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Estimating Merchantable Stem Biomass (Bole Biomass) of Nine Hardwood Species in Myanmar

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မြန်မာနိုင်ငံရှိသစ်မာ(၉) မျိုး၏ ပင်စည်ပိုင်းဇီဝဒြပ်ထုပမာဏအား ခန့်မှန်းလေ့လာခြင်း

ဖြူဖြူလွင်၊ ဦးစီးအရာရှိ
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စာတမ်းအကျဉ်း

လေ့လာမှုများအရ ကမ္ဘာကြီးပူနွေးမှုမှာ တစ်နေ့တစ်ခြားတိုးလာပြီးလူသားများအတွက် ပြင်းထန်သော ဆိုးကျိုးသက်ရောက်မှုများကို ဖြစ်ပေါ်စေနိုင်ကြောင်း တွေ့ရှိရပါသည်။ ကမ္ဘာ့အပူချိန်မြင့်တက်ပြောင်းလဲလာခြင်းသည် လေထုအတွင်း မှန်လုံအိမ်ဓါတ်ငွေ့များ (အထူးသဖြင့် ကာဗွန်ဒိုင်အောက်ဆိုဒ်၊ မီသိန်း၊ နိုက်ထရပ်အောက်ဆိုဒ်ဓါတ်ငွေ့များ) များပြားလာခြင်းကြောင့် ဖြစ်ကြောင်းကို လေ့လာသိရှိပြီး ဖြစ်ပါသည်။ သစ်တောသစ်ပင်များသည် ပင်စည်ပိုင်းနှင့် မြေဆီလွှာထဲတွင် ကာဗွန်ကိုသိုလှောင်ထားနိုင်သဖြင့် ကမ္ဘာ့ကာဗွန်သံသရာတွင် အရေးကြီးသောအခန်းကဏ္ဍတွင် ပါဝင်ဆောင်ရွက်သည်မှာ အထင်အရှားပင် ဖြစ်ပါသည်။ အပင်များတွင် သစ်သားပမာဏများပြားစွာပါဝင်ဖွဲ့စည်းထားသဖြင့် သစ်တောများသည် ကမ္ဘာပေါ်ရှိ သက်ရှိများအားလုံးတွင် ကာဗွန်ပမာဏများစွာကို သိုလှောင်ထားနိုင်သော သက်ရှိတစ်မျိုး ဖြစ်ပါသည်။ ထို့ကြောင့်သစ်တောများသည် ကာဗွန်ထုတ်လွှတ်မှုနှင့် ကာဗွန်စုပ်ယူသိုလှောင်နိုင်မှုပမာဏကို လေ့လာရာတွင် အဓိကဦးစားပေးလေ့လာရမည့် နေရာများဖြစ်ပါသည်။ ဤလေ့လာမှုသည် မြန်မာနိုင်ငံတွင် စီးပွားရေးအရ အရေးပါသည့် သစ်မာ(၉)မျိုး၏ ပင်စည်ပိုင်းဇီဝဒြပ်ထုပမာဏအား နှိုင်းယှဉ်လေ့လာခြင်းဖြင့် ၎င်းတို့၏ ကာဗွန်သိုလှောင်နိုင်မှုပမာဏကို သိရှိအကဲဖြတ်နိုင်ရန် ရည်ရွယ်ပါသည်။ လေ့လာခဲ့သည့် သစ်မျိုး(၉)မျိုးမှာ ကျွန်း၊ ပျဉ်းကတိုး၊ ပိတောက်၊ ရေမနေ၊ သင်းဝင်၊ ယင်းမာ၊ ထောက်ကြံ့၊ ဘင်္ဂ၊ မအူလက်တံတို တို့ဖြစ်ကြပါသည်။ သစ်မျိုးများ၏ ပင်စည်ပိုင်းထုထည်နှင့် ရေချိန်သိပ်သည်းဆကို လေ့လာတွက်ချက်ခြင်းဖြင့် ပင်စည်ပိုင်း ဇီဝဒြပ်ထုပမာဏကို နှိုင်းယှဉ်လေ့လာခြင်း ဖြစ်ပါသည်။ လေ့လာခဲ့သော သစ်မျိုးများအားလုံးမှာ ရေချိန်သိပ်သည်းဆအားဖြင့် အသင့်အတင့်မှ လေးသောသစ်မျိုးများဖြစ်သဖြင့် သစ်အတွက်အသုံးဝင်ရုံသာမက ဇီဝဒြပ်ထုပမာဏအားဖြင့်လည်း မြင့်မားသော သစ်မျိုးများဖြစ်သဖြင့် ကမ္ဘာ့မှန်လုံအိမ်ဓါတ်ငွေ့လျှော့ချရာတွင် အရေးပါသောသစ်မျိုးများဖြစ်ကြောင်း တွေ့ရှိရပါသည်။ သင်းဝင်သည် ရေချိန်သိပ်သည်းဆ အများဆုံးဖြစ်သဖြင့် အလေးဆုံးဖြစ်သော်လည်း ကြီးထွားနှုန်းဆက်စပ်မှုအရ နှိုင်းယှဉ်လေ့လာရာတွင် ပိတောက်သည် သစ်မျိုး(၉)မျိုးအနက် ပင်စည်ပိုင်းဇီဝဒြပ်ထုပမာဏ အမြင့်ဆုံးဖြစ်ကြောင်း တွေ့ရှိရပါသည်။

Estimating Merchantable Stem Biomass (Bole Biomass) of Nine Hardwood Species in Myanmar

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Abstract

Increasingly convincing evidences show that the Earth is getting warmer and in the future warming could have serious effects on human. It is now generally accepted that this change in global temperature is caused primarily by rising atmospheric concentrations of greenhouse gases, principally carbon dioxide(CO_2), methane (CH_4), nitrous oxide(N_2O).Forests act as an important part of the global carbon cycle, storing carbon in both trees and soil. The large quantity of woody tissue that trees contain means forests have the highest carbon density of all living things. The world forests are prominent sites to study of climate change, not only in terms of total net carbon emissions but also in terms of global storage capacity.Therefore this study is focusing on carbon sequestration, specifically in terms of merchantable stem biomassof different hardwood species. Merchantable stem biomass is a key variable in the annual and long term changes in the global terrestrial carbon cycle and other earth system interactions. Selected species that have been assessed were*Tectonagrandis*(Teak), *Xyliaxylocarpa*(Pyinkado), *Pterocarpusmacrocarpus*(Padauk), *Gmelinaarborea*(Yemane), *Milletiapendula*(Thinwin), *Chukrasiavelutina*(Yinma), *Terminaliacrenulata* (Htauk-kyant), *Mitragynarotundifolia*(Binga) and *Naucleaorientalis*(Maulettan-to). The method used in this study is to estimate wood volume to dry biomass using an estimate of basic timber density. Among the nine different species, Thinwin (*Millettiapendula*Benth.) has the highest basic specific gravity that means it is the heaviest wood in terms of weight and Yemanae (*Gmelinaarborea*Roxb.) has the lowest value in specific gravity so it might be the lightest wood among all species. In this study, depending on the DBH and Total Height of species tested, most correlations between them showed that the linear relation is not much strong. According to the results, *Pterocarpusmacrocarpus* (Padauk) has the highest values in terms of estimated merchantable stem biomass and it is heavy wood regarding to its basic density of 706 kg/m^3.

Key Words: Basic specific gravity, carbon sequestration, merchantable stem biomass, timber density, wood volume

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1. Introduction

Given the potential impacts of rising atmospheric CO_2 concentrations on global climate (IPCC, 2001) and government commitments to climate change initiatives through the United Nations Framework Convention on Climate Change, there is an increasing demand for countries to assess their contributions to sources and sinks of CO_2 and to evaluate processes that control CO_2 accumulation in the atmosphere. Imperatives to such assessments are the development of techniques for measuring stocks and fluxes of carbon in terrestrial ecosystems.

Estimation of tree biomass is anessential aspect of studies of carbon stocks and the effectsof deforestation and carbon sequestration on the globalcarbon balanceand also provides valuable informationfor many global issues. Estimating tree biomass is a usefulmeasure for comparing structural and functional attributesof forest ecosystems across a wide range of environmental conditions.

So far different studies have beenconducted to estimate stem biomass and they mostly useddiameter, height and wood specific gravity to assess stem biomass of tree species although manyfactors can influence the accuracy of biomass estimation intropical forests and are known to vary with soil type,soil nutrients, climate, disturbance regime,successional status, topographic position, landscapescaleand human impacts. Variation inenvironmental factors such as topography, hydrology, andedaphic characteristics (e.g. soil nutrient availability) mayalso complicate attempts to generalize stand density anddry biomass over regional or landscape scale.

Wood specific gravity is an important factor in convertingforest volume data to biomass and may alsostrongly depend on location, climate, and possibly management. However, it is a convenient indicator for lifehistory strategy in trees and one with direct importance forecosystem studies, and highly correlated with thedensity of carbon per unit volume and is thus of directapplied importance for estimating ecosystem carbonstorage and fluxes.

Because there is increased interest in estimating thebiomass of forests and their role in regulating the cycling ofcarbon and nutrients, fewstudies on the AGB in terms of merchantable stem biomass andwood specific gravity are available from tropical hardwood species of Myanmar, the present studywas undertaken.

Thus the main objectives of this study were:

1) To comparatively study and estimate merchantable stem biomass of even-aged 9species using values of diameter, tree height and specific gravity
2) To provide an acceptable non-destructive method for the estimation of merchantable stem biomass of some commercial species planted in Myanmar
3) To highlight the important role of some commercial species in Myanmar in combating global warming

2. Rationale of the Study

Increasingly convincing evidences show that the Earth is getting warmer and in the future warming could have serious effects on human. It is now generally accepted that this change in global temperature is caused primarily by rising atmospheric concentrations of greenhouse gases, principally carbon dioxide(CO_2), methane (CH_4), nitrous oxide (N_2O).

Forests act as an important part of the global carbon cycle, storing carbon in both trees and soil. During photosynthesis, trees absorb carbon dioxide (CO_2) from the air and convert it to carbon in plant matter.The large quantity of woody tissue that trees contain means forests have the highest carbon density of all living things. The world forests are prominent sites to study of climate change, not only in terms of total net carbon emissions but also in terms of global storage capacity.

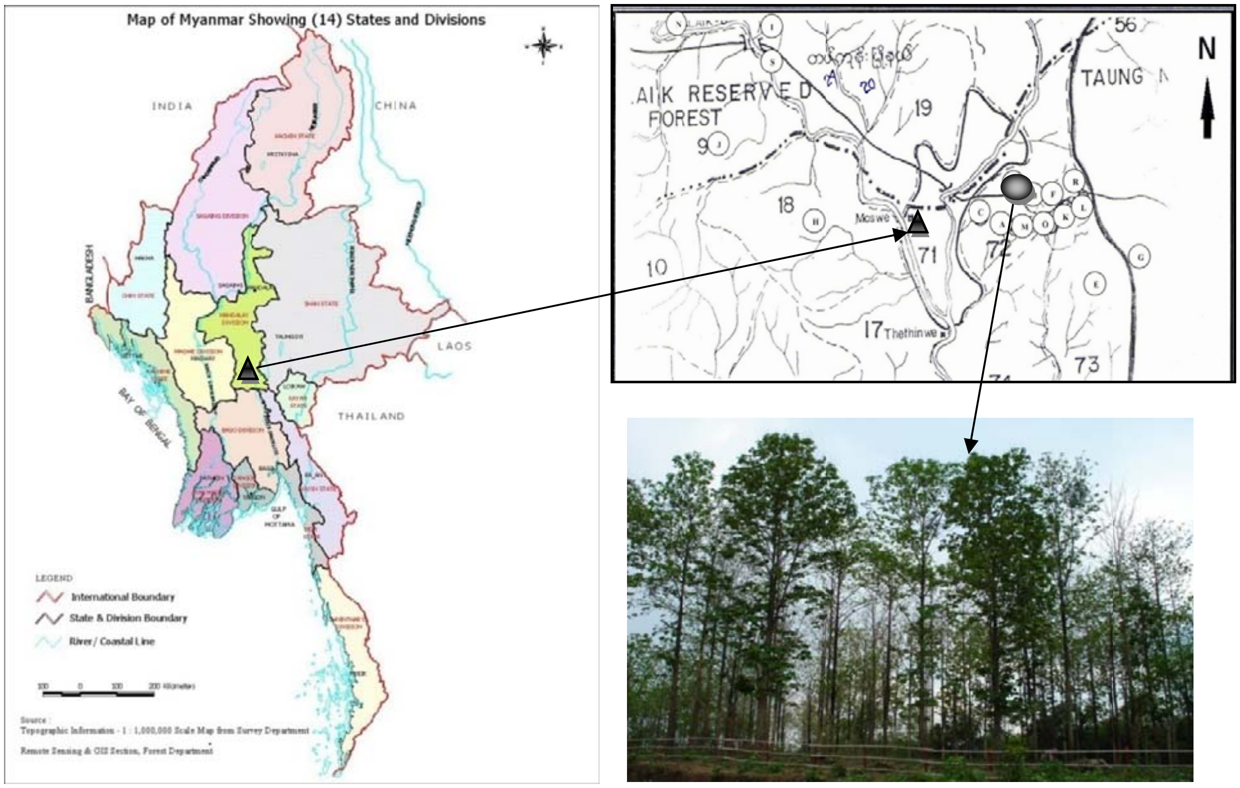
Therefore this study is focusing on carbon sequestration, specifically in terms of merchantable stem biomass of different hardwood species.Stem biomass is a key variable in the annual and long term changes in the global terrestrial carbon cycle and other earth system interactions.

Direct measurements of tree biomass are labor intensive,time consuming, and destructive, requiring the harvestingand handling of large amounts of plant samples. Furthermore,such destructive techniques are not suitable for studieswhere plants cannot be removed from the experimentalplots. As an alternative, an indirect regression approach iscommonly used to develop predictive equations for estimatingbiomass from attributes that can be measured easily.

3. Materials and Methods

3.1 Location of the study area

The study area lies between approximately 19˚ 56' N and 95˚ 56' E at an elevation of about 600 m abs approximately. It is located in Moeswe Research Station situated in Nay Pyi Taw Region, Myanmar. The arboretum (mixed) plantation which has been focused study area, was established in compartment no. (72), Ngaleik reserved forest of this research station in 1983. Location of study area and growing stocks of the arboretum (mixed) plantation is shown in Figure 1 and Figure 2.



▲Moeswe Research Station

● Arboretum Plantation, Ngalaik Reserved Forest, Comp.no. (72)

Figure 1. Location of the Study Site

Figure 2. Growth Performance of arboretum plantation (1982)

The topography of the study area is generally flat. Soil is laid by buff to yellowish color, medium to thick bedded, coarse to gritty, poorly consolidated sand stone. The soil is drained, and has a sandy loam texture with pH 6.3 (Kyi, 1991).

The area lies tropical savannah climate with a pronounced dry period between the monsoon rains. According to the climatic data of study area between 1990-2008, raining season begins at the end of April or the first week of May and ends in October, and there are occasional rains in the month of December. According to WEIDELT (1999), months with an aridity index below 20 are termed as arid months. The study area shows a pronounced dry season of 6 months from November to April. Climatogram of the study areas from 1999 to 2008 is shown in figure 3.

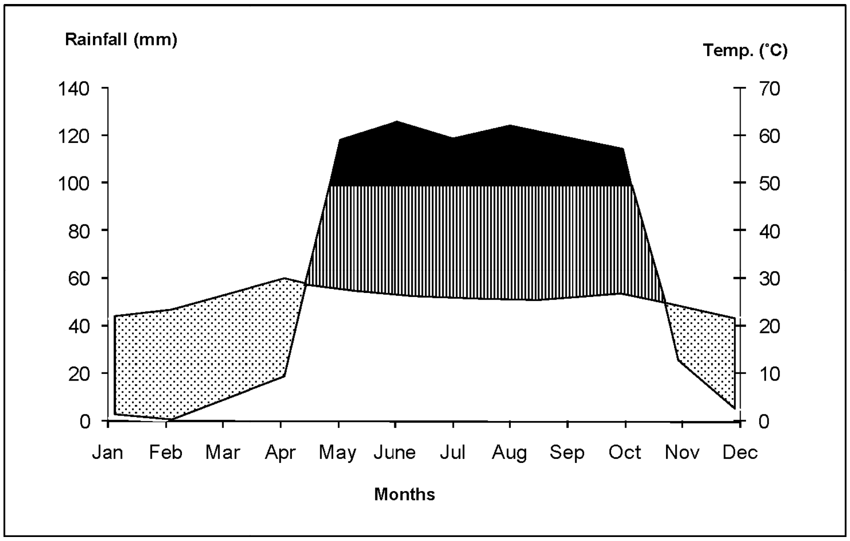


Figure 3. Climatogram (1999-2008) of study area

3.2 Methodology

Selected species that have been assessed were*Tectona grandis*(Teak), *Xylia xylocarpa*(Pyinkado), *Pterocarpus macrocarpus*(Padauk), *Gmelina arborea*(Yemane), *Milletia pendula*(Thinwin), *Chukrasia velutina*(Yinma), *Terminalia crenulata*(Htauk-kyant), *Mitragyna rotundifolia*(Binga) and *Nauclea orientalis*(Ma-u-lettan-to).

In order to collect data, a total of 16 square plots (total of 1 hectare) with an area of 625 m^2 (25 m × 25 m) were laid out systematically over the arboretum plantation for each species.Three square plots (25 m × 25 m) were randomly selected for each species. Within each sub-plot, Diameter at Breast Height (DBH), bole height and crown height were measured and recorded.Basic Specific Gravity and Basic Density were studied and accumulated for each species.

Live tree biomass is generally divided into five major components, including merchantable stem biomass (also called bole biomass including both bark and wood), stump biomass, foliage biomass, branches/top biomass, and root biomass. This study focuses on aboveground live tree biomass estimation especially for merchantable stem biomass (also called bole biomass).

3.2.1 Estimating merchantable stem volume

Using measures of Diameter at Breast height (DBH) and Total Tree Height (Ht), an estimation of total tree volume can be made by assuming the tree has a particular form. All that is required is an estimate of the tree taper or rate at which the diameter decreases with height (Equation-1). The merchantable stem volume of each species was assessed and investigated by using Newton's formula which has been using for estimation of merchantable volume of tropical hardwood species since many centuries (Equation-2).

Table 1. Equations used

Sr. no.	Equations	Remarks
1.	Taper of a tree = D/[Ht-1.3] cm/m	Where D is Diameter at Breast Height (cm) and Ht is relevant stem height of the tree at each portion (m)
2	$(b^2+4m^2+t^2)L/24\pi$ (Newton's formula)	Where b is the girth of the log at the basal portion, m is the girth of the log at the middle portion, t is the girth at the thin end of the log and l is the length of the log or height of the log
3	***Sp. Gr =*** $\frac{ODW}{V} \times \frac{1}{\rho(water)}$	Where Sp.Gr is basic specific gravity, ODW is oven-dry weight of the stem (g), V is green volume of the stem (cm^3**)** and ρ is density of water at 1.0000 g/cm^3

3.2.2 Estimating merchantable stem biomass

For estimation of tree biomass, the first is to estimate wood volume to mass using an estimate of timber densityin terms of basic specific gravity (Equation-3). Individual tree biomass, values produced using this approach are summed to produce the biomass of the entire population, which can be multiplied by a standard value of carbon concentration to produce an estimate of carbon stock. Stem biomass have been derived by transforming available volume data directly as a function of growing stock density (IPCC, 2006). In this case, merchantable stem volume must be converted to dry weight (kg) by multiplying with a conversion factor known as basic wood density (kg/m^3) (IPCC, 2006).

To standardized comparisons of species or products and estimations of product weight, specific gravity is used as a standard reference basis, rather than density. The traditional definition of specific gravity is the ratio of the density of the wood to the density of water at a specified reference temperature (often 4.4°C (40°F)) where the density of water is 1.0000 g/cm^3). To reduce confusion introduced by the variable of moisture content, the specific gravity of wood usually is based on the ovendry weight and the volume of some specified moisture content.

Commonly used bases for determining specific gravity are ovendry weight and volume at (a) green, (b) ovendry, and (c) 12% moisture content. ***Ovendry weight and green volume are often used in databases to characterize specific gravity of species, which is referred to as basic specific gravity****(Equation-3)****.***

3.2.3 Statistical Analysis

Mean values of live tree biomass (merchantable stem biomass) accumulation was processed and statistically analyzed by using Microsoft Excel 2003, Genstat Statistical Software and Statistical Package for Social Science (SPSS). One way analysis of variance (ANOVA) was used to test differences between biomass accumulations of different species tested.

4. Results and Discussions

4.1 Comparison of basic specific gravity of nine different species

The basic specific gravities (calculated on ovendry weight and volume in the green condition) of the commercial woods included in this study range from 0.419 (*Gmelina arborea* Roxb.) to 0.85 (*Millettia pendula* Benth.), most of them falling between 0.554 to 0.815. Woods with basic specific gravities of 0.36 or less are considered to be light; 0.36 to 0.50, moderately light to moderately heavy; above 0.50, heavy. The groupings of specific gravity classes apply to woods from both the temperate and tropical zones; groups of timbers from either zone show about the same specific-gravity distribution among the three classes.Density and Basic Specific Gravity of all species tested in this study is shown in table 2.

Table 2. Density and Basic Specific Gravity of nine species

No.	Common Name	Scientific Name	Moisture Content %	Density (kg/m^3)	Basic Specific Gravity	Basic Density (kg/m^3)
1	Teak	*Tectona grandis* Linn. F.	51.8	913	0.596	596
2	Pyinkado	*Xylia xylocarpa* (Roxb.) Taub.	48.6	1154	0.779	779
3	Padauk	*Pterocarpus macrocarpus* kurz.	58.6	1106	0.706	706
4	Yemanae	*Gmelina arborea* Roxb.	151.2	1058	0.419	419
5	Thinwin	*Millettia pendula* Benth.	44.3	1199	0.85	850
6	Yinma	*Chukrasia velutina* Roem.	59.2	1239	0.781	781
7	Taukkyant	*Terminalia crenulata* (Heyne) Roth	44.8	1221	0.815	815

8	Binga	*Mitragyna rotundifolia* (Roxb.) Kuntze	67.0	925	0.554	554
9	Ma-U-Lettan-To	*Nauclea orientalis L.*	114.5	979	0.464	464

Source: Cho Cho Win and Prof. Win Kyi-1, 2008.Syarif Hidayat and William T. Simpson, 1994.

All of the commercial species tested in this study fall within the groups of moderately heavy to heavy wood so that all species have the potential to use as construction timber but their workability and durability should be considered for this purposes. Among the nine different species, Thinwin (*Millettia pendula* Benth.) has the highest basic specific gravity that means it is the heaviest wood in terms of weight and Yemanae (*Gmelina arborea* Roxb.) has the lowest value in specific gravity so it might be the lightest wood among all species. But for this research, growth rate is needed to be considered for comparison of their dry weight. Basic specific gravity of nine different species tested in this study was compared in figure 4.

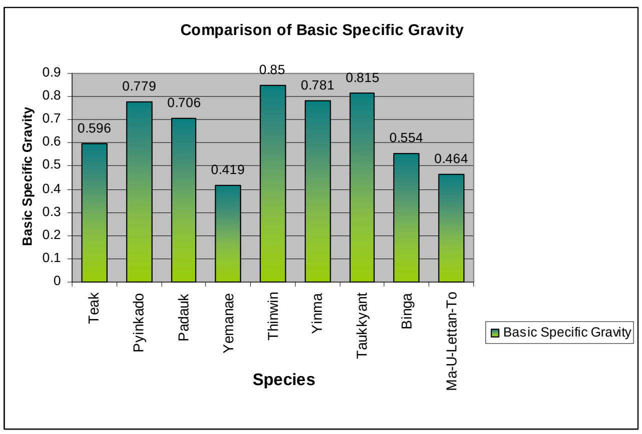


Figure 4. Comparison of basic specific gravity of nine different species tested

4.2 Comparison of green volume of nine different species

In several areas of forestry research such as in silviculture, ecology or wood science, it becomes necessary to determine the volume or biomass of trees. Since the measurement of volume or biomass is destructive, one may resort to pre-established volume or biomass prediction equations to obtain an estimate of these characteristics. These equations are found to vary from species to species and for a given species, from stand to stand. Although the predictions may not be accurate in the case of individual trees, such equations are found to work well when applied repeatedly on several trees and the results aggregated, such as in the computation of stand volume.

According to the ANOVA table computed by analysis of one-way classified data, it has been found that there is statistically significant difference among the computed value for volume of nine species. Ma-u-lettan-to(*Nauclea orientalis* L.) has received the highest value in volume while Binga

(*Mitragyna rotundifolia* (Roxb.) Kuntze) has the lowest value. This means that the former species has the great compatibility with the site conditions of these plantation areas. Computed ANOVA table was shown in table 4 and values of volume for each species was compared in table 3 and figure 5.

Table 3. Mean volume per stem (m^3) of nine species

no.	species	Mean DBH (cm)	mean top height (m)	mean volume/stem (m^3)
1	Teak	26.58	20.16	0.373
2	Pyinkado	28.94	19.83	0.435
3	Padauk	32.79	25.94	0.730
4	Yemanae	22.80	19.55	0.266
5	Thinwin	23.85	15.49	0.231
6	Yinma	25.58	19.49	0.334
7	Htaukkyant	28.03	18.61	0.383
8	Binga	14.19	12.41	0.065
9	Maulettan	41.61	22.70	1.028

Table 4. Analysis of Variance for mean volume of nine different species

Variate: Volume-m^3

S . V	d.f	SS	MS	Computed F	CV%
Between Species	8	22.12927	2.76616	30.91**	63.2
Within Species	261	23.35591	0.08949		
Total	269	45.48518			

** Highly significant at 1% level

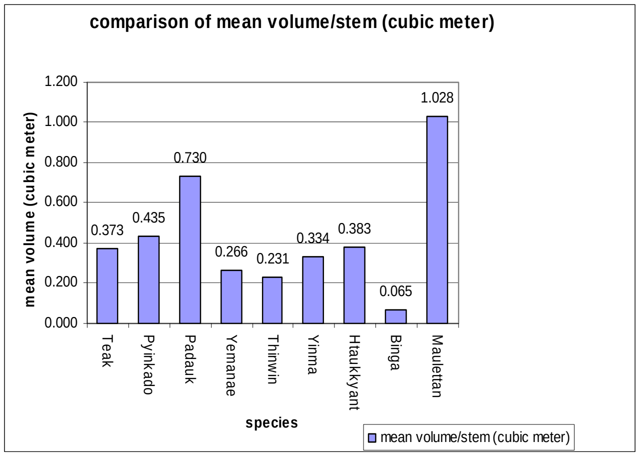


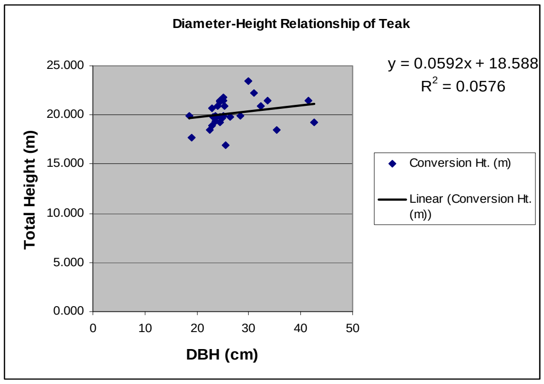
Figure 5. Comparison of green volume of nine different species tested

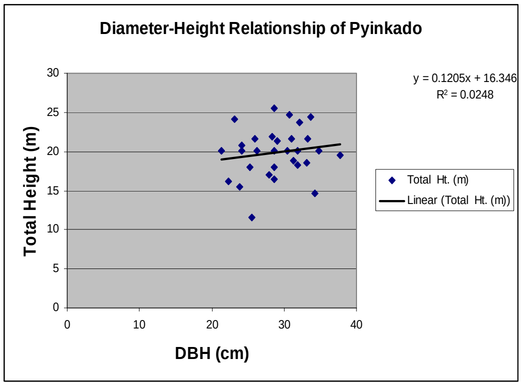
4.3 Diameter-Height Relationship of each species

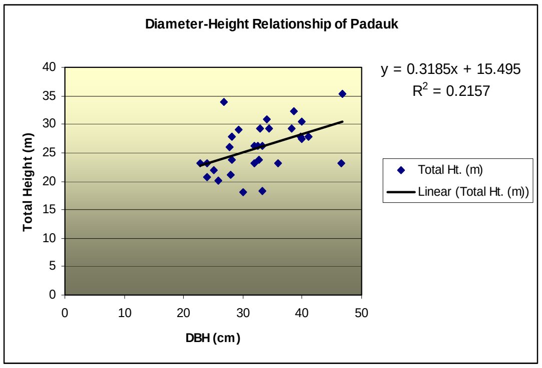
In this study, relationship between diameter at breast height and total height of individual species were also investigated in order to assess their relationship dependently in terms of their increment with age. Correlation coefficient measures the extent of interrelation between two variables which are simultaneously changing with mutually extended effects. In certain cases, changes in one variable are brought about by changes in a related variable but they need not be any mutual dependence. The relationship between diameter and heightwas strong enough to stimulate the future growth performance of the stands.

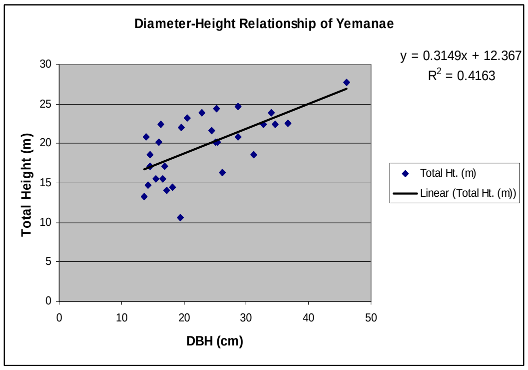
The type of model to use in deriving a regression equation depends upon the nature of the relationship between or among the variables concerned. When the relationship is linear, then the model should be appropriate for a straight line. When the relationship is non-linear, then the model should be based on the nature of the curve representing the relationship. Scatter diagrams and best-fit regression equation for DBH and Total height of the stems for each species are presented in the following figures. In this study, depending on the DBH and Total Height of species tested, most correlations between them showed that the linear relation is not much strong.

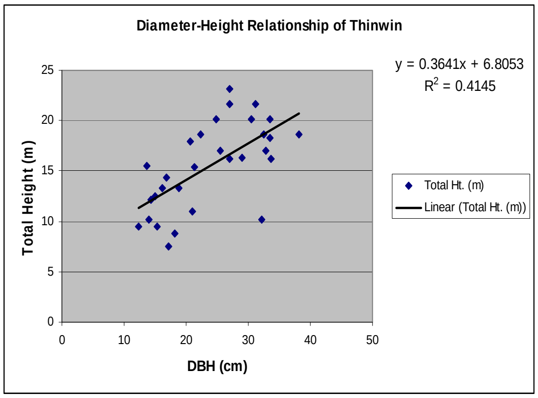
Regarding to diameter-height relationship for species of Teak, Pyinkado, Padauk and Ma-u-lettan-to, it is found that diameter at breast height and total height of the stems is not strongly correlated. In terms of values for other species, there is correlation between the increments of diameter growth and total height as shown in figure 6.

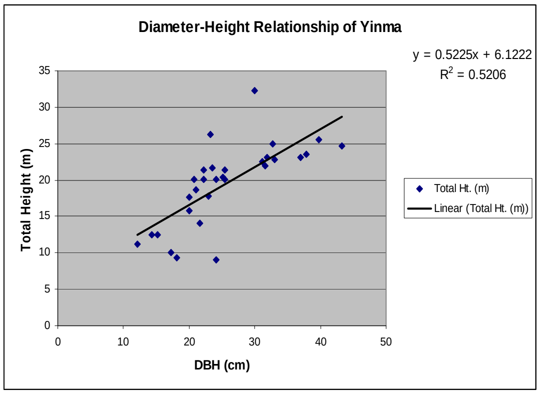

Diameter-Height Relationship of Teak
y = 0.0592x + 18.588
R2 = 0.0576
Total Height (m)
DBH (cm)
Conversion Ht. (m)
Linear (Conversion Ht. (m))

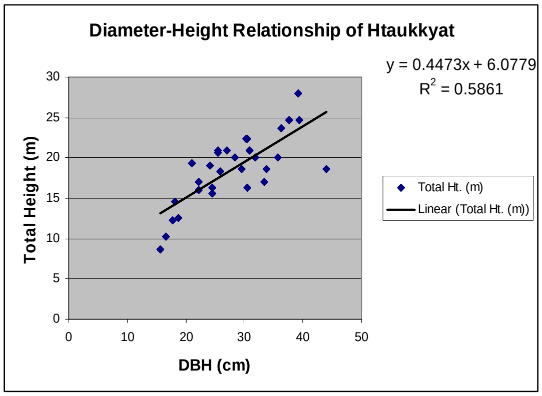

Diameter-Height Relationship of Pyinkado
y = 0.1205x + 16.346
R² = 0.0248
Total Height (m)
DBH (cm)
Total Ht. (m)
Linear (Total Ht. (m))

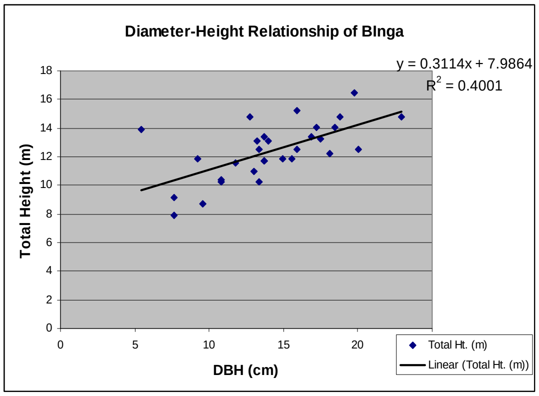

Diameter-Height Relationship of Padauk
y = 0.3185x + 15.495
R2 = 0.2157
Total Height (m)
DBH (cm)
Total Ht. (m)
Linear (Total Ht. (m))


Diameter-Height Relationship of Yemanae
y = 0.3149x + 12.367
R2 = 0.4163
Total Height (m)
DBH (cm)
Total Ht. (m)
Linear (Total Ht. (m))


Diameter-Height Relationship of Thinwin
y = 0.3641x + 6.8053
R2 = 0.4145
Total Height (m)
DBH (cm)
Total Ht. (m)
Linear (Total Ht. (m))


Diameter-Height Relationship of Yinma
y = 0.5225x + 6.1222
R2 = 0.5206
Total Height (m)
DBH (cm)
Total Ht. (m)
Linear (Total Ht. (m))


Diameter-Height Relationship of Htaukkyat
y = 0.4473x + 6.0779
R2 = 0.5861
Total Height (m)
DBH (cm)
Total Ht. (m)
Linear (Total Ht. (m))


Diameter-Height Relationship of BInga
y = 0.3114x + 7.9864
R2 = 0.4001
Total Height (m)
DBH (cm)
Total Ht. (m)
Linear (Total Ht. (m))

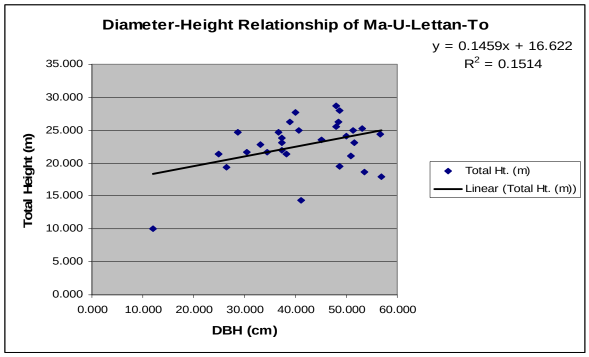


Figure 6. Regression relationships between DBH and Total Height of species tested

4.4 Estimation of Merchantable stem biomass(Bole Biomass) of nine species

Although all of the species tested are the same age and planted under the same favorable condition, *Pterocarpus macrocarpus*(Padauk) has the highest bole biomass among all but in terms of volume, *Nauclea orientalis*(Ma-u-lettan-to) has the highest value. *Milletia pendula*(Thinwin) has the highest value of basic density. (Figure-7)

According to ANOVA table constructed, there is highly significant difference among all species tested. Estimation of merchantable stem biomass has been found that it depends on the values of basic specific gravities for their comparison. According to the results, *Pterocarpus macrocarpus*(Padauk) has the highest values in terms of estimated aboveground biomass and it is heavy wood regarding to its basic density of 706 kg/m^3. The constructed ANOVA tablefor values of merchantable stem biomass of different species are shown in table 6. According to the results calculated for nine different species tested, all species have relatively considerable high bole biomass values which is important in capturing atmospheric carbon dioxide apart from their values in terms of timber and ecological benefits.

Stem biomass is related to many important components, such ascarbon cycles, soil nutrient allocations, fuel accumulation, and habitat environmentsin terrestrial ecosystems. Its estimation governs the potential carbon emission that could be released to the atmosphere due to deforestation and change of values for regional estimation of biomass isassociated with changes in climate and ecosystem. Hence, the biomass estimation usingforest inventory data orremotely sensed data has obtained increasing interests in the past decade.

However, it is necessary to obtain more accurate and precise biomass estimates for tropical forest tree species in order to improve understanding of the role of tropical forests in the global carbon cycle.Many biomass equations have been developed, variously including tree diameter, height, wood density, and tree form factor as explanatory variables. The choice in any particular study is important, as different methods can give rise to very different biomass estimatesof trees when applied to the same forest inventory data.Equation choice therefore poses a significant problem forregional-scale comparisons of biomass estimates, becausevariation caused by environmental, structural, and compositionalgradients, may be confounded withvariation resulting from the use of different equations.Ideally, therefore, comparisons of biomass estimates over large spatial scales need to be based on a consistentregression approach.

Table 5. Merchantable stem biomass or Bole biomass/stem(kg) of nine species

no.	species	Scientific name	Bole biomass/stem(kg)
1	Teak	*Tectona grandis* Linn. F.	222.141
2	Pyinkado	*Xylia xylocarpa* (Roxb.) Taub.	338.576
3	Padauk	*Pterocarpus macrocarpus* kurz.	515.101
4	Yemanae	*Gmelina arborea* Roxb.	111.450
5	Thinwin	*Millettia pendula* Benth.	195.941
6	Yinma	*Chukrasia velutina* Roem.	260.544
7	Htaukkyant	*Terminalia crenulata* (Heyne)Roth	311.772
8	Binga	*Mitragyna rotundifolia* (Roxb.) Kuntze	36.208
9	Maulettan	*Nauclea orientalis L.*	476.987

Table 6. Analysis of Variance aboveground biomass of nine different species

Variate: Aboveground_Biomass_kg

S . V	d.f	SS	MS	Computed F	CV%
Between Species	8	6527170.	815896.	22.76**	62.2
Within Species	261	9354919.	35843.		
Total	269	15882089			

** Highly significant at 1% level

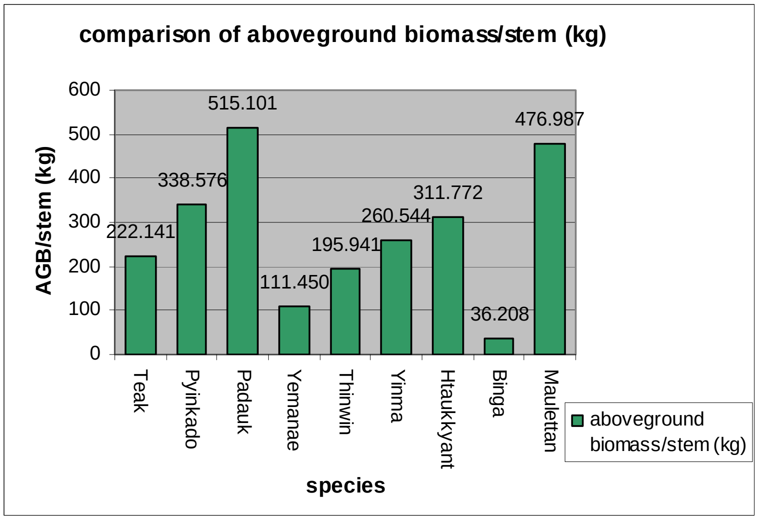


Figure 7. Comparison of mean aboveground biomass of nine different hardwood species

5. Conclusion

This study assessed the values of biomass for merchantable stem of nine hardwood species in which most of them are regarded as commercially important species in Myanmar such as Teak, Pyinkado, Padauk. Among the nine different species, Thinwin (*Millettia pendula* Benth.) has the highest basic specific gravity that means it is the heaviest wood in terms of weight. In this study, depending on the DBH and Total Height of species tested, most correlations between them showed that the linear relation is not much strong. Of all the species assessed, *Pterocarpus macrocarpus*(Padauk) has the highest values in terms of estimated merchantable stem biomass and it is heavy wood regarding to its basic density of 706 kg/m^3.According to the results, *Tectona grandis*(Teak), *Xylia xylocarpa*(Pyinkado) and *Pterocarpus macrocarpus*(Padauk) have high stem biomass values as well as high values in merchantable stem volume so that they can be regarded as highly prioritized species for reforestation activities for CDM projects apart from their economic importance.This study can fulfill the objectives of assessing biomass growth of some commercial hardwood species in Myanmar and can support reliable non-destructive methods for estimation of aboveground merchantable stem biomass of these species.

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