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AN EVALUATION OF WOOD PROPERTIES OF *Pinus Caribeae* (MORELET) IN OLUWA FOREST RESERVE, ONDO STATE, NIGERIA

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Abstract

This paper examines the effects of within tree variation on wood density, ring width and anisotropic shrinkage of Pinus caribeae (Morelet) among tree partitions in Oluwa pine plantation. Five 15-year old Pinus caribeae (Morelet) in three partitions were randomly selected from the plantation and felled for the study. Wood samples were prepared from five height levels, 10%, 30%, 50%, 70% and 90% and also among the wood type; inner wood, middle wood and outer wood positions of the stem according to standard procedures. The result showed the wood is dense, dimensionally stable with an average density of 0.55g/cm3. Among three partitions, ring width variation had a marked effect on wood density and anisotropic shrinkage of the wood (p < 0.05). A strong positive correlation was established between density and shrinkage properties. The relationship between ring width and anisotropic shrinkage was positive. Thus, it may be possible to use wood density and grain orientation biometry to predict anisotropic shrinkage of the wood and its dimensional stability.

Key words: *Density, Ring width, anisotropic shrinkage, Pinus caribeae (Morelet)*

Introduction

Pinus caribeae are fast growing, early maturing species of conifers. They represent a potentially large source for material for paper production (Spanos *et al.,* 2001). *Pinus caribeae* wood, which is light white in color, has little or no smell or taste, is easy to process, and has been widely used for many years. Some of its most important uses are in veneer, plywood, and saw wood manufacture, matches and match boxes, pulp and paper, and cellulose products (Spanos *et al.,* 2001). One important factor in the use of *Pinus caribeae* is knowledge of the variation in wood properties within a stem; for instance, the wood density for pulping and mechanical processing, and shrinkage for mechanical processing. This leads to better chemical optimization; for example, high wood density is important for chemical pulping, and moderate wood density is the most suitable for plywood production (Moherdiek, 1979). As the need for paper in Nigeria is increasing in geometrical proportion, pulp and paper companies are interested in using over aged *Pinus caribeae* wood for manufacturing paper, and these materials must meet the specifications.

In general, researchers agree that wood density is one of the most important factors affecting wood quality (Keith, 1986; Tsoumis, 1991). The methodology for determining the variation in specific gravity within and between trees was studied by Mutibaric and Cemerikic (1971), and Panetson *et al*. (1969). They studied the influence of wood raw material on shrinkage and swelling properties; however, until now only a few studies on wood shrinkage in *Pinus caribeae* have been carried out (Koubaa and Smith, 1959; Karki 2001; Pliura *et al*. 2005). As such, data on the variation within and between *Pinus caribeae* trees are very limited. Such data are needed to enable the inclusion of wood shrinkage and wood density as selection criteria for the improvement of wood properties that play a major role in the raw material for domestic and industrial uses (Panshin and Dezeeuw, 1980).

The objectives of the present study were to investigate the variation in wood density and wood shrinkage in the *Pinus caribeae* stem and to examine the relationship between wood density and shrinkage in *Pinus caribeae*.

Materials and Method

Study area

Oluwa forest reserve is located in Ondo State in the Western part of Nigeria on latitude 10˚37'N

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and longitude 9˚20'E with an area of 827 km^2 and falls within the tropical rainforest (Adekunle and Bakare, 2004). It is 50km east of Omo and 26km from Ore (Anifowose, 1989). The topography is undulating with a mean elevation of 90m above sea level, mean relative humidity of 80% and daily temperature of 25˚C. The vegetation of the study area is a mixed/moist semi-evergreen rainforest (Dauda *et al*., 2004).

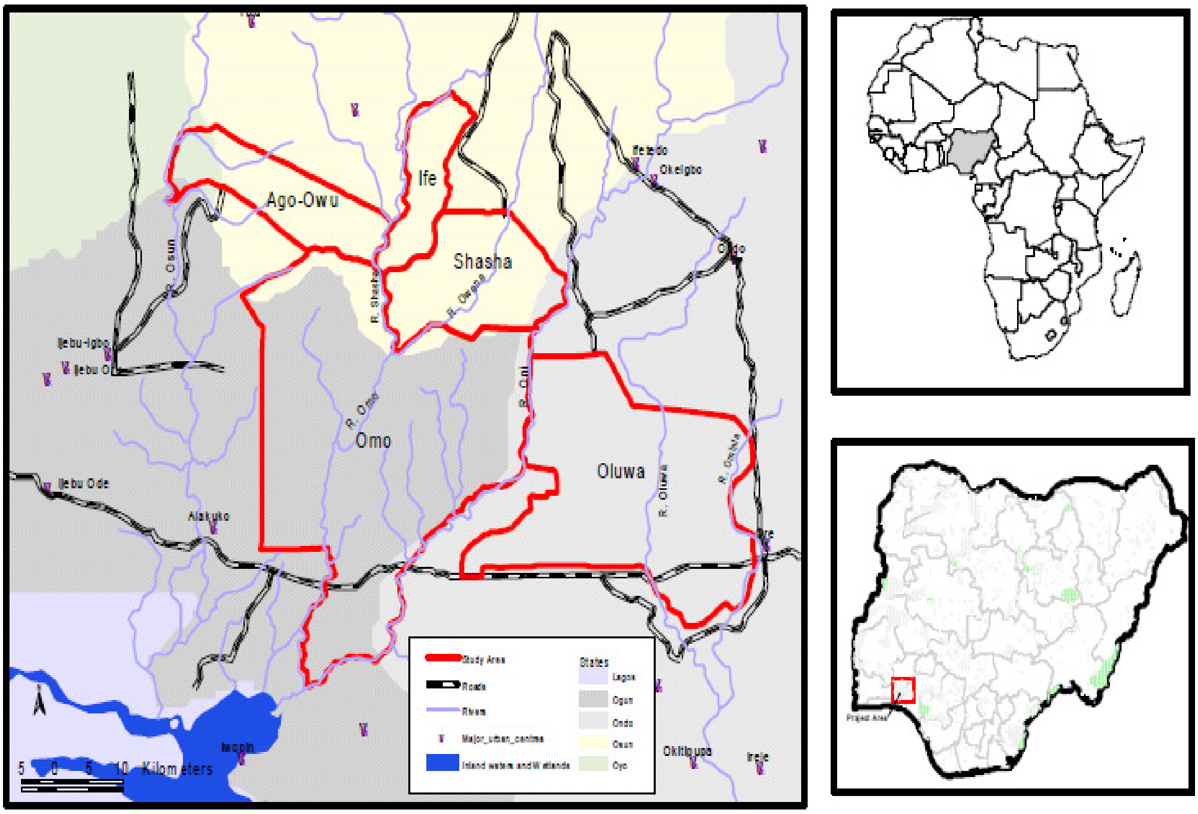

Figure 1 Map of the study area showing major rivers and road (Insert is map of Nigeria and Africa showing location of the study area)
Source: NCF (2008)

Data collection

The materials for the study were obtained from a *Pinus caribeae* (Morelet) plantation grown in Oluwa forest reserve (World Bank assisted project). The wood samples were collected from a 15 years old plantation with an area of 25 ha. The plantation was divided into a 5 partitions with an area of 5ha each. 5 trees with good bole were randomly selected from 3 of the partitions for the study (P1, P2 and P3). The diameter at breast height (dbh), four cardinal points on the tree trunk with the aid of a meter tape and compass were recorded as described by TAPPI (1995) and Browning (1977) were observed in all the selected trees before they were felled.

Five (5) discs with a thickness of 50mm were obtained from the felled trees at 10%, 30%, 50%, 70% and 90% of their merchantable length. The discs were individually labeled and their surfaces coated with paraffin and stored separately in polythene bags. Each of the discs was subsequently debarked carefully and a strip of 50mm wide obtained after careful marking and rip-sawing to the pith from the bark. Half of the strip was used for the wood properties investigated – wood density, shrinkage variations and ring width while the other halves were carefully preserved and stored for further study. From each of the sampling levels, the strips were partitioned radially into Inner wood (A) 1-5 rings, Middle wood (B) 6-10 rings and Outer wood (C) 10-15 rings respectively based on the number of rings counted from the pith to the bark and also carefully labeled after obtaining strips of 20mm x 20mm according to their wood type.

Wood density

The wood density was measured using the gravimetric method as prescribed by Smith (1954). $\mathbf{W_D = 1/((Ws - Wo / Wo) + 1 / 1.53)}$ expressed in g/cm^3 **(1)**

Where W_D = wood density, Ws = saturated weight of specimen, Wo = Oven dry weight of specimen and 1/1.53 = reciprocal of the density of actual wood substance

Volumetric shrinkage

The specimens of 20mm x 20mm x 20mm were properly aligned to show the radial and tangential planes and diligently coded for identification and measurement carried out with the aid of a venier caliper during wet condition. Specimens from each of the sampling height and partition were completely saturated with water by boiling and oven drying to a constant weight at 103˚C±2˚C for 48hrs as prescribed by Smith (1954) before measurement taken. Percentage shrinkage was determined for both the radial and tangential planes while the volumetric shrinkage was calculated from the sum of the tangential and radial shrinkage and expressed as a percentage of the original green dimension of the wood when dried to a constant weight (Chris, 2006; Onilude and Ogunsanya, 2000).

Ring width

The ring width was determined according to the procedures used by Smulski (1996) and Onilude and Oluwadare (2000) by measuring the growth ring in the four cardinal positions by superimposing a double biconcave lens over a calibrated transparent ruler. The width was measured from the first formed early wood to the last formed latewood bands of each growth ring.

Statistical analysis

The data obtained were analyzed using described statistics, analysis of variance (ANOVA), correlation and regression methods (Ezekiel and Fox, 1961; Snedecor and Cochran, 1997; McDonald, 2008).

Results

Within-tree density variation

Density variation within the partition followed a pattern within the annual growth rings and along the radial and axial direction of the trees in each partition (Figure 2). The wood density among the partition was observed to increase in increments near the pith before remaining more or less constant, decreasing in the last formed increment close to the bark. Analysis of variance from pooled data from the three partitions on density revealed that variation in density due to partition was significant at P>0.05 and the regression coefficient where positive (Figure 2).

Variation in density among sampling level of merchantable height

The mean values of wood density in Partition 1 was observed to be highest at 90% (0.687g/cm^3), followed by 10% (0.648 g/cm^3) and least at 70% (0.526 g/cm^3) as indicated in Figure 3. In Partition 2, the tree density was highest at 30% (0.575 g/cm^3), followed by 50% (0.509 g/cm^3) and least at 10% (0.469 g/cm^3). The mean wood density in Partition 3 was highest at 30% (0.575 g/cm^3), seconded by 70% (0.491 g/cm^3) and least at 10% (0.470 g/cm^3). In general, it was observed that the mean wood density in all the level of merchantable height in Partition 1 was higher than the values obtained in Partition 2 and 3. Analysis of variance on the effect of levels in the study area indicated that the variation of wood density due to level was significant at P>0.05 (Table 1), thus, indicating an inconsistent relationship between the wood density and sampling levels of the tree length.

Ring width variation and wood density

The result in Figure 4 shows the relationship between growth rate (ring width) and wood density among the three partitions. Trees in partition 1 had the least mean value for the ring width (1.6%) while Partition 2 and 3 shared the highest ring width value of 1.8%. The values obtained for wood density was highest in Partition 1 (0.61g/cm^3) and least in Partition 3 with 0.46 g/cm^3 (Figure 4). Moreover, when the samples were pooled, the coefficient of variation was 72% when the ring width was regressed against the wood density (Table 2).

Radial shrinkage

Radial shrinkage height variation for trees in each partition is indicated in Figure 5. Radial shrinkage variation for Partition 1 was highest at 30% (5.9mm) while Partition 2 and 3 had their highest mean value at 90% (4.2mm) and 30% (5.6mm) respectively. Moreover, tree level effect on the axial variation in the radial shrinkage was statistically significant with a positive relationship in all the partitions (Figure 5). The result obtained above was at variance with the observation of Onilude and Ogunsanya (2000) that radial shrinkage across the bole of Obeche was 2.8% and decreased vertically from the tree base to the top. However, the results obtained gave a mean radial shrinkage that ranged between 3.3% and 5.9%.

Effect of wood type on radial shrinkage among the partitions

The result obtained shows that Radial shrinkage was highest in the Middle wood (5.2%) for Partition 1, Inner wood (5.3%) for Partition 2 and also Middle wood (5.2%) for Partition 3 respectively (Figure 6).

Effect of level on tangential shrinkage of trees among the partitions

The tangential shrinkage across the level of merchantable height showed that in Partition 1, the highest shrinkage value was obtained at 90% (5.9%), 50% of merchantable height (5.7%) in Partition 2 and 30% of merchantable height (5.0%) of Partition 3 (Figure 6). Variation in tangential shrinkage due to effect of level of merchantable height was statistically significant (P>0.05). There was also a strong correlation when the tangential shrinkage of the trees was regressed against the level of merchantable height and the prediction levels were positive (Figure 7). The tangential shrinkage of the species lay between 3.2% and 5.9%. Effect of wood type on radial shrinkage among the partitions

The result in Figure 8 indicates that the mean tangential shrinkage obtained from Partition 1 at the Inner wood and the Middle wood were the same (5.4%). In Partition 2, the Inner wood had the highest shrinkage value (5.5%) and the Middle wood in Partition 3 had the highest tangential shrinkage value (4.4%). In order to obtain the prediction level, tangential shrinkage was regressed on the wood type of the various partitions, and the showed there was a strong prediction among all the wood types in the three partitions (Figure 8). The tangential shrinkage increased from the pith to the bark of the tree with values that lay between 3.7% and 5.5%.

Effect of wood type on radial shrinkage among the partitions

The result in Figure 8 indicates that the mean tangential shrinkage obtained from Partition 1 at the Inner wood and the Middle wood were the same (5.4%). In Partition 2, the Inner wood had the highest shrinkage value (5.5%) and the Middle wood in Partition 3 had the highest tangential shrinkage value (4.4%). In order to obtain the prediction level, tangential shrinkage was regressed on the wood type of the various partitions, and the showed there was a strong prediction among all the wood types in the three partitions (Figure 8). The tangential shrinkage increased from the pith to the bark of the tree with values that lay between 3.7% and 5.5%.

Effect of level on volumetric shrinkage of trees among the partitions

The result obtained shows that in Partition 1, the mean volumetric shrinkage value was highest at 90% of merchantable height (10.8%) while Partition 2 and 3 had their highest mean at 30% of merchantable height with 9.4% and 10.7% respectively (Figure 9). The regression model gave a positive correlation of the volumetric shrinkage with percentage level of merchantable height in all the three partitions. This showed that the volumetric shrinkage of the trees in the study area increased with increasing level of percentage tree length except for trees in Partition 3 (Figure 9). In general, the mean tangential shrinkage among the Partition ranged between 7.1% and 10.8% with the highest prediction level of 32.6% obtained in Partition 3.

Effect of wood type on volumetric shrinkage among the partitions

The variation in volumetric shrinkage among the different wood types shows that the Middle wood in Partition 1 had the highest mean shrinkage value (10.6%). In Partition 2, the Inner wood had the highest mean shrinkage value (10.8%) and Middle wood in Partition 3 had the highest mean shrinkage value of 9.6% (Figure 10). The regression of volumetric shrinkage against wood types also showed a positive correlation and they were very high for each of the Partitions (Figure 10). From the study, the results showed that the effect of wood type was significant to the overall volumetric shrinkage variations. The shrinkage values lay between 6.1% and 14.5% with a prediction level of 78%.

Effect of level and axial direction on ring width variation

The result in Figure 11 shows that the ring width was highest at 90% level of merchantable level (2.7%) in Partition 1. In Partition 2, the mean ring width value was highest at 50% level of merchantable length (2.5%) and in Partition 3, the highest ring width value was obtained at 10% level of merchantable length (2.3%). The regression result also showed that there existed a strong correlation between the ring width and the level of merchantable length. The predictions from the linear models showed a positive relationship (Figure 11) although the ring width variation did not follow a definite pattern.

Ring width variation among different wood types

The result of ring width variation among the wood type shows that the ring width increased from the Inner wood to the Outer wood (Figure 12). The highest mean value of 1.9% was obtained for Partition 1 at the Outer wood. In Partition 2, the Middle and Outer wood shared the same highest value of 2.1% respectively and Partition 3, the Outer wood had the highest value of 2.1%. The region values for all the wood types showed a high prediction value indicating that the wood types had a significant effect on the ring width variation (Figure 12).

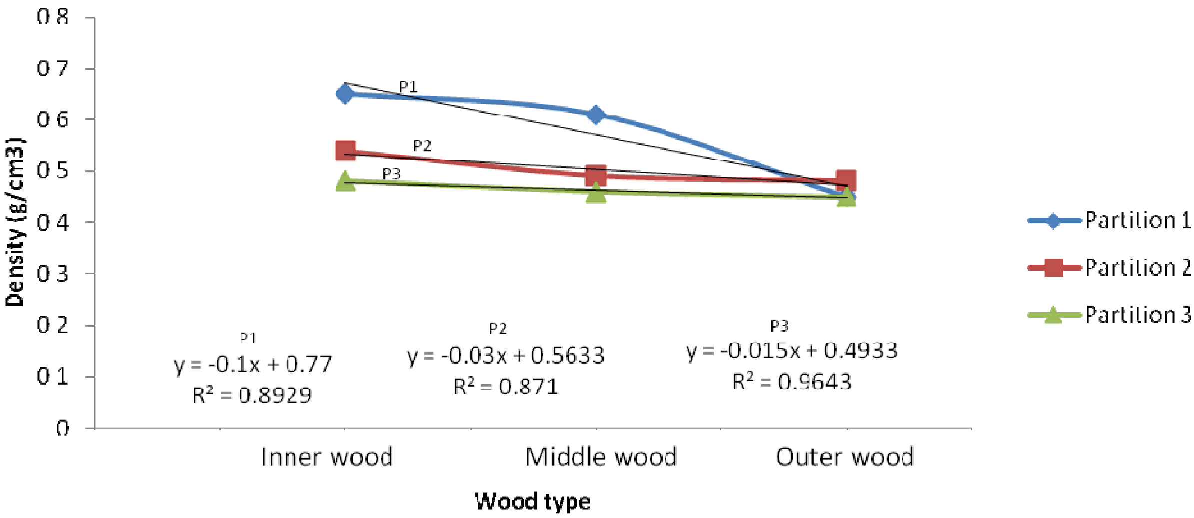

Figure 2 Variation in density of trees among wood types

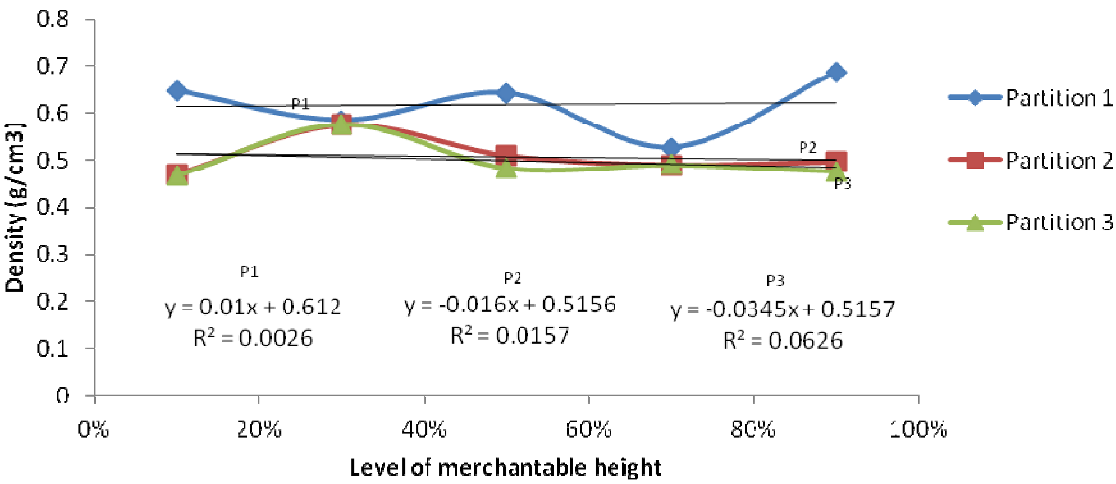

Figure 3 Density variation in percentage merchantable height

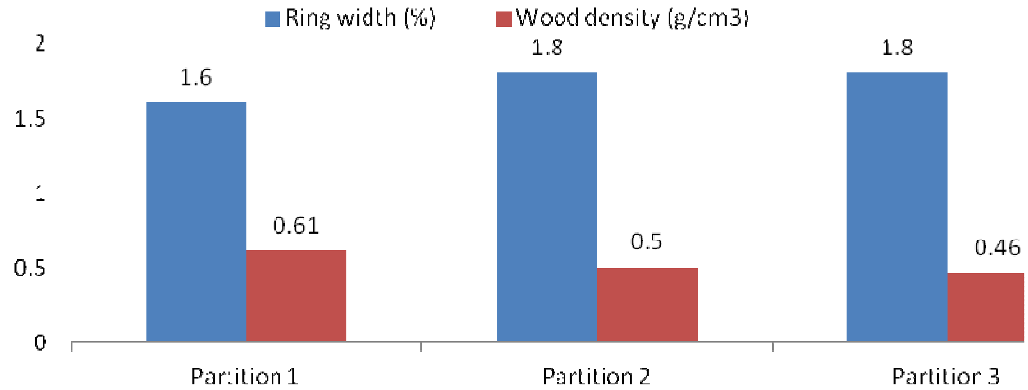

Figure 4 Variation of ring width and wood density among Partitions

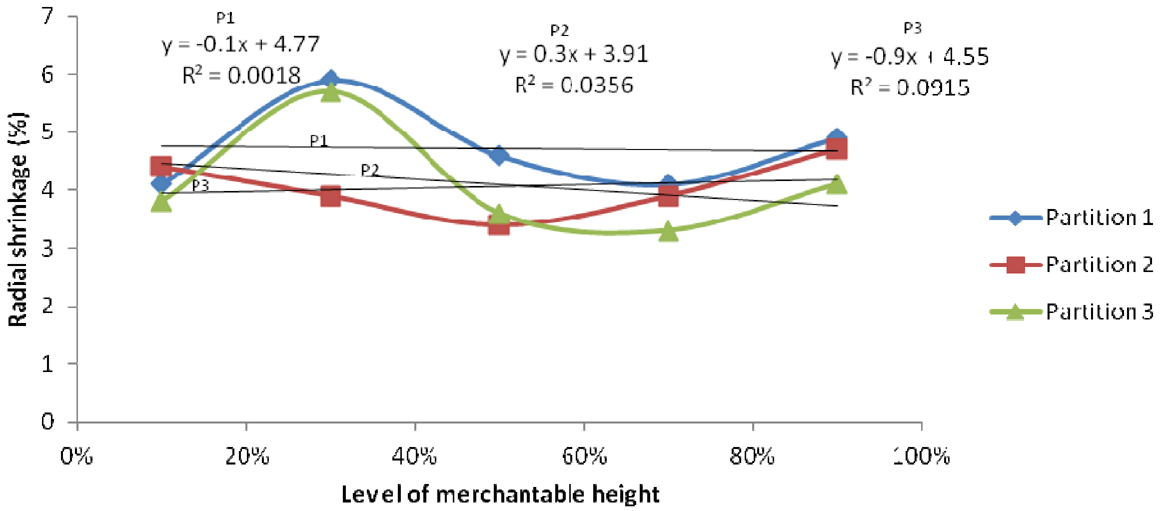

Figure 5 Radial shrinkage variation for different tree level and Partition

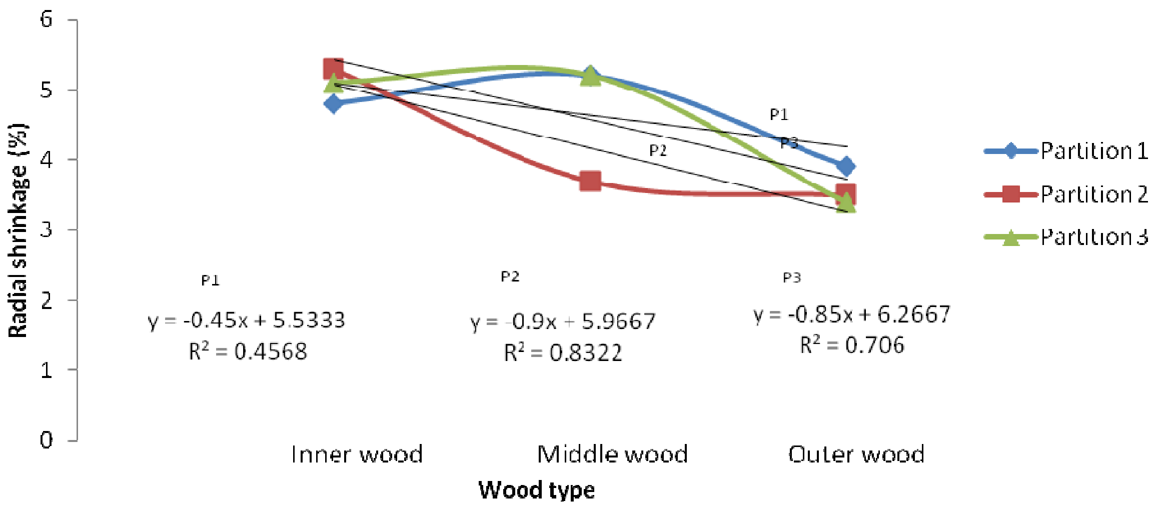

Figure 6 Radial shrinkage variation for different types of wood

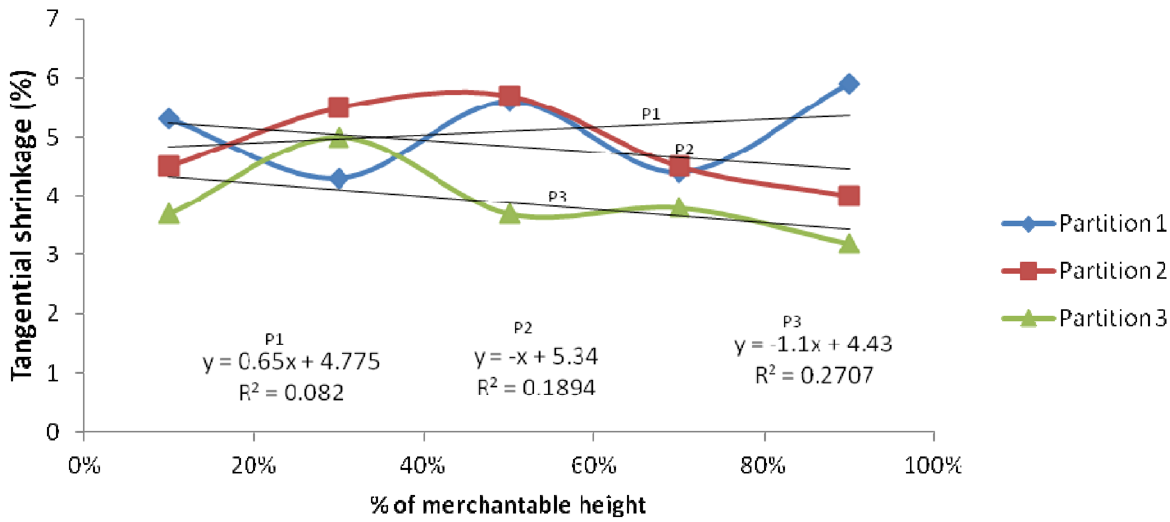

Figure 7 Tangential shrinkage variation for different tree level and Partition

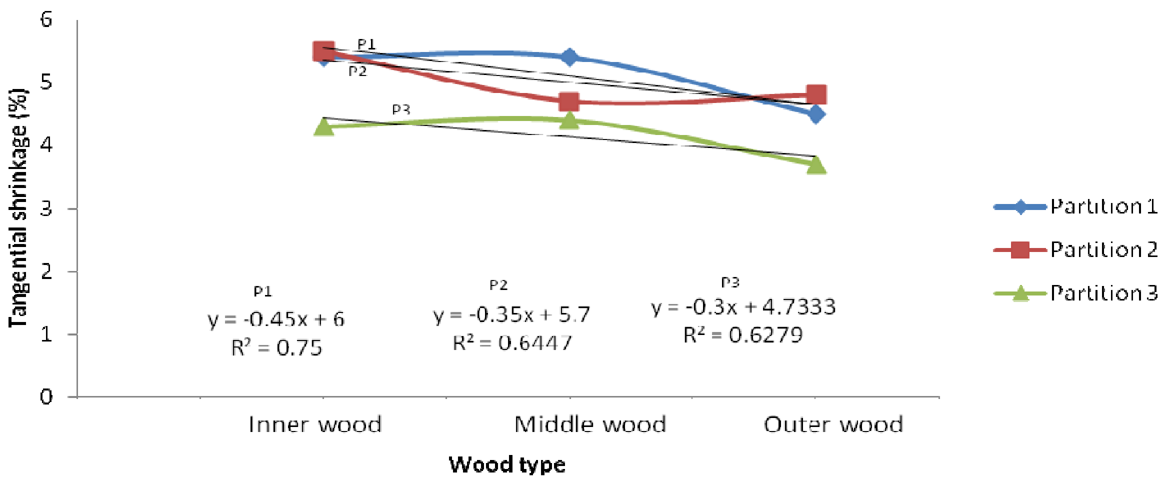

Figure 8 Tangential shrinkage variation for different types of wood

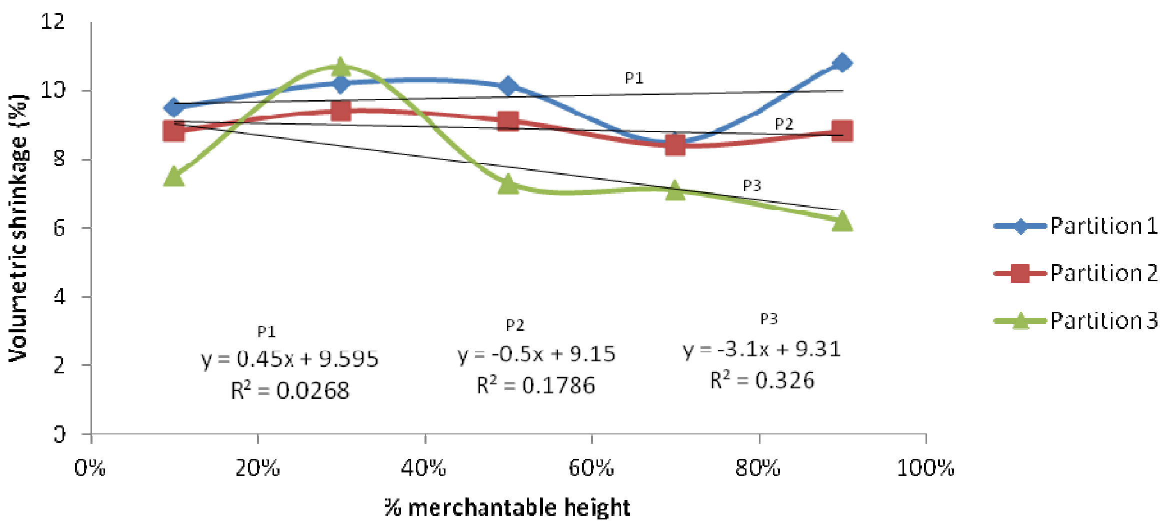

Figure 9 Volumetric shrinkage variation for different tree level and Partitions

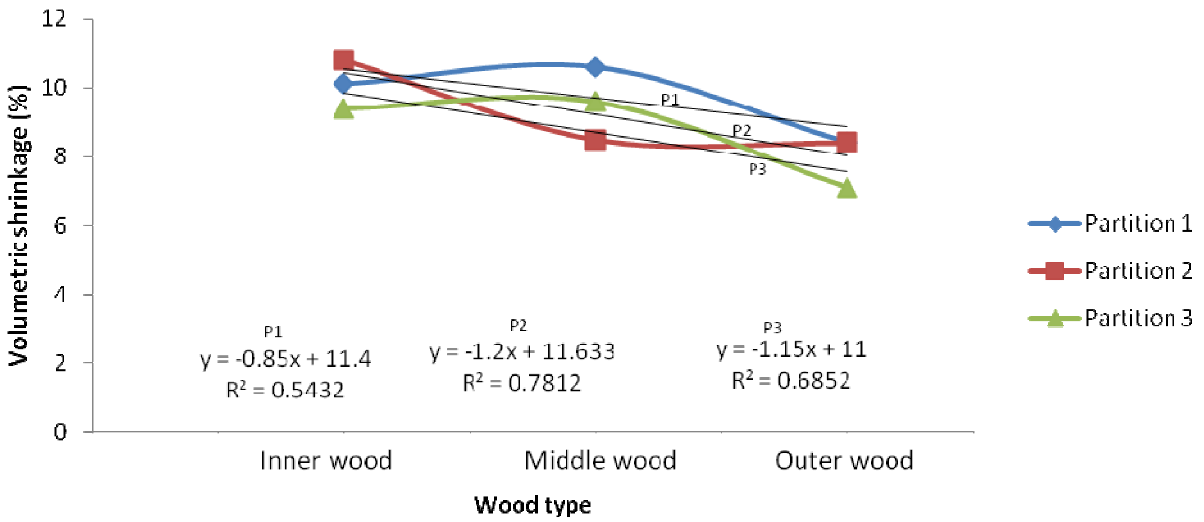

Figure 10 Volumetric shrinkage variation for different types of wood

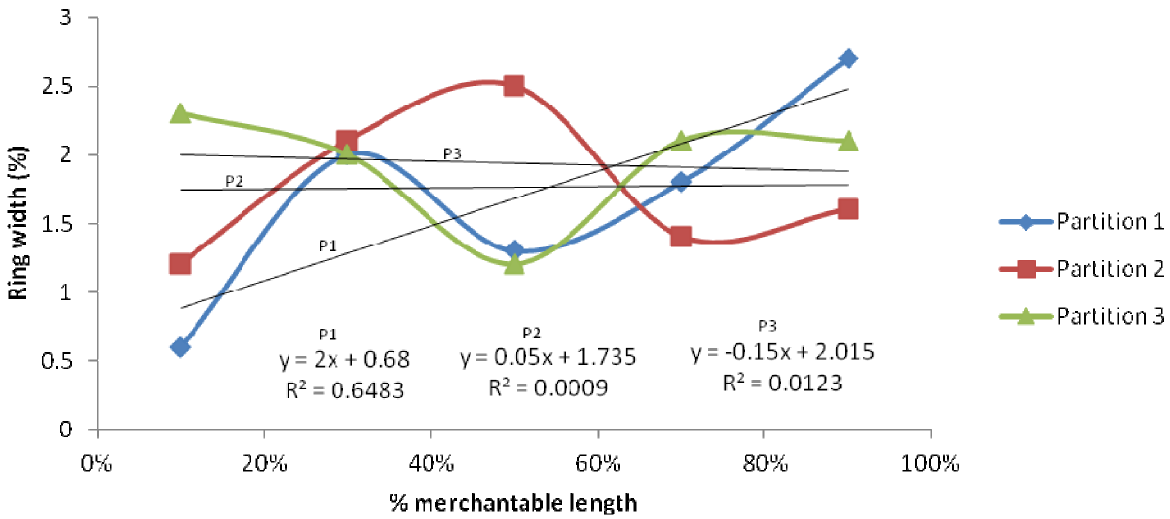

Figure 11 Ring width variation for different tree level and Partitions

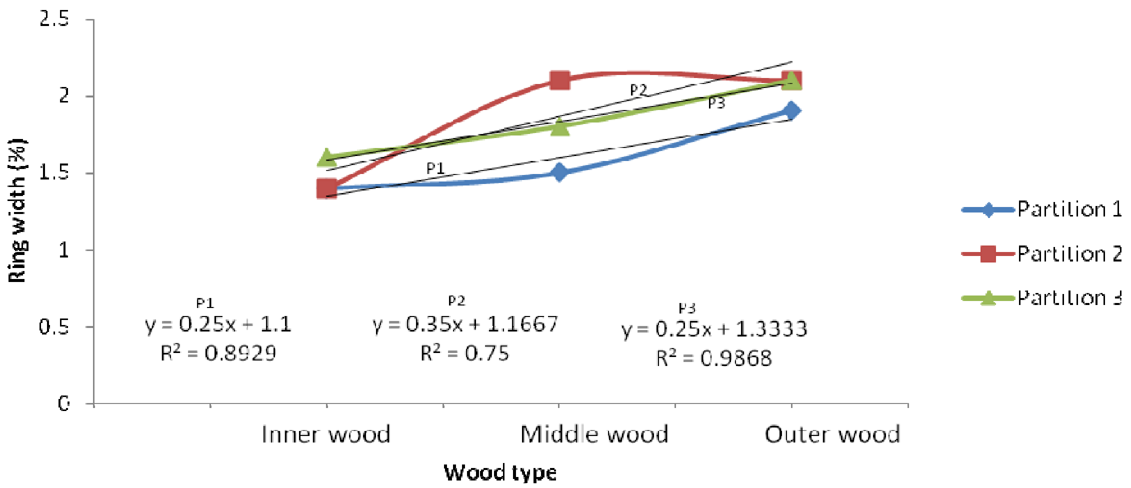

Figure 12 Ring width variation for different types of wood

Discussion

Some researchers have reported that wood density increases with age or distance from the pith (Boyce and Kaiser 1961; Farmer and Wilcox 1968; Bonneman 1980). This is supported by the fact that juvenile wood is usually known to be of lower density than mature wood (Dadswell 1958; Zobel and Buijtenen 1989). From the result, it was observed that wood density decrease with increase in ring width. This relationship follows a pattern described by Akachukwu (1982). Wood density changes in the present study may have been due to the inclusion of trees that had entered the wood maturity phase, thus exhibiting a corresponding increase in wood density. This observation also agrees with the observation of Panshin and De Zeeun (1970) that the higher density of *Pinus caribaea* at the pith region declining toward the bark could be attributed to the presence of heartwood and extraneous materials resulting in the higher density values at the earlier growth rate or ring width. This trend of inconsistency could be explained by the difficulties in ascertaining all the silvicultural practices/treatments receive by a stand or individual tree and the topography of the plantations. However, differences in growth rate have been reported to cause differences in wood density variation patterns in the axial direction of the tree (Larson, 1963; Jourex *et al*., 2001).

Dense wood results from fiber with thick walls and a low micro fibril angle produce minimal longitudinal shrinkage, and increases radial and tangential shrinkage (Dadswell 1958). Changes in wood shrinkage with cambium age are likely related to radial inter-tree variation in wood density, which often displays an inverse pattern of changes (Johnson, 1942; Okkonen *et al.,* 1972; Yanchuk *et al*., 1984). Increase in tangential shrinkage was more on the 30% level than any other levels with values ranging between 4.3% and 5.5% against the reported value of 6 – 8% of Chris (2006), indication that pulping liquor will increase slightly in the tangential section than in the radial section that gave a shrinkage value that lay between 3.3% and 5.9% across the tree bole. The values for the volumetric shrinkage were also in accordance with the observation of Chris (2006) and Martins (1984) with the range of 5.0% - 18%. The positive correlations between basic wood density, radial, tangential, and volumetric shrinkage in Pinus caribaea were in accordance with the observations of Koubaa and Smith (1959) with *P. euramericana* hybrid clones. Furthermore, the decreasing pattern of ring width towards the pith in the study implies that the sample trees of *Pinus caribeae* experienced slow response in the early growth years that resulted in the production of lower growth rings. However, as the trees mature with age, the rate of growth gradually increases culminating in wider growth rings development. It is evident from the study that variations in the growth rate had considerable and direct effect on the cell length development.

Conclusion

The wood of *Pinus caribeae* is heavy. With-in tree, wood density decreased from the base to the top and from sapwood to heartwood. The range of density values obtained in this study lay within the range of 0.45 – 0.65g/cm3. Moreover, the wood ring width had a characteristic variation among the partitions. A strong positive correlation was established between density and shrinkage properties and the relationship between ring width and anisotropic shrinkage was also positive. Thus, it may be possible to use density and grain orientation biometry to predict anisotropic shrinkage of the wood. Volumetric and radial shrinkage increased from the base to the top and from heartwood to the sapwood while tangential shrinkage was highest in the middle and lowest at the top. The range of values of volumetric shrinkage along the height and radial positions shows that the wood is dimensionally stable, with low consumption of pulping liquor and hence suitable for pulp and paper making, veneer, plywood, and composite board manufacture.

Table 1 Analysis of variance of wood density

Source of varaiation	Df	SS	MS	Fcal	Ftab (0.05)	Significant level
Level	4	0.09	0.02	5.0	3.84	**
Partition	2	0.01	0.01	2.5	4.45	Ns
Error	8	0.03	0.004			
Total	14	0.13				

** = Signiicant at P > 0.05, ns = Not significant at p < 0.05

Table 2: Regression of ring width on wood density

Source of varaiation	Df	SS	MS	Fcal	Ftab (0.05)
Regression	1	0.010	0.010	33.505	4.67
Residual	13	0.004	0.000		
Total	14	0.014			

Correlation co-efficient = 0.849, Co-efficient of determination (R^2) = 0.720
Standard error of the estimate = 0.01768

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