Assessment of Timber Degradation by Wood-Fungus and Insects in Afghanistan's Diverse Climatic Zones

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Abstract:

Wood has been a fundamental material throughout human history due to its versatility and performance. However, wood's susceptibility to biodeterioration, primarily due to fungi and insects, poses significant challenges. This study assesses timber degradation by wood fungi and insects across Afghanistan's diverse climatic zones, including arid, temperate, and cold mountainous regions. To address this, a multifaceted descriptive method for data collection has been employed. The findings reveal distinct impacts of climatic conditions on wood degradation. In the arid climatic zone, 7.3% of species were affected by wood-decay fungi, with 5.5% attributed to brown rot and 1.8% to white rot. Additionally, 52.7% of degradation was caused by wood-stain fungi, with 25.5% due to sap-stain, 3.6% to mold, and 23.6% by chemical stain. Furthermore, 40% of wood decay in this zone was caused by insects, with termites accounting for 30.9%, beetles 3.6%, and carpenter ants 5.5%. In the temperate zone, 49.6% of species were affected by wood-decay fungi, with 34.7% due to brown rot and 14.9% to white rot. Moreover, 40.4% of degradation was attributed to wood-stain fungi, with 19.8% due to sap-stain, 12.3% to mold, and 8.3% to chemical stains. Insect activity in this zone accounted for 10% of wood decay, with termites affecting 1.7%, beetles 7.5%, and carpenter ants 0.8%. In the cold mountainous region, 69.2% of species were affected by wood-decay fungi, with 51.6% due to brown rot and 17.6% to white rot. Additionally, 30.8% of degradation was caused by wood-stain fungi, with 12.1% due to sap-stain, 13.2% to mold, and 5.5% by chemical stains. Notably, no insect activity was found in the cold mountainous climatic zone, as the severe freezing conditions deter insect presence. The results highlight the need for sustainable forestry practices and effective timber preservation strategies tailored to specific climatic conditions to mitigate the adverse effects of wood fungus and insect degradation.

Keywords: Construction wood, Wood-Decay Fungus, Wood-Stain Fungus, Insects**,** Weather.

I. INTRODUCTION

Wood, a natural and renewable resource, has been used by humans since ancient times due to its exceptional versatility and performance [1],[2].Timber degradation is a significant concern in the global forestry sector, affecting the sustainability and longevity of wooden structures and products [3]. The challenges associated with timber degradation vary widely across different climatic zones, including arid, temperate, and mountainous regions [4]. Each climate presents unique environmental stresses that can accelerate the degradation process, necessitating tailored management strategies to mitigate these effects [5].

Arid climates, present a different set of challenges for timber preservation. While the low humidity levels can reduce the incidence of fungal decay, they can lead to rapid desiccation of wood, causing it to crack and warp [6]. The extreme temperature variations common in arid regions can further exacerbate these issues, leading to structural failures over time [7]. Moreover, the risk of insect infestations, particularly from wood-boring beetles, remains a concern in these environments, as many of these pests are adapted to dry conditions [8].

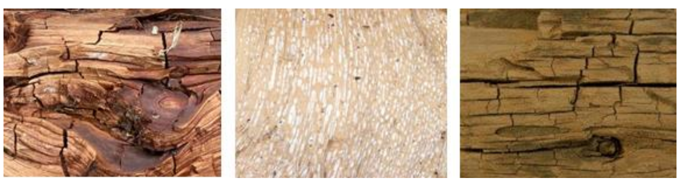
In temperate climates, the challenges of timber degradation shift towards moisture management [9]. These regions experience significant seasonal variations in temperature and humidity, which can lead to issues like wood rot and mold growth [10]. The presence of moisture is a critical factor in the decay process, as prolonged exposure can facilitate the growth of decay fungi [11].

Mountainous climatic zones introduce their own set of challenges. The combination of altitude, temperature variability, and moisture levels can lead to unique difficulties [12]. In mountainous areas, wood is often exposed to harsh weather conditions, including snow, rain, and high winds, which can accelerate wear and tear [13]. The elevation can also affect the types of wood species available, as certain trees may not thrive in high-altitude conditions, limiting options for environmentally compatible and locally sourced wood [14].

The lack of proper control measures may create favorable conditions for the proliferation of wood fungi and insect infestations. These fungus are typically categorized into two types based on their impact on wood: Wood-decay fungi, which decompose and weaken wood structures, and wood-stain fungi, which discolor and blemish wood surfaces [15], [16].

A. *Wood-Decay Fungi*

Wood-decay fungi, as illustrated in Figure 1, also known as wood-rotting fungi, alter the physical and chemical properties of wood, conceding its durability [17]. These fungi thrive particularly in the heartwood and core of the wood [18]. They can manifest as string-like, cottony, or root-like structures within the wood, breaking down cellulose, hemicellulose, and lignin, which are essential components of wood [19], [20]. This enzymatic breakdown leads to structural damage and discoloration of the wood, often turning it white, brown, yellow, or reddish. Major types of wood-decay fungi include brown-rot, White-rot, and soft-rot [21]. Brown rot darkens the wood, causes shrinkage, and forms granular eruptions [22]. White rot lightens the wood and gives it a spongy texture [23]. Soft rot creates cavities within the wood by breaking down cellulose and hemicellulose, resulting in surface softening and gradual loss of structural integrity, typically affecting the wood to a depth of 3-4 mm, hence termed soft erosion [22].



Brown rot White rot Soft rot

Figure 1: Wood-Decay Fungi

B. *Wood-Stain Fungi*

Wood-stain fungi as shown in Figure 2, primarily transform the color of wood, impacting its appearance and aesthetic appeal rather than causing extensive structural damage, thus falling its commercial value [24]. These fungi categories include Sap-staining and Mold fungi, as well as chemical stains [25]. Sap-staining fungi infiltrate plant sap, changing the wood's color without significant structural harm, and this discoloration cannot be removed by scraping or brushing [26], [27]. Mold fungi initially appear as green, yellow, brown, or black powders on the wood surface and are generally easy to remove [28]. Thus, Chemical stains result from chemical reactions within the wood, often appearing as brown discolorations, particularly during drying processes such as in kilns or under high temperatures [29], [30].

Sap-stain Mol Chemical

Figure 2: Wood-stain Fungi

C. *Wood-Decay Insects*

Another challenge for wood degradation is the presence of insects that affect its structural integrity [31]. Key wood-degrading insects, as depicted in Figure 3, include termites, wood-boring beetles, and carpenter ants [21]. Subterranean termites build colonies in the soil and consume wood from the inside out, whereas dry-wood termites infest dry wood and create small exit holes to expel fecal pellets [32].

Wood-boring Carpenter

Figure 3: Wood-Decay Insects

II. Literature Review

Timber degradation through wood fungus is an extensive challenge in many regions, impacting both monetary and structural integrity [33]. In Afghanistan, which is a landlocked country in South Asia, known for its diverse climatic zones including arid, semi-arid, temperate, and mountainous areas, the assessment of timber degradation is specifically important [34].

Approximately, 71% of Afghanistan's population lives in rural areas, where timber is considered as a primary construction material [35], [36]. The rapid decay caused by fungi can intensify maintenance costs and posture safety hazards [37]. Furthermore, the depletion of timber resources can profoundly affect local economies reliant on forestry and wood-related industries [38]. Additionally, the degradation process releases stored carbon from wood into the atmosphere, contributing to greenhouse gas emissions and worsening climate change [39]. Therefore, implementing local strategies for sustainable forestry practices is crucial to mitigate these challenges [40].

Wood is prone to fungal infestation when exposed to specific environmental conditions, including high moisture content exceeding 20%, ample oxygen availability, and temperatures ranging between 15°C and 45°C [2]. This fungal deterioration primarily impacts outdoor wooden structures, compromising both their mechanical strength and aesthetic appeal, and notably shortening their lifespan [41].

In arid regions of Afghanistan, such as Nangarhar province, which experiences low annual precipitation (20.05mm), high summer temperatures (up to 45.15°C), and cold winters (down to 3.07°C), where moisture is scarce with an average annual humidity of 31.23%, fungi like Aspergillus and Penicillium species are notably prevalent [42], [43]. These fungi contribute to a slow but progressive decay of timber in such dry conditions. The lack of humidity can lead to severe cracking and warping. Additionally, these regions are prone to termite infestations, especially dry wood termites. Furthermore, the extreme temperature fluctuation of arid climates can induce rapid expansion and reducing the life span of wood products.

In mountainous and more humid areas of Afghanistan, such as Nuristan province, where summer temperatures reach up to 34°C, winter temperatures drop up to -10°C, humidity averages 44.46%, and precipitation totals reach 70.44mm annually, fungi such as Trametes versicolor and Gloeophyllum sepiarium thrive [44], [45]. These fungi are dominant in environments with higher humidity and temperatures, leading to rapid and extensive wood degradation. Their presence stances significant threats to timber structures and forest resources in these regions. Steep terrain, heavy snowfall, ice, and variations in moisture and temperature can physically damage both trees and wood structures.

In the temperate zone of Afghanistan, such as Kunar Province, where summer temperature can reach up to 34.1°C and winters often fall below freezing with an average of -5°C, seasonal precipitation totals 70.44mm, and annual humidity averages 44.49%, fungi like Trametes versicolor, Pleurotus Ostreatus, dry-rot fungi, and Chaetomium Globosum are prevalent [46], [47]. These fungi crumble lignin and cellulose, contributing to wood degradation in this climatic region. High humidity levels and seasonal temperature variations are fundamental challenges for wood preservation against fungus and insects.

Research conducted in various regions provides insights into timber decay caused by wood decay fungi. A study in an arid region of Northern China revealed that 53.75% of timber decay was attributed to wood decay fungi, with Eurotiomycetes fungi accounting for 19.78% of cases under humid conditions [48]. In another investigation, brown-rot fungi were responsible for 6% of wood decay cases [18]. Similarly, research from Germany analyzing 74 samples found that 59.5% were affected by white-rot fungi and 40.5% by brown-rot fungi [49]. Further studies have shown varying proportions of brown-rot and white-rot fungi in different settings, such as in Poland where outdoor wooden structures showed 17 cases of decay by brown-rot and 16 by white-rot among 34 samples [50]. In Austria, an extensive study examining 645 samples identified Serpula brown-rot fungi as responsible for 61.5% of decay cases, followed by Gloeophyllum brown-rot at 8.2%, Atrodia spp brown-rot at 10.7%, and other contributors including insects [51].

There is a significant lack of comprehensive studies quantifying timber degradation rates caused by fungi and insects across various climatic zones in Afghanistan. This study aims to evaluate timber degradation caused by wood fungus and insects across diverse climatic zones, focusing on arid, temperate, and cold mountainous regions. These regions are chosen to provide insights into global environments with similar conditions, offering a comprehensive understanding of how wood fungi interact with varying climates worldwide.

III. Research Methodology

In this study, we employed a multifaceted descriptive method for data collection, including genera and species observations, interviews, and form completion with experts, laborers, and stock managers. This approach aimed to quantify the percentage of timber decay caused by fungi and insects in specific climatic zones. Data collection was conducted in Nangarhar province to represent the arid climatic zone, Kunar province for the temperate climatic zone, and Nuristan for the cold mountainous climatic zone of Afghanistan. The collected data will be analyzed using Microsoft Excel and presented in tabular form to showcase the research outcomes.

IV. Finding And Discussions

In this study, we examined 267 species in the arid, temperate, and cold mountainous climatic zones of Afghanistan. Out of these, 55 species are associated with the arid zone, 121 with the temperate zone, and 91 with the cold mountainous zone. Additionally, we conducted interviews and collected data from 324 experts, laborers, stock managers and timber users as part of the research process. The study reveals distinct impacts of varying climatic zones on wood degradation.

A. Harvesting and Sawmilling Procedure of Timber Trees in Afghanistan

Before delving into the classification of wood degradation caused by fungi and insects, it is crucial to understand the intricacies of timber harvesting and sawmilling in Afghanistan. This understanding will illuminate the challenges encountered in wood preservation and treatment. The data in Table 1 is derived from interviews and on-site form data collected from 324 individuals, including experts, laborers, stock managers, and timber users, providing insights into their practices.

Table 1. Harvesting and Sawmilling Procedure in Afghanistan

Harvesting Procedure							Sawmilling Procedure					
Formal Permits	Area selection for harvesting	Tree Selection and marking	Skills labor	Bucking	Extraction	Transport	Debarking	Canting	Grading	Seasoning	Treatment	Storage
Yes	Yes	No	No	Own Desired	Cable logging, using donkeys, and carrying logs by shoulder	Trucks & Other Transportation vehicles	At the site of harvesting	At the site of harvesting	No Grading System	Air dry	No treatment	Usually Open Space

As demonstrated in Table 1, timber harvesting and sawmilling procedures in Afghanistan timber reflect a blend of traditional methods and practical considerations. The harvesting process begins with obtaining formal permits and conducting site assessments to ensure compliance with regulations and assess environmental impact. However, the specific method for tree selection and marking is described as Own Desired, suggesting variability or reliance on individual preferences rather than standardized practices. There is no standardized method for marking trees for harvesting, and the labor force lacks specialized skills, relying solely on individual expertise. Consequently, the bucking process is conducted based on individual preferences, where harvested trees are cut into shorter sections or logs without specific size requirements. Extraction primarily involves cable logging, with lesser use of methods such as donkey or horse transport, which can potentially damage trees during extraction. Subsequently, the timber is transported for further processing via trucks and other vehicles.

At the sawmilling stage in Afghanistan, debarking and canting operations are conducted directly at the harvesting site to minimize its transportation costs and distances. Additionally, the absence of a formal grading system means there is no standardized quality classification, which could affect market competitiveness and product consistency. After canting, the timber is air dried using a simple method exposed to sunlight to reduce moisture content; however, this method may lead to issues such as cracking and shrinkage. Moreover, no preservation treatments are applied during processing, potentially impacting the timber's durability and resistance to decay over time. Furthermore, processed timber is typically stored in open spaces, leaving it vulnerable to environmental elements and susceptible to fungal attacks and infestations by various insects upon contact with soil.

B. *Timber Degradation by Wood-Decay Fungi, Wood-Staining Fungi, and Insects in Different Climatic Zones of Afghanistan*

A thorough investigation was undertaken across all three zones to assess how many of the 267 species and genera were affected by wood decay fungi, wood-stain fungi, and insect infestations. The findings are summarized in Table 2.

Table 2. Species Affected by Wood-decay fungi, Wood-stain fungi & Insects

Climatic Zone	Province	Wood type	Total Examined Species	Wood-decay Fungi	Wood-stain Fungi	Insects
Arid	Nangarhar	Hardwood	55	4	29	22
Temperate	Kunar	Softwood	121	60	49	12
Cold Mountainous	Nuristan	Softwood	91	63	28	0

The results from Table 2, indicate that among the 55 species of hardwood in the arid climatic zone, only 4 were affected by wood-decay fungi, whereas 29 species showed signs of wood-stain fungi, and another 22 species were infested by insects. Hardwoods, which are predominant in arid zones, typically exhibit greater resilience to decay compared to softwoods. Due to lower moisture levels and higher temperatures, the environment is less conducive to wood-decay fungi, explaining the minimal number of affected species. In contrast, wood-stain fungi can thrive in drier environments, accounting for the higher incidence observed among the species examined. Additionally, the dry conditions in the environment enhance insect activity, contributing to the observed levels of infestation among the 55 species studied.

The temperate zone, which is characterized by temperate humid conditions with warm temperatures that can drop below freezing in winter, provides an optimal environment for timber degradation primarily by wood-decay fungi rather than wood-stain fungi. Additionally, a temperate wet, and drier environment is conducive to insect attacks. Accordingly, the results indicate that out of 121 species examined in this zone, 60 were affected by wood-decay fungi, 49 by wood-stain fungi, and only 12 by insects.

On the contrary, the cold mountainous region experiences wet summers and cold winters with snow, creating a high-moisture environment that favors fungal activity more than insect infestations. The data reveals, that out of 91 species examined, 63 were affected by wood-decay fungi, and 28 species showed signs of wood-stain fungi, with no instances of insect attacks recorded.

Figure 4, illustrates the findings of the species examined, presented as percentages. In the arid climatic zone, 7.3% of species were affected by wood-decay fungi, 52.7% by wood-stain fungi, and 40% by insects. Conversely, in the temperate zone, these percentages were 49.6%, 40.4%, and 10% respectively. In the cold mountainous region, 69.2% of species showed signs of wood-decay fungi, 30.8% of wood-stain fungi, and there were no recorded instances of insect infestation (0%).

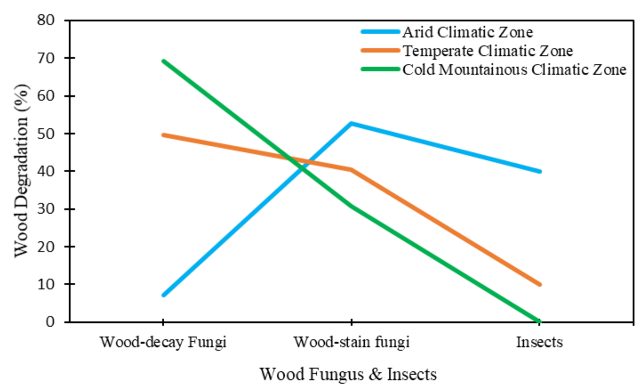


Figure 4: Timber Degradation by Wood-decay Fungi, Wood-Stain fungi & Insects

C. *Assessment of Timber Degradation by Wood Fungus and Insects in Different Climatic Zones of Afghanistan*

To go on a wide concept, Table 3 comprehends a broad spectrum of wood degradation agents, including various types of wood-decay fungi such as Brown-rot, and White-rot. Wood-stain fungi are categorized into sap-staining fungi, mold fungi, and chemical-stain fungi. Additionally, common insects known to be active in wood degradation include termites, beetles, and carpenter ants.

Table 3. Species Affected by Types of Wood Fungi and

Insects

Climatic Zone	Province	Wood Type	Total Examined Species	Brown-rot Species	White-rot Species	Sap-staining Species	Mold Species	Chemical stain Species	Termites	Beetles	Carpenter Ant
Arid	Nangarhar	Hardwood	55	3	1	14	2	13	17	2	3
Temperate	Kunar	Softwood	121	42	18	24	15	10	2	9	1
Cold Mountainous	Nuristan	Softwood	91	47	16	11	12	5	0	0	0

Table 3 shows, that in the arid climatic zone wood-decaying insects such as termites, beetles, and carpenter ants thrive due to the availability of wood for food and nesting more than fungus. Of 55 hardwood species 14 were attacked by sap-staining fungi, thus 17 by termites, and 3 by Carpenter ants according to the conditions that drive these fungus and insects to seek out moist wood, contributing significantly to degradation.

In the temperate zone, a diverse array of wood-decaying fungi is observed, including 42 species of brown rot and 18 species of white rot out of a total of 121 examined species. Additionally, 24 species associated with sap-staining and 15 with mold growth are prevalent, alongside 10 species causing chemical stains. Thus, the Beetle activity is relatively restrained, with only 9 species identified among the examined 121, indicating a lesser impact compared to fungal degradation processes.

In cold mountainous regions, the prevalence of wood-degrading fungi is notable, with 47 species of brown rot and 16 species of white rot identified out of a total of 91 examined species. These climates are conducive to fungal growth, facilitated by extended periods of moisture retention from snow and rain. Additionally, 11 species of sap-staining fungi, 12 species of mold, and 5 species causing chemical stains were observed. The absence of termites, beetles, and carpenter ants in this environment can be attributed to the severe cold conditions that deter insect activity, allowing fungal decay to dominate the wood degradation processes effectively.

Observing Figure 5, which details percentages of fungus and insect degradation in all three climatic zones of Afghanistan, in the Arid climatic zone, wood is affected 5.45% by brown-rot, 1.8% by white-rot, 25.5% by sap-stain, 3.6% by mold, and 23.6% by chemical stain. Additionally, termites affect 30.9% of the wood, beetles 3.6%, and carpenter ants 5.5%. In the temperate climatic zone, 34.7% of wood is attacked by brown rot, 14.9% by white rot, 19.8% by sap stain, 12.3% by mold, and 8.3% by chemical stain. Furthermore, 1.7% of wood is attacked by termites, 7.5% by beetles, and 0.8% by carpenter ants. For the cold mountainous climatic zone, wood degradation is predominantly caused by fungi, with 51.6% attributed to brown rot, 17.6% to white rot, 12.1% to sap-stain, 13.2% to mold, and 5.5% to chemical stains. No insect activity was found in this climatic zone affecting wood.

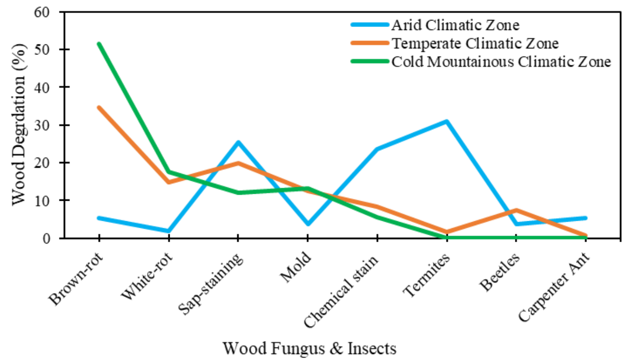


Figure 5: Timber Degradation by Various Kinds of Wood-fungus & Insects

V. Conclusions

This study has provided an in-depth analysis of timber degradation caused by fungi and insects across different climatic zones in Afghanistan. In the arid climatic zone, wood degradation is heavily influenced by insect activity, rather than fungus. In this region, 5.45% of wood is affected by brown-rot fungi, 1.8% by white-rot fungi, 25.5% by sap-stain fungi, 3.6% by mold, and 23.6% by chemical stains. Termites affect 30.95% of the wood, beetles 3.6%, and carpenter ants 5.5%. In the temperate climatic zone, wood degradation is primarily driven by a diverse array of fungi due to the humid conditions that favor fungal growth. Here, 34.7% of wood is attacked by brown-rot fungi, 14.9% by white-rot fungi, 19.8% by sap-stain fungi, 12.3% by mold, and 8.3% by chemical stains. Insect activity is relatively restrained, with 1.7% of wood affected by termites, 7.5% by beetles, and 0.8% by carpenter ants. In the cold mountainous climatic zone, fungal activity predominates due to the prolonged moisture retention from snow and rain, which creates an environment highly conducive to fungal growth. In this zone, 51.6% of wood degradation is attributed to brown-rot fungi, 17.6% to white-rot fungi, 12.1% to sap-stain fungi, 13.2% to mold, and 5.5% to chemical stains. No insect activity was found, as the severe cold conditions deter insect presence.

VI. Acknowledgment

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