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EFFECTS OF TEMPERATURE ON SOME SELECTED WOODS IN UMUAHIA, ABIA STATE

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ABSTRACT

Wood has many helpful benefits, with high ratio of strength to weight and a remarkable record for durability and performance as a structural material, but the properties can be manipulated by the impact of environmental factors. Therefore, wood should be processed and stored adequately to uphold the value of the biomaterial. This work exposes the effects of temperature and relative humidity in the tropical environment of Umuahia on the storability of commonly available wood. Four of the most available wood samples, namely, Iroko, White Afara, Black Afara and Nauclea Diderrichi, were collected, fresh from the mill, and used for laboratory and field experiments to determine the moisture content and storage effects of wood as seen in conventional storage patterns adopted by regional timber dealers. The results showed that Nauclea Diderrichi wood has highest percentage of water absorption in the field by 7.94%, followed by Iroko with 5.93%, and Black Afara with 5.36%, while the lowest was White Afara with 4.63%. The level of absorption or percentage moisture contents in ascending order resulted to Iroko, White Afara, Black Afara and Nauclea Diderrichi was 2.81, 2.82. 2.88 and 3.5% respectively. The environmental factors, mainly, variation in temperature and relative humidity at different season, has effect on the length, width, thickness, volumes and moisture content of the wood samples as seen from the outcomes of the research.

Keywords: Wood, Temperature, Storability, Moisture Content, environmental factors.

1.0 INTRODUCTION

There is increase demand in the natural resources like wood in the construction industry because of constant increase in population (Anejo *et al*., 2014), which shows importance of wood and the need to make more research in wood. The importance of wood, the unique characteristics and comparative abundance of wood have made it a natural material for homes and other structures, furniture, tools, vehicles, and decorative objects (Okigbo, 1996). Today, for the same reasons, wood is prized for a multitude of uses. The load bearing capacity of wood is one of the reasons why it is useful for building and other construction applications, a source of fuel, and a raw material for various products, playing a significant role in construction as alternative construction material for furniture, paper and more, as stated by Ede *et al.,* (2021) and Ede *et al.* (2014a). Its renewability and relatively low environmental impact compared to some alternatives also make it valuable for sustainable development. It has unending mode of utilization, like glue-laminated timber, laminated veneer lumber, structural composite lumber etc. (Ede *et al.,* 2014b). It's also used for various household items like utensils, tools, and decorative pieces. The natural beauty and warmth of wood contribute to the comfort and aesthetic appeal of living spaces. Wood processing generally requires less energy than the production of other materials like steel or concrete. Wood is also biodegradable and can be sustainably harvested, reducing its environmental impact compared to some non-renewable resources (Ohagwu *et al*., 2011). In sawmill, woods are processed for immediate use or for storage. The sawing are into different sizes for multipurpose usage, based on utilization and market demand. In the storage of wood, the moisture content needs to be reduced to maintain its size and shape. The two main methods adopted are natural/air seasoning and artificial seasoning through kiln (Okigbo, 1996). Other methods of drying and moisture reduction for storage purpose are temperature gradient method, radio frequency method (Le Van *et al*., 1990) and chemical drying method (Liese, 1995).

Woods compose of cellulose, lignin, hemicelluloses, these are all organic polymers that make up the cell walls of wood and minor amounts (5% to 10%) of extraneous materials contained in a cellular structure, which are organic compounds that influence properties like color, smell, and resistance to decay (Ohagwu *et al*., 2011). The composition of the fibrous cells in wood, its characteristics and pattern of their arrangement differentiates the properties of the wood species, like strength, shrinkage and grain pattern (Ohagwu *et al*., 2011). Putting some properties of wood into consideration helps in its maximum utilization for engineering purposes. According to historical knowledge, in terms of utilization wood species are in two parts, which are the highly and the lowly desired woods respectively. The desirability depends on their properties and purpose of utilization. Examples of such is white oak, that is on high demand because of its toughness, strength, durability, which made it to be useful for farm implement sheds, barns, storage platform, fence posts, etc. Black nut and Cherry woods are majorly utilized for cabinet and furniture (Katarzyna et al., 2024). The properties of wood is significantly a function of the place of storage and environmental factors. The advancement in technology has increased the usefulness in wood as engineering material. There is high demand in wood utilization in Nigeria because of many applications, hence, depletion in the natural form of wood in the forest (Abanikannda et al., 2021). The main factors while woods cannot be neglected as raw materials for production of wooden materials are varieties of wood species with high level of usefulness, adaptation to varying environmental conditions, shapes and sizes. Hence, it has durability properties as a structural material and high strength to weight ratio. According to Peter *et al*. (2023), dry wood is a good insulator, as it has ability to resist heat, sound and electricity. According to Kaura *et al*. (2015), research on white Afara (Terminalia Superba) from Kaduna and Zaria timber markets, indicated that the environmental factors in that area did not affect its strength.

Wood has the ability to absorb and dissipate sound vibrations, hence it is used for many musical instruments. It can be sharpened into any desired form to make good aesthetical appearance and joined using adhesives, screws, bolt and nut, nails. Many wood species can be protected using preservatives and fire retardants, remolded, and resists chemical oxidation from acid, saltwater and some other corrosive agents (Vani *et al*., 2022). The grading of lumbers, that is sawed woods, are based on utilization by individuals and industries, presence of knots, species and other physical and engineering properties. The grading is mostly done by the association of wood producers. There are many constraints in the research of the available wood species in Umuahia. Generally, research in wood that is lacking has generated many assumptions in wood properties and utilization. Some of which are the properties of wood in various environmental conditions, limited knowledge on the mechanical properties of the many species of wood in Nigeria. The limited knowledge made the utilization of wood to be based on past experiences with some wood species and on speculation or assumptions. Hence, many potentials of wood species have not been utilized, which make the saw miller most of the time to make use of the available wood in the area and also based on speculation. Environmental factors significantly impact wood, influencing its physical, structural, engineering and durability properties respectively, including its lifespan. Key factors include sunlight (UV radiation), moisture, temperature, and soil contact, all of which can cause degradation, warping, and weakening of the wood. The research is to study the effects of the major environmental factors, period of storage and location of wood storage on the dimensions and moisture contents of some common wood species available at sawmill of Umuahia. In addition, to model the changes in wood volume (mm^3) as a function of ambient temperature (°C) over a seven-month period (February to August) and to present the calculated moisture content for each species and condition.

2.0 MATERIALS AND METHODS

Figure 1: Map of Nigeria showing Umuahia, Abia State, Nigeria

Umuahia is the capital of Abia state, in southern Nigeria. The coordinates are 5°32′N 7°29′E. It is bordered by the states of Enugu and Ebonyi to the north, Akwa-Ibom to the east and southeast, Rivers to the south and southwest, and Imo and Anambra to the west. Abia includes areas of oil-palm bush and tropical rain forest in its southern part and woodland savanna in its hilly north. Umuahia's climate is classified as tropical. During most months of the year, there is significant rainfall in Umuahia. There is only a short dry season. The climate here is classified as Am, by the Köppen-Geiger system. The altitude is 122m above the sea level. It has bimodial climate of wet season between May – October and dry season between November – April. The mean annual rainfall is between 750mm to 1100mm. the highest temperature is 34^{o}C which mostly occurs in april and lowest temperature is 25^{o}C, that is experienced between December and January. The relative humidity has a variation during the months. It is between 50-60% in dry month of January – March and 80 – 95% in highest rainy season of July – September (Esomchi *et al.,* 2025).

2.1 Materials

The instrument used to carry out this work includes: liquid-in-glass thermometer, anemometer, electric oven model Y147893/17, steel ruler/ tape, T-square, pencil, pen and paper. Digital Venier caliper, hand gloves.

2.2 Methods

2.2.1 Sampling

There are four common wood species available at the milling site in Timber Market Saw Mill, Umuahia, where these common woods available are used for construction or structural works were collected and used for this study. Their names are Black Afara (Terminalia Irorensis), White Afara (Terminalia Superba), Iroko (Milicia excelsa) and Nauclea diderrichii. In order to make the movement of the samples easy for the research work, the wood samples were cut into smaller and equal dimensions of 500mm X 200mm by length and width respectively, with different breadths (thicknesses) is 50.8mm, 101.6mm, 63.5mm and 50.8mm for Black Afara (Terminalia Irorensis), White Afara (Terminalia Superba), Iroko (Milicia excelsa) and Nauclea diderrichii respectively. The woods were collected fresh from mill, after thorough examination to make sure they had no defects and were of high quality for examination. Each of the four samples was kept under laboratory environmental conditions and the other subsection in open field environment. A cut sample was taken from the subsections for laboratory testing and analysis.

2.2.2 Moisture Content Determination of Wood

The moisture content of the wood samples was determined using oven-drying method, where samples are taken from the specimens (piece of timber) with timber dimension 50mm X 50mm X 50.8mm of the Lengths X Widths X Depths for all the four specie samples respectively. The samples were chosen randomly, with no defects and other unwanted patches like roots, barks, checks, and pitch pockets. Each of the chosen sample was weighed immediately, before any drying to know the weight before oven drying and after weighing, the samples were placed in an oven heated gradually until it reached temperature of 105^{o}C. When the oven temperature reached 105^{o}C, the samples were left in the oven for four hours, to observe that there is no significant weight difference again, that is, constant weight and this was achieved by regular checking of weight of the samples on the weighing balance. The percentage of moisture content was determined using the formula in equation 1:

$$\text{Moisture Content (\%)} = \frac{Weight\ before\ oven\ drying - Oven\ dryweight}{Weight\ before\ oven\ drying} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots 1$$

3.0 RESULTS AND DISCUSSION

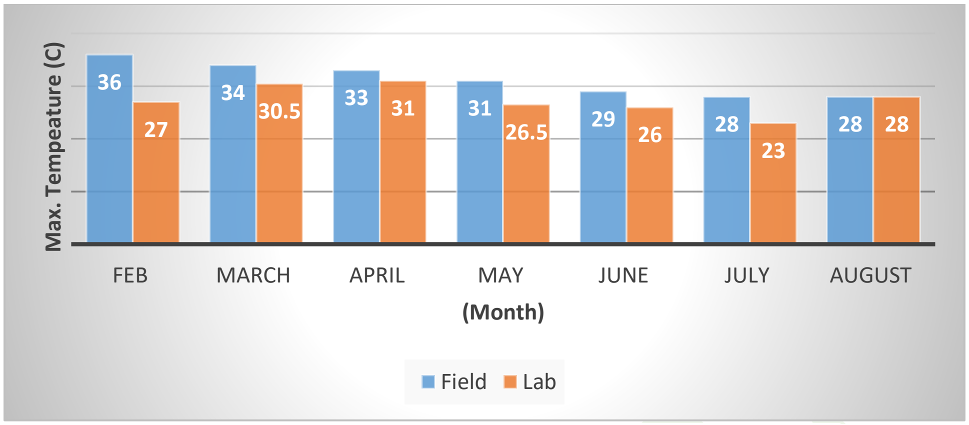

Figure 2: Mean Monthly Temperature in the Laboratory and Field

In figure 2, from the field environment, the highest temperature was in February with 36°C and lowest temperature of 28 °C in July and August respectively. This is a margin of 8°C. The highest temperature in the laboratory environment was 30.5°C and lowest temperature of 23°C, with a margin of 7.5°C. The higher margin of the field temperature than laboratory (controlled environment) temperature will be one of the reasons for the higher fluctuations in the dimensions, weight and moisture contents in the field than the controlled environment. In the month of August, the field and laboratory has the same average temperature of 28°C. This can happen as the laboratory lacks thermal insulation and the doors and windows were always opened, hence, environmental balance will set in to give response to thermal equilibrium, therefore, possibility of equal temperature in the month of August.

Table 1.0: Monthly Variation in Volume of the Wood Species

Month	Black Afara (mm^3)		White Afara (mm^3)		Iroko (mm^3)		Nuclei Diderrichi (mm^3)	
	Field	Lab	Field	Lab	Field	Lab	Field	Lab
Feb	5080000	5080000	10160000	10160000	6350000	6350000	5080000	5080000
March	5080000	5080000	10160000	10160000	6350000	6350000	5080000	5080000
April	5080000	5080000	10164064	10190000	6360000	6350000	5090000	5080000
May	5093054	5100000	10194076	10174068	6360000	6360000	5090000	5080000
June	5090000	5102040	10194076	10166096	6360000	6350000	5090000	5081016
July	5090000	5110000	10170000	10109200	6360000	6350000	5080000	5080000
August	5085080	5105100	10187292	10085105	6350000	6350000	5080000	5080000

The effect of environmental difference due to location can be seen from the results in table 1.0. Different location may differ in their temperature, relative humidity and other factors.

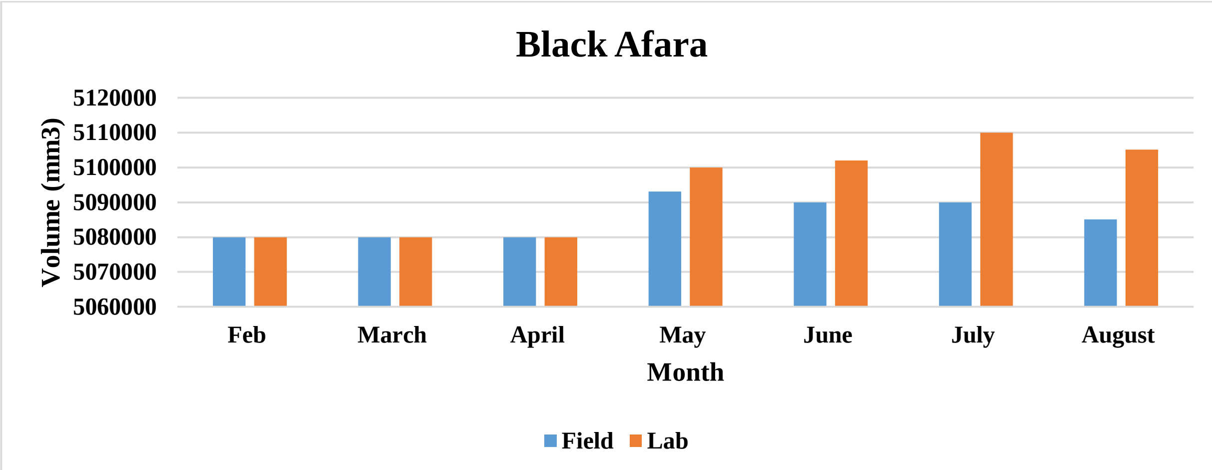

Figure 3: Monthly Variation in Volume of Black Afara wood species

Figure 3 shows the results of variation in monthly volume of Black Afara wood specie in the field and laboratory, with no change in volume from February to April, which shows that environmental factors did not affect significant effects on the size of the wood in the field and laboratory. The months of May, June, July and August showed increase in the volume of the wood in the laboratory than the field environment, that is, Greater volume fluctuation was observed in the controlled laboratory environment than in the field. In the month of May, lab volume increased by 20,000 mm³; Field volume increased by 13,054 mm³. in the month of June, lab volume increased further while the field volume was stable. In July, the wood specie was at the peak of its volume while the field volume was stable. In the month of August, there was slight volume decrease in both conditions. The effects of variation in the temperature during these months in the laboratory shows that the wood specie is preferably stored outside, in order to limit change in dimensions. There was little increase in the thickness of the black Afara specie by 0.1mm between May and June, as a result of variation in temperature and relative humidity. Also, from the results of laboratory storage condition, the environmental effect made variation in the thickness of the Black Afara specie in May, June and August by 0.2mm, while it was 0.3mm increase in July.

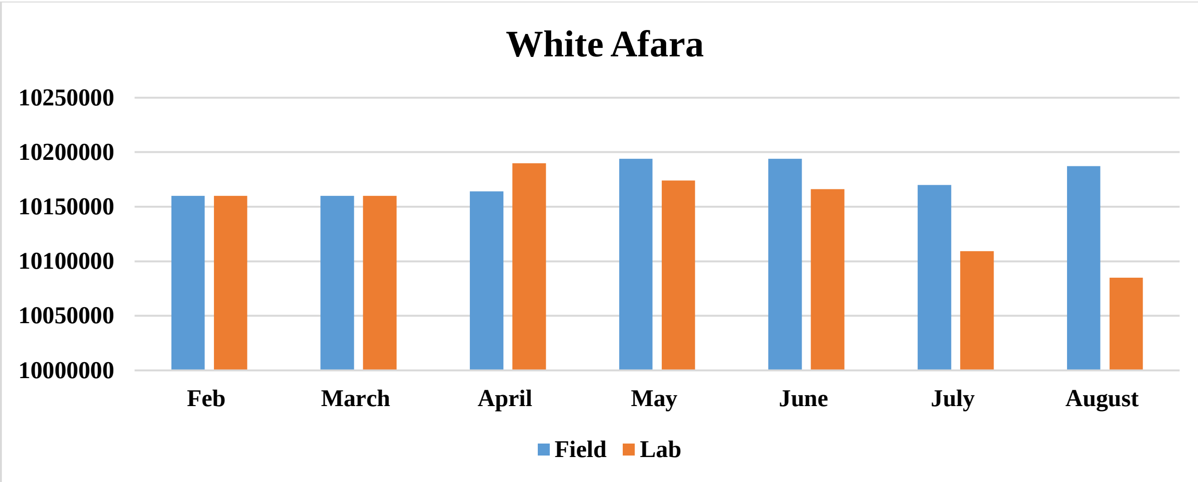

Figure 4: Monthly Variation in Volume of White Afara wood species

The white afara wood specie maintains a steady volume in February and March, but early volumetric increase in the laboratory and field volume was stable in the month April, as shown in figure 4. The months of May and June showed significant increase in volumes in the field, indicating peak field volume, compared to the previous dimensions, while the laboratory volume decreased in these months showed very little difference from the record of February and March. The effects of temperature in the environment significantly affected the woods in the months of July and August, which was more in the laboratory than in the field, it shows that the temperature of the field is more adequate than laboratory for the storage of white Afara wood specie. The volume decreased in both conditions in July, while the lab volume was at its lowest point in August. In figure 4, the field environmental condition did not show any significant effect on the thickness of white Afara wood specie till May, with an increase of 0.3mm to 101.90mm and a drop to 101.70mm in the month of July and August, as this may be attributed to the increase in relative humidity from February till August from 78.3 to 90.1% respectively. According to the laboratory observation of white Afara wood specie, with initial thickness of 101.6mm in February and march, but and increase to 101.9 and 101.7mm in the month of April and May, a reverse to its initial thickness of 101.6mm in June and July as a result of reduction in temperature and increase in relative humidity. The results showed that there were more fluctuations from initial thickness on the field than in the laboratory environment.

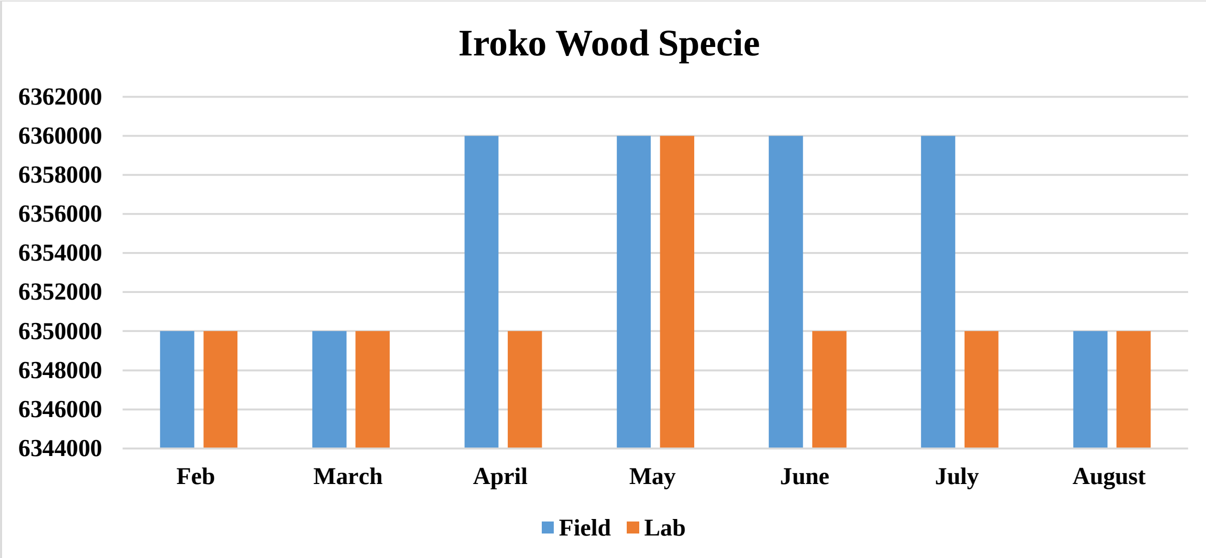

Figure 5: Monthly Variation in Volume of Iroko wood species

According to figure 5, in the laboratory, the Iroko wood specie did not experience fluctuation in the dimensions, hence maintained stable volume of 6350000mm^3 except in April and May with an increase in volume by 10,000mm^3. In the field environment, there was steady volume in the months of February, March and August. In June, lab volume returned to initial value. In July, lab volume was stable and field volume remains elevated. In the month of August, field volume returned to initial value. Iroko showed a minor but noticeable volume increase in both conditions, with the field environment showing a more prolonged change. Overall, it was dimensionally stable in the lab except for a brief increase in May. These are attributed to the variation of the environmental factors in the field. It shows that Iroko specie is better stored in a controlled environment to avoid changes in its dimensions.

The laboratory investigation shows that there was constant thickness of 63.50mm throughout the months except a small increase in May by 0.1mm, as a result of increase in relative humidity to 89.0% in May and 90.3% in July from initial 78.3% in January, as reported in figure 1. This shows that Iroko wood specie maintains its physical properties in controlled environment than open environment.

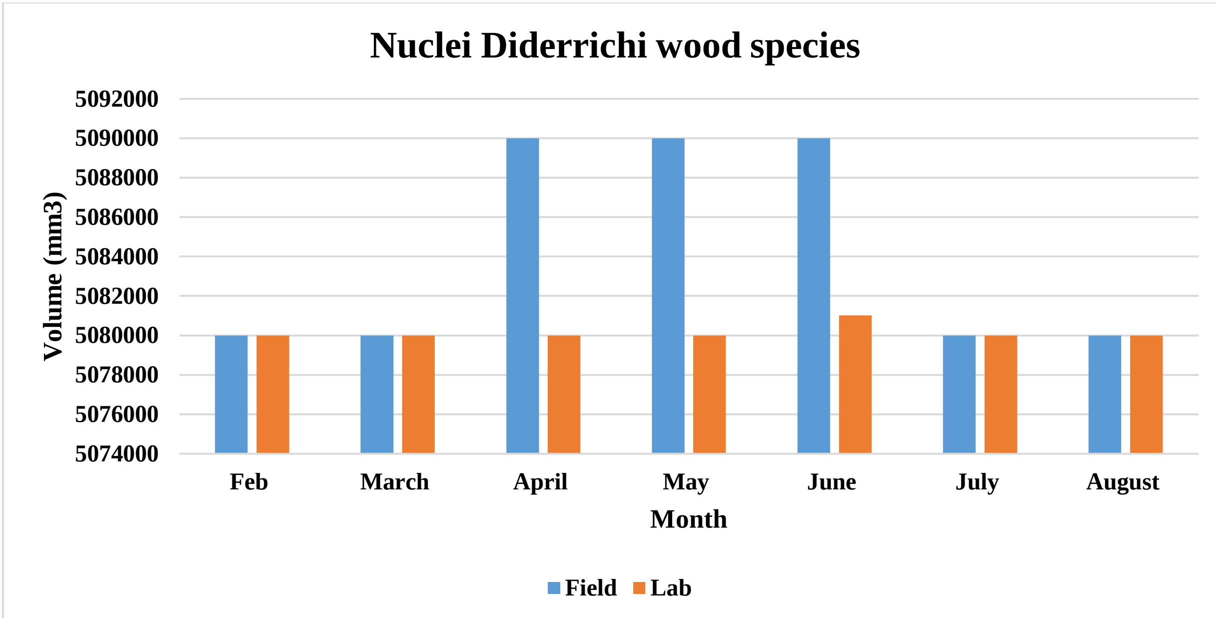

Figure 6: Monthly Variation in Volume of Nuclea Diderrichi wood species

The observations in the storage of Nuclei Diderrichi wood species as shown in figure 6 shows that in the months of February and March, the wood specie has steady volumetric dimensions, both in the controlled and field environment, that is resistant to environmental factor conditions. In the month of April, field volume increased by 10,000mm^3. In May, the field volume remained elevated. In June, there was Slight increase in Lab volume by 0.02%. In the month of July, field volume returned to initial value and by August, both the one in the field and lab returned to initial volume.

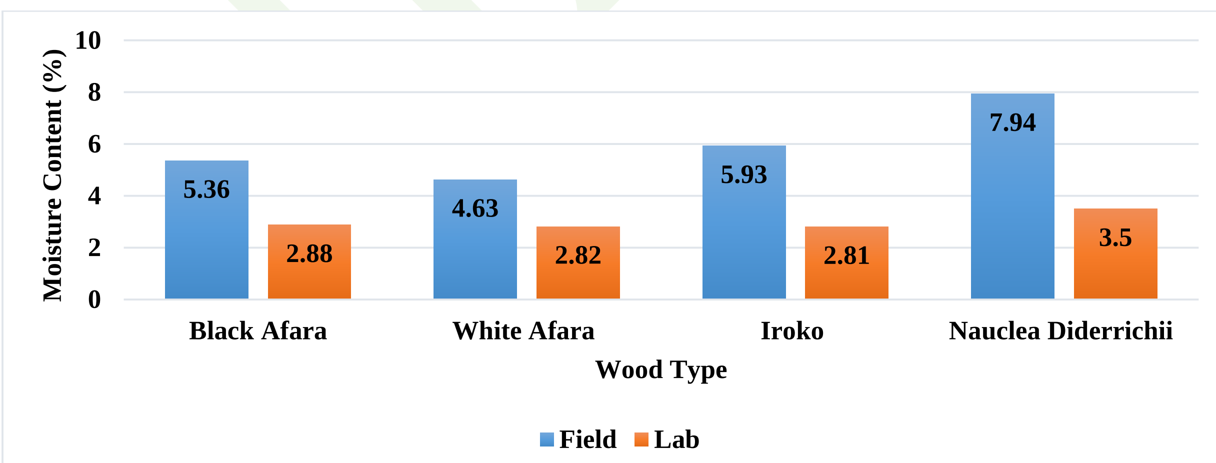

Figure 7: Percentage Moisture Content of the Wood Types in the Field and Controlled Environment

According to the results of figure 7, Nauclea Diderrichi wood has highest percentage of water absorption in the field by 7.94%, followed by Iroko with 5.93%, and Black Afara with 5.36%, while the lowest was White Afara with 4.63%. The level of absorption or percentage moisture contents in ascending order resulted to Iroko, White Afara, Black Afara and Nauclea Diderrichi was 2.81, 2.82, 2.88 and 3.5% respectively. All wood species absorbed significantly more moisture in the field environment compared to the controlled laboratory environment. Nauclea Diderrichi showed the highest propensity for moisture absorption in the field. It can be seen that preservation in a controlled environment reduces the rate of absorption of moisture by all the types of wood. The environmental factors at different season, has effect on the length, width, thickness, volumes and moisture content of the wood samples as seen from the outcomes of the research.

Table 2.0: Summary of the Model Developed for the Wood Species

S/NO.	Wood Species	Environmental Condition	Model Type	Model Equation	Model Statistics
1	Black Afara	Laboratory	Quadratic	V = 5,254,542.86 – 9,788.57T + 192.86T^2	R^2 = 0.89
2	Black Afara	Field	Linear	V = 5,041,371.43 + 1,435.71T	R^2 = 0.76
3	White Afara	Laboratory	Quadratic	V= 10,425,714.29-34,285.71T + 714.29T^2	R^2 = 0.85
4	White Afara	Field	Quadratic	V = 10,073,571.43 + 10,357.14T – 178.57T^2	R^2 = 0.82
5	Iroko	Laboratory	Intercept-Only	V = 6,351,428.57	R^2 = 0.12 (very weak temperature correlation)
6	Iroko	Field	Linear	V = 6332,857.14 + 857.14T	R^2 = 0.68
7	Nuclea Diderrichi	Laboratory	Intercept-Only	V = 5,080,142.86	R^2 = 0.08 (negligible temperature correlation)
8.	Nuclea Diderrichi	Field	Quadratic	V = 5,047,857.14 + 2,571.43T – 42.86T^2	R^2 = 0.79

Where: V = Volume (mm^3) and T = Temperature (°C)

Table 2.0 shows the development of model equation using second order quadratic model with design expert software. Model equations for each condition and wood species were developed as shown in table 2.0, where the dependent variable is the volume and temperature is the independent variable.

In further discussion of the research outcome in terms of the model equations as shown in table 2.0; At laboratory condition for the Black Afara, $R^2 = 0.89$, volume increases at lower temperatures (23-27°C) with peak around 25-26° C and relatively stable at higher temperatures; at field condition $R^2 = 0.76$, Volume increases slightly with increasing temperature, most stable at lower temperature range (28-33°C). In modelling White Afara wood specie at laboratory condition, the Model Statistics showed that $R^2 = 0.85$, Volume decreases notably at lower temperatures (<26°C) and Optimal volume at mid-range temperatures (26-30°C). The field condition showed that $R^2 = 0.82$, Volume increases up to approximately 29-30°C, then decreases and Maximum volume around 29°C.

The modelling of Iroko wood specie indicated that, at lab condition, $R^2 = 0.12$ (very weak temperature correlation), with Volume remains essentially constant across all temperatures and temperature has negligible effect on Iroko volume in laboratory conditions, meanwhile, at the field condition, $R^2 = 0.68$, very slight increase in volume with temperature and most stable wood species overall. The model statistics of Nuclea Diderrichi showed that, at lab condition is $R^2 = 0.08$ (negligible temperature correlation), extremely stable volume across all laboratory temperatures and similar behavior to Iroko in laboratory conditions. The field condition was best model as Quadratic, $R^2 = 0.79$ with volume increases at mid-range temperatures (29-33°C) and Slight decrease at extreme temperatures.

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

The field environment exhibited a wider temperature range (28°C to 36°C) compared to the laboratory (23°C to 31°C), contributing to greater material stress. All wood species showed volume fluctuations in response to temperature changes, particularly during the months of April-July, which correlates with the onset of the rainy season and increased relative humidity. The data models a clear pattern, signifying that, woods stored in a controlled laboratory environment maintained more stable dimensions and lower moisture content than those stored in the open field. In the Species-Specific Behavior, the model highlights distinct behaviors, which are Nauclea Diderrichi had the highest moisture absorption rate but showed good dimensional recovery. Iroko was highly dimensionally stable in the lab but less so in the field and White Afara exhibited the lowest moisture absorption overall but significant volume changes in the field. It was discovered that the Most Stable Species are the Iroko and Nuclei Diderrichi, which showed minimal temperature sensitivity in laboratory conditions. In terms of the most responsive specie, White Afara shows the greatest volume variation with temperature changes. In the case of condition effect, field conditions generally show more temperature-related variation than laboratory conditions. According to the model patterns, Quadratic models were most common (5 out of 8 cases), indicating non-linear temperature-volume relationships.

4.2 Recommendation

The behavioral pattern of wood with respect to environmental factors, type of wood, age of wood has been established to be different, hence, wood users should investigate the nature of each wood before recommending it for any utilization. It is recommended that wood should be standardize, with different codes for different types of wood usages, as different woods have their own behavioral pattern. The tradition of cutting down timber that is not yet matured should be avoided by saw millers, with proper monitoring of our forest reserve. Support for research by the government should not be abandoned and development and training of personnel that are in the area of wood production and the industry at local, state or private sector level in the production of improved types of wood based on utilization. Also from the findings, the types of wood under consideration have the tendency of enlarging or shrinking depending on the environmental conditions of the wood in service with Iroko, White Afara, Black Afara and Nauclea Diderrichi susceptible to deformation. As such, design factors should be given when using these materials as a building and construction components.

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