

EFFECTIVENESS OF USED MOTOR OIL TREATMENT AND APPLICATION TECHNIQUES ON CASUARINA EQUISETIFOLIA LUMBER IN PREVENTING TERMITE AND FUNGAL ATTACK

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Abstract:

Degradation of termites and fungi on forest products including lumber and bamboo-based products and services in the areas of industry and construction sectors in Ethiopia is a serious dilemma. This research was conducted to evaluate natural durability of Casuarina equisetifolia lumber species and performance of used motor oil control measure/treatment against subterranean termites and fungal degradation. Fifty-four lumber samples having dimension of 2x5x50 cm were prepared and treated with used motor oil (UMO) using hot- and-cold dipping (HCD) and brushing methods, besides the untreated controls. The samples were installed at Bako and Adami Tulu Grave-yard Research Stations and study conducted for four years. The multi-factor ANOVA analysis results revealed that there were significant differences ($P < 0.001$) in the extent of subterranean termite and fungal damages on C. equisetifolia lumber stakes among control measures and application techniques, graveyard stations, length of exposure periods, and between the interactions on control measures and stations. The results revealed that deterioration rate of stakes due to subterranean termite and fungi damage increased as the period of exposure (3rd month-4th years) increased at graveyards. Subterranean termites mean degradation at Bako station on stakes of C. equisetifolia treated with UMO using hot- and- cold dipping (HCD), brushing application methods, and untreated controls at the last 4th year evaluation period were 75%, 100% and 100%, respectively and that of fungi was 50%, 75% and 50%, respectively. Mean termites' degradation at Adami Tulu station treated with UMO using HCD, brushing application methods, and untreated controls were 75%, 100% and 100, respectively whereas mean fungal degradation was 50%, 75%, and 75%, respectively. The UMO treatment using HCD method increased service life/life span of C. equisetifolia lumber stakes about two folds compared to the brushing treatment and untreated control stakes. Therefore, used motor oil treatment using HCD application technology was better to increase service life of C. equisetifolia lumber for ground and moisture contact applications. The lumber of C. equisetifolia in service shall not be completely exposed to rain that will lead to leach ability of UMO that will increase environmental and health concerns.

Key Words: effectiveness; bio-deteriorating agents; Casuarina equisetifolia; used Motor Oil.

INTRODUCTION

Bio-deteriorating agents such as fungi and termites are important causes of deterioration of forest products in Ethiopia (Desalegn & Tadesse 2014; Desalegn 2015). Their activities contribute to the deterioration of timber and bamboo products and can increase pressure on forest resources through premature replacement and repeated lumber species harvesting. Indigenous lumber species such as *Juniperus procera*, *Hagenia abyssinica*, and *Cordia africana* are among the important forest resources requiring appropriate protection and

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utilization strategies (Desalegn et al. 2013; Desalegn & Tadesse 2014). Termites, particularly *subterranean termites*, together with wood-decay fungi, are among the principal biological agents responsible for deterioration of wood and bamboo (Desalegn & Tadesse 2014; Desalegn 2015). Wood-decay fungi include brown, white, and soft-rot groups, which differ in their mechanisms of degradation and effects on wood properties (Brischke & Alfredsen 2020; Schwarze 2018). In tropical environments, termites can also make a substantial contribution to wood decomposition, especially for wooden services in contact with the ground (Law et al. 2019).

In Ethiopia, Subterranean termites are a major cause of deterioration of wooden structures and bamboo products (Desalegn 2013; Desalegn 2015; Ethiopian Environment and Forest Research Institute [EEFRI], 2021). Field observations and durability studies have reported rapid deterioration of untreated wood and bamboo under favorable termite and moisture conditions, resulting in substantial maintenance and replacement requirements (Desalegn et al. 2013; Desalegn & Tadesse 2014; Desalegn 2015). The Ethiopian bamboo durability study demonstrated that untreated *Oldeania alpina* and *Oxytenanthera abyssinica* culms were highly susceptible to biodeteriorating agents, whereas preservative treatments considerably improved their durability and service life (Desalegn G 2015; Desalegn 2015). The importance of moisture in fungal deterioration is also well established, because maintaining wood below critical moisture conditions is one of the most effective ways of reducing fungal decay (Brischke & Alfredsen 2020). Consequently, effective preservation and moisture management can extend the service life of lumber and bamboo products, reduce maintenance costs, and lower the frequency of replacement (Desalegn & Tadesse 2014; Brischke & Alfredsen 2020). In Ethiopian field trials, preservative treatments including Tanalith and used motor oil substantially improved the resistance and service life of bamboo culms compared with untreated materials (Desalegn 2015). Recent Ethiopian work has also shown that preservative treatment can substantially improve the resistance of lumber to termite and fungal attack (Desalegn et al. 2024). Despite the importance of biological durability for wood and bamboo utilization, research in Ethiopia remains geographically limited, with much of the available evidence generated from a relatively small number of sites and experimental conditions (Desalegn & Tadesse 2014; Desalegn 2015).

Casuarina equisetifolia, a fast-growing evergreen tree, has potential as an alternative source of lumber and fuelwood in Ethiopia (Bekele-Tesemma 2007; Orwa et al. 2009; Desalegn et al. 2020). The species is characterized by rapid growth and production of dense, heavy wood, making it potentially suitable for several industrial and construction-related applications (Warrier et al. 2015; Tiwari & Talreja 2023). Recent research conducted on *C. equisetifolia* grown in Bishoftu, Oromia Regional State, Ethiopia, reported high wood density and favorable mechanical properties, supporting its potential use for flooring, furniture, particleboard, chip wood, tool handles, and other wood products (Mussa et al. 2025). Studies on the species have also reported considerable energy value, supporting its utilization for fuelwood and charcoal production (Kumar et al. 2011; Tiwari & Talreja 2023). Thus, the species has potential not only for energy production but also for diversification of Ethiopia's raw material base for wood-based industries.

Casuarina equisetifolia is native to Australia and is now widely distributed across tropical and subtropical regions, including Africa and the Indo-Pacific (Warrier et al. 2015). In Ethiopia, the species has been established in plantation and farm-forestry systems, and studies have investigated its growth, wood density, seasoning characteristics, and mechanical properties (Mussa et al. 2025). Nevertheless, although its basic physical and mechanical properties have increasingly been documented, its natural durability under Ethiopian outdoor exposure conditions and its resistance to locally important termite and fungal agents remain insufficiently investigated. Therefore, the present study aims to investigate the natural durability of *C. equisetifolia* wood under outdoor conditions and to evaluate the effectiveness of different methods for controlling termite and fungal deterioration.

MATERIALS AND METHODS

Harvesting of sample trees and preparation of test samples

Sample trees of *C. equisetifolia* were harvested from the compound of Debere-Zeit Agricultural Research Center. The sample trees had 19.3 cm average breast height diameter (dbh) and total volume of 7.4 m³. Sample trees were cut down, and then crosscut into several lengths of 2.5 m each up to the top merchantable diameter of 12 cm. The logs were sawn into 3 cm thickness planks using circular sawmill machine in their green state (> 30% MC) and dried to 12% moisture content (Desalegn et al. 2020). Then, the dried planks were converted to test samples with appropriate dimensions of 2x5x50 cm (thickness, width and length, respectively) (NWPC 2011; NWPC 2017).



Fig. 1.

***C. equisetifolia* sample trees selection and harvesting at Debre- Zeit Agricultural Research site (a and b) logs preparation activity C. Sawn boards C. equisetifolia.**

Stations for the studies

The two study stations for the experiments were Bako Agricultural Research Center (BARC) and Adami Tulu Agricultural Research Center (ATARC). Bako Agricultural Research Center is located approximately 258 km west of Addis Ababa at 09°06'N latitude and 37°09'E longitude, at an elevation of about 1,650 m above sea level. The area has a mid-altitude, sub-humid agro-ecology with a warm and humid climate. The mean annual rainfall is approximately 1,210 mm, with rainfall mainly occurring from April to October, while the mean minimum and maximum temperatures are approximately 13°C and 27°C, respectively. Nitisol is the predominant soil type in the area (Haftu et al. 2009; IQQO 2026).

On the other hand, Adami Tulu Agricultural Research Center is located approximately 167 km south of Addis Ababa in the Central Rift Valley of Ethiopia, at 7°09'N latitude and 38°07'E longitude and an elevation of approximately 1,650 m above sea level. The area receives an average annual rainfall of approximately 766 mm and is characterized by a relatively warm and dry climate. The center represents the mid-Rift Valley agro-ecological environment and experiences considerable seasonal moisture variation (Petros et al. 2014; IQQO 2026).

Design of experiment

The experimental design of the study was split plot design under the complete randomized design (CRD). This entailed a main plot factor which is the origin of stakes (compound of Debre-Zeit Agricultural Research Center about 47 Km from the capital city of Ethiopia, Addis Ababa) and sub-plot factors which were control measures (UMO and untreated control) and positions along height (bottom, middle and top) of the tree. The main plot consisted of one level that was lumber stakes. For combined analysis of data, the two study stations Bako and Adami Tulu were considered as block factors. Control measures which were one of the sub-plot factors in the case of graveyard test consisted of three levels which were: (i) used motor oil with hot and cold dipping method (ii) used motor oil with brushing method and (iii) untreated controls.

Treatments of lumber stakes

Used motor oil with mixture of Shell Rimula diesel oil 40 and Helix Ultra 40 were used to treat lumber stakes against bio-deteriorative organisms (Liese and Tang 2015). Lumber stakes underwent non-pressure treatment (hot and cold dipping-HCD treatment and brushing). HCD treatment was done by dipping stakes in 25 liters of oil at cold temperature, heating up to about 90°C temperature for four hours, then cooling. Brush treatment entailed brushing/coating of stakes upper surface using oil for half of the stake and all treated stakes were kept dry for one week before being installed (BS EN 599-2, 2016; BS EN 351-1, 2023). Untreated stakes (control stakes) until graveyard installation were kept in controlled condition (not exposed to sunlight, rainfall and othering weathering conditions) and moisture content (15%) to evaluate natural durability of wood according to British standards, on a scale of very perishable (<6 months) to very durable (>15 years) based on resistance to termites and fungal attack (BS EN 460 2023).

Installing Lumber Stakes and evaluation at graveyard stations

The graveyard stations had a 20m² by 20m² plot area with barbed wire fencing to avoid any intrusion into the plots. The pits dug were 25cm deep; spacing of 25cm apart and 50cm apart from each other. *C. equisetifolia* stakes (stakes treated with used motor using oil hot and cold dipping method; stakes treated with used motor oil using surface brushing method and untreated stakes as controls), with identification, were

installed with 25 cm below and 25 cm above ground level, subjected to natural elements such as rain, sunlight, and vegetation among others which affect resistance and degradation of both treated and untreated stakes (BS EN 599-2 2016). The stakes were replicated per treatments and study stations. The stations also did durability and efficiency of control measures tests.

The deterioration rate of treated and untreated lumber stakes with regards to subterranean termites and fungal attack were estimated using observations and techniques such as sounding and indenting according to Desalegn et al. (2007). For the evaluation of termite and fungal attack on the lumber stakes, all the stakes were removed. The Evaluations were done after one month, six months, and twelve months after treatment, followed by annual evaluations (Kebede 2011). One to Five grade scale (1-5) was used in biodeterioration evaluations; grade 1 is an indication of sound wood (100% resistant), grade 2 is indicative of superficial or moderate biodeterioration (75% resistant), grade 3 means slight biodeterioration (50% resistant), grade 4 is an indication of severe biodeterioration (25% resistant), and grade 5 indicates total biodeterioration (0% resistant). Observations were made until at least 50% of the underground portion of untreated stakes totally rotted.

Data Analysis

SAS Statistical Package (2002) version 9.00 statistical software package was used for analysis. Multi-factor ANOVA or combined analysis was used for determination of degradation by subterranean termites and fungi and preservatives. The means of stake degradation values which were transformed into continuous values were used in the standard ANOVA. For ease of presentation of results, the scaled values were converted to percentage values.

RESULTS AND DISCUSSION

The results revealed that at both Bako and Adami-Tulu stations, degradation was consistently more severe from subterranean termites than from fungal attack; a pattern most plausibly explained by higher termite population density and greater termite resistance to fungal competition at the two sites, rather than by any inherent susceptibility difference in the wood itself (Tables 1 and 2, Fig. 3).

At the last 4th year evaluation period, all untreated control stakes had reached complete (100%) termite degradation and substantial (75%) fungal degradation at both stations. Hot-and-cold dipping with UMO roughly doubled the service life of the stakes relative to untreated controls, while brushing conferred little practical protection: upper surface brushed stakes degraded at rates statistically indistinguishable from untreated controls for both termites and fungi (Tables 1 and 2, Fig. 3). This indicates that treatment penetration not just chemical presence on the wood surface is the operative variable governing protective performance.

Table 1

Summary of mean (%) degradation of *C. equisetifolia* stakes 3rd month to the last 4th year evaluation period by subterranean termites and fungi under the two graveyard stations

Date of inspection	3 rd. month		6th month		9th month		1st year		1.5 year		2nd year		2.5 year		3rd year		3.5 year		4th year	
Treatment method	T	F	T	F	T	F	T	F	T	F	T	F	T	F	T	F	T	F	T	F
Bako Graveyard Research Station																				
UMO-HCD	0	0	0	0	0	0	25	0	25	0	25	2	25	5	5	0	75	0	75	5
Control	5	0	7	7	7	7	7	10	7	10	7	10	7	10	7	10	7	10	7	7
	0	0	5	5	75	5	95	5	0	5	0	5	0	5	0	5	0	5	0	5
UMO_B	2	0	5	2	2	10	5	10	5	10	5	10	5	10	5	10	5	10	5	5
	5	0	0	5	50	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adami Tulu Graveyard Research Station																				
UMO-HCD	0	0	0	0	0	0	0	0	25	5	25	2	5	50	5	5	75	5	75	5
Control	5	0	5	0	50	0	50	0	75	5	75	7	5	75	5	10	7	10	7	7
	0	0	0	0	50	0	50	0	75	5	75	5	5	75	5	0	5	0	5	5
UMO-B	2	0	2	0	25	0	25	2	7	5	75	7	10	7	10	7	10	7	10	7
	5	0	5	0	25	0	25	5	75	5	75	5	0	5	0	5	0	5	0	5

Table 1 summarizes the four-year degradation rates of *Casuarina equisetifolia* stakes at the Bako and Adami Tulu graveyard stations under three treatment regimens: hot-and-cold dipping with used motor oil (UMO-HCD), used motor oil by brushing (UMO-B), and untreated controls.

Table 2

Summary of mean degradation of *C. equisetifolia* stakes at the last 4th year evaluation period by subterranean termites and fungi under three control measures at two graveyard stations

Station	Treatments & Application methods	Termite degradation rate (%)	Fungal degradation rate (%)
Bako	UMO – Hot & Cold Dipping (HCD)	75	50
	UMO – Brushing (B)	100	75
	Untreated Control	100	75
Adami Tulu	UMO – Hot & Cold Dipping (HCD)	75	50
	UMO – Brushing (B)	100	75
	Untreated Control	100	75

Abbreviations: HCD = hot and cold dipping treatment with used motor oil; B = brushing treatment with used motor oil; Control = untreated stakes.

Degradation trend increased progressively across the four-year monitoring period (Fig. 3). By the third year, mean termite degradation across HCD, brushing, and control treatments reached 50%, 58%, and 67% respectively, while fungal degradation reached 50%, 50%, and 58%. Some untreated control stakes at Bako had already failed structurally by the end of year one, underscoring the rapid vulnerability of untreated *C. equisetifolia* wood under field exposure. The lumber of *C. equisetifolia* in service shall not be completely exposed to rain that will lead to leach ability of UMO that will increase environmental and health concerns.

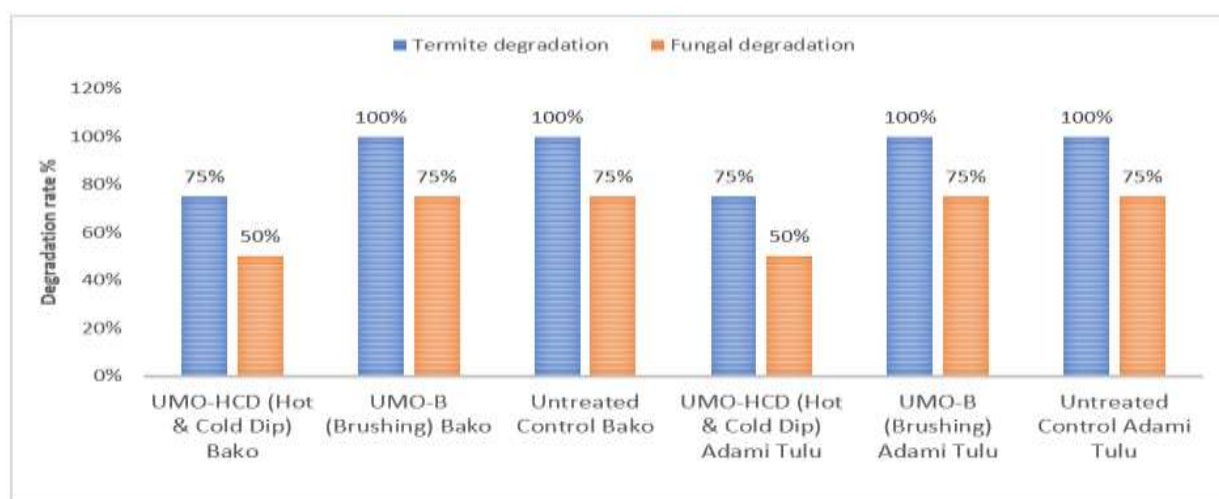


Fig. 2.

Summary of mean subterranean termite degradation rate (STDR) and fungal degradation rate (FDR) against treatment type, comparing HCD, brushing (BUMO), and untreated controls (C) at the last 4th year evaluation period.

Statistical Data Analysis Results

A multi-factor ANOVA confirmed that control measure, exposure duration, station, and the control measure × station interaction each had a significant effect ($P < 0.001$) on both termite and fungal degradation (Table 3). The control measure × duration interaction was significant for termite damage ($P = 0.0052$) but not for fungal damage ($P = 0.5803$), suggesting that treatment effectiveness against termites erodes at a different rate over time than effectiveness against fungi. Station alone was a significant driver of termite degradation ($P < 0.0001$) but not of fungal degradation ($P = 0.2137$), consistent with site-specific differences in termite species composition (see Section 3.4) rather than site-driven differences in fungal pressure.

Table 3

Multi-factor ANOVA for subterranean termite and fungal degradation of treated and untreated *C. equisetifolia* stakes

Source	Biodegrading Agent	DF	Sum of Squares	Mean Square	F Value	P
Control measure	Termite	2	30,450.83	15,225.42	249.33	<0.0001
	Fungi	2	15,270.83	7,635.42	33.83	<0.0001
Duration	Termite	9	33,620.42	3,735.60	61.17	<0.0001
	Fungi	9	27,250.00	3,027.78	13.42	<0.0001
Station	Termite	1	1,983.75	1,983.75	32.49	<0.0001
	Fungi	1	375.00	375.00	1.66	0.2137
Control measure × Duration	Termite	18	3,890.83	216.16	3.54	0.0052
	Fungi	18	3,687.50	204.86	0.91	0.5803
Control measure × Station	Termite	2	992.50	496.25	8.13	0.0031
	Fungi	2	1,562.50	781.25	3.46	0.0535
Duration × Station	Termite	9	3,187.08	354.12	5.80	0.0008
	Fungi	9	4,000.00	444.44	1.97	0.1057

Abbreviations: x = interaction effect; DF = degrees of freedom.

The results revealed that deterioration rate (service life) of stakes due to subterranean termite and fungi damage increased as the period of exposure (3rd month-4th years) increased at graveyards (Fig. 3).

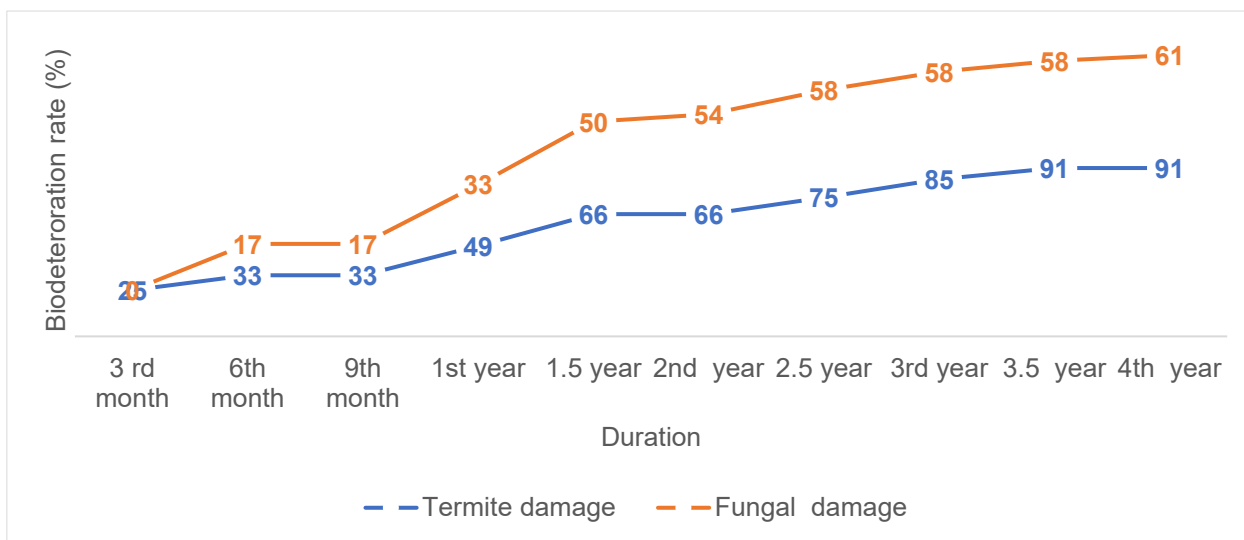


Fig. 3.

Tracks the deterioration trend of all treatment groups across the full four-year exposure periods, illustrating the divergence between HCD-treated stakes and the brushing/control groups as exposure time increases.

Service life (life span) is the total length of time a product, machine, or structure is expected to function effectively and safely for its intended purpose. Service life of wood ranges from less than 5 years to over 50 years, depending heavily on the wood's natural durability class, whether it is treated or exposed to moisture and soil, and the level of maintenance it receives.

Durability Classes and Lifespan

Wood is categorized into five main natural durability classes for outdoor or exposed use:

- Class 1 (Very Durable): 25 to 50+ years (e.g., Teak, Ipé). Lasts longest even when exposed to harsh weather or above-ground conditions.
- Class 2 (Durable / Permanent): 15 to 25 years (e.g., Oak, Bangkirai).
- Class 3 (Moderately Durable): 10 to 15 years (e.g., Douglas fir, Larch).
- Class 4 (Slightly Durable): 5 to 10 years (e.g., Pine, Spruce).
- Class 5 (Not Durable): Less than 5 years (e.g., Birch, Beech).

Key Factors Affecting Service Life

- Moisture and Temperature: The two biggest drivers of fungal decay and rot. Wood in direct contact with the ground deteriorates much faster than above-ground or indoor wood.
- Preservative Treatments: Chemical treatments or thermal modifications extend the life of lower-durability softwoods or hardwoods significantly.
- Application and Design: Proper architectural detailing prevents water traps. For example, utility poles can last 30 to 50 years, while small garden fences may need replacing in 10 years.
- Maintenance: Regular cleaning, sealing, and repainting or oiling prevents premature weathering and insect damage.

These results classify untreated *C. equisetifolia* lumber as non-durable under Ethiopian graveyard test conditions, consistent with its known poor natural resistance to fungal and termite attack (Orwa et al., 2009). Untreated controls at both stations had already reached 50% degradation by the third month of exposure. The heartwood's resistance to preservative penetration attributed to a high density of tyloses that occlude the wood's vascular pathways likely explains why the brushing treatment, which relies on surface coating rather than pressure-assisted penetration, failed to achieve meaningful protection despite using the same preservative oil as the HCD treatment.

Termite species composition differed between the two stations and likely contributed to the observed station effect on termite degradation: *Microtermes* and *Pseudacanthotermes* *militaris* dominated at Bako, while *Macrotermes bellicosus*, a mound-building species, dominated at Adami Tulu a site sharing the agroecological profile of Zeway (Desalegn et al. 2007).

The data also suggest a facilitative relationship between the two biodeteriorating agents: fungal colonization appears to precede and enable more extensive termite attack, consistent with the hypothesis that fungal decay softens wood tissue and reduces its structural resistance to termite feeding. At 18 months, termite degradation exceeded fungal degradation at both stations, and was more advanced at Bako (100%) than at Adami Tulu (75%) a gap that narrowed by year four, when both stations converged nearly 50% degradation under UMO treatment via both application methods, indicating that the protective advantage of UMO treatment diminishes over extended exposure regardless of station. No significant damage effect occurred on positions along height (bottom, middle and top) of the tree.

Brushing with used motor oil offered negligible improvement over untreated controls, a finding that parallels results reported for *Trichilia dregeana* stakes subjected to the same treatment over a comparable four-year period (Desalegn et al. 2025). Because brushing deposits only a superficial coating without deep penetration or fixation into the wood's internal structure, its protective effect is vulnerable to leaching and diminishes as exposure duration increases. On this basis, UMO brushing can be recommended only for short-service applications of approximately two years' service time of lumber for ground and moisture contact applications, where cost or accessibility constraints preclude dipping treatments.

By contrast, hot-and-cold dipping achieved deep preservative penetration and approximately doubled the service life of *C. equisetifolia* lumber stakes service time of lumber for ground and moisture contact applications relative to untreated controls, making it the preferred low-cost treatment method for ground- and moisture-contact applications in similar agroecological settings. The lumber of *C. equisetifolia* in service shall not be completely exposed to rain that will lead to leach ability of UMO that will increase environmental and health concerns.

CONCLUSIONS AND RECOMMENDATIONS

The four-year graveyard tests demonstrated that *Casuarina equisetifolia* lumber stakes were highly susceptible to biological deterioration under field exposure, with degradation increasing progressively over time (3rd month- 4th year). Untreated stakes experienced the greatest deterioration, reaching complete termite degradation (100%) and substantial fungal degradation (75%) during the exposure period, while some untreated stakes at Bako had already failed structurally within the first year. Termite degradation consistently exceeded fungal degradation at both Bako and Adami Tulu, indicating that subterranean termites were the more important biodeteriorating agents under the conditions of this study. The significant effects of treatment, exposure duration, and station on degradation, together with differences in termite species composition between the two sites, further demonstrate that both treatment application methods and local environmental and biological conditions influence the durability and service life of *C. equisetifolia* wood. The lumber of *C. equisetifolia* in service shall not be completely exposed to rain that will lead to leach ability of UMO.

Hot-and-cold dipping (UMO-HCD) with used motor oil provided significantly greater protection against both termite and fungal degradation than surface brushing with used motor oil. The superior performance of the HCD treatment is attributed to greater penetration of the preservative into the wood, whereas surface brushing mainly provides a superficial coating that is more susceptible to weathering and loss during prolonged

field exposure. In contrast, surface brushing provided little improvement over untreated stakes over the longer exposure period and therefore has limited applicability for prolonged ground-contact use. Nevertheless, its relatively simple and low-cost application may be appropriate for temporary or short-service applications not completely exposed to rain that will lead to leach ability of UMO, where a service life of approximately two years is acceptable and more effective treatment facilities are unavailable. Overall, hot-and-cold dipping with UMO appears to be a practical low-cost treatment option for improving the service life of *C. equisetifolia* stakes intended for ground- and moisture-contact applications in agroecologically similar areas. The lumber of *C. equisetifolia* in service shall not be completely exposed to rain that will lead to leach ability of UMO that will increase environmental and health concerns.

Since termite species composition and degradation pressure varied between the two stations, treatment performance should be evaluated under local conditions before recommendations are extended to other areas. Further research should therefore assess the durability of additional economically important wood species and compare UMO treatments with alternative preservative systems, including commercially available preservatives and environmentally safer treatment options. Long-term studies involving multiple graveyard test stations and representative agroecological zones of Ethiopia are also needed to determine treatment durability, service life, cost-effectiveness, and environmental implications. Such research would provide a stronger scientific basis for selecting appropriate wood-preservation technologies and contribute to more rational, sustainable, and efficient utilization of Ethiopia's forest resources.

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