farming) and be harvested for construction purposes. This will reduce the depletion of the traditional wood species, make more material available for woodworkers to keep them in business, and bring more economic benefits to farmers and the government from its exportation. Knowledge gathered on the properties of *A. mangium* had positioned it as a quality wood that can compete equally with the traditional wood species. It will help expand the wood resource base and be accepted by the industry for its practical use.

6. REFERENCES

ASTM_American Society for Testing and Materials. **ASTM D143-22:** Standard methods of testing small clear specimens of timber. West Conshohocken: ASTM, 2022.

ASTM_American Society for Testing and Materials. **ASTM D 2017:** Standard test method of accelerated laboratory test of natural decay resistance of woods. West Conshohocken: ASTM, 2014.

AWANG, K; TAYLOR, D. ***Acacia mangium*: Growing and utilization**. MPTS monograph series n. 3. Arlington, VA (United States): Winrock International Inst. for Agricultural Development, 1993.

COLEMAN, H. G. **Marketing of lesser-used species to impact the timber industry. International conference on value-added processing and utilization of lesser-used timber species**. Forest Research Institute of Ghana-Kumasi, 1998. p. 139-144.

DUKE, J. A. **Handbook of energy crops: growing and utilization**. MPTS Monograph Series n. 3. Arlington, VA (United States): Winrock International Inst. for Agricultural Development, 1983. p. 78-110.

GHANA DISTRICT ARCHIVED. **Ada East**, 2017. Available in: http://ghanadistricts.com/About-District-Details.aspx?distID=105&distName=Ada%20East

HEGDE, M.; PALANISAMY, K.; YI, J. S. *Acacia mangium* Willd. A fast growing tree for tropical plantation. **Journal of Forest and Environmental Science**, v. 29, n. 1, p. 1-14, 2013.

KRISNAWATI, H.; KALLIO, M.; KANNINEN, M. ***Anthocephalus cadamba* Miq.: ecology, silviculture and productivity**. Bogor Barat (Indonesia): Center for International Forestry Research (CIFOR), 2011. 22p. https://doi.org/10.17528/cifor/003396

MARSOEM, S. N.; IRAWATI, D. Basic properties of *Acacia mangium* and *Acacia auriculiformis* as a heating fuel. **AIP Conference Proceedings**, v. 1755, n. 1, p. 130-147, 2016. https://doi.org/10.1063/1.4958551

MENSAH, P.; OWUSU, F. W.; APETORGBOR, M. M.; SEIDU, H. M. Natural durability of three selected Ghanaians lesser used/known timber species using accelerated laboratory test. **European Modern Studies Journal**, v. 6, n. 17, p. 2522-2594, 2022.

NAULT, J. Radial distribution of thujaplicins in old growth and second growth western red cedar (*Thuja plicata* Donn). **Wood Science Technology**, v. 22, n. 1, p. 73-80, 1988. https://doi.org/10.1007/BF00353230

RAFAEL, A.; EMMANUEL, E.; ALBERTA, A. S. I.; EBEHEAKEY, K. A. B.; OPHILIOUS, L.; RICHARD, S.; ALEX, C.; WIEDENHOEFT, Z. **Field identification manual for Ghanaian timbers**. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 2020. 130 p. (General Technical Report, 277)

VIITANEN, H. **100 years' service life of wood in service class 1 and 2 – dry and moderately humid conditions**. Helsinki: Finnish Wood Research Limited, 2014. 32p. (Research Report, VTT-R-04689)

Acknowledgments: The authors acknowledge Dr. Prosper Mensah of the Forestry Research Institute of Ghana (FORIG) for the technical support he provided for the preparation and testing of the material.

Authors contribution: All the authors were involved in all stages of the article and have read and agreed to the published version of the manuscript.

Financing: *Not applicable.*

Data availability: Study data can be obtained by e-mail from the corresponding author or the second author upon request. It is not available on the website as the research project is still under development.

Conflicts of Interest: The authors declare no conflict of interest. Supporting entities had no role in the study's design; in the collection, analysis, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.