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DECLARATION

I, Md. Jahangir Alam, declare that this thesis is the result my own work and that has not been submitted or accepted for a degree in any other University/Institutions. I, hereby, give consent for my thesis, if accepted, to be available for inter-library loans, and for further research.

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30-05-16

Name of the candidate: Md. Jahangir Alam

DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

Mahogany and sissoo trees are widely planted in Bangladesh both in block plantation and agricultural land. Density and moisture content are the important traits of wood that are related to quality of wood. This study was conducted to know the distribution of moisture content and density within tree and between trees grown in block plantation and in agricultural land. Moisture content was determined by oven dry method. Density was calculated by using the dry volume of wood with the oven dry weight. It was observed that moisture content increased when moved from the inner portion to the outer portion of the tree at any height position. Moisture content was higher at the top of the tree compared to the butt. Mahogany showed higher moisture content compared to the sissoo. Trees grown in agricultural land showed higher moisture content compared to the block plantation. However, the phenomenon was completely reversed for density. The results indicated that trees grown in block plantation had better properties compared to that of grown in agricultural land.

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ABREVIATION AND ACRONYMS

AF	Agroforestry
BARI	Bangladesh Agricultural Research Institute
DBH	Diameter at Breast Height
MC	Moisture Content
MMC	Maximum Moisture Content
FAO	Food and Agricultural Organization
FD	Forest Department
OD	Oven Dry
ICRAF	International Council for Research in Agroforestry
IITA	International Institute of Tropical Agriculture

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Moisture content of wood is defined as the weight of water in wood expressed as a fraction, usually a percentage of the oven dry weight of wood. The behavior of wood is well-known to depend on its moisture content which affects strength, electrical resistance, thermal and other properties. In trees, moisture content can range from about 30 to more than 200% of the weight of wood substance. In softwood, the moisture content of sap wood is usually greater than that of heartwood. In hardwood, the difference in the moisture content between heartwood and sapwood depend on the species (Simpson and Tenwolde, 1999). Moisture content have been seen variations in plants from inner portion to outer portion, season to season, upper portion to lower portion, heart wood to sap wood, between species, within the same species grown in different site, within height and site condition of the tree.

Wood density is an important indicator of mechanical properties (Panshin and de Zeeuw, 1970). It also has a direct relationship with tree growth, because the volume of wood produced for a given unit of biomass is inversely proportional to its density (King *et al.*, 2005), though some hardwoods produce the density timber from the fastest-growing trees (Haygreen and Bowyer, 1989). Wood density is related to a number of plant functional traits and is an important indicator of the mechanical properties of woods (Panshin and de Zeeuw, 1980; Chave *et al.*, 2009). A direct relationship between wood density and tree growth is expected because the volume of wood produced for a given unit biomass is inversely proportional to its density (King *et al.*, 2005). Variation of wood density is found between species, within the same species grown in different site, from inner portion to outer portion, season to season, upper portion to lower portion and heart wood to sap wood. Within individual trees, wood density often varies vertically along the main axis of the stem and/or radially from the pith to the bark (Panshin and de Zeeuw, 1980; Grabner and Wimmer, 2006).

Agroforestry is a form of integrated land use systems, which consists of woody perennial favorably mixed with annual crops and other production enterprises like animals to derive various benefits and utilities from the same piece of land (Bhuiya, *et al.,* 2001). The practice of agroforestry is an age-old practice in the traditional farming systems in the tropics including Bangladesh, although it is newer as a discipline (Karim and Savil, 1991). Agroforestry practices in both encroached forestland and homestead areas have, therefore, emerged as a pressing national land use, demanding for tree production along with crop and other areas (Bhuiya, *et al.,* 2001). In the present context of Bangladesh, agroforestry practices are appropriate for long-term benefits. A unique combination of different species of fruits, timber and biomass yielding trees can generate high amount of earnings for the farmers of Bangladesh (Abedin *et al.,* 1990; Chowdhury and Satter, 1993). Agroforestry significantly contributes towards carbon balance. The role of soils in carbon storage has been somewhat overshadowed by tree-planting efforts. While planting tree is important to increase carbon storage, conserving soils is essential. Soils are the largest non-fossil land based organiccarbon reservoir (Gavenda, 2000).

Mahogany and sissoo are the two important species which are practiced in agroforestry land in the southern part of Bangladesh. The wood of these species are used in different purpose like furniture, constructional works, particle board industries etc. All the portions cannot be used for a particular use. It's used heart portion mainly in constructional purpose, medium density portion is used in furniture works and sap portion (low density) used in particle board industries.

No study was conducted till now to compare the moisture and density distribution of mahagony and sissoo planted in block plantation and agricultural land in the southern part of Bangladesh. Thus, this study was designed to measure and compare the moisture and density distribution of these two species. The result of this study might help to ensure the proper use of wood of these two species grown in different land.

1.2 Objectives of the Study

Density and moisture content (MC) are important criteria that is related to efficient uses of wood. Wood has its importance in manufacturing of furniture, floor, wall cover etc. Moisture content (MC) is one of the most important technical specifications for quality in wood industry. The measurement of moisture content (MC) of wood is important due to its influence on the

CHAPTER TWO

LITERATURE REVIEW

2.1 Moisture Content

Moisture content of wood is defined as the weight of water in wood expressed as a fraction, usually a percentage, of the oven dry wood. Weight, shrinkage, strength and other properties depend upon the moisture content of wood. In trees, moisture content can range from about 30% to more than 200% of the weight of wood substance. In softwood, the moisture content of sap wood is usually greater than that of heartwood. In hardwood, the difference in the moisture content between heartwood and sapwood depend on the species (Simpson and Tenwolde, 1999).

2.1.1 Factors affecting the moisture content of wood

Moisture is an important trait of wood and is affected by different factors. The effect of moisture content on the mechanical strength of wood is especially important at moisture content below fiber saturation point (FSP). Above FSP, moisture content (MC) affects mechanical strength when temperature decreases below 0°C. In this case, the portion of liquid water freezes, expands, and reinforces the strength of wood (Mishiro and Asano, 1984; Mishiro, 1990).

Density: If the moisture content is constant then the high density wood contain large portion of cell wall and this cell wall is hygroscopic substance so it observes more water. On the other hand, low density wood contains less amount of cell wall than high density wood so it contains less moisture.

Temperature: If relative humidity is kept constant, the higher the temperature lower the moisture content Temperature influences of moisture content by increasing the moisture holding capacity of air ,as well as by accelerating the rate of diffusion of moisture trough the wood.

Relative humidity: If temperature is kept constant, higher the relative humidity higher the moisture content and in the low relative humidity causes low moisture content in wood.

Air Circulation: With constant temperature and relative humidity, the lowest moisture content is obtained by rapid circulation of air across the surface of wood and higher moisture content shows, when air circulation rate is low.

Species: Moisture content depends on species. Some species contain more moisture and some species contain low moisture contain due to, dimension, alignment and structure and of the capillary system of wood, and the nature and extent of plugging of this structure by gums, extractives, organic growths like tylose, pit aspiration etc. (Anon, 2007).

2.1.2 Methods for moisture content determination

2.1.2.1 Oven dry method

The standard method of determining the moisture content of any piece of wood is to cut a small sample from it, weight it and reweights it. The loss in weight gives the amount of moisture which was in the sample when cut and the moisture content is calculated from the simple formula:

$$\text{Moisture content (\%)} = \frac{\text{Initial wet weight} - \text{Dry weight}}{\text{Dry weight}} \times 100$$

2.1.2.2 Distillation method

Moisture content in wood can be accurately determined by the distillation method. The method for finding moisture content of wood containing appreciable quantities substances that volatilized at temperature below or at the boiling point of water is by distillation

$$\text{Moisture content(\%)} = \frac{\text{Weight of water in grain}}{\text{Final weight of the wood}} \times 100$$

2.1.2.3 Electric moisture meter method

Electric moisture meter permit the determination of moisture content without cutting seriously marring the board. Such meters are rapid and reasonably accurate through the range from 7% to 25% moisture content. With some types of electrodes, a minor consideration is that small needlepoint holes are made in the lumber being tested. Electric moisture meter are extensively used, particularly the portable or hand meters (Madison, 1999).

Two types, each based on a different fundamental relationship have been developed: (1) the resistance or pin type, which uses the relationship between moisture content and electrical resistance and 2 the capacitance type, which uses the relationship between moisture content and the dielectric properties of wood and its included water.

Portable, battery operated, resistance type moisture meters are wide range ohmmeters. Most models have a direct reading meter, calibrated in percentage for one species; the manufacturer provides corrections for other species, either of the drying board are obtained by driving the pins deep enough in the lumber so that the tip reaches a fifth to a fourth of the thickness of the board. If the surface of the lumber has been wetted by rain, the meter indications are likely to be much greater than the actual average moisture content unless insulated shank pins are used.

Capacitance type hand meters use surface contact-type electrodes. The electric field radiating from the electrode penetrates about 19 mm (3/4 inch) into the wood so that lumber thicknesses to about 38 mm (1-1/2 inch) can be tested. However the moisture content of the surface layers of the lumber has a predominant effect on the meter reading, simply because the electric field is stronger near the surface in contact with the electrode (Maddison, 1999).

2.1.3 Moisture distribution

One of the important characteristics necessary for utilizing wood is the moisture content of wood. Wood in growing trees contains a considerable amount of moisture, which accounts for about 50% of the green weight (Larcher, 1995). Most of the moisture should be removed to obtain satisfactory performance for most uses of wood. Reduction in drying time and energy consumptions offers the wood industries for a great potential for economic benefit. But the reduction in drying time often results in an increase of defect relating drying such as checks, splits and warp (Wu and Milota, 1995) though high temperature drying can reduce drying time and checks to some extent. Most of these defects are caused by drying stresses which are developed from moisture gradients and retained shrinkage within the wood. Therefore, the key to improve drying quality and to reduce time lies in understanding and controlling moisture movement in wood during drying (Rice, 1988). Drying quality of most wood products is mainly dependent on the distribution of moisture.

Moisture content varies within the tree (pith to bark and stem to crown) and seasonally. Knowing these types of variations could be important if you routinely buy and sell wood by weight. Most variation in moisture content was observed in the wood nearest the bark. Moisture content will vary from year to year so moisture content should be calculated for individual cases if it is to be precise. In addition to, compare the weight of winter-cut and summer-cut, the samples should include equal proportions of top, middle, and bottom logs because of moisture content variations within the tree (Bendsen, 1962).

Information on the moisture content in timber is useful because it is directly related to the weight of green timber. It varies between sapwood and heartwood (Haygreen and Bewyer, 1982). The amount of moisture decreases slightly in heartwood due to deposition of extractives which replace the water molecules in building cellulose and hemicellulose. However, the difference in small in hardwoods compared to softwoods which can differ by four times. Shrinkage in timber is the result of dimensional movement when season timber is subjected to environmental changes. This movement is caused by the change in moisture content of the timber below the fiber saturation point due to general climatic change, heating or cooling or wetting and drying at particular intervals. Normally, the moisture content of wood varies from the time the tree is felled unit its reaches equilibrium (Chu, 1979).

2.2 Wood Density

Wood is a complex composite material that can contain varying amounts of water absorbed within the fiber. Density therefore needs to be defined in relation to standard conditions, such as green, air dry, oven dry or basic. The most common (and useful) expression is the basic density, which is calculated as the oven dry weight divided by the green wood volume, expressed in kg/m3. Basic density varies greatly within and between species, being strongly influenced by geographic location, site fertility, age and genetics. Wood density indicates the amount of actual wood substance present in unit volume of woodsy: It is the affected by the cell wall thickness, the cell diameter, the early to late wood ratio and the chemical content of the wood (Cave *et al.*, 1994).

The density of wood is an interesting variable because it tells how much carbon the plant allocates into construction costs. Wood density varies within the plant, during the life of the plant and between individuals of the same species (Chave, 2005).

The weight of wood is the sum of the weight of: (1) the wood substance; (2) extraneous matter, consisting of mineral and non-mineral substance, contained in it; and (3) the water present while the amount the water in a piece of wood varies according to its green or dry condition, the other two ingredients in it remain more or less constant (Anon, 1970).

2.2.1 Factors affecting density of wood

Wood density is regarded as one of the most important characteristics of wood, significantly influencing the majority of its other physical and mechanical properties (Bosshard, 1974; Zobel and Van Buitenen, 1989). It is often perceived as one of the main indicators of quality (Barnett and Jeronimidis, 2003). There is a very close correlation between density and the strength characteristics of wood (Kolmann, 1951; Niemz and Sonderegger, 2003; Sonderegger *et al.*, 2008), so it can be used as an indicator for the primary assessment of mechanical properties (Niemz, 1993; Perelygin, 1965; Vikram *et al.*, 2011). Unlike for other materials, density of wood fluctuates depending on moisture. It is therefore desirable to always determine the density for a specific moisture content. For practical reasons, wood density at 12 % moisture content is typically expressed (Pozgaj, 1997).

Density of wood and all its properties in general, are subject to great variability. Differences can be found among genera and species, among sites, and even among trees on one site. In fact, differences can even be observed within a single tree (Kollmann, 1951; Panshin and De Zeeuw 1980, Tsoumis, 1991; Zobel and Van Buitenen, 1989). It is affected by the cell wall thickness, the cell diameter, the earlywood to latewood ratio and the chemical content of the wood (Cave and Walker, 1994).Characteristic properties of wood may be inherent to different tree species, but are largely influenced by the surrounding environment, including Silvicultural practices (Barnett and Jeronimidis, 2003; Jozsa and Middleton, 1994). Variability is caused by differences in the wood structure, notably the width of annual rings and the proportion of late wood (Adamopoulos *et al.,* 2010; Dekort, 1991). The proportion of juvenile wood also plays an important role (Guler *et al.*, 2007; Pazdrowski, 2004).

Factors contributing to the vertical variability include primarily the width of annual rings, the wood structure (Bosshard, 1974) and the different proportion of juvenile wood in different parts of the stem (Zobel and Van Buitenen, 1989). The presence of juvenile wood is quoted as one of the main causes of horizontal variability, particularly in coniferous trees (Barnett and Jeronimidis, 2003; Panshin and De Zeeuw, 1980; Zobel and Van Buitenen, 1989). Juvenile wood is a zone at the centre of the stem occupying approximately 5 to 20 annual rings. It exhibits a different structure, and thus different wood properties, compared to mature wood (Haygreen and Bowyer 1989; Zobel and Van Buitenen, 1989). Other causes of variability in wood density in the horizontal direction are the width of annual rings and the frequently related proportion of late wood (Požgaj *et al*., 1997, Kolmann, 1951; Niemz, 1993). It is generally the case with coniferous trees that wood density decreases with the increasing width of annual rings. The assumption is that increasing width of annual rings and the proportion of late wood (Adamopoulos *et al*., 2010; Dekort, 1991). The proportion of juvenile wood also plays an important role (Guler *et al*., 2007; Pazdrowski, 2004).

2.2.2 Methods of density determination

Density of each sample was measured according to the Equation 1. Diameter and length of the samples were calculated by using slide calipers.

$$\rho = \frac{m}{v} \qquad \text{Eq.1}$$

Where,

ρ= density in g/cm^3

m= mass of the sample in g

v= Volume in cm^3

2.2.3 Types of different wood densities

2.2.3.1 Green volume (GV) density (d= Mg /Vg)

This method is simpler the oven dry and maximum moisture content (MMC) methods since the measurement of volume and mass easy. The green volume (Vg) is dimensionally measured with a micrometer and the mass at green state (Mg) is measured on a balance accurate to four decimal places without any oven dry procedure because density is calculated at the same moisture content as in the living tree, so green volume (Vg) and green mass (Mg) can be measured (Kollmann and cote, 1986).

2.2.3.2 Oven dry density (d=Mg/Vg)

The green volume (Vg) is directly comparative study of wood density by specific amount of void volume (Porosity) dimensionally measured using a micrometer, likewise with the green volume method. Oven dry mass(Mo in method) is measured after oven drying of the wood at 103±2°C to a constant mass within a repeat weighting time of 24 hour (Panshin and de Zeeue, 1980).

2.2.3.3 Maximum moisture content density (d=Mo/ [(Mo/G) + (Ms-Mo)])

Determination the green volume in this method is by recourse to know the consistent value for the specific gravity of the cell wall substance (G), which is taken to be 1.53 g/cm^3 (Smith, 1994), and hence, before measuring the oven dried mass(Mo), the wood must fully be saturated(Ms) by deionized water to measure the real volume according to the Archimedes principle, which states that a body immersed in a fluid experiences an up thrust equal to the weight of the fluid displaced. This completely saturated wood block displaces an amount of water equal to its own volume (Oleses, 1971). Procedure was taken continually performed for 10 days (a: application of -80 kPa (600mmHg) vacuum for 12 hours, b: the desiccator was kept closed for 12 hour, c:activation of the application of the former vacuum stage). After completing the soaking time under vacuum, the experimental blocks were assumed to be fully saturated, and were then individually weighed in a beaker of deionized water to determine the saturated mass (Ms). Subsequently, the blocks were dried in an oven at 103±2°C for 24 hours. After drying, the block were dried in a desiccators charged with granulated silica and reweighed to determine the oven dry mass(Mo).Mo data were first taken for density determination by the oven dry (OD) method, and then used in the maximum moisture content (MMC) method with Ms to determine the wood density.

2.2.4 Density distribution

Wood is a cellular /porous material (Kollmann and Cote, 1968) composed of cell wall substance and cavities containing air and extractives (Tsoumis, 1991). Without cavities and intercellular spaces the relative density(d), used here synonymously with specific gravity, of the cell wall materials is practically constants for all timber with a specific gravity of 1.53 gm/cm3-3 on an oven dry mass and volume basis , and the cell wall s are therefore one-and –half times heavier than water (Dinwoodie, 1981). Wood density is one of the most important properties to be considered in determining the suitable use of the timber species. It also indicates whether the timber is suitable for structural use or useful in non-structural application (Haygreen and Bowyer, 1982). Density of perfectly dry wood varies widely depending upon the air space (cell cavities) present inside the material. The density of wood substance (cell-wall substance) alone for all the species is ascertained as 1.53. As such, the overall density of the different species depends upon the relative amount of the cell and the cell cavity. Density variation between species is basically due to differences in anatomical structure. Species differ with regard to cell types and their proportional participation. In addition, differences in extractives and chemical composition of cell walls may influence density (Anon, 1970)

2.2.5 Density variation

Wood density is a key variable for understanding life history strategies in tropical trees. Differences in wood density and its radial variation were related to the shade-tolerance of canopy tree species in seasonally dry tropical forest in Asia. In addition, using tree ring measurements, the influence of tree size, age and annual increment on radial density gradients was analyzed. In contrast, shade-tolerant tree species grow more slowly and invest in dense, strong and damage-resistant wood that in turn lowers their mortality rates (Putz *et al.*, 1983; Muller-Landau2004; van Geldere *et al.*, 2006).

In addition to interspecific variation in wood density in forests, within individual trees wood density often varies vertically along the main axis of the stem and/or radially from the pith to the bark (Panshin and de Zeeuw, 1980; Grabner and Wimmer, 2006). It is thought that radial increases in wood density result from a shift in allocation from low density wood and rapid height growth early on in tree development to denser wood and structural reinforcement as trees increase in size, age and height and are exposed to increasing wind speeds within the forest (Wiemann and Williamson, 1989).

2.3 Block plantation

Block planting involves treating the entire block of trees as the management unit, with each block receiving relatively uniform treatment (e.g. weed control, fertilization, shearing, insect and disease control, etc.) as the tree mature. Following removal of all trees, either by harvest or cleanup of non-harvested trees, the area is replanted with new seedling/transplants.

The Lands required for block plantations have been identified in advance and in contiguous areas as against scattered individual plots. This has resulted in economies of scale. This has acclaim from all quarters. Block plantation ensures full participation by the stakeholders in raising, maintenance and in protection of the plantation. The Block plantation officer (BPO) is the focal point for all services at the block plantation level. Several ongoing state government schemes like immunization drives, health camps, sanitation campaign and animal husbandry camps are organized for the families in the block plantation.

2.3.1 Advantages of block plantation

A commonly cited advantage associated with block planting is the harvesting of all the trees within a block within a one-to three year period. The completely harvested area permits extensive site modification and/or preparation before the next planting of trees. Where sites are favorable, it also permits species change. Furthermore, the uniformity of trees with in a block facilities the application of pesticides and fertilizers, as well as annual shearing and some cultural practices, such as mowing. The uniformity of trees also allows for the use of other mechanized equipment inappropriate for inteplanted plantations.

2.3.2 Disadvantages of block plantation

A disadvantage of block plantation is that, because no trees are planted until the entire block has been harvested and cleared, a significant amount of growing space remains non-productive for several years. Another commonly cited disadvantage is that significant acreage is necessary to maintain this type of a management system. For this reason, effective block planting is usually practiced where plantation size is at least 20 acres and more commonly, 40 acre or more.

2.4 Agroforestry

Agroforestry is the art and science of growing woody and non-woody together on the same unit of land for range of benefits. Agroforestry is the use of land for a combination of agriculture and forestry. In other word, the practice of growing tree crops or some other fast growing trees along with the main crops. Agroforestry is one the important sustainable land management techniques, involving a combination of different agricultural, horticultural, forestry and livestock practices. Sometimes it is closely related to community forestry and homestead forestry (Hasanuzzaman, 2009).

Agroforestry is a land use system that involves socially and ecologically acceptable integration of trees with agricultural crops and/or animals, simultaneously or sequentially, so to get increased total productivity of plant and animal in a sustainable manner from a unit of farm land, especially under conditions of low levels of technology inputs and marginal lands. (P.K.R. Nair, ICRAF).

2.4.1 History of agroforestry

Agroforestry is not a new system but the term "Agroforestry" is very new. Many years ago, tree species and agricultural crops are cultivated in combination. The examples are numerous. It was the general custom in Europe, at least until the Middle Ages. They cleared the forest, burnt the slash, cultivated food crops for varying periods on the cleared areas and plant or sow tree species before, along with or after the sowing of the agricultural crop (King, 1968).

By the end of the nineteenth century, however, the establishment of forest plantations had become the dominant objectives wherever agroforestry was being utilized as a system of land management. At first, it was less deliberate and began fortuitously enough in the British Empire. In 1806, U Pan Hle, a Karen in the Tonze forests of Thararrawaddy Division of Burma, establishes Teak plantation through taungya system. Sir Dietrich Brandis alleged that it may become most efficient way of planting teak (Blanford, 1958).

The taungya system spread to other parts of Burma. From the beginnings, the practice more and more widespread. It was introduced into South Africa as early as 1887 (Hailey, 1957) and was taken from Burma to the Chittagong area in 1890 and to Bengal in 1896 (Raghavan, 1960). The concept of agroforestry was developed gradually from this taungya system. This system is dispersed in Africa from 1920 to 1925 and today it is practiced in varying degrees in all the tropical countries of the world. It is clear that the tremendous possibilities of production systems involving some combination of trees with agricultural crops are widely recognized and that research aim at developing the potential of such system is planned or exists in a number of scattered areas.

It was apparent that, despite the growing awareness of the need for factual information on which agroforestry systems might be effectively based, very little research was being undertaken. The research that was being conducted was haphazard, unplanned and coordinated. The IDRC Project

Report therefore recommended the establishment of an internationally financed organization, now known as the International Council for Research in Agroforestry (ICRAF), which would support, plan and co-ordinate, on a world-wide basis, research in combined land management systems of agriculture and forestry. This proposal was generally well received by international and bilateral agencies and subsequently, ICRAF was established in 1977. Thus agroforestry an old practice was institutionalized for the time.

The International Institute of Tropical Agriculture (IITA),Ibadan, Nigeria, was extending its work on farming systems to include agroforestry, and many research organizations had begun serious work on, for example, the integration of animals with plantation tree crops such as rubbers and the intercropping of coconuts (Nair,1979).

This congruence of men and of concepts and of institutional change provided the materials and the basis for the development of agroforestry since then. Although many individuals and institutions have made valuable contributions to the understanding and expansion of the concept of agroforestry since the 1970s, ICRAF has played leading role. Now it is more developed and the system is being more and more utilized as an agricultural system, particularly for small scale farmers. Indeed, agroforestry is first becoming recognized as a system which capable of yielding both food and wood and at the same time of conserving and rehabilitating ecosystems (Nair, 1989).

Due to severe scarcity of fuel wood and timber, and increasing demand for land in alternative production systems to produce food, fodder and other products in order to meet the needs of a fast growing population, there has been a growing interest in agroforestry in the recent years. Although community forestry and social forestry activities were started in Bangladesh in the early 1980's, specific interest in agroforestry was noticed when it was included as a component of farming systems research in 1986 in the research agenda of the Bangladesh Agricultural Research Institute (BARI).

2.4.2 Species selection criteria for agroforestry

Once covered by dense forests, Bangladesh is now almost devoid of forested land, except in a few selected areas of the country (Giri *et al.,* 1996). Although the Forest Department presently considers 14.6% of the total land area of Bangladesh as forested, in reality, only about 6–8% of the total land area of Bangladesh merits the term 'forested' (Giri *et al.,* 1996; FAO, 1995). Despite the presence of a large government Forest Department dedicated to protecting and managing the forests, forest cover in Bangladesh has been shrinking rapidly both in terms of area and volume. Massive degradation and depletion of natural forest resources created the difficult challenge of balancing production and consumption of rural fuel energy (Imam, 1991). The high rate of deforestation and landscape conversion has led to widespread soil fertility loss, massive erosion, watershed deterioration, and floods (personal communications).

The amount of forest land in Bangladesh has already been reduced to a level far below that necessary to maintain the ecological balance of the country. The scope of horizontal expansion of forest area in Bangladesh is narrow because the majority of officially demarcated forestland in Bangladesh is situated in remote areas in the southwest, southeast, and northeast parts of the country. Thus, it would not be possible to meet the ecological needs of the country even if total forest cover within the officially demarcated forestland exceeded 25%.

2.5 Description of Mahogany (*Swietenia macrophylla*)

2.5.1 Phenology

The tree is nearly evergreen, shedding its leaves for a brief period during February to March. The new leaves which are red or pinkish appear mostly in March. The inconspicuous white flowers appear in open clusters among the leaves in April to May. The mahogany fruiting time starts early in life at the age of 15 years Fruit ripe every year from February to March (Luna, 1996).

2.5.2 Distribution

2.5.2.1 Global distribution

Over the last century mahogany has been planted on a wide range of sites including cleared ground, grasslands, Secondary forest, distributed natural forest and even relatively undisturbed natural forest. (Mayhew and Newton, 1998)

Swietenia macrophylla is widely distributed through latitude 23N in Central America to latitude 18S in South America. It was first planted in Indian Sun content in 1872 at the Calcutta Botanical Garden by the seeds from Honduras (Gamble, 1985) It has been introduced in most tropical countries where it becomes a major reforestation species especially in the Philippines and India (Troup, 1921), Myanmar, Bangladesh, the South pacific, Papua New Guinea (Zabala 1990). It is also found in Trinidad, Fiji Island, Indonesia, Costa Rica, Brazil, Australia, Cuba, Portugal, Mexico, Solomon Island, Philippines (Abdurrohim, 1996; Soesilitoma, 1992; zabala, 1990; siregar *et al.*, 1986; Singh *et al.*, 1980; Boone and Chundoff, 1970).

2.5.2.2 Distribution in Bangladesh

Swietenia macrophylla is an exotic species in Bangladesh (Zabala, 1990). It originated from Caribbean countries (Gamble, 1985). In 18889, the species was first planted in kaptai forest area of Bangladesh (Troup, 1921). Now it became naturalized in some introduced range's including Bangladesh and widely planted everywhere in Bangladesh including forest land, along roads and highways and at homestead areas. *Swietenia macrophylla* timber is prized particularly for its colour and workability; it is primarily valued for construction of high-value furniture and interior fitting (Palmer, 1994).

2.5.3 Wood quality

Swietenia macrophylla is reddish color that darkens over time, and the beauty of its grain. It is very easy to work with and not particularly hard. But if the logs are properly milled and cured, can be quite strong in spite of its' relative lightness. That, along with the beauty of the grain and the richness of its color is why it is so valuable as a material for firearms, musical instruments, and fine furniture. Mahogany has a generally straight grain and is usually free of voids and pockets. It has a reddish-brown color, which darkens over time, and displays a reddish sheen when polished. It has excellent workability, and is very durable. Historically, the tree's girth allowed for wide boards from traditional mahogany species. These properties make it a favorable wood for crafting cabinets and furniture (Berhaut 1976; Burkill 1995; Dommergues *et al.*, 1999).

2.6 Description of Sissoo (*Dalbergia sissoo*)

2.6.1 Phenology

Within the area of natural distribution the leaves are shed in November-December and new leaves appear in January-February. The first flowers appear together with the new leaves and in March-April the flowers open. By the end of April, young green pods appear and in October when the dry season sets in the fruits begin to ripen. The flowers are pollinated by bees, trips and other insects. Seed production starts when the trees are 3-4 years old and normally a good crop is produced every year with yields of 1-3 kg per tree.

2.6.2 Distribution

The area of natural distribution is the foothills of the Himalayas from eastern Afghanistan through Pakistan and India to Nepal. It is a primary coloniser of new alluvial soils along riverbanks and forms forest, either pure or mixed with other species.

2.6.3 Wood quality

Heartwood ranges from golden brown to a darker reddish brown. The pale, straw-colored sapwood is clearly demarcated from the heartwood. Sissoo generally has a straight grain, though it can be interlocked. Texture is medium to coarse with a good natural luster. Has good decay resistance and is rated as durable to very durable. Sissoo has good working characteristics, and responds well to nearly all machining operations (the exception being sections of wood with interlocked grain, which tend to tear out during surfacing). However, chalky deposits occasionally present in the wood can dull cutters quickly. Turns, glues, and finishes well.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Collection of Wood Cores

Ten trees of mahogany having the diameter of around 18 cm were selected from the Khulna University campus (block plantation). Those trees had straight bole having the maximum height of around 11 m. Cores were collected by the increment wood borer from those trees at different height positions, *i.e.* breast height (1.3 m), 2.3 and 3.3 m. On the other hand, wood cores were collected from another ten mahogany trees growing in the agricultural land near Zero point, Khulna having same diameter and height. All the cores were collected in the month of November, 2015.

Ten trees of sissoo having straight bole and having the diameter of around 17 cm were selected from the Khulna University campus (block plantation). Those trees had the maximum height of around 11 m. Cores were collected by the increment wood borer from those trees at different height positions, *i.e.* breast height (1.3 m), 2.3 and 3.3 m. On the other hand wood cores were collected from another ten sissoo trees growing in the agricultural land near Zero point, Khulna having same diameter and height. All the cores were collected in the month of November, 2015.

3.2 Preparation of Wood Cores

The lengths of mahogany and sissoo cores were 15 and 14 cm, respectively. Each core was divided into two parts from the pith with the help of a surgical knife. Each half of the core was then divided into 15 and 14 pieces, respectively for mahogany and sissoo. The length of each small piece was 0.5 cm having the diameter of 0.28 cm. Those samples were used in this study.

3.3 Determination of Properties

3.3.1 Determination of moisture content

Oven dry method was used to determine the moisture content of the sample by the Equation 2. Samples were kept in the oven at 103±2°C temperature until constant weight. Weighting was done by using was done by using an electric balance (0.001 g).

$$MC\% = \frac{W_G - W_{OD}}{W_{OD}} \text{...Eq.2}$$

Where,

MC = Moisture content

W_G = Green weight (g)

W_{OD} = Oven dry weight (g)

3.3.2 Determination of density

Density of samples was determined according to the Equation 3. Diameter and length of the samples were calculated by using digital slide calipers.

$$\rho = \frac{m}{v} \text{..Eq. 3}$$

Where,

ρ = Density of wood (g/cm^3)

m = mass of wood (g)

v = volume of wood (cm^3)

3.4 Data analysis

Initial data analysis, *i.e.* average, standard deviation, standard error etc. were done by Microsoft Office Excel (2010, USA). Independent t-test was done by using SPSS software (V21, USA) with 95% confidence level.

CHAPTER FOUR

RESULTS AND DISCUSSION

4. Results and Discussion

4.1 Variation in moisture content distribution of *Swietenia macrophylla* for agricultural land and block plantation

Variation in moisture content distribution of mahogany at 1.3 m (h) is shown in Fig. 4.1. It was found that the MC% of mahogany at 1.3m height in agricultural land (57.7%) was higher that the MC% of mahogany in block plantation (56.2%). The moisture content was lowest in the pith and it gradually increased to the outer portion. The rate of change of MC% from pith (47.5%) to outer portion (65.9%) was higher for the trees in agricultural land.

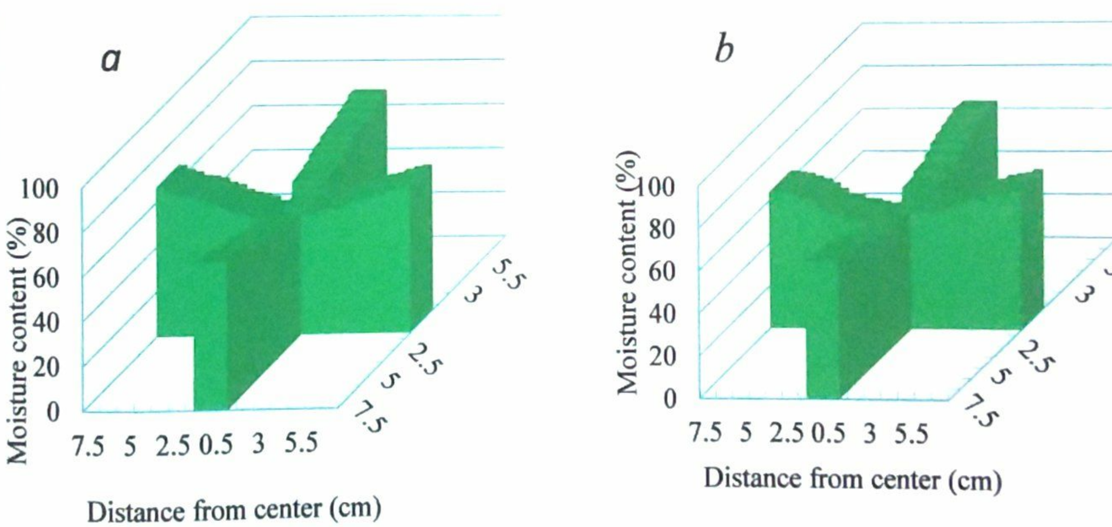

Fig. 4.1. Variation in moisture content (%) distribution of mahogany at 1.3 m height for agricultural land (a) and plantation (b)

This was found that the MC% of mahogany species at 2.3 m height in agricultural land (62.0%) was higher that the MC% of mahogany in block plantation (59.9%). The moisture content was lowest in the pith and it gradually increased to the outer portion (Fig. 4.2). The rate of change of MC% from pith (53.9%) to outer portion (69.9%) was higher for the trees in agricultural land.

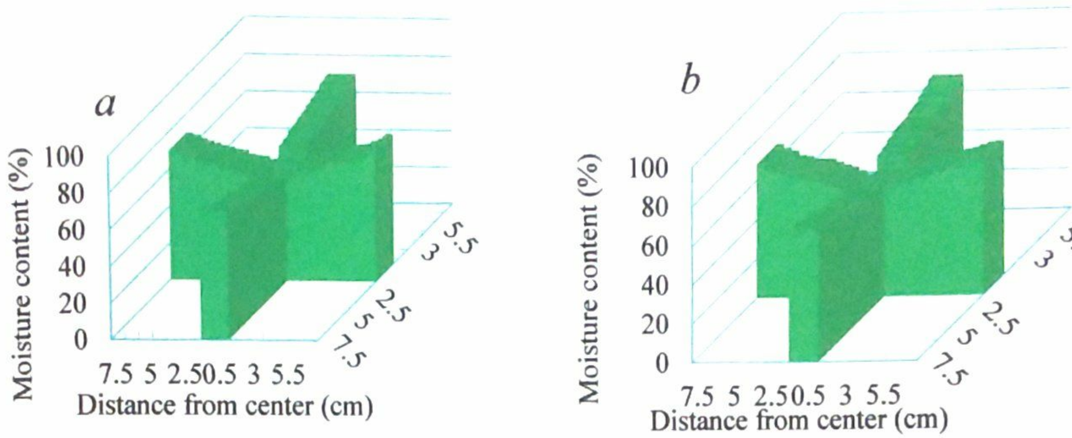

Fig. 4.2. Variation in moisture content (%) distribution of mahogany at 2.3 m height for agricultural land (a) and block plantation (b)

It (Fig. 4.3) was found that the MC% of mahogany species at 3.3 m height in agricultural land (65.8%) was higher than that of the MC% of mahogany in B. plantation (62.8%). The moisture content was lowest in the pith and it gradually increased to the outer portion. The rate of change of MC% from pith (56.5%) to outer portion (72.9%) was higher for the trees in agricultural land.

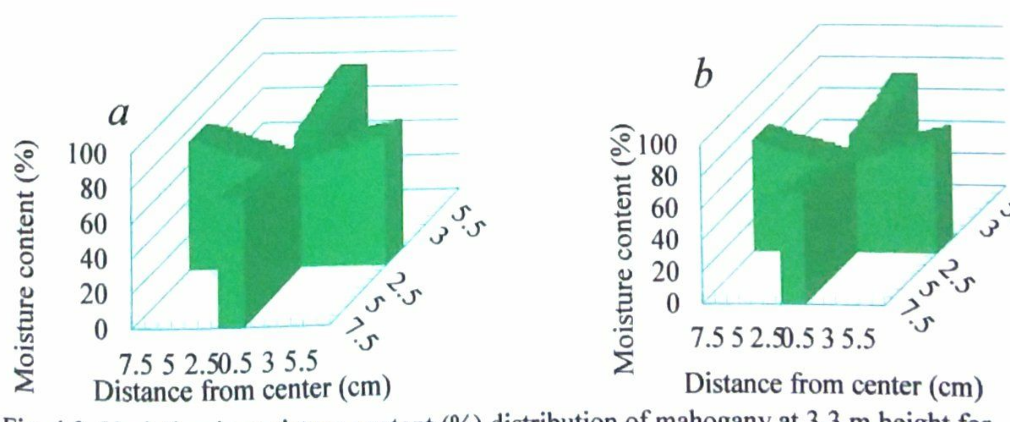

Fig. 4.3. Variation in moisture content (%) distribution of mahogany at 3.3 m height for agricultural land (a) and block plantation (b)

In case of moisture content distribution within mahogany trees in both the land, it was found that lower portion of the tree contain less amount of moisture than the upper portion. This might be because of the higher percentage of early wood in the upper portion of the tree, which contained higher quantity of moisture than the late wood in the lower portion. It was also found that moisture content in outer portion was higher than that of the inner portion. This might be because of the higher percentage of sapwood in the outer portion of the tree, which contain higher quantity of moisture than the heartwood portion.

Large variations may occur not only between species but also within the same species and even in the same tree. In softwood species, sapwood usually contains more water than heartwood. In species such as redwood, the butt logs of trees may contain more water than the top logs (Skaar, Christen, 1972)

4.2 Variation in moisture content distribution of *Dalbergia sissoo* for agricultural land and plantation

It was found that the MC% of sissoo species at 1.3 m height in agricultural land (58.1%) was higher that the MC% of sissoo in block plantation (57.2%). The moisture content was lowest in the pith and it gradually increased to the outer portion (Fig. 4.4). The rate of changes of MC% from pith (52.3%) to outer portion (63.8%) was higher for the trees in agricultural land.

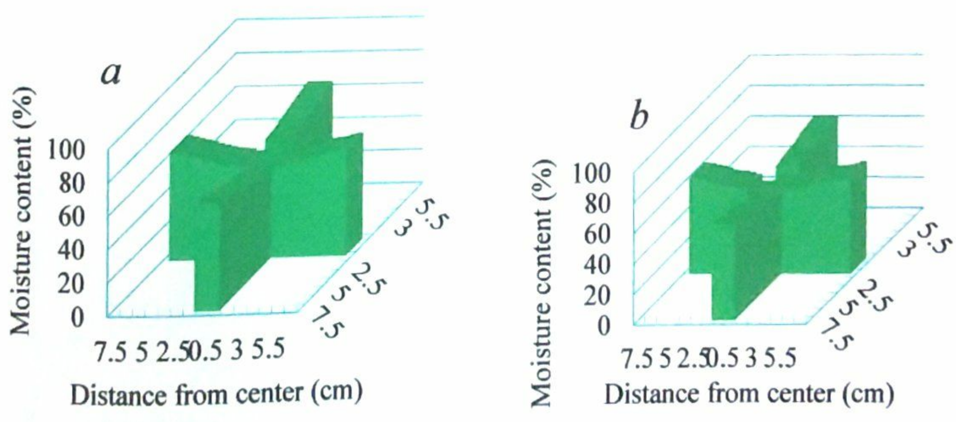

Fig. 4.4. Variation in moisture content (%) distribution of sissoo at 1.3 m height for agricultural land (a) and block plantation (b)

This (Fig. 4.5) was found that the moisture content distribution of sissoo at 2.3 m height in agricultural land was greater than that grown in agricultural land species. It can vary from agricultural to block plantation is 63.1 to 60.8%. The moisture content was lowest in the pith and it gradually increased to the outer portion. The rate of changes of MC% from pith (57.7%) to outer portion (67.7%) was higher for the trees in agricultural land.

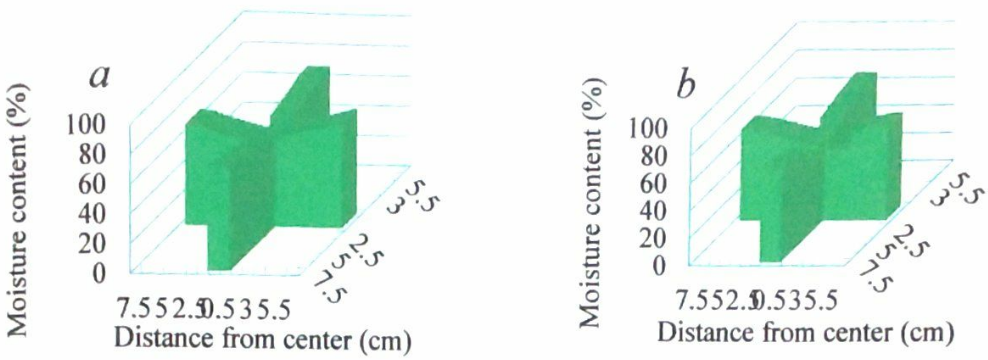

Fig. 4.5. Variation in moisture content (%) distribution of sissoo at 2.3 m height for agricultural land (a) and block plantation (b)

Moisture content distribution of sissoo trees in agricultural land and inblock plantation at 3.3 m height is shown in Fig. 4.6. It was found that the average moisture content of sissoo at 3.3 m height in agricultural land (66.0%) was higher than the trees in block plantation (64.9%). The moisture content was lowest in the inner portion and gradually increased to the outer portion. The rate of changes of MC% from inner (59.9%) to outer portion (71.7%) was higher for the trees planted in agricultural land than the trees planted in plantation.

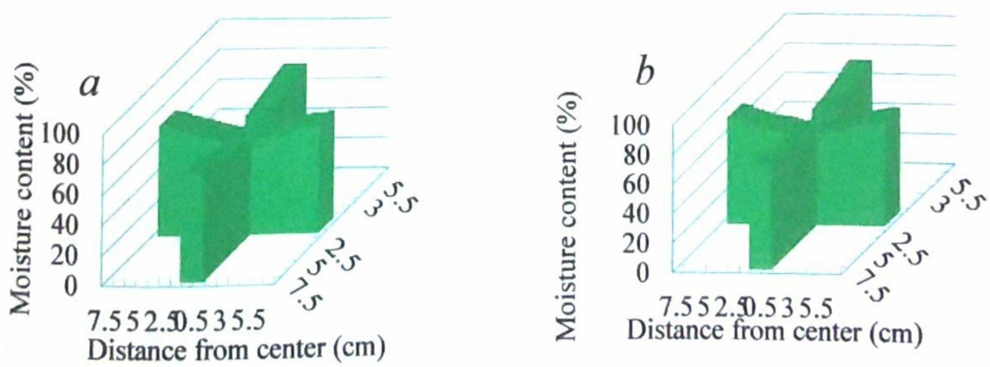

Fig. 4.6. Variation in moisture content (%) distribution of sissoo at 3.3 m height for agricultural land (a) and block plantation (b)

This pattern of variation in moisture content caused may be because of the difference in growth rate of trees in two different land conditions. In plantation, the growth of tree is slow because of higher competition and lower water availability. On the other hand, in agricultural land the growth of tree is very fast because of regular use of fertilizer and irrigation. Generally fast growing species have low density and high moisture content. In case of moisture content distribution within sissoo trees in both land, it was found that lower portion of the tree contain less amount of moisture than the upper portion. Caused may be because of the higher percentage of early wood in the upper portion of the tree, which contain higher quantity of moisture than the late wood in the lower portion. It was also found that moisture content in outer portion was higher that the inner portion. Caused may be because of the higher percentage of sapwood in the outer portion of the tree, which contain higher quantity of moisture than the heartwood portion in the inner portion.

4.3 Variation in density distribution of *Swietenia macrophylla* for agricultural land and block plantation

It (Fig. 4.7) was found that value of density variation of mahogany at 1.3 m height from block plantation to agricultural land was 0.71 to 0.70 g/cm^3. The density was higher in the pith and it gradually decreased to the outer portion. The rate of changes of density from outer portion 0.61 g/cm^3 to pith 0.81 g/cm^3 was higher for the trees in block plantation.

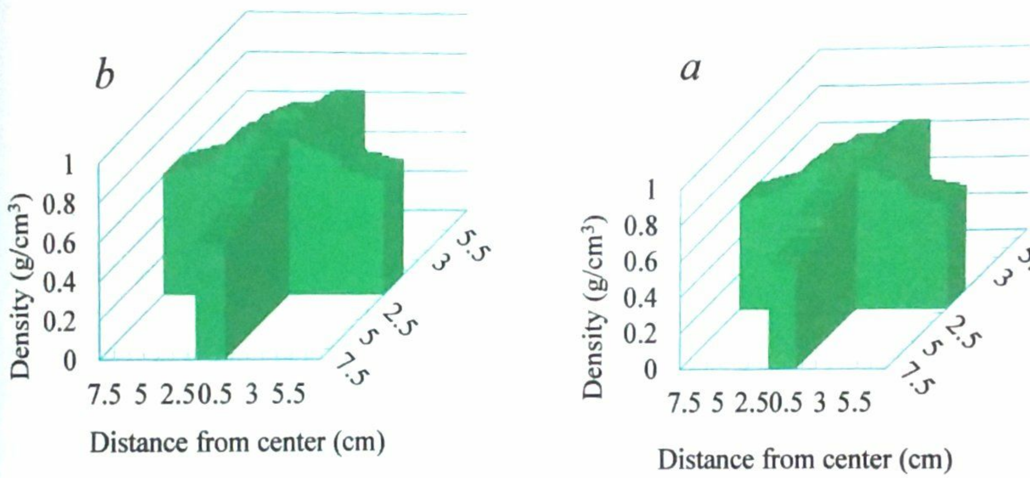

Fig. 4.7. Variation in density distribution of mahogany at 1.3 m height for agricultural land (a) and block plantation (b)

It (Fig. 4.8) was found that value of density variation of mahogany at 2.3 m height from block plantation to agricultural land was 0.67 to 0.65 g/cm^3

The density was height in the pith and it gradually decreased to the outer portion. The rate of changes of density from pith 0.79 g/cm^3 to outer portion 0.55 g/cm^3 was lower for the trees in agricultural land. On the other hand, the rate of changes of density from outer portion 0.55 g/cm^3 to pith 0.80 g/cm^3 was higher for the trees in block plantation.

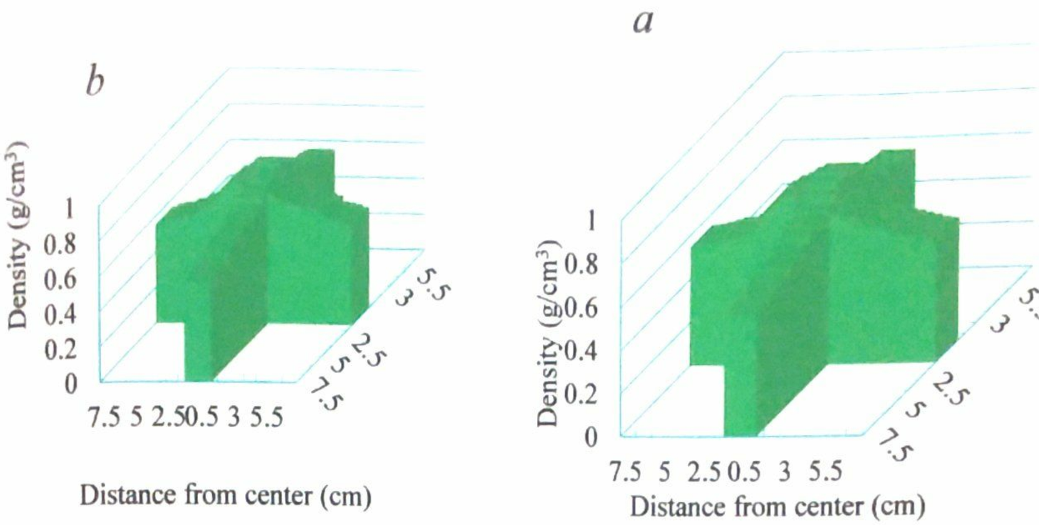

Fig. 4.8. Variation in density distribution of mahogany at 2.3 m height for agricultural land (a) and block plantation (b)

It (Fig. 4.9) was found that the density of mahogany species at 3.3 m height in block plantation 0.66 g/cm^3 was higher that the density of mahogany in agricultural land 0.64 g/cm^3. The density was higher in the pith and it gradually decreased to the outer portion. The rate of changes of density from outer portion 0.52 g/cm^3 to pith 0.75 g/cm^3 was higher for the trees in block plantation.

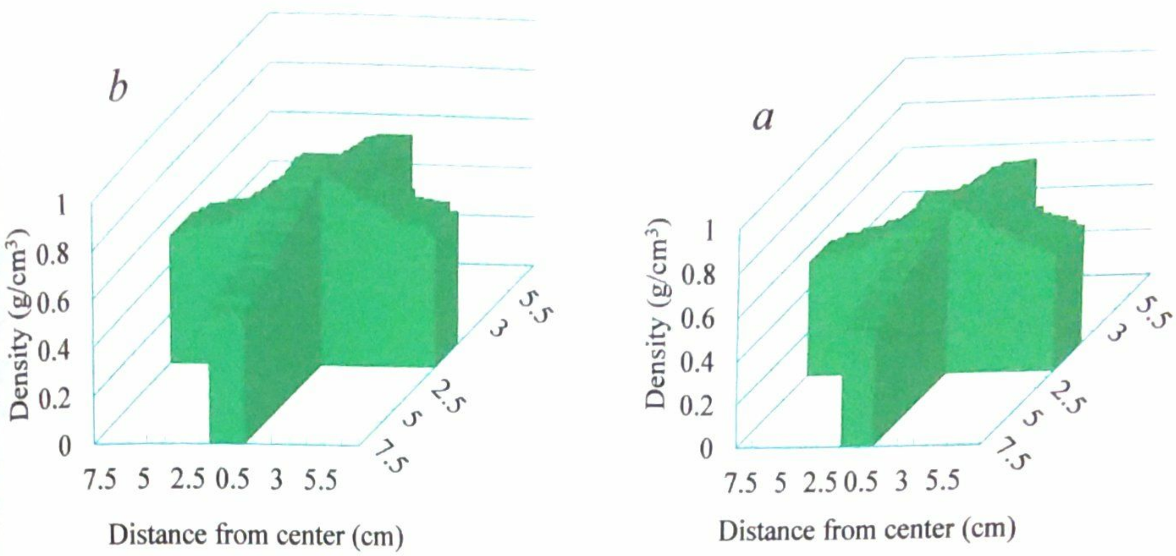

Fig. 4.9. Variation in density distribution of mahogany at 3.3 m height for agricultural land (a) and block plantation (b)

There is considerable variation in density among different samples of the species. This variation is caused by the rate of growth, site conditions and genetic composition. Heaviest wood was found at the base of tree and decrease successively levels in trunk. In most of the heart wood, density reduces towards the bark (Dinwoodie, 1993). In this study was found that density increases from outer position to inner position.

Density within a tree varies from pith to bark and with height in the stem. Wood density varies from early wood tissue to latewood tissue within each annual ring. Latewood tissue is composed of cells of relatively small radial diameter with a thick wall and a small lumen and therefore, has a higher density than thin walled early wood cells with a larger cell lumen (Haygreen and Bowyer, 1996). Usually a tree with high-density early wood will also have high density latewood (Zobel and Jett, 1995). Some species exhibit greater density variation than others. In Sitka spruce density is very high in the innermost rings and then decreases from the pith outward until a minimum is reached about rings 8 to 12, after which it rises gradually towards the bark (Harvald and Olesen, 1987).

Each growth ring consists of lighter early wood and darker latewood. Latewood is made of cells which have thicker walls and smaller lumina in comparison to early wood. This results in a higher density of latewood (Fromm *et al*., 2001) and explains why the density of wood increases with increasing proportion of latewood (Panshin and de Zeeuw, 1980; Tsoumis 1991).

4.4 Variation in density distribution of *Dalbergia sissoo* for agricultural land and plantation

It (Fig. 4.10) was found that the density of sissoo species at 1.3 m height in plantation 0.67 g/cm^3 was higher that the density of sissoo in agricultural land 0.66 g/cm^3. The density was higher in the pith and it gradually decreased to the outer portion. The rate of changes of density from outer portion 0.58 g/cm^3 to pith 0.70 g/cm^3 was higher for the trees in plantation.

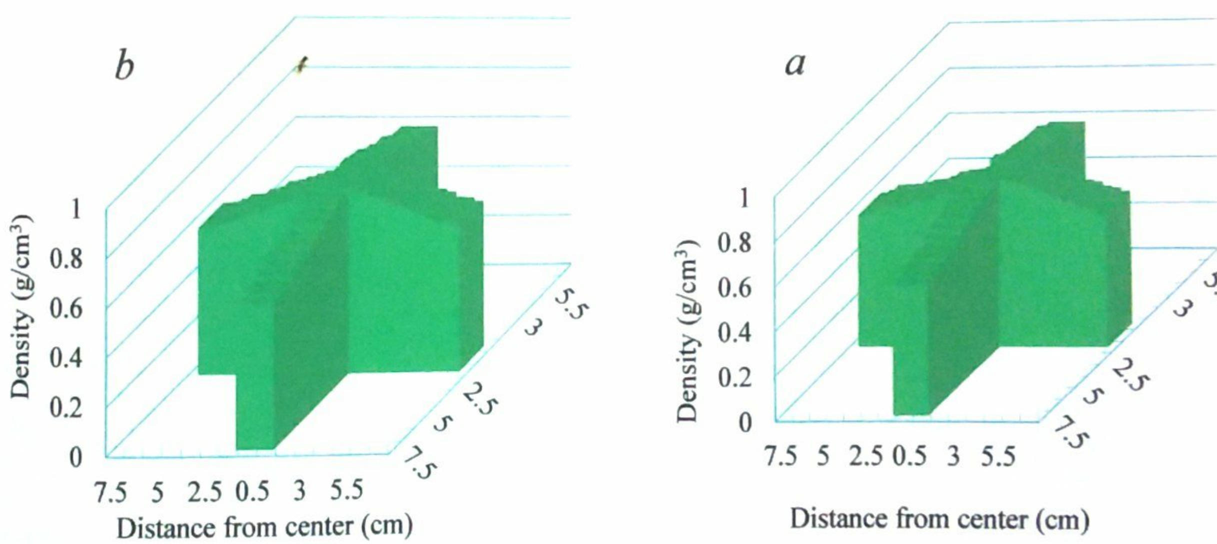

Fig. 4.10. Variation in density distribution of sissoo at 1.3 m height for agricultural land (a) and block plantation (b)

It (Fig. 4.11) was found that value of density variation of sissoo at 2.3 m height from block plantation to agricultural land was 0.60 to 0.63 g/cm^3. The density was higher in the pith and it gradually decreased to the outer portion. The rate of change of density from outer portion 0.54 g/cm^3 to pith 0.70 g/cm^3 was higher for the trees in plantation.

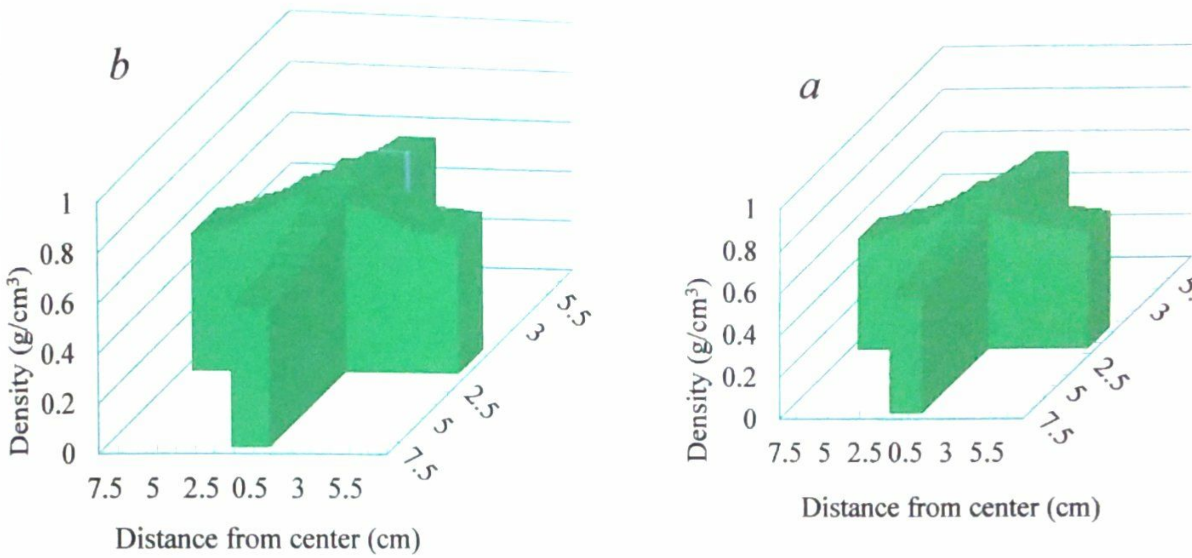

Fig. 4.11. Variation in density distribution of sissoo at 2.3 m height for agricultural land (a) and block plantation (b)

It (Fig. 4.12) was found that the density of sissoo species at 3.3 m height in block plantation 0.61 g/cm^3 was higher that the density of sissoo in agricultural land 0.59 g/cm^3. The density was higher in the pith and it gradually decreased to the outer portion. The rate of changes of density from outer portion 0.57 g/cm^3 to pith 0.65 g/cm^3 was higher for the trees in block plantation.

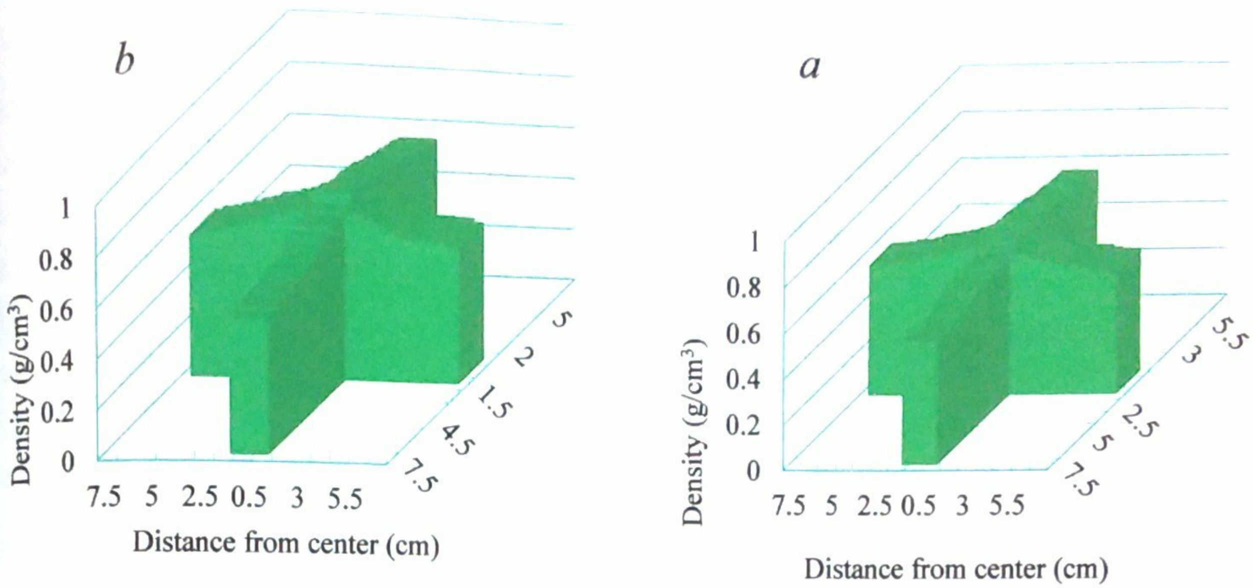

Fig. 4.12. Variation in density distribution of sissoo at 3.3 m height for agricultural land (a) and block plantation (b)

There is considerable variation in density among different samples of the species. This variation is caused by the rate of growth, site conditions and genetic composition. Heaviest wood was found at the base of tree and decrease successively levels in trunk. In most of the heart wood, density reduces towards the bark (Dinwoodie, 1993). In this study was found that density increases from outer portion to inner portion.

It is observed that there is variation of density among different height position of *Dalbergia sissoo*. It is also observed that density is increased gradually from top position to lower position with decrease living cell of tree from top position to lower position. In this study reveals that the density of sissoo wood increases from outer position to inner position. It was showed that density is higher in inner position than outer position because it's composed of heart wood that contains various extractives, oils and many contain other materials which increase density of heart wood. On the other hand outer portion of these tree contain huge amount of sap portion which decrease density of sap wood.

The lower densities found in the inner twelve rings coincide with the juvenile wood zone. Density in this juvenile wood zone is low because there are relatively few latewood cells and a high proportion of cells have thin wall layers (Haygreen and Bowyer, 1996).

Density increases by up to 50% from the pith outwards and is reflected in an increase in the thickness of the S_2 layer of the cell walls. Thus, in moving outward from the pith, the wood mass increases (Walker and Butterfield, 1996). Donaldson *et al.,* (1995) found that ring density for Monterey pine (*Pinus radiata* D. Don) changed from approximately ring 10 outwards, with increases in both earlywood and latewood density, as well as an increase in the amount of latewood . In a study carried out by Harvald and Olesen (1987) on the variation of basic density within the juvenile wood of Sitka spruce, it was found that basic density decreased with increasing height in the stem.

Wood density can vary among provenances and is very variable among trees and within individual trees of a given provenance (Zobel and Van Buijtenen, 1989). The faster growing more southerly Sitka spruce provenances produce timber which is less dense than that from the slower growing more northerly provenances.

Wood density is influenced by the environment, which determines the rate of tree growth. The density of Sitka spruce wood is known to decrease in response to increased growth rate (Savill and Sandels, 1983). This decrease in density has been recorded in the juvenile wood of fast grown Sitka spruce. Mitchell and Denne (1997) found that on sites where Sitka spruce stands were fast growing, wood density decreased more rapidly across the juvenile wood, down to a lower minimum value, than on sites where Sitka spruce stands were slower growing. In fast grown Sitka spruce lower density was recorded for mature wood sections. Growth rate also influences the extent of the juvenile core and the proportion of stem it comprises. In fast grown trees cultivated on a short rotation, a larger proportion of the stem will comprise juvenile wood. Trees from shorter rotations have lower densities because the proportion of low density juvenile wood is higher (Zobel and Jett, 1995).

CHAPTER FIVE

CONCLUSION

5. Conclusion

For proper utilization of wood, moisture content and density are the most important factors to be considered. When moisture content and density distribution is known for different parts of a tree, it is easier to use the different parts for different purposes, i.e. construction, composite, pulping etc. From the results, it was found that moisture content was higher in trees planted in agricultural land than the trees in plantation and density was higher in trees planted in plantation than the trees in agricultural land. Moisture content was lower at the butt portion of the trees and increased towards the top and also increased from inner to the outer portion. But it was just reverse for density distribution, where top portion of the trees had low density which increased towards the butt and also increased from outer to inner portion. The found knowledge of variations in density and moisture content distribution might help to ensure the efficient use of mahogany and sissoo wood. However, further studies are needed on moisture and density distribution of these trees before and after harvesting for wide scale utilization.

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APPENDIX-1

1. Variation in moisture content (%) distribution of mahogany at 1.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MC	Equal variances assumed	.008	.927	-1.006	58	.319	-1.48170	1.47264	-4.42951	1.46611
	Equal variances not assumed			-1.006	57.999	.319	-1.48170	1.47264	-4.42951	1.46611

2. Variation in moisture content (%) distribution of mahogany at 2.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MC	Equal variances assumed	.008	.929	-1.704	58	.094	-2.08287	1.22219	-4.52936	.36362
	Equal variances not assumed			-1.704	57.989	.094	-2.08287	1.22219	-4.52937	.36363

3. Variation in moisture content (%) distribution of mahogany at 3.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MC	Equal variances assumed	.142	.708	-2.417	58	.019	-3.11297	1.28805	-5.69128	-.53466
	Equal variances not assumed			-2.417	57.731	.019	-3.11297	1.28805	-5.69153	-.53440

4. Variation in moisture content (%) distribution of sissoo at 1.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MC Equal variances assumed	.090	.766	-.902	54	.371	-.93364	1.03530	-3.00930	1.14201
Equal variances not assumed			-.902	53.725	.371	-.93364	1.03530	-3.00954	1.14226

5. Variation in moisture content (%) distribution of sissoo at 2.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MC Equal variances assumed	5.371	.024	-1.949	54	.057	-2.46857	1.26688	-5.00852	.07138
Equal variances not assumed			-1.949	49.831	.057	-2.46857	1.26688	-5.01339	.07625

6. Variation in moisture content (%) distribution of sissoo at 3.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

	Levene's Test for Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
MC Equal variances assumed	.120	.731	-1.014	54	.315	-1.04439	1.03000	-3.10942	1.02063
Equal variances not assumed			-1.014	53.951	.315	-1.04439	1.03000	-3.10946	1.02067

7. Variation in density distribution of mahogany at 1.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Densiy	Equal variances assumed	.007	.936	.424	58	.673	.00889	.02098	-.03311	.05089
	Equal variances not assumed			.424	57.995	.673	.00889	.02098	-.03312	.05089

8. Variation in density distribution of mahogany at 2.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Density	Equal variances assumed	.003	.955	.970	58	.336	.02036	.02098	-.02164	.06237
	Equal variances not assumed			.970	57.904	.336	.02036	.02098	-.02164	.06237

9. Variation in density distribution of mahogany at 3.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Density	Equal variances assumed	.464	.499	.735	58	.466	.01579	.02149	-.02723	.05880
	Equal variances not assumed			.735	57.598	.466	.01579	.02149	-.02723	.05881

10. Variation in density distribution of sissoo at 1.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Density	Equal variances assumed	.505	.480	.811	54	.421	.01075	.01326	-.01583	.03733
	Equal variances not assumed			.811	53.390	.421	.01075	.01326	-.01583	.03734

11. Variation in density distribution of sissoo at 2.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Density	Equal variances assumed	1.291	.261	1.680	54	.099	.02386	.01420	-.00462	.05234
	Equal variances not assumed			1.680	53.159	.099	.02386	.01420	-.00463	.05235

12. Variation in density distribution of sissoo at 3.3 m height for agricultural land (a) and block plantation (b)

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Density	Equal variances assumed	2.615	.112	1.615	54	.112	.01828	.01132	-.00441	.04097
	Equal variances not assumed			1.615	50.940	.112	.01828	.01132	-.00444	.04100