A STUDY ON VARIATIONS IN PHYSICAL AND MECHANICAL PROPERTIES OF TWO MYANMAR LESSER-USED TIMBER SPECIES

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ABSTRACT

Leza (*Lagerstroemia tomentosa*, Presl.) and Pyaukseik (*Holoptelea integrifolia*, Planch) are large deciduous and timber-producing trees. With the objectives of finding the potential of increased utility and also of studying trends of variations in wood properties within and between trees and between species as it affects the choice of logs and timbers, the physical and mechanical properties of the two species were investigated. It is found that in both species that shrinkage varies significantly between and within trees. In a tree, shrinkage decreases with distances from the pith, but is not increasing or decreasing with height. The green density and specific gravity decreases with heights and increases with distances from the pith. The moisture content decreases with distances from the pith in both species, and increases with heights in most sample trees of Pyaukseik and is not increasing or decreasing with heights in Leza. The mechanical properties vary significantly between and within trees. The dimensional stability of the two species is less than 2 and thus they are stable. According to the investigated data, the two species are found suitable for constructions and other utilities.

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(*Lagerstroemia tomentosa* and *Holoptelea integrifolia*)

1. Introduction

In Myanmar there are eight different kinds of forest types, the total forest area being 50.8% of the country area that is 676,577 km^2. In these forests, a lot of flora enjoy growing, their number being 4757. Of these, about 2088 trees, big and small can be assumed to be able to produce timber. The number of big trees amount to 1347, of which a small number of timber-producing species can be considered economically important. Teak and the species in Groups 1 and 2 are considered as commercial.

Most of the timber-producing species are accepted as lesser-used at present. All of the species in Groups 3, 4 and 5 seem to be defined as lesser-used. There are various opinions concerning the meaning of lesser-used timber species. The importance of a species is an acceptance to the market. If good timbers ("good timber" means "timber that has good physical and mechanical properties") are available, other timbers will not be used and they will become lesser-used. But there are cases in which one species is liked but its availability is scare, then it becomes lesser-used. But it will be the main reason of many timber species being lesser-used that their utilization-oriented technological properties are still unknown or insufficient.

Sure is that most of species described as lesser-used are characterized by the facts:

(1) Their compositions are very low compared to Teak and Pyinkado.
(2) They are not as valuable as Teak and Pyinkado.
(3) They are not available uniformly in one region.
(4) They are utilized only locally, but not nation-wide.
(5) Their utilization-oriented technological properties are still unknown or insufficient.

With the objective that these lesser-used timber species could be introduced to the markets nationally and internationally, the properties of 54 so-called lesser-used timber species were investigated during 1997-2000. Unfortunately, one sample tree could be used to investigate their physical and mechanical properties because of limited time. As the variability of these properties is pronounced within and among trees, the resulted data might not be able to represent a species. It will be note-worthy that most species in Myanmar forests enjoy growing in various locations. Different locations will affect the properties of the species due to climatical conditions, topography, soil, silvicultural treatment, and so on. Even in the same location, different sample trees show different properties that are significantly different. Even in the same tree, there are variability in physical and mechanical properties with height (vertically) and wood-zones (horizontally).

2. Literature review

In wood utilization, basic information on various aspects of wood properties is inevitably important for efficient utilization of log (Salang et. al, 1996). The choice of log should be through evaluation of log quality that can be determined by physical features such as size or shape, and also by physical properties such as density or specific gravity and green moisture content. Density and moisture content can be used to classify timber species and to determine and specify timber quality such as durability and strength. Many species of wood have unique physical and mechanical properties. Log quality can also be assessed by mechanical properties such as modulus of rupture (MOR), modulus of elasticity (MOE), etc, which are very important for timber used as construction material.

The choice of species for specific utilization will depend on their physical and mechanical properties.

It is stated that density and moisture content vary in a tree, between trees and species (Panshin & de Zeeuw, 1980). In softwoods the moisture content of sapwood is slightly higher than heartwood and in hardwoods the differences in moisture content depend on the species (USDA, 1999). Variability, or variation in properties is common to all material. Wood properties vary considerably even in clear material (USDA, 1989). It is stated that strength and hardness are roughly proportional to weight (Roger, 1963). It is also mentioned that specific gravity is an index of clear wood mechanical properties (USDA, 1999). Thus, mechanical properties should show variation in a tree, between trees and species. Most timber species grown in Sarawak show variations in density and green moisture content in a single tree, between trees and species.

The variation of density and moisture content and other mechanical properties should affect the quality of sawn timber, seasoning of timber, preservation processes, working properties, mechanical properties and final products quality (Salang et. al., 1996). The variation in mechanical properties will affect the use of species for construction and furniture making. The variability in properties can be important in both production and consumption of wood products (USDA, 1999).

Thus, the variation of mechanical and physical properties among logs and species affects choice of log and species for specific utilization.

In this study, the variation in physical and mechanical properties of two lesser-used timber species grown in Myanmar was investigated in order to provide the information on the wood quality variation for specifying and classifying the utilization of species. It is hoped to answer the following questions.

(i) How do physical and mechanical properties vary vertically in a tree?
(ii) How do physical and mechanical properties at the same height vary horizontally in a tree?
(iii) Is there any variation of these properties between trees of the same species?
(iv) Is there any variation in these properties between species grown in Myanmar?
(v) Are the physical and mechanical properties of the lesser-used timber species are lower than those of commercially accepted timber species in Myanmar?

Thus, the objective of this study will be:

(i) to give the reliable data of physical and mechanical properties for the tested species for the locality from where the sample trees were collected,
(ii) to investigate the variation in mechanical and physical properties within a tree (vertical variation at different heights and horizontal variation at the same height among wood zones),
(iii) to put the two species to suitable end uses,
(iv) to compare the investigated properties of the two species with those of commercially important timbers of Myanmar, and
(v) to be able to introduce methodology for testing other timber species grown in Myanmar.

If lesser-used timber species are extracted and utilized to their best, the following two advantages can be obtained (Tint, 1982; Htun & Swe, 1999).

(i) Felling of lesser-used timber species could provide room to other economically important species for growth as well as generation. Extraction of lesser-used species will serve as improvement felling, which include felling of less important trees and cutting of climbers and ficus trees and is an important operation in Myanmar Selection System applied in Myanmar forest for more than 100 years. Exploitation of low valued species could improve species composition of the forests (Silvicultural gain).

(ii) Extraction of lesser-used timber species will increase yield and minimize the pressure on a few commercial timber species while the yield of teak and commercial hardwoods are steadily declining due to reduced growing stock and increased domestic demand. The export of valuable species can be increased, leading to a better earning of foreign exchange for the country. Moreover, the forests could be enriched by extraction of lesser-used timber species. Harvesting cost per area will be lowered and consumer cost to timber will rise less rapidly. (Economic gain).

3. Material and methodology

In the choice of timber species, the following points are essential.

(i) The timber species could attain diameters at breast height of at least 65 cm.
(ii) It is important that the Authorities of the Forest Department are willing to allow the extraction of the timber species that have been proposed to test (Note: This paper is an extraction from a research thesis work presented in Institute of Wood Technology and Wood Biology, Faculty of Forestry, Georg-August University, Goettingen; time limited).
(iii) Their distributions must be fairly good in Myanmar forests.
(iv) The species that have been never investigated before, or those with insufficient information on mechanical and physical properties, are given top priority in selection of species to be tested.

The species selected for this study are:

(1) *Lagerstroemia tomentosa*, Presl. (Leza)
(2) *Holoptelea integrifolia,* Planch. (Pyaukseik)

Leza is chosen as the information on its physical and mechanical properties is assumed insufficient even though the stated properties were investigated for this species with three sample trees. In fact, its distribution is fairly to highly good in Myanmar forests. The physical and mechanical properties are very variable from one locality to another, from one tree to another and within a tree, and if the more precise approximation of such properties is investigated for this species, it can be put to the best use.

Pyaukseik is chosen as the information on its physical and mechanical properties is insufficient; in fact, one tree was used for investigation on mechanical properties and physical properties. This species is valuable to the farmers as it grows mostly in dry forests. It has also a bad reputation because of the relative high total shrinkage. This bad reputation arises from the interpretation on the results of one sample tree and literature.

The species chosen for this research have been tested, but the information is insufficient. The sample trees for both species were collected from Ngalaik Reserve Forest, Takkone Township, Yamethin District, and randomly selected. The number of sample trees is 10 for each species.

3.1 Material

3.1.1 Leza: its general description and habitat

Leza belongs to the family Lythraceae, the genera of which found in Myanmar forests are Ammannia, Duabanga, Hydrolythrum, Lagerstroemia and Woodfordia. The genus Ammannia comprises of herbs only, which are, therefore, not important for timber production. The genus Duabanga consists of one timber producing species. It is Myaukngo (*Duabanga grandiflora*) that is also a lesser-used species.

The genus Hydrolythum has only one species; it is not a tree, but an aquatic herb. The genus Woodfordia consists of only one species, which grows in Pegu Yoma forests, but it is only a shrub. The genus Lagerstroemia consists of a number of timber producing species, of these three species are relatively well-known, but described as lesser-used in Myanmar and the wood from such species are also locally accepted and utilized for various purposes. They are

(1)	*Lagerstroemia villosa* Wall	(Zaungbale)
(2)	*Lagerstroemia speciosa* (L.) Pers	(Pyinma)
(3)	*Lagerstroemia tomentosa* Presl.	(Leza)

Lagerstroemia villosa, a moderate-sized deciduous tree, is not as high as Lagerstroemia tomentosa, obtaining a height of about 30 m. It can attain a girth of 2.44 m at breast height in favourable condition, but it is a rare case to find such large-diametered tree. Its distribution and composition is not so common in Myanmar forests as Lagerstroemia tomentosa. It does not grow near stream, but it can grow up to 915 m in Shan State and Pegu Yoma.

Lagerstroemia speciosa is a moderate-sized to large deciduous tree. It can attain a height of 30 m in favourable condition as in the drainage of Little Taninsserim River in southern lower part of Myanmar. But in Bago Yoma, it can rarely reach such height, there growing as a very branching tree. The trees grow near water.

Lagerstroemia tomentosa is a large deciduous tree with a straight bole and a large closed crown. It attains 24.3 or 30 m (80 or 100 ft) in height and a girth of 153 to 243 cm (5 to 8 ft) (Some commercial Hardwoods of Burma, 1961). It is stated that it can reach a height of over 30 m (100 ft) and a girth of 304 to 365 cm (10 to 12 ft) in favourable localities (Troup, 1909). Alex Rodger stated in the same way that it is a straight-stemmed tree with a height of 30 m (100 ft) or so and a girth of 153 to 243 cm (5 to 8 ft).

During carrying out the fieldwork of selection of trees, selection-felling marking, felling and logging operations, the length and the girth of sample trees were measured exactly. The results are shown in table 1:

Table 1: Diameter at breast height (DBH), crown length, bole length and the whole length of ten Leza sample trees.

No	DBH	Crown Length	Bole Length	Stump	Whole length	
	(m)	(m)	(m)	(m)	(ft)	(m)
1	0.89	12.19	20.12	0.64	108.08	32.94
2	0.68	19.45	7.47	0.64	90.38	27.55
3	0.85	25.02	13.41	0.56	127.93	38.99
4	0.74	17.37	14.39	0.51	105.87	32.27
5	0.67	12.25	13.05	0.66	114.26	25.96
6	0.88	21.43	16.31	0.79	126.38	38.52
7	0.77	12.22	19.20	0.66	105.27	32.09
8	0.66	17.68	17.89	0.74	119.12	36.31
9	0.64	15.54	13.72	0.86	98.83	30.12
10	0.91	16.15	15.54	0.76	106.50	32.46

In table 1, the bole length is the length of the stem from the base to the point where the first branch appears. The crown length is the distance from the point where the first branch appears and the tip of the crown. According to the data in table 1, the height of a Leza tree is usually more than 30 m (100 ft), having an average length of 33 m (110.26 ft) with a standard error of ±1.357 m (±3.734 ft) for these stated ten sample trees.

The girth of a Leza tree at breast height is about 241.3 cm (76.85 cm in diameter) in average, which is measured at 1.3 m above the ground, with a standard error of ±10.5 cm.

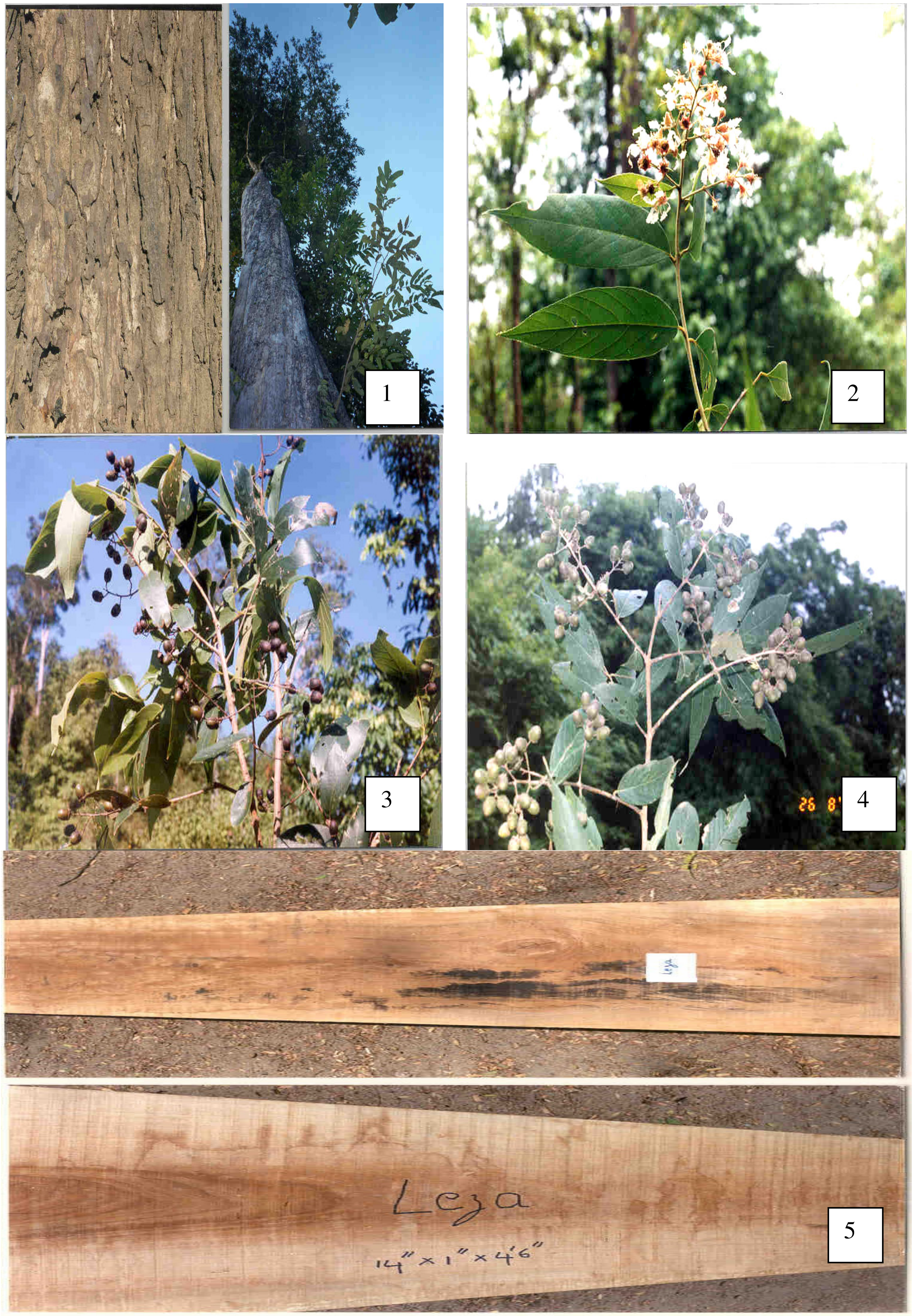
1
2
3
4
5
Leza
14"×1"×4'6"

Figure 1: Leza (*Lagerstroemia tomentosa*)
(1) Bark (2) Flowers
(3) Fruits (4) Fruits
(5) Sapwood and heartwood showing its natural colour of air-dried Leza wood and some knots
(6) Stem with flute (7) A whole tree growing in its natural habitat

The bole of a Leza tree is usually straight and clean up to a height of 20 m without branching. But most of Leza trees are fluted, normally at the base up to 4 m in height. Some Leza trees bear bulges, which is not common. The bole form is normally similar to Teak (*Tectona grandis* Linn.) in colour and straightness, but different crown branching and with different shapes of leaves.

The bark of a Leza tree is very thin, light grey and fairly smooth and about 8 to 9 mm thick.

The leaves are simple, lanceolate, entire, and stellately pubescent beneath. The leaves might be glabrous. The flowers have petals that are scattered on the panicle. The number of calyx ribs is 12 and prominent in the bud. The leaves are about 3 to 6 inches long.

The growth rings are present and normally distinct, and are possible to be counted at the base of tree after felling. The counts of growth rings of five Leza trees during felling operation shows that most of Leza trees sampled have about 50 rings.

Leza trees grow in most parts of Myanmar, from Taninthayi in the south to East and West Katha, Mandalay and upper Chindwin in the north. It enjoys growing in Bago Yoma, especially in the eastern aspect. It grows abundantly in North Toungoo, Pyinmana, and

Yemethin. It grows in riverine evergreen forests, typical evergreen forests, moist upper mixed deciduous forests, lower mixed deciduous forests, dry upper mixed deciduous forests, high indaing (Dipterocarps) forests and even in bamboo forests. But it cannot grow in giant evergreen forests, thorn dry forests and than-dahat (*Terminalia oliveri* and *Tectona hamiltonia*) forests. It prefers the moister forest types. In drier forest types, it is absent or grows in stunted form.

Even though it can grow in almost all forests, its growth is not uniform through the whole forest. It prefers growing near the streams, in the lower slopes and well-drained valley with fertile alluvial soil. It also grows on low-lying plains, not very far from streams. It is almost absent in ridge stands.

It is one of the commonest companions of Pyinkado (*Xylia dolabriformis*) in the moister types of upper mixed forests.

It is associated mostly in Ngalaik Reserves, esp. in Compartment 24 with Thande, Chin-yoke, Leza, Thanthat, Teak and Pyinkado.

3.1.2 Pyaukseik: its general description and habitat

It belongs to the family Ulmaceae and is also called Indian Elm. The genera of this family found in Myanmar are Celtis, Gironniera, Holoptelea, Trema and Ulmus. Pyaukseik is the only species of the genus Holoptelea, found in Myanmar.

Pyaukseik is a large deciduous tree, which can attain a height of 20 m and a diameter of 0.64 to 0.80 m (Doo et. Al., 1989; Rodger, 1963). It is a large to very large tree, which can attain in Myanmar 0.96 m to 1.11 m in diameter and a cylindrical, straight bole of about 15 m (Pearson & Brown, 1932). The size of tree is rather small in the United Provinces, which is about 1.8 m to 2.0 m girth and 6 m of clear stem. In the Central Provinces and Bihar and Orissa, the trees grow smaller, with a diameter of 0.48 to 0.57 m. It is stated that in the Punjab it is only found in relatively small sizes.

Table 2: Diameter at breast height (DBH), crown length, bole length and the whole length of ten Pyaukseik sample trees

No	DBH	Crown Length	Bole Length	Stump	Whole length	
	(m)	(m)	(m)	(m)	(m)	(ft)
1	0.86	19	14	0.09	35	114
2	0.73	19	11	0.05	30	99
3	0.89	15	20	0.08	36	117
4	1.52	20	16	0.08	37	121
5	0.87	20	14	0.08	35	114
6	0.83	20	17	0.06	37	123
7	0.70	12	12	0.06	25	81
8	0.93	17	16	0.08	34	112
9	0.69	21	16	0.06	38	123
10	0.75	20	16	0.08	37	121

The size of the tree is even smaller in the North Coimbatore, Rollegal, Tinneverlly and Madura Districts, which is about 0.28 to 0.38 m in diameter.

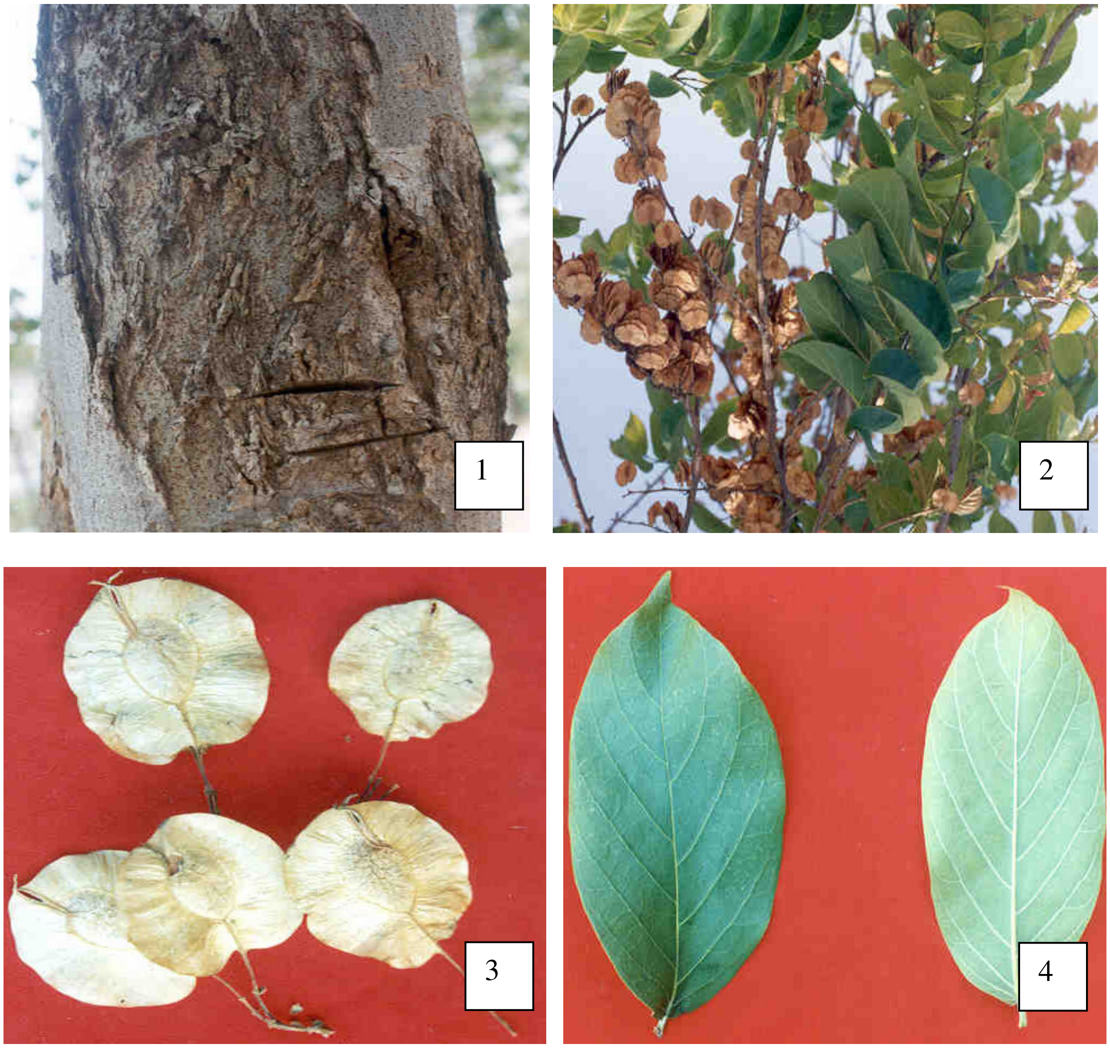

Figure 2: Some parts of a Pyaukseik tree

(1) Bark
(2) A branch of a Pyaukseik tree with leaves and fruits
(3) Fruits of Pyaukseik
(4) Leaves of Pyaukseik

In fact, very big trees were left in selection of sample trees because of the use of elephants for hauling. This means that Pyaukseik is a very large tree that can attain a height of more than 40 m and a diameter of more than 1.5 m in alluvial flat soil. But in table 2, the height is about 35 m and the diameter is about 0.8 m. But on the bole exist buttresses. It has a very branching habit, generally the crown length being higher than the bole length. The number of growth rings counted at the cross-sectional surface after felling ranges from 40 to 91, most trees possessing around 60.

The bark of Pyaukseik is very thick; it is about 25 to 38 mm thick. The outer bark is dry and grey, the central bark is fleshy and pale-yellow and the inner bark is very pale-reddish. The bark has a characteristic odour.

The leaf of Pyaukseik is simple, oblique, quite entire and glabrous.

Figure 3: Pyaukseik (*Holoptelea integrifolia*)
(5) A tree grown in its natural habitat
(6) A quarter-sawn timber showing its natural colour after air-drying.

Pyaukseik is widely distributed throughout Myanmar, from Kachin State and Magwe Division in the north to Pyay and Ayeyawady Division in the south. It grows scattered in the open forests of Upper and Lower Myanmar. Pyaukseik enjoys growing in mixed deciduous forests of rather dry types. It can also be found in evergreen forests of low elevation. It is found from the Kangra District in the Punjab eastwards to Bengal. It can also be found throughout the Peninsula in the rainforests. It grows in very small quantities in the neighbourhood of Tura in Assam. It cannot grow in the Eastern Himalaya. It can grow up to 600 m elevation.

It grows in the mixed deciduous forests on alluvial flat soil, where the growth is much better than those growing on the ridges. Normally, Pyauseik can be found growing rather near streams.

3.2 Methodology

The standard of the American Society for Testing and Material (ASTM) was used for this research. It was adopted in 1948 and then revised in 1952. Then it was re-approved in 1965. It is issued under the fixed designation D143.

The sizes of specimens for this research were shown Table 3.

Table 3: Size of specimens in British units and converted values to SI-units

NO	TESTS	SIZE OF SPECIMEN	
		British unit (In)	SI-unit (mm)
1	2	3	4
1	Mechanical Properties		
a	Static Bending	2 x 2 x 30	50.8 x 50.8 x 762.0
b	Compression parallel to grain	2 x 2 x 8	50.8 x 50.8 x 203.2
c	Compression perpendicular to grain	2 x 2 x 6	50.8 x 50.8 x 152.4
d	Hardness	2 x 2 x 6	50.8 x 50.8 x 152.4
2	Physical Properties		
a	Specific gravity	2 x 2 x 6	50.8 x 50.8 x 152.4
b	Volumetric shrinkage	2 x 2 x 6	50.8 x 50.8 x 152.4
c	Radial shrinkage	1 x 1 x 4	25.4 x 25.4 x101.6
d	Tangential shrinkage	1 x 1 x 4	25.4 x 25.4 x101.6
e	Longitudinal shrinkage	1 x 1 x 4	25.4 x 25.4 x101.6

3.2.1 Preparation of bolts and disks

The logs 5.486 m (18 ft) long were cut into 2.743 m (9 ft) long bolts so that all bolts are of the same length.

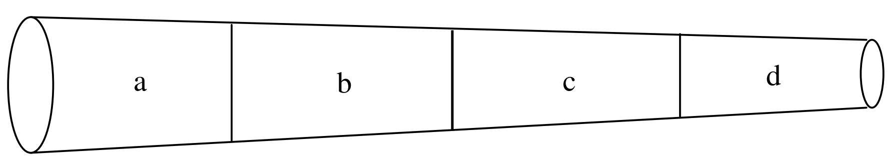

Figure 4: Four bolts of each tree.

Two disks, each about 127 mm thick, and one disk about 203.2 mm thick were cut from the base of each. The two disks about 127 mm thick were used for preparation of specimens for testing radial and tangential shrinkage and the other for testing volumetric shrinkage, density or specific gravity and longitudinal shrinkage.

For each disk, specimens were prepared according to wood zones: specimens for sapwood, specimens for heartwood 1 and specimens for heartwood 2 (Here: sapwood means the wood near the bark, heartwood 2 the wood near the pith and heartwood 1 the wood between the two other zones).

Table 4: Number of specimens for heartwood 2, heartwood 1 and sapwood

Sr. No	Test	No. of Specimens		
		Heartwood 2	Heartwood 1	Sapwood
1	Radial shrinkage	6	6	6
2	Tangential shrinkage	6	6	6
3	Longitudinal shrinkage	6	6	6
4	Volumetric shrinkage	6	6	6
5	Specific gravity	6	6	6

The bolts left after cutting three disks were used for testing mechanical properties.

Table 5: Number of specimens for mechanical tests

Sr. No	Test	No of Specimens/tree
1	Static Bending	10-15
2	Compression parallel to grain	10-15
3	Compression perpendicular to grain	10-15
4	Hardness	10-15

Some of them were converted into sticks of the sizes 70 x 70 mm as shown in figure 5. The sticks had to be selected for green and air-dry test according to the designations in ASTM. Then the specimens of required size were prepared.

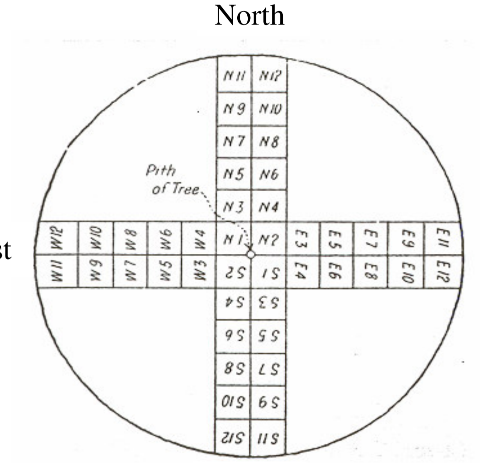

Figure 5: Sketch showing method of cutting up the bolt and marking the sticks.

3.2.2 Testing procedures

After preparation of specimens for testing physical properties, they were sanded and cleaned to remove the loose material so that they could not affect the moisture content. They were weighed and measured for determination of shrinkage and moisture while green and the data were recorded. Then they were air-dried. When the specimens had attained constant weights and measurements under air-drying, the data was recorded. They were then oven-dried at a temperature of 103±2°C. On attaining constant weights and measures, the data were recorded again.

For determination of specific gravity, the volume was determined by water displacement method.

For mechanical properties, green and air-dry tests were conducted according to the designations in ASTM standards.

The tests and calculated properties are:

(1) Physical properties

- (a) Density
- (b) Specific gravity
- (c) Radial shrinkage
- (d) Tangential shrinkage
- (e) Longitudinal shrinkage
- (f) Volumetric shrinkage
- (g) Dimensional stability
- (h) Moisture content

(2) Mechanical properties

- (a) Static bending
  - (i) Modulus of elasticity (MOE)
  - (ii) Modulus of rupture (MOR)
  - (iii) Fiber stress at proportional limit (FS@PL)
- (b) Compression parallel to grain
  - (i) Maximum crushing strength (MCS)
  - (ii) Fiber stress at proportional limit (FS@PL)
- (c) Compression perpendicular to grain
  - (i) Fiber stress at proportional limit (FS@PL)
- (d) Hardness
  - (i) Radial
  - (ii) Tangential
  - (iii) Longitudinal or end

4 Data analysis

In this research, the influence of two factors on physical and mechanical properties has been analysed for **a single tree**: Wood zones in horizontal direction and Tree height in vertical direction.

Factor A:	Wood zones with three levels of source of variation	: h1 (heartwood 1) : h2 (heartwood 2) : s (sapwood)
Factor B:	Tree height with four levels of sources of variation	: a (2.743 m high above ground) : b (5.486 m high above ground)

: c (8.230 m high above ground)
: d (10.973 m high above ground)

Amount of repetition = 6 per each zone.

The experimental design is a completely randomized two-factorial model:

$$Yijk = \mu + Ai + Bj + (AB)ij + \varepsilon ijk$$

where

Yijk	=	Value of variable Y due to the effect of the i^{th} level of wood zones and j^{th} level of tree height at k^{th} repetition.
μ	=	Mean value of expectation of variable Y
Ai	=	Influence of i^{th} level of wood zones
Bj	=	Influence of j^{th} level of tree height
(AB)ij	=	Influence of interaction between i^{th} level of wood zones and j^{th} level of tree height
εijk	=	Experimental error

But **for a species**, the influence of three factors as sources of variation of properties has been analysed: Trees, Tree heights and wood zones. The third factor C is added to the above model.

Factor C : Trees with 10 levels of source of variation

The experimental design is a completely randomized three-factorial model.

$$Yijkl = \mu + Ai + Bj + Ck + (AB)ij + (AC)ik + (BC)jk + (ABC)ijk + \varepsilon ijkl$$

where

Yijkl	=	Value of variable Y due to the effect of the i^{th} level of wood zones, j^{th} level of tree height and k^{th} level of trees at l^{th} repetition.
μ	=	Mean value of expectation of variable Y
Ai	=	Influence of i^{th} level of wood zones
Bj	=	Influence of j^{th} level of tree height
Ck	=	Influence of k^{th} tree
(AB)ij	=	Influence of interaction between i^{th} level of wood zones and j^{th} level of tree height

(AC)ik	=	Influence of interaction between i^{th} level of wood zones and k^{th} level of trees
(BC)jk	=	Influence of interaction between j^{th} level of tree heights and k^{th} level of trees
(ABC)ijk	=	Influence of interaction among i^{th} level of wood zones, j^{th} level of tree heights and k^{th} level of trees
εijkl	=	Experimental error

If the influence of mentioned factors and their interactions are significant, the test of significant difference will be conducted according to Tukey's test.

5 Results and discussions

5.1 Radial shrinkage

The mean radial shrinkage from green to oven-dry is for Leza between 4.360% and 4.980% and that for Pyaukseik between 4.278% and 4.918% with a risk of 5%. The value of coefficient of variation for radial shrinkage can be high up to 15% (USDA; 1989, 1999). It is found that these values for both species are much less than 15%.

Leza and Pyaukseik show significant variations in oven-dry radial shrinkage in a tree and between trees.

It can be found that oven-dry radial shrinkage of Leza and Pyaukseik decreases with distance from the pith, and in a vertical direction even though there is significant variation in both species the trend is not increasing or decreasing.

5.2 Tangential shrinkage

Leza can shrink tangentially from green to oven-dry condition in the range from 6.570% to 7.250% and Pyaukseik from 7.204% to 8.304% at a probability of 95% level. It is found that the coefficients of variation for tangential shrinkage are normally less than 15%.

Leza and Pyaukseik show significant variations in oven-dry tangential shrinkage in a tree and between trees.

In Leza, most of sample trees show a decreasing trend with height at the lower part, but a decreasing one or no much variation and the shrinkage is decreasing with distance from the pith.

In Pyaukseik, in most sample trees the shrinkage decreases up to the first three sections and again increases upwards, and decreases with distance from the pith.

The tendency to shrink tangentially more than radially causes V-cracks in pieces that include the pith (Wilcox et. al., 1991).

5.3 Longitudinal shrinkage

The mean longitudinal shrinkage of Leza from green to oven-dry condition is from 0.188% to 0.228% and that of Pyaukseik from 0.181% to 0.243% with a 95% probability level. The shrinkage is quite small and ranges from 0.1% to 0.2% for many specimens from green to oven-dry (USDA, 1989). Again, it is stated that the longitudinal shrinkage suffered by timber during seasoning to an absolutely dry state is, on the average, about 0.1% to 0.3% (Ivanov, 1962).

Longitudinal shrinkage also shows variation in a tree and between trees in both species. But a few sample trees show significant variation between trees in both species in comparison with radial and tangential shrinkage.

In Leza and Pyaukseik it is not decreasing or increasing with height, but decreasing with distance from the pith in Leza. Longitudinal shrinkage is the greatest near the pith, decreases rapidly in the first 10 rings and then decreases irregularly (Panshin & de Zeeuw, 1980). In Pyaukseik there is no significant difference between the two heartwood zones, but sapwood has the smallest shrinkage.

It is found that some specimens become even longer than the original length, thus resulting in elongation from green to oven-dry condition. Longitudinal elongation may be accounted for by the existence of internal stresses that may result from seasoning (Ivanov, 1962). Longitudinal shrinkage is not in a direct ratio to the moisture content, but seems to depend on the size of fibril angle. The smaller the angle, the greater the longitudinal shrinkage is observed to become (Ivanov, 1962).

5.4 Volumetric shrinkage

It is from 10.930% to 12.970% in Leza and lies in the intervals of 13.15±0.56% at 95% probability level. The coefficient of variation of volumetric shrinkage can be high up to 15% (USDA, 1999). These values for both species are less than 15%.

Both species show significant variations in volumetric shrinkage in a tree and between trees.

Volumetric shrinkage of Leza seems to decrease with height even though it is not much pronounced, and is decreasing with distance from the pith in both species. In Pyaukseik, it decreases with height, but the trend is not clear. It increases markedly from ground level to breast height, but does not vary much in the upper level (Panshin & de Zeeuw, 1980).

5.5 Dimensional stability

It is the ratio of tangential to radial shrinkage of the same species. As a rule of thumb, the tangential movements exceed the radial movement by a factor of 2 (Wilcox et. al., 1991). The wood having a low ratio is best suited for use (Panshin & de Zeeuw, 1980). Those timbers, which have dimensional stability less than or equal to 2.0 and dimensional changes i.e. radial shrinkage and tangential shrinkage less than or equal to 3.5% and 7% are found to be suitable for making high quality wood products (Kyi, 2000).

It is in the range from 1.424 to 1.524 for Leza and 1.52 to 1.82 for Pyaukseik, stating that Leza is more stable than Pyauseik, but both species are suited for uses as the dimensional stability is less than 2.

5.6 Green density (the ratio of green weight to green volume)

It ranges from 1,057 to 1,093 kg/m^3 for Leza and from 940 to 985 kg/m^3 for Pyaukseik. The coefficients of variation of these species are found to be less than 10%.

It is found that both species show significant variations between and trees. In Leza, most of trees show a tendency that green density decreases with heights in vertical direction but in Pyaukseik it is difficult to define the vertical variation in green density with height.

Green density is found to increase with distance from the pith and then show a slight decrease towards the bark or shows no variation in Leza, but in Pyaukseik most trees it is increasing with distance from the pith.

5.7 Basic specific gravity

The basic specific gravity of Leza ranges from 0.536 to 0.570 and that of Pyaukseik from 0.558 to 0.602 at a 95% probability level. The coefficient of variation can be high up to 10% (USDA, 1999). These values of Leza and Pyaukseik are found less than 10%. According to the Negi (1997), Leza is moderately heavy and Pyaukseik heavy.

The effects of trees, sections, and wood-zones are found significant at a 95% probability level in both species.

Specific gravity may decrease uniformly, or decrease in the lower trunk and increase in the upper trunk, or increase in the stem from the base to the top in a non-uniform pattern (Panshin & de Zeeuw, 1980). Leza might follow the uniformly decreasing trend in basic specific gravity with height.

In Pyaukseik, the trend of basic specific gravity is somewhat difficult to be defined with height. It decreases with heights in some sample trees.

In both species, the basic specific gravity increases with distance from the pith. The specific gravity either tends to increase from the pith outward or shows a decreasing trend towards the bark side (Panshin & de Zeeuw, 1980).

5.8 Moisture content

Leza has a moisture content of 94.03±3.61% and Pyaukseik 67.5±0.77% at a 95% probability level.

Both species show significant variation in moisture content between and within trees. In Leza, the moisture content is not increasing or decreasing with height, but variable. In Pyaukseik, the moisture content is increasing with height in most sample trees. The distribution pattern of moisture content of the height of a clear bole can be categorized into four types: fairly even, increasing, decreasing or variable (Salang et. al., 1996). Leza belongs to variable type and Pyaukseik to increasing one.

In both species, the moisture content is decreasing with distance from the pith in horizontal direction.

5.9 Mechanical properties

The mechanical properties of the two species are given in Appendices (VIII) and (IX). They vary significantly between trees. Within trees the variations are not pronounced except in hardness. The probable reason for non-significant variation within trees may be due to the insufficient number of specimens (10 to 15 specimens per tree).

6 Recommendations

The physical and mechanical properties of Leza and Pyaukseik are compared with those of some Myanmar commercial timber species and given in Appendices (X) and (XI).

The basic specific gravity of Leza (0.553) is almost equal to those of Binga (0.553) and Taungthayet (0.551), higher than that of Pyinma (0.518) and lower than that of Zaungbale (0.610). It is also lower than those of some commercial species such as Teak, Pyinkado, Padauk, In, Kanyin and Taukkyan.

The green density of Leza (1,075 kg/m^3 at 94.03% moisture content) is found higher than those of most of Myanmar commercial timber species. It is higher than those of Pyaukseik, Binga, Hnaw, Taungthayet, Thingadu, and Zaungbale. It is almost equal to those of Thadi and Paduak.

The basic specific gravity of Pyaukseik (0.583) is found higher than those of Leza, Binga, Taungthayet, almost equal to those of Hnaw and Thingadu, and approaches that of teak. It is lower than those of Pyinkado, Paduak, In and Kanyin.

Its green density (964 kg/m^3 at 67.50% moisture content) is higher than those of Taungthayet, Binga, Teak and Pyinma.

The dimensional stability of Leza is 1.46 and that of Pyaukseik 1.66. These values can be found less than 2, and these two species are more stable than Teak, In, Kanyin, Thadi and Thingadu. Teak has a dimensional stability of 1.83.

Leza is found to be similar to Binga, Teak and Thingan, more or less superior to Pyinma, Hnaw, Taungthayet and many others, and lower than Pyinkado, Padauk, Taukkyan and Thadi with respect to mechanical properties.
According to the strength grouping of some Myanma commercial timbers proposed by Tint (1987) based on properties at green conditions, Leza and Pyaukseik would be in Group III.

If the strengths of teak are taken as 100 in each property, the properties of Leza and Pyaukseik are mentioned in Appendix (XIII). It can be found that Leza is better than teak as a beam, especially at 12% moisture content. Its suitability as post or strut is less than teak. Pyaukseik is not as suitable for beam and post as teak at green and at 12% moisture content.

According to Negi (1997), two factors are taken into account for end-uses of timbers as construction material. These are modulus of elasticity and modulus of rupture. According to this grouping, Leza should go to Group I (MOE 14,373 and MOR 105 N/mm^2) and Pyaukseik to Group II (MOE 12,108 and MOR 95 N/mm^2). Thus, the two species are fit to use as construction material. They can also be used for other purposes such furniture making, kitchen utilities, etc.

7. Conclusion

The utilization-oriented technological properties of the two species are found significantly different between trees and species. Thus, if insufficient number of sample trees is tested, it is quite difficult for the data to represent a species. The result may be over-estimated, or under-estimated. Even though under-estimation of wood properties could be accepted in comparison with over-estimation, both will not be good for efficient and specific utilization of wood. Thus, sufficient number of sample trees should be tested for a species from one locality. If the species grows in different localities, the sample trees from different localities should be tested in order to represent a species. Moreover, as the significant variation exists within a tree, the sufficient number of specimens should be tested from every wood zone (heartwood 2, heartwood 1 and sapwood) so that the resulted data could represent a single sample trees.

8 Appendices

APPENDIX I: RADIAL SHRINKAGE

Table 1: Significant test results of the effect of trees, sections, wood zones and their interaction on oven-dry radial shrinkage of Leza

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	8	9.489981	535	0.073366	129.3521	0.000000*
2	3	1.056051	535	0.073366	14.3944	0.000000*
3	2	3.421438	535	0.073366	46.6355	0.000000*
12	24	1.131204	535	0.073366	15.4187	0.000000*
13	16	0.592341	535	0.073366	8.07380	0.000000*
23	6	0.425541	535	0.073366	5.80030	0.000007*
123	48	0.193835	535	0.073366	2.64200	0.000000*

Note: '*'means 'significantly different at 95% confidence level'.

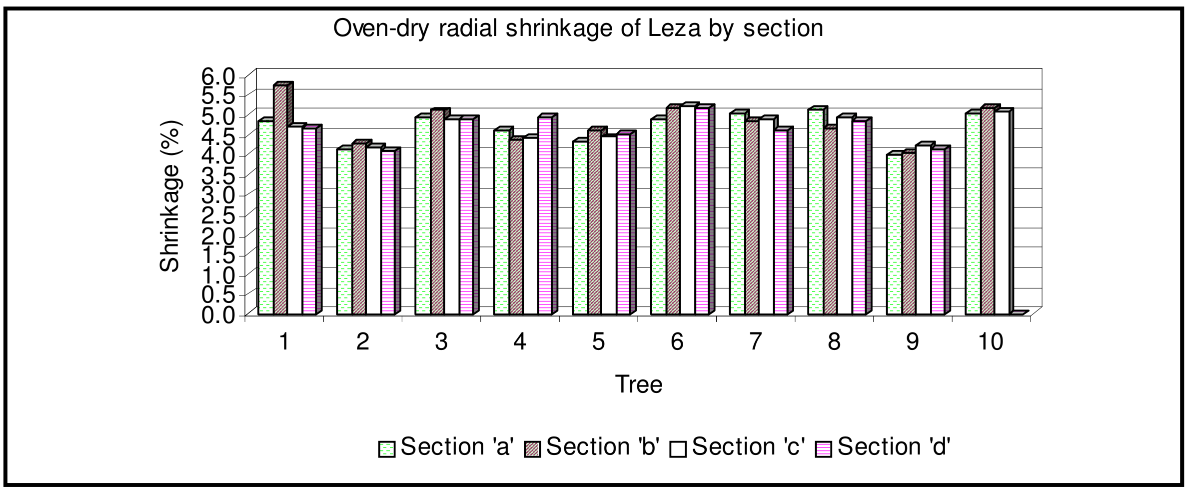

Figure 1: Graph showing sectional oven-dry radial shrinkage of Leza wood.

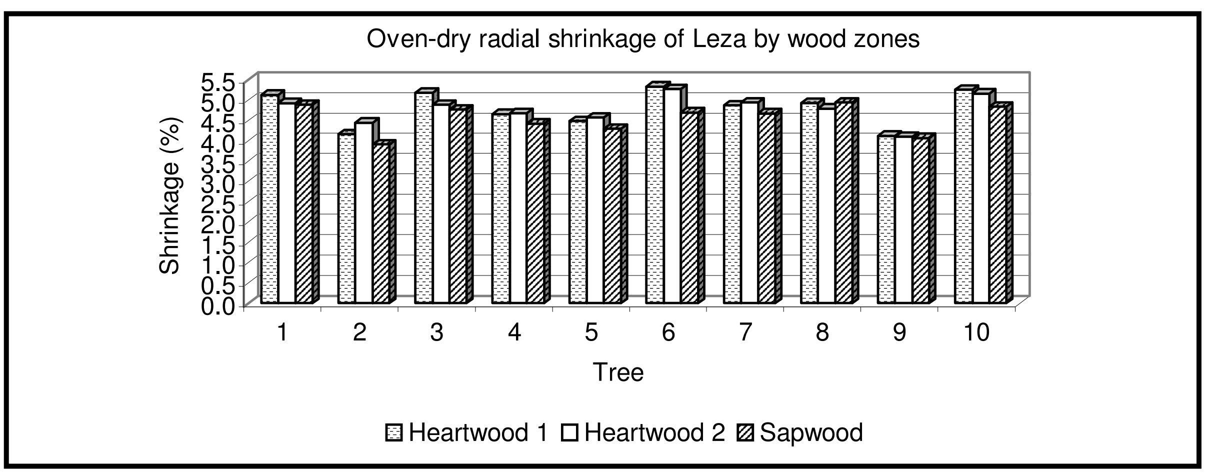

Figure 2: Graph showing zonal oven-dry radial shrinkage of Leza wood.

Table 2: Results of significance test of the effects of trees, sections, wood zones and their interactions on oven-dry radial shrinkage of Pyaukeik.

1-TREE, 2-SECTION, 3-WOODZONE

Source of variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	7	17.80927	477	0.033447	532.4652	0.000000*
2	3	0.42039	477	0.033447	12.5688	0.000000*
3	2	25.08434	477	0.033447	749.9768	0.000000*
12	21	0.84218	477	0.033447	25.1798	0.000000*
13	14	0.65534	477	0.033447	19.5936	0.000000*
23	6	0.40751	477	0.033447	12.1837	0.000000*
123	42	0.25278	477	0.033447	7.5577	0.000000*

Note: * means 'significant at 95% probability level'.

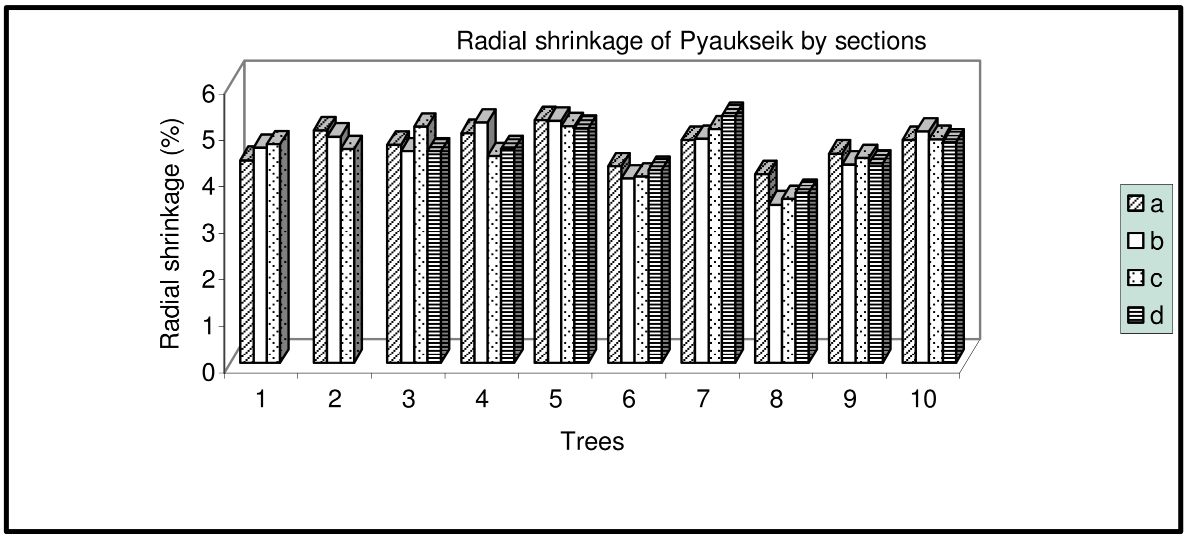

Figure 3: Graph showing sectional radial shrinkage of Pyaukseik

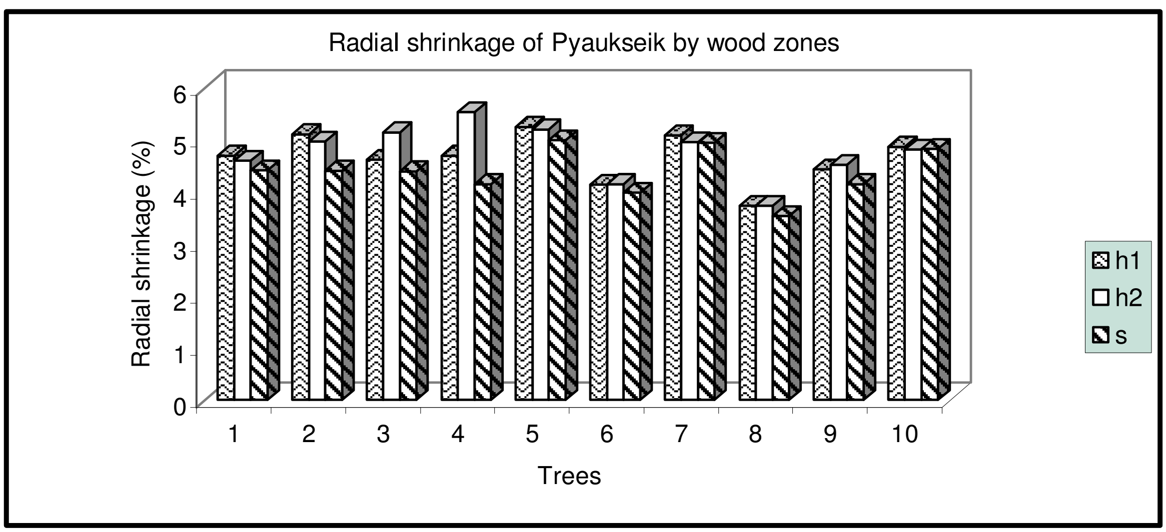

Figure 4: Graph showing zonal radial shrinkage of Pyaukseik

APPENDIX II: TANGENTIAL SHRINKAGE

Table 1: Test results of the significance of the effects of trees, sections, wood zones and their interactions on tangential shrinkage of Leza from green to oven-dry condition.

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	8	18.33270	536	0.174804	104.8756	0.000000*
2	3	0.54174	536	0.174804	3.0991	0.026430*
3	2	8.21305	536	0.174804	46.9842	0.000000*
12	24	1.68540	536	0.174804	9.6417	0.000000*
13	16	1.85009	536	0.174804	10.5838	0.000000*
23	6	0.54733	536	0.174804	3.1311	0.005029*
123	48	0.45150	536	0.174804	2.5829	0.000000*

Notes: * means "significant at a 95% probability level".

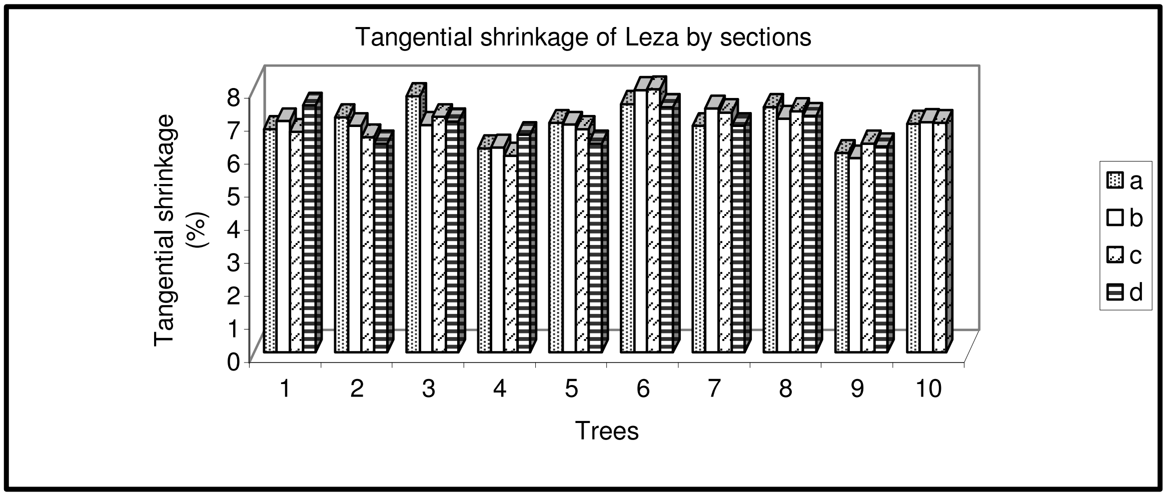

Figure 1: Graph showing sectional oven-dry tangential shrinkage of Leza

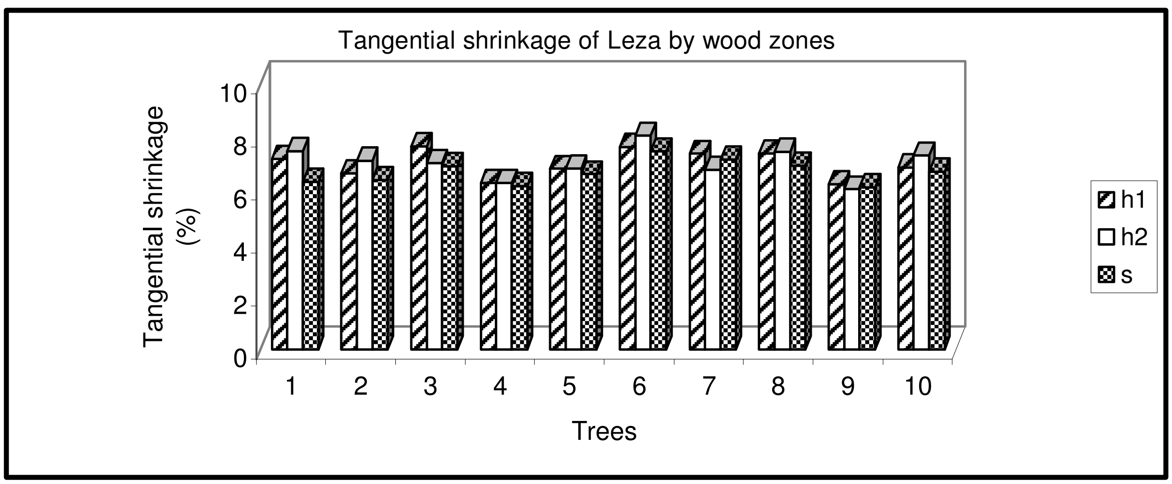

Figure 2: Graph showing oven-dry zonal tangential shrinkage of Leza

Table 2: Results of significant test of effects of trees, sections, wood zones and their interactions on oven-dry tangential shrinkage of Pyaukseik

1-TREE, 2-SECTION, 3-WOODZONE

Source of variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	7	32.1579	477	.269061	119.5189	0.000000*
2	3	7.9340	477	.269061	29.4876	0.000000*
3	2	130.3410	477	.269061	484.4285	0.000000*
12	21	1.8856	477	.269061	7.0079	0.000000*
13	14	5.8738	477	.269061	21.8308	0.000000*
23	6	2.3648	477	.269061	8.7891	0.000000*
123	42	1.2007	477	.269061	4.4626	0.000000*

Note: * means 'significant at 95% probability level'.

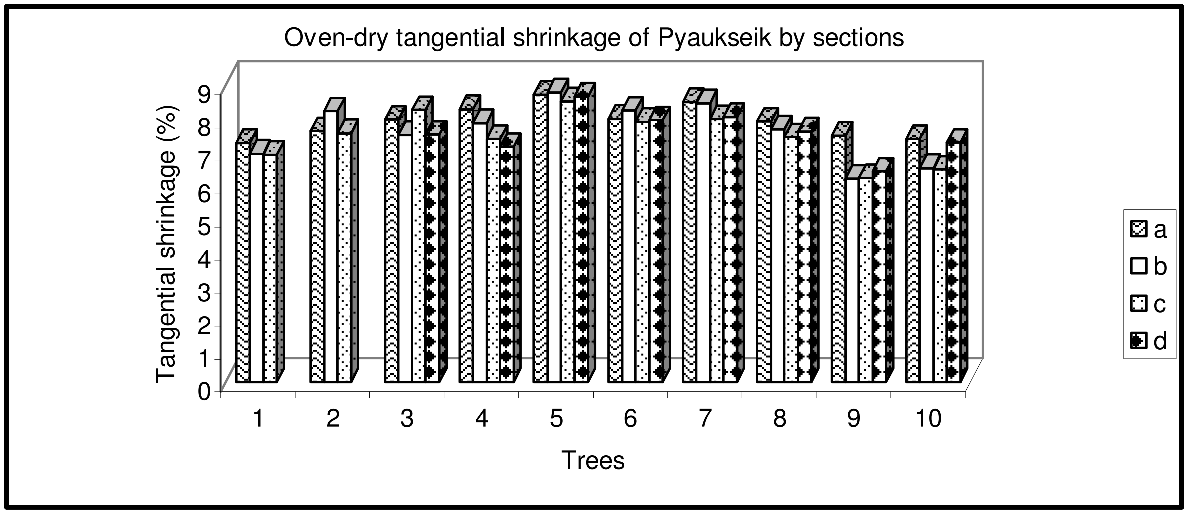

Figure 3: Graph showing sectional oven-dry tangential shrinkage of Pyaukseik

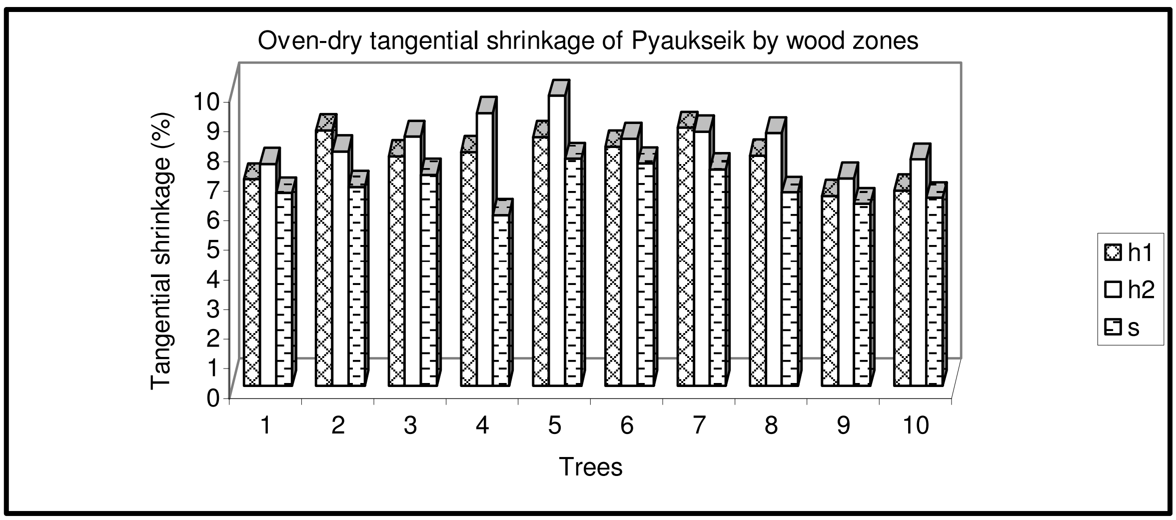

Figure 4: Graph showing zonal oven-dry tangential shrinkage of Pyaukseik

APPENDIX III: LONGITUDINAL SHRINKAGE

Table 1: Result of significant test of the effects of trees, sections, wood zones and their interactions on oven-dry longitudinal shrinkage of Leza

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	8	0.085347	390	0.008597	9.927387	0.000000*
2	2	0.034020	390	0.008597	3.957169	0.019890*
3	2	0.005702	390	0.008597	0.663296	0.515731
12	16	0.065061	390	0.008597	7.567748	0.000000*
13	16	0.029113	390	0.008597	3.386395	0.000013*
23	4	0.028425	390	0.008597	3.306361	0.011085*
123	32	0.022230	390	0.008597	2.585756	0.000011*

Notes: * means 'significant at 95% confidence level'.

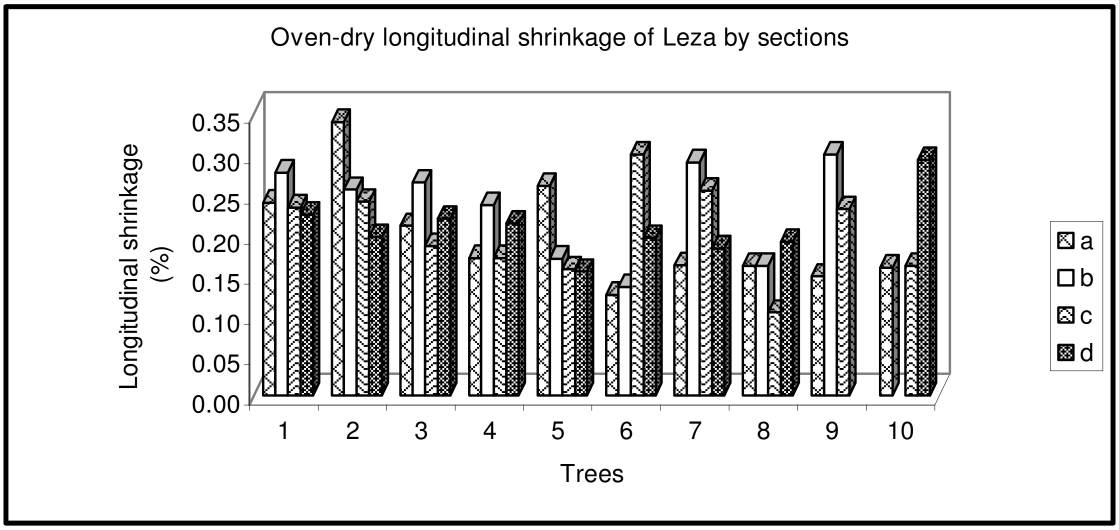

Figure 1: Graph showing sectional longitudinal shrinkage of Leza

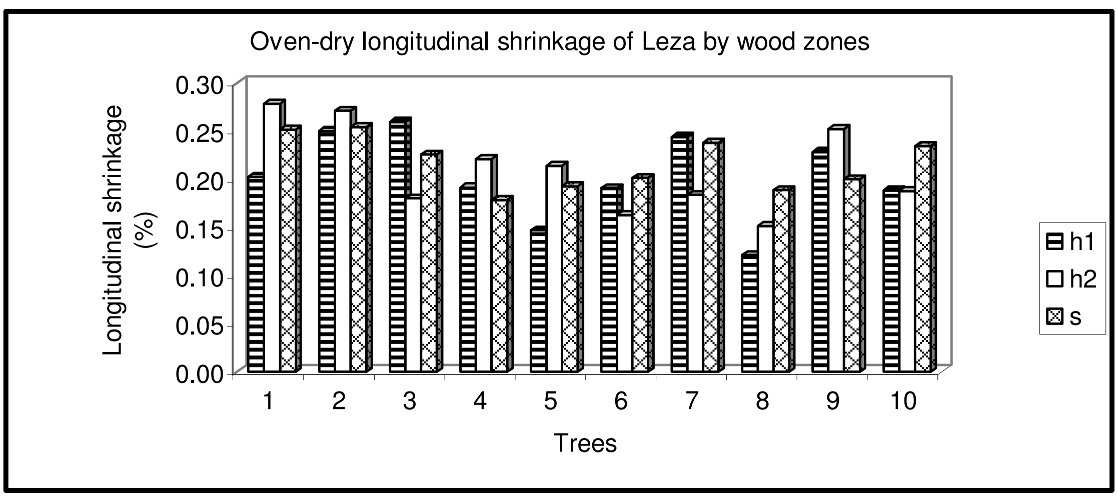

Figure 2: Graph showing zonal longitudinal shrinkage of Leza

Table 2: Results of significant test of the effects of trees, sections, wood zones and their interactions on oven-dry longitudinal shrinkage of Pyaukseik

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	9	.109712	443	.013406	8.184046	.000000*
2	2	.052396	443	.013406	3.908507	.020766*
3	2	.071697	443	.013406	5.348257	.005069*
12	18	.117975	443	.013406	8.800372	.000000*
13	18	.037513	443	.013406	2.798274	.000124*
23	4	.012454	443	.013406	.929040	.446818
123	36	.024086	443	.013406	1.796736	.003862*

Notes: * means 'significant at 95% confidence level'.

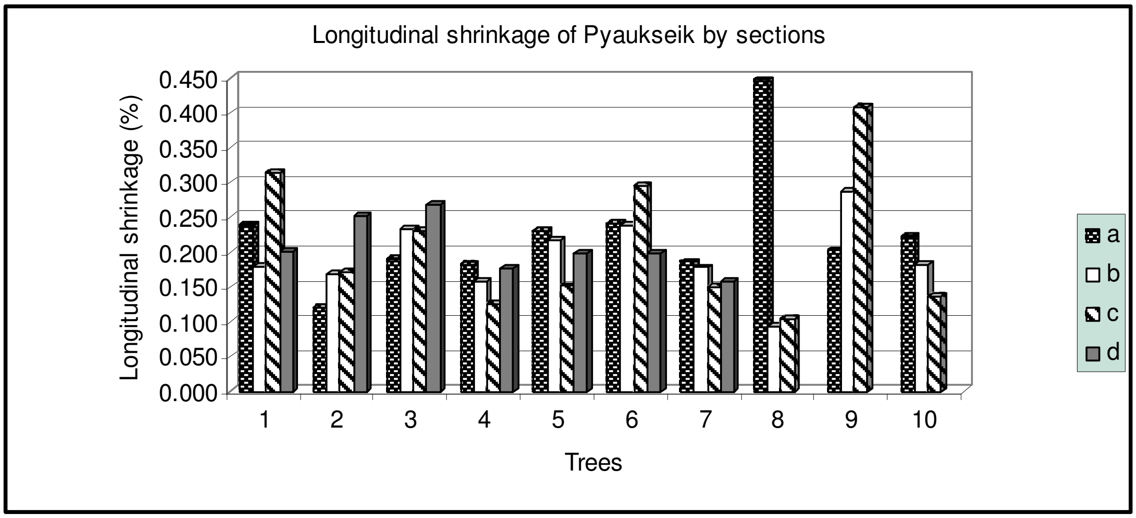

Figure 3: Graph showing sectional longitudinal shrinkage of Pyaukseik

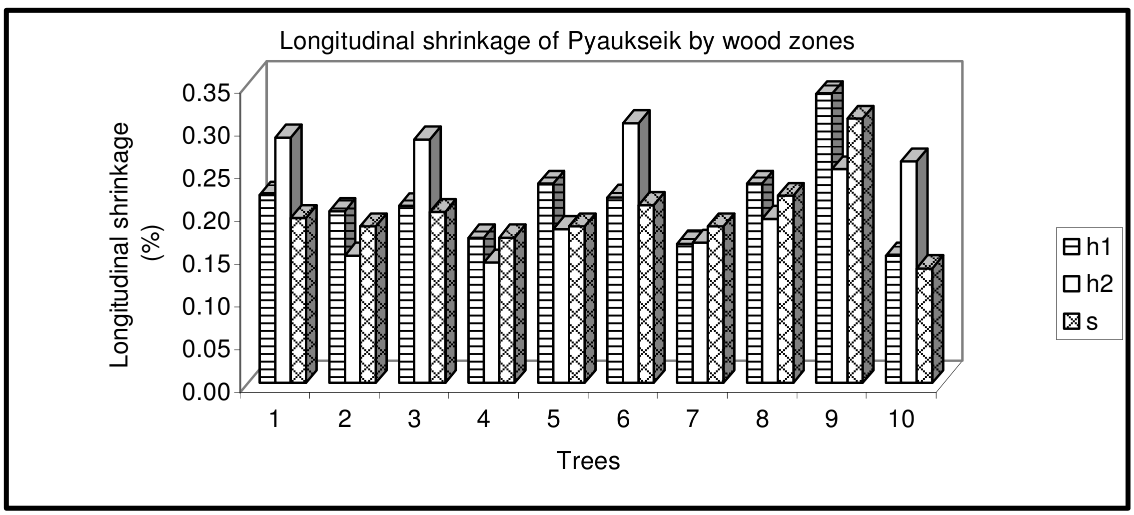

Figure 4: Graph showing zonal longitudinal shrinkage of Pyaukseik

APPENDIX IV: VOLUMETRIC SHRINKAGE

Table 1: Results of significance of the effect of trees, sections and wood zones on oven-dry volumetric shrinkage of Leza

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	8	62.59198	537	0.523354	119.5979	0.000000*
2	3	22.09245	537	0.523354	42.2132	0.000000*
3	2	30.04527	537	0.523354	57.4091	0.000000*
12	24	17.03581	537	0.523354	32.5512	0.000000*
13	16	2.01666	537	0.523354	3.8533	0.000001*
23	6	1.88098	537	0.523354	3.5941	0.001674*
123	48	0.59783	537	0.523354	1.1423	0.243671

Note: * means ‘significant at 95% probability level’.

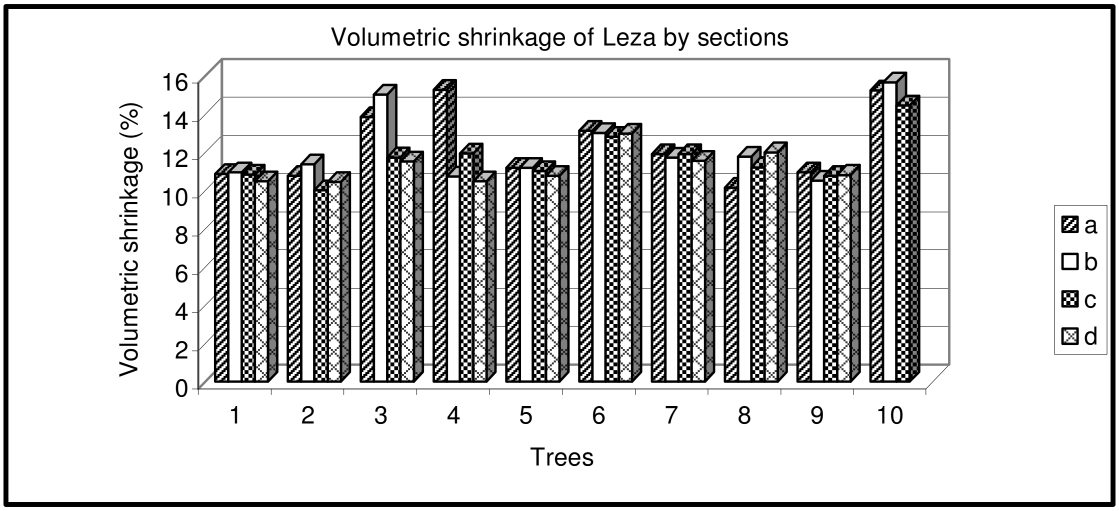

Figure 1: Sectional volumetric shrinkage of Leza by sections

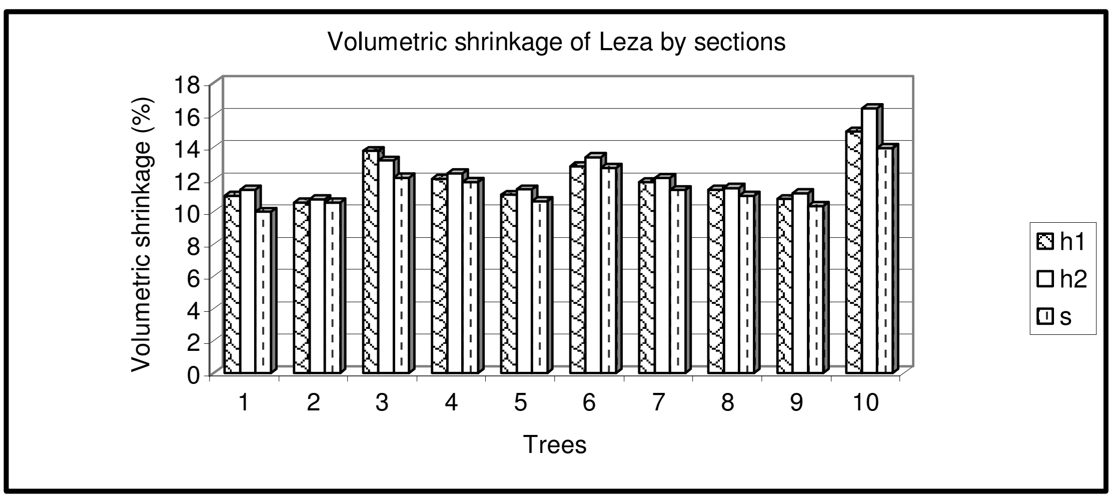

Figure 2: Graph showing zonal volumetric shrinkage of Leza

Table 2: Significance test of the effects of trees, sections, wood zones and their interactions on oven-dry volumetric shrinkage of Pyaukseik

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	9	31.3771	442	1.538842	20.3901	.000000*
2	2	15.6715	442	1.538842	10.1839	.000047*
3	2	304.3475	442	1.538842	197.7769	0.000000*
12	18	5.0573	442	1.538842	3.2864	.000007*
13	18	7.8418	442	1.538842	5.0959	.000000*
23	4	3.1680	442	1.538842	2.0587	.085296
123	36	1.7812	442	1.538842	1.1575	.249085

Note: * means 'significant at 95% probability level'.

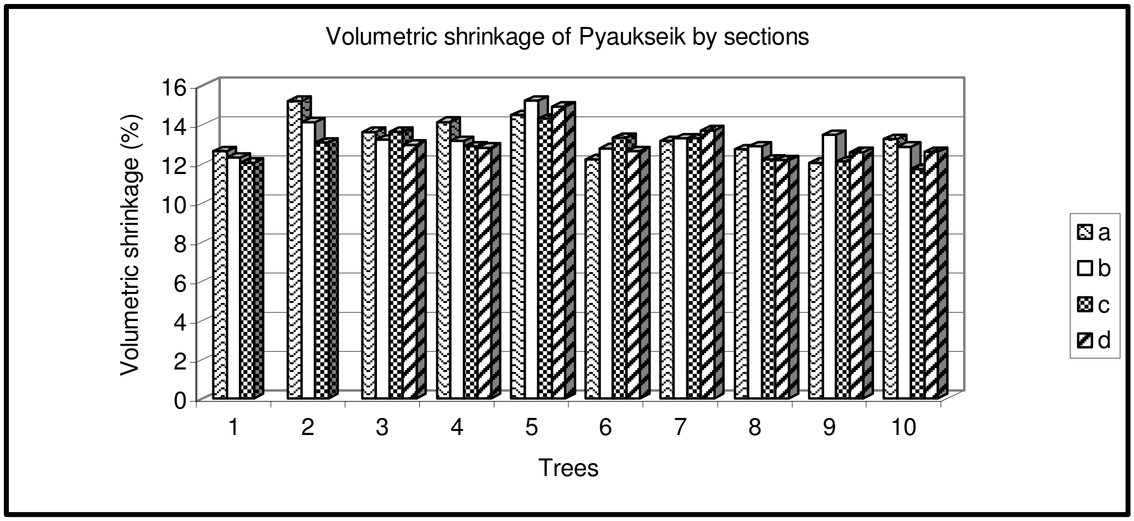

Figure 3: Graph showing sectional volumetric shrinkage of Pyaukseik

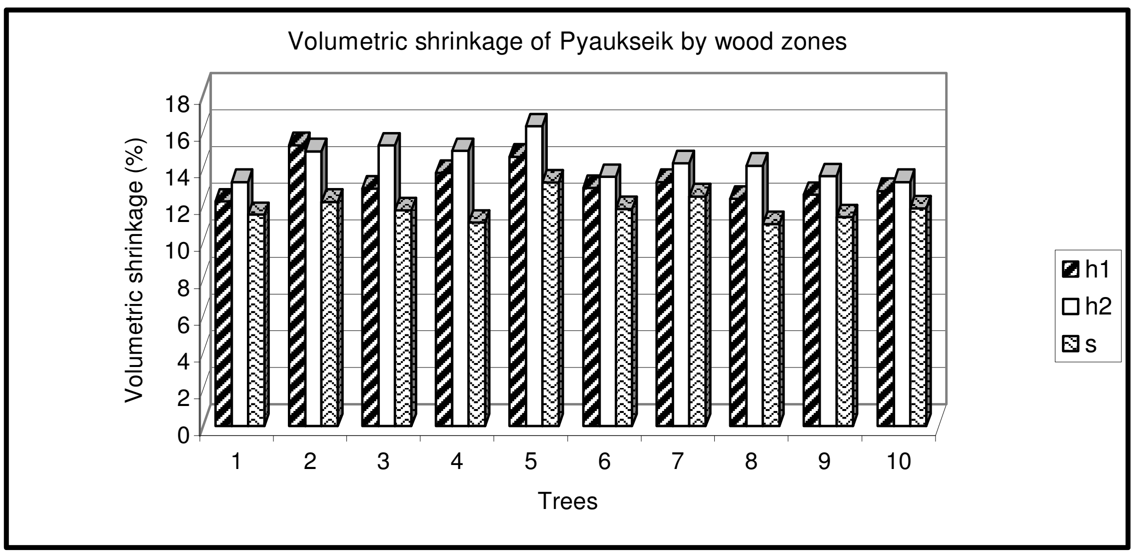

Figure 4: Graph showing zonal volumetric shrinkage of Pyaukeik

APPENDIX V: GREEN DENSITY

Table 1: Results of significant of the effects of trees, sections, wood zones and their interactions on green density of Leza

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	8	39997.70	537	713.8867	56.02808	0.000000*
2	3	19945.61	537	713.8867	27.93946	0.000000*
3	2	6760.83	537	713.8867	9.47045	0.000091*
12	24	12312.17	537	713.8867	17.24667	0.000000*
13	16	3784.76	537	713.8867	5.30162	0.000000*
23	6	899.15	537	713.8867	1.25951	0.274412
123	48	1439.65	537	713.8867	2.01663	0.000114*

Note: * means 'significant at 95% probability level'.

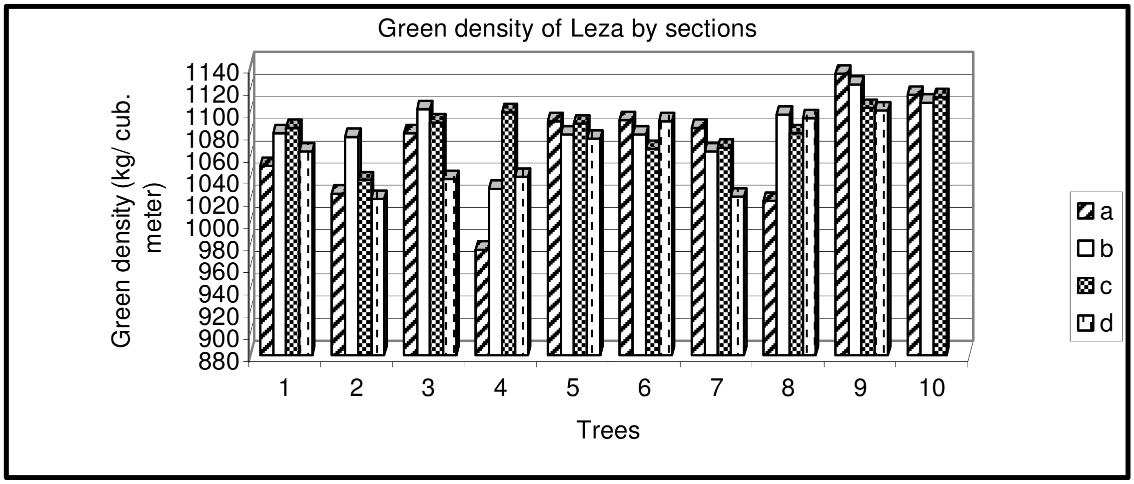

Figure 1: Graph showing sectional green density of Leza

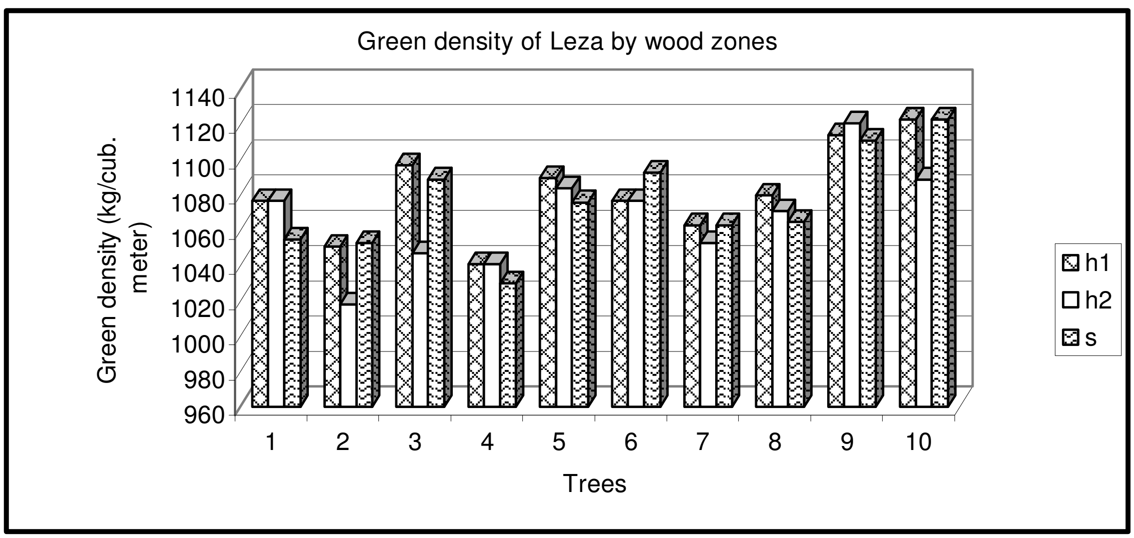

Figure 2: Graph showing zonal green density of Leza

Table 2: Results of significant test of effects of trees, sections, wood zones and their interactions on green density of Pyaukseik

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	7	56398.83	465	466.0009	121.0273	0.000000*
2	3	17718.20	465	466.0009	38.0218	0.000000*
3	2	43671.63	465	466.0009	93.7158	0.000000*
12	21	8820.41	465	466.0009	18.9279	0.000000*
13	14	3696.72	465	466.0009	7.9329	0.000000*
23	6	1013.90	465	466.0009	2.1757	0.044166*
123	42	774.30	465	466.0009	1.6616	0.007114*

Note: * means 'significant at 95% probability level'.

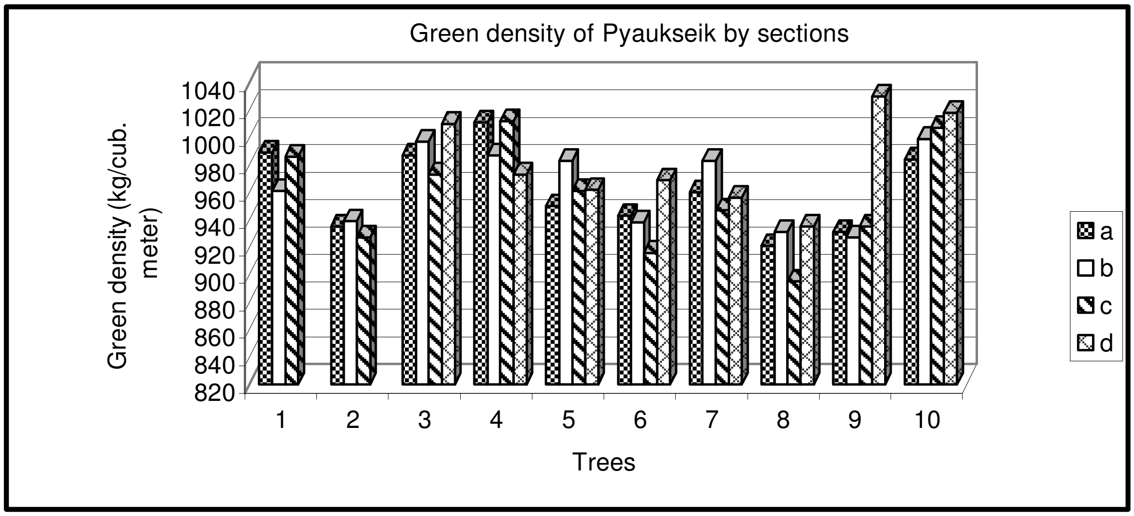

Figure 3: Graph showing sectional green density of Pyaukseik

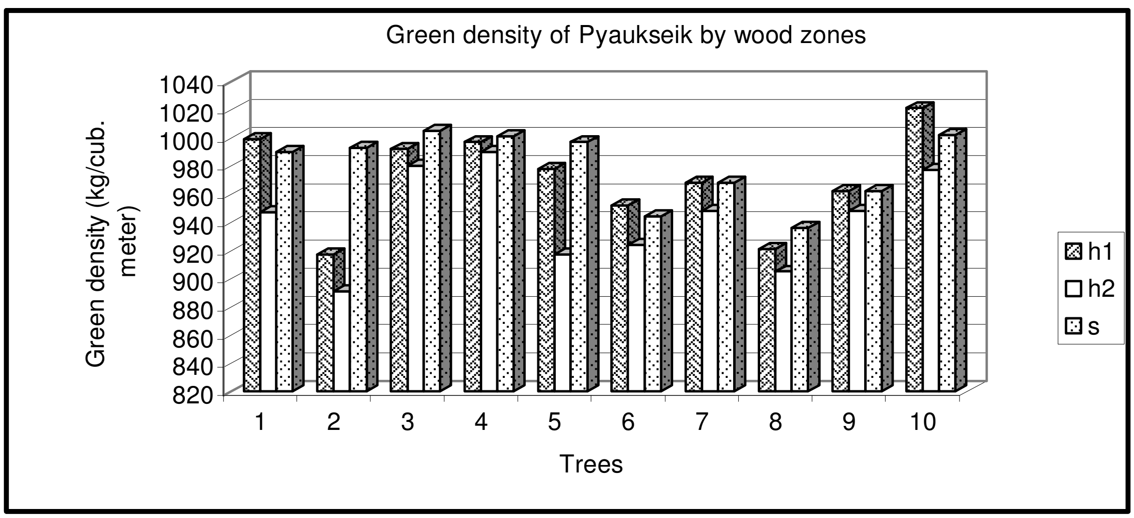

Figure 4: Graph showing zonal green density of Pyaukseik

APPENDIX VI: SPECIFIC GRAVITY

Table 1: The results of significance test of the effects of trees, sections, wood zones and their interactions on basic specific gravity of Leza

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	8	0.042535	537	0.000457	93.16022	0.000000*
2	3	0.004145	537	0.000457	9.07850	0.000007*
3	2	0.001672	537	0.000457	3.66171	0.026332*
12	24	0.007678	537	0.000457	16.81692	0.000000*
13	16	0.001349	537	0.000457	2.95421	0.000101*
23	6	0.000333	537	0.000457	0.72899	0.626411
123	48	0.000441	537	0.000457	0.96499	0.542485

Note: * means 'significant at 95% probability level'.

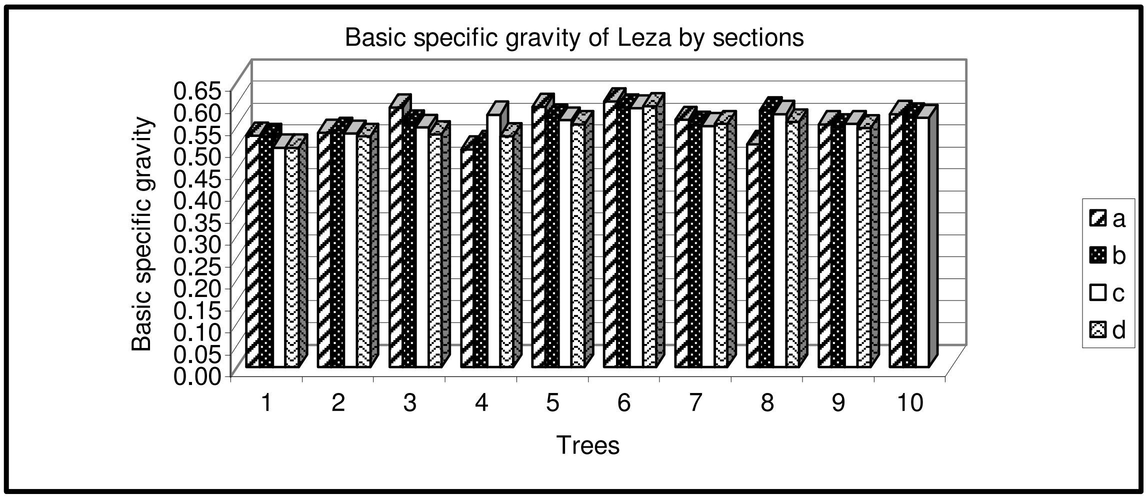

Figure 1: Graph showing sectional basic specific gravity of Leza

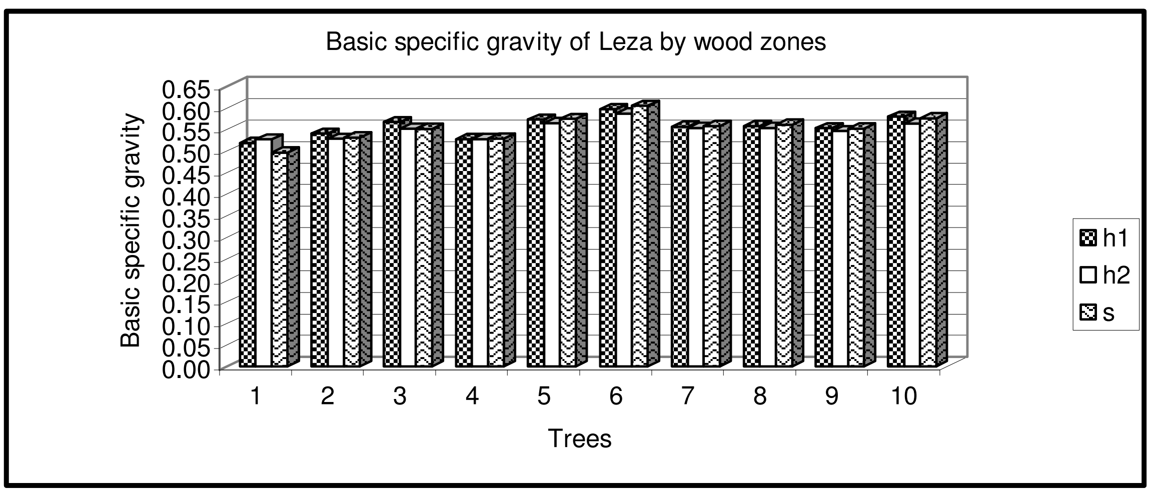

Figure 2: Graph showing zonal basic specific gravity of Leza

Table 2: Results of significance test of the effects of trees, sections, wood zones and their interactions on basic specific gravity of Pyaukseik.

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	7	0.070256	465	0.000407	172.5903	0.000000*
2	3	0.002449	465	0.000407	6.0172	0.000500*
3	2	0.058538	465	0.000407	143.8035	0.000000*
12	21	0.005527	465	0.000407	13.5774	0.000000*
13	14	0.001454	465	0.000407	3.5710	0.000013*
23	6	0.000238	465	0.000407	0.5845	0.742786
123	42	0.000379	465	0.000407	0.9303	0.598633

Notes: * means ‘significant at 95% probability level’.

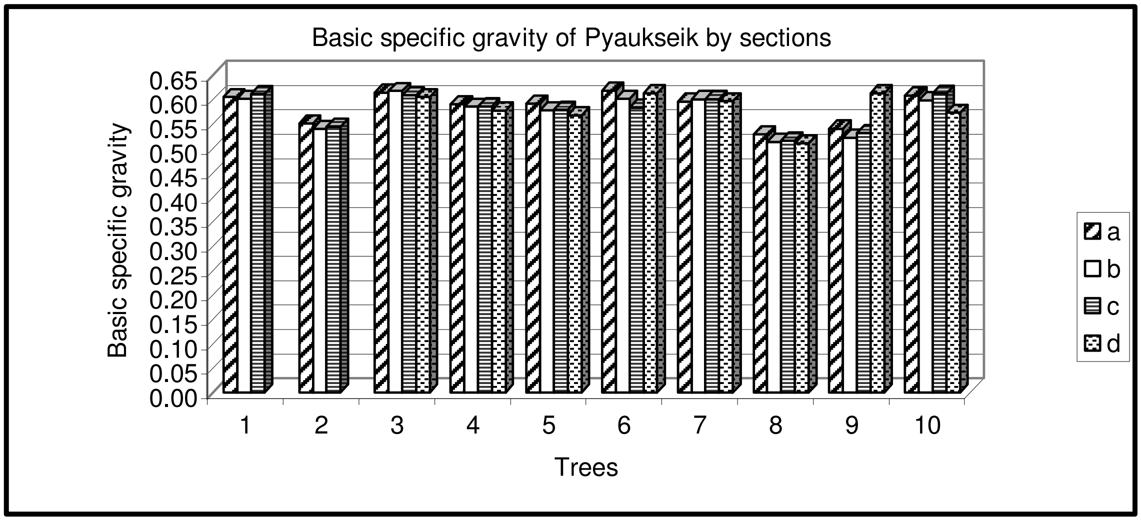

Figure 3: Graph showing sectional basic specific gravity of Pyaukseik

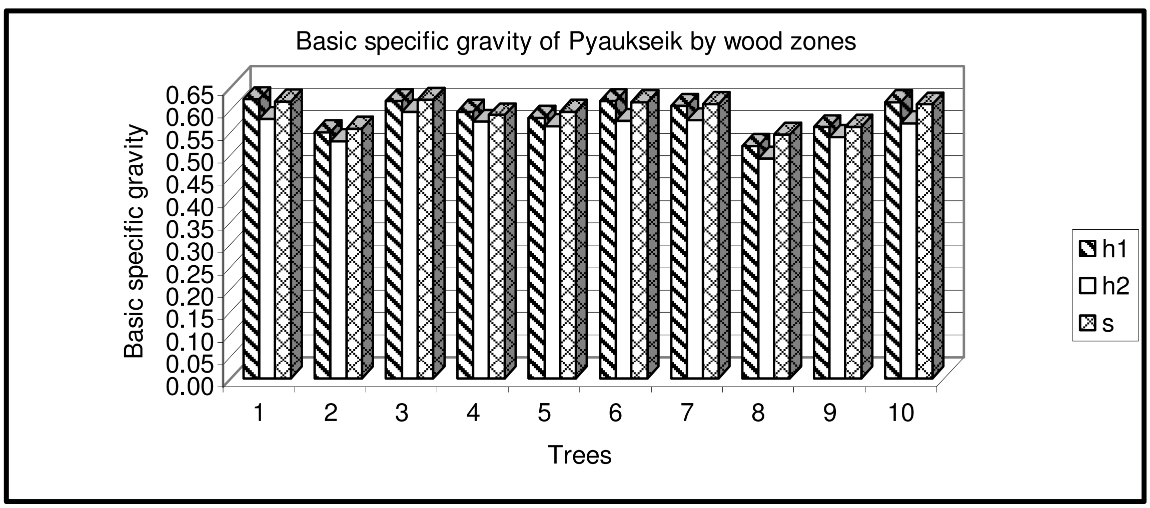

Figure 4: Graph showing zonal basic specific gravity of Pyaukseik

APPENDIX VII: MOISTURE CONTENT

Table 1: The test of significance of the effects of trees, sections, wood zones and their interactions on moisture content of green Leza wood.

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	8	1977.279	533	15.58965	126.8328	0.000000*
2	3	449.239	533	15.58965	28.8165	0.000000*
3	2	1715.222	533	15.58965	110.0231	0.000000*
12	24	386.666	533	15.58965	24.8027	0.000000*
13	16	252.590	533	15.58965	16.2024	0.000000*
23	6	93.460	533	15.58965	5.9950	0.000004*
123	48	80.661	533	15.58965	5.1740	0.000000*

Note: * means 'significant at 95% probability level'.

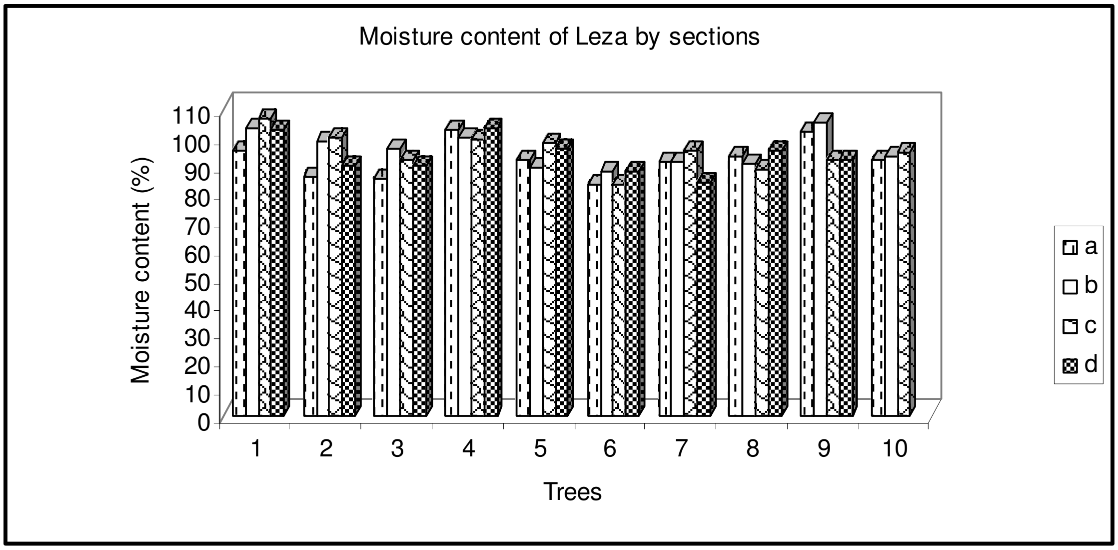

Figure 1: Graph showing sectional moisture content of Leza

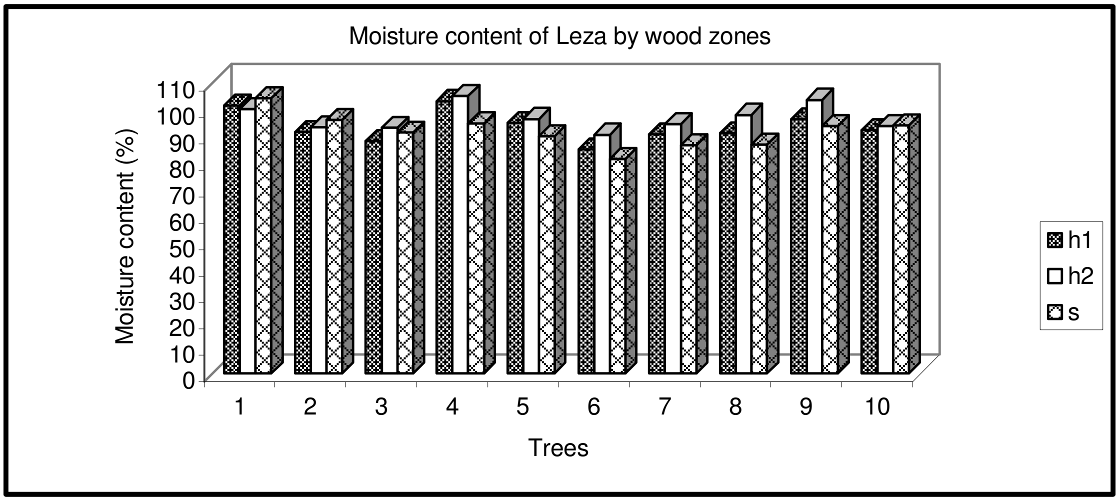

Figure 2: Graph showing zonal moisture content of Leza

Table 2: Results of the test of significant differences of the effects of trees, sections, wood zones and their interactions on green moisture content of Pyaukseik.

1-TREE, 2-SECTION, 3-WOODZONE

Source of Variation	df Effect	MS Effect	df Error	MS Error	F	p-level
1	7	5084.047	469	12.64152	402.1705	0.000000*
2	3	716.021	469	12.64152	56.6404	0.000000*
3	2	2258.604	469	12.64152	178.6656	0.000000*
12	21	429.786	469	12.64152	33.9979	0.000000*
13	14	244.277	469	12.64152	19.3234	0.000000*
23	6	28.830	469	12.64152	2.2806	0.035154*
123	42	36.953	469	12.64152	2.9231	0.000000*

Note: * means 'significant at 95% probability level'.

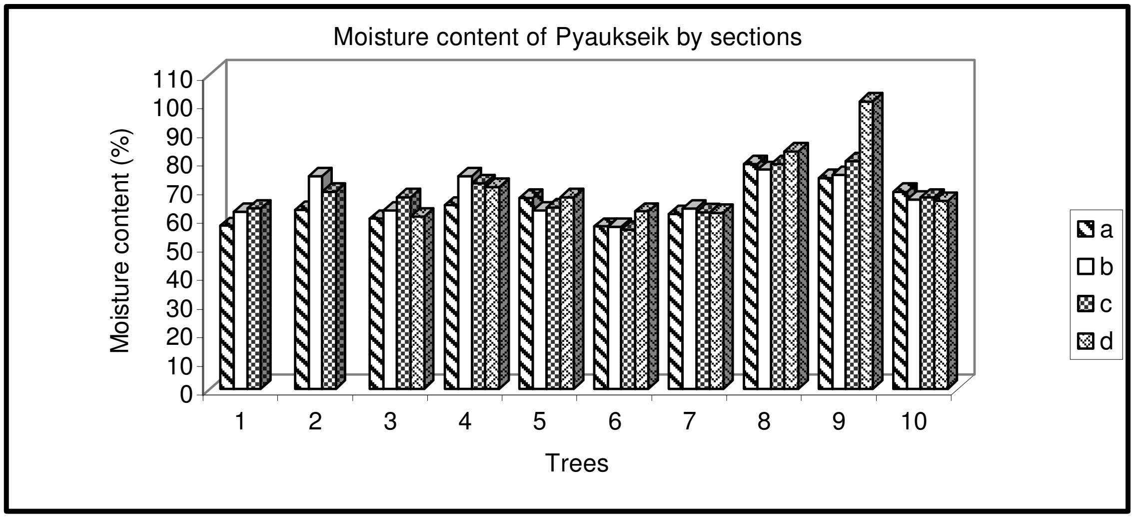

Figure 3: Graph showing sectional moisture content of Pyaukseik

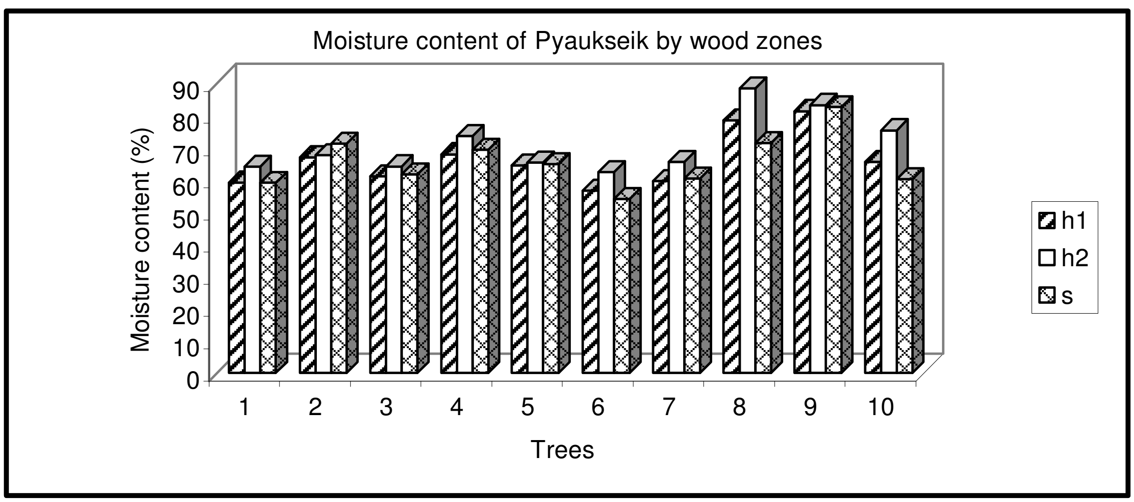

Figure 4: Graph showing zonal moisture content of Pyaukseik

APPENDIX VIII: PHYSICAL AND MECHANICAL PROPERTIES OF LEZA (*LAGERSTROEMIA TOMENTOSA*)

Property	Seasoning	Mean	N	Std. Dev.	Min.	Max.	CV%	95%Confid. Limit
1. Shrinkage (%)								
a) Radial	Oven-dry	4.7	694	0.4	4.1	5.1	8	0.3
	12%	2.8	679	0.2	2.5	3.1	8	0.2
b) Tangential	Oven-dry	6.9	698	0.5	6.1	7.7	7	0.3
	12%	4.1	685	0.3	3.7	4.6	7	0.2
c) Longitudinal	Oven-dry	0.2	662	0.0	0.2	0.3	15	0.0
	12%	0.1	662	0.0	0.1	0.2	15	0.0
d) Volumetric	Oven-dry	12.0	699	1.4	10.7	15.1	12	1.0
	-	-	-	-	-	-	-	-
e) Total transverse	Oven-dry	11.8	117	0.8	10.4	13	7	0.6
	-	-	-	-	-	-	-	-
2. Dimensional Stability (%/%)	Oven-dry	1.5	117	0.1	1.4	1.6	5	0.1
3. Moisture Content (%)	Green	94	695	5.1	85.5	101.9	5	3.6
4. Specific Gravity	Green	0.55	699	0.02	0.51	0.60	4	0.02
	12%	0.61	699	0.03	0.56	0.66	5	0.02
	Oven-dry	0.63	699	0.03	0.58	0.69	5	0.02
5. Density (kg/m^3)	Green	1075	699	26	1037	1115	2	18
	12%	679	697	32	625	704	5	23
	Oven-dry	628	697	34	575	685	5	24
6. Static bending (N/mm^2)								
a) FS@PL	Green	54	25	7	40	66	13	3
	12%	71	24	9	54	91	12	4
b) MOR	Green	74	25	11	51	93	14	4
	12%	105	24	14	64	130	13	6
c) MOE	Green	12035	25	1874	8004	15417	16	774
	12%	14375	24	2069	11557	18469	14	874
7. Compression parallel to grain (N/mm^2)								
a) FS@PL	Green	24	20	4	17	31	16	2
	12%	38	24	5	30	48	12	2
b) MCS	Green	31	20	2	26	34	7	1
	12%	47	24	5	38	54	11	2
8. Compression perpendicular to grain (N/mm^2)								
a) FS@PL	Green	9	25	1	7	11	11	0.4
	12%	12	24	2	9	15	14	0.7
9. Hardness (N)								
a) Radial	Green	4493	50	790	3470	6316	18	225
	12%	5478	46	533	4460	6939	10	158
b) Tangential	Green	4374	50	938	3292	6761	21	267
	12%	5399	46	583	4553	7402	11	173
c) End	Green	5286	50	468	4626	6761	9	133
	12%	6614	46	795	5241	8425	12	236
10. Fiber saturation point %	Green		-	-	-	-	-	-
a) Heartwood 1	Green	24	-	-	-	-	-	-
b) Heartwood 2	Green	26	-	-	-	-	-	-
c) Sapwood	Green	24	-	-	-	-	-	-

APPENDIX IX: PHYSICAL AND MECHANICAL PROPERTIES OF PYAUKSEIK (*HOLOPTELEA INTEGRIFOLIA*)

Property	Seasoning	Mean	N	Std. Dev.	Min	Max.	CV%	95%Confid. Limit
1. Shrinkage (%)								
a) Radial	Oven-dry	4.6	691	0.5	3.7	5.1	10	0.3
	12%	2.8	673	0.3	2.2	3.1	10	0.2
b) Tangential	Oven-dry	7.6	681	0.6	6.5	8.6	8	0.4
	12%	4.6	681	0.4	3.9	5.2	8	0.3
c) Longitudinal	Oven-dry	0.2	647	0.0	0.2	0.3	20	0.0
	12%	0.1	648	0.0	0.1	0.2	21	0.0
d) Volumetric	Oven-dry	13.2	669	0.8	12.3	14.7	6	0.6
	-	-	-	-	-	-	-	-
e) Total transverse	Oven-dry	12.4	114	0.9	11.2	13.4	7	0.6
	-	-	-	-	-	-	-	-
2. Dimensional Stability	Oven-dry	1.7	114	0.2	1.4	2.1	12	0.1
3. Moisture Content%	Green	67.5	673	8	57.7	82.4	12	5.7
4.Specific Gravity	Green	0.58	669	0.03	0.52	0.61	5	0.02
	12%	0.64	669	0.04	0.60	0.67	6	0.03
	Oven-dry	0.67	669	0.04	0.59	0.71	5	0.02
5. Density (kg/m^3)	Green	964	669	27	920	1001	3	20
	12%	715	668	42	631	758	6	30
	Oven-dry	668	669	36	591	705	5	26
6. Static bending (N/mm^2)								
a) FS@PL	Green	42	38	6	28	51	13	2
	12%	64	25	10	41	80	16	4
b) MOR	Green	73	38	11	46	87	16	4
	12%	95	25	18	46	122	19	8
c) MOE	Green	9366	38	1688	5252	12385	18	556
	12%	12108	25	1434	8546	14022	12	592
7. Compression parallel to grain (N/mm^2)								
a) FS@PL	Green	25	35	5	15	37	19	2
	12%	34	25	5	20	42	15	2
b) MCS	Green	32	35	5	20	42	15	2
	12%	45	25	5	29	50	11	2
8. Compression perpendicular to grain (N/mm^2)								
a) FS@PL	Green	9	37	1	6	12	16	0
	12%	11	22	2	7	14	16	1
9. Hardness (N)								
a) Radial	Green	4354	70	736	2402	5872	17	175
	12%	5583	50	809	3296	7016	14	230
b) Tangential	Green	4474	70	669	3025	6228	15	159
	12%	5260	50	906	2874	6853	17	258
c) End	Green	5203	70	675	3292	6672	13	161
	12%	8059	50	981	5729	9489	12	279
10. Fiber saturation point	Green							
a) Heartwood 1	Green	25	-	-	-	-	-	-
b) Heartwood 2	Green	26	-	-	-	-	-	-
c) Sapwood	Green	24	-	-	-	-	-	-

APPENDIX X: COMPARISION OF PHYSICAL PROPERTIES OF LEZA AND PYAUKSEIK WITH THOSE OF SOME MYANMA COMMERCIAL TIMBER SPECIES

No	Species	Moisture Content	Specific Gravity	Density	Radial Shrinkage	Tangential Shrinkage	Dimensional Stability
		(%)	-	(kg/m^3)	(%)	(%)	-
1	Leza	94.0	0.553	1075	4.7	6.9	1.46
		12.0	0.606	679	2.8	4.1	1.46
2	Pyaukseik	67.5	0.580	964	4.6	7.6	1.66
		12.0	0.639	715	2.8	4.6	1.66
3	Binga*	58.4	0.553	881	3.8	7.3	1.92
		12.0	0.606	679			
4	Hnaw*	81.4	0.583	1058	2.8	5.6	2.00
		12.0	0.643	720			
5	In*	50.3	0.726	1090	4.4	9.1	2.07
		12.0	0.821	919			
6	Kanyin-ni*	65.7	0.655	1090	4.2	8.9	2.12
		12.0	0.731	819			
7	Teak*	51.8	0.598	913	2.3	4.2	1.83
		12.0	0.661	740			
8	Padauk*	43.8	0.752	1074	3.4	5.1	1.50
		12.0	0.854	957			
9	Pyinkado*	48.6	0.779	1154	3.3	6.7	2.03
		12.0	0.889	996			
10	Pyinma*	118.1	0.518	1122	4.4	6.8	1.55
		12.0	0.564	632			
11	Taukkyan*	53.5	0.707	1090	4.8	7.1	1.48
		12.0	0.797	892			
12	Taungthayet*	58.5	0.551	865	3.2	6.0	1.88
		12.0	0.604	676			
13	Thadi*	43.7	0.710	1072	5.5	8.9	1.62
		12.0	0.800	896			
14	Thingan*	73.9	0.637	1106	3.4	6.5	1.91
		12.0	0.709	794			
15	Thinkadu*	70.7	0.589	1010	4.2	9.8	2.33
		12.0	0.650	728			
16	Zaungbale*	39.1	0.610	974	4.2	7.6	1.81
		12.0	0.676	757			

*Data source: Physical and mechanical properties of some Myanma Timbers (Kyi, 1993)

APPENDIX XI: COMPARISON OF MECHANICAL PROPERTIES OF LEZA AND PYAUKSEIK WITHTHOSE OF SOME MYANMA COMMERCIAL TIMBER SPECIES

No.	Species	Moisture Content (%)	Static Bending (N/mm^2)			Compression Parallel to grain (N/mm^2)		Compression Perpendicular to grain (N/mm^2)	Hardness (N)		
			FS@PL	MOR	MOE	FS@PL	MCS	FS@PL	Radial	Tang-ential	End
1	Leza	94.0	54	74	12035	24	31	9.0	4493	4374	5286
		12.0	71	105	14375	38	47	12.0	5478	5399	6614
2	Pyaukseik	67.5	42	73	9366	25	32	8.7	4354	4474	5203
		12.0	64	95	12108	34	45	10.7	5583	5260	8059
3	Binga*	58.4	44	73	9170	28	36	6.8	4781	4693	5467
		12.0	55	100	11229	41	54	9.7	5277	5686	7250
4	Hnaw*	81.4	39	65	8377	27	34	7.5	4713	4889	5575
		12.0	45	79	9429	29	46	10.3	5199	5780	6449
5	In*	50.3	48	80	12093	25	39	8.4	6310	6310	6467
		12.0	69	124	15546	33	68	8.7	8510	8243	9066
6	Kanyin-ni*	65.7	48	76	13928	27	40	6.6	4536	4487	4713
		12.0	62	118	16155	29	60	9.2	6559	6041	6377
7	Padauk*	43.8	65	110	13080	38	57	13.6	8936	9220	9220
		12.0	90	145	14464	54	77	19.7	9742	9811	9404
8	Pyinkado*	48.6	66	107	15617	44	55	11.7	8554	8514	8113
		12.0	71	132	16851	45	71	13.8	9213	10151	8611
9	Pyinma*	118.1	38	59	8860	23	29	8.5	4889	4821	4801
		12.0	37	78	9837	30	40	7.7	4256	4300	5258
10	Taukkyan*	53.5	48	78	11459	27	39	8.8	6849	6535	6447
		12.0	68	111	13457	36	61	12.6	9385	9819	10268
11	Taungthayet*	58.5	32	59	11294	20	28	3.9	3331	3263	3351
		12.0	46	84	13210	26	43	6.5	3912	3984	4887
12	Teak*	51.8	49	79	11535	28	40	7.3	4644	4576	4066
		12.0	69	103	13011	41	60	10.7	5234	5183	5018
13	Thadi*	43.7	47	84	10873	20	35	9.3	7642	7309	7319
		12.0	62	117	13135	30	57	15.9	8882	8904	9652
14	Thingan*	73.9	55	79	10432	33	43	10.5	6084	6045	5889
		12.0	60	95	11551	35	46	10.8	6218	6797	7142
15	Thinkadu*	70.7	44	70	13204	27	38	6.4	3929	4047	3684
		12.0	62	101	15284	39	56	6.8	4805	5397	4308
16	Zaungbale*	39.1	45	79	12239	24	34	5.6	4703	4909	5369
		12.0	69	114	14823	38	66	8.7	5804	5793	7630

*Data source: Physical and mechanical properties of some Myanma Timbers (Kyi, 1993).

Data at 12% moisture content are originally given at air-dry (Different moisture contents). For ease of comparison they are converted into 12% moisture content.

APPENDIX XII: BOTANICAL NAME OF SOME MYANMAR TIMBER SPECIES MENTIONED IN THIS RESEARCH PAPER

Sr. No.	***Vernacular Name***	***Botanical Name***	***Family***
1	Binga	*Mitragyna rotundifolia* Roxb.	Rubiaceae
2	Chinyok	*Garuga pinnata* Roxb.	Burseraceae
3	Dahat	*Tectona hamiltonia* Wall.	Verbenaceae
4	Hnaw	*Adina cordifolia* Hk.f.	Rubiaceae
5	In	*Dipterocarpus tuberculatus* Roxb.	Dipterocapaceae
6	Kanyin-ni	*Dipterocarpus turbinatus*	Dipterocarpaceae
7	Leza	*Lagerstroemia tomentosa* Presl.	Lythraceae
8	Myaukngo	*Duabanga frandiflora* Walp.	Lythraceae
9	Padauk	*Pterocarpus macrocapus* Kz.	Papilionaceae
10	Pyaukseik	*Holoptelea integrifolia* Planch	Ulmaceae
11	Pyinkado	*Xylia dolarbriformis* Benth	Mimosaceae
12	Pyinma	*Lagerstroemia speciosa* Pers.	Lythraceae
13	Taukkyan	*Terminalia tomentosa* W. & A.	Combretaceae
14	Taungthayet	*Swintonia floribunda* Griff.	Anacardiaceae
15	Teak	*Tectona grandis* Linn	Verbenaceae
16	Thadi	*Protium serratum* Engler.	Burseraceae
17	Than	*Terminalia oliveri* Brandis	Combretaceae
18	Thande	*Stereospermum personatum* Chatt.	Bignoniaceae
19	Thanthat	*Albizzia lucida* Benth.	Mimosaceae
20	Thingan	*Hopea odorata* Roxb.	Dipterocarpaceae
21	Thinkadu	*Parashorea stellata* Kz.	Dipterocarpaceae
22	Zaungbale	*Lagerstroemia villosa* Wall.	Lythraceae

APPENDIX XIII: STRENGTH OF LEZA AND PYAUKSEIK AS PERCENTAGE OF THE SAME QUALITIES FOR TEAK

Species	Moisture Content (%)	Strength as beam	Stiffness as beam	Suitability as post or strut	Hardness			Weight
					Radial	Tangential	End	
Teak	-	100	100	100	100	100	100	100
Leza	Green	94	104	78	97	96	130	118
	12	102	110	78	105	104	132	92
Pyaukseik	Green	92	81	80	94	98	128	106
	12	92	93	75	107	101	161	97

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