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VOLUME EQUATIONS OF Pinus brutia TEN. IN ZAWITA FOREST, DUHOK PROVINCE, IRAQ

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By

SAGVAN MOHAMMED HAJI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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DEDICATION

To:

* Our Prophet (PBUH)..... .... Taught us how to learn

* The spirit of my father..... ... To his wish and a prayer

* My dear mother ..... …… symbol of sacrifice and altruism

* My brothers and sisters..... love and appreciation

* From my wife, who supports me always ..... expensive paper

* Accessories of life and the apple of my eye..... Darvan and Warvan

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Master of Science

VOLUME EQUATIONS OF *Pinus brutia* TEN. IN ZAWITA FOREST, DUHOK PROVINCE, IRAQ

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Chairman : Associate Professor Shamsudin Ibrahim, PhD
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Planning for forest management depends upon the forest dynamics, which includes integration of all forest disciplines and understanding of forest resource characteristics including its growth dynamics. The forest growth and yield modeling can provide valuable information about forestry, which can be used to determine harvest levels or allowable cut and to analyze alternative stand treatments. The lack of technical information on forests in the Zawita region is one of the main obstacles to the development of growth and yield, environmental policy and forest evaluation indicators. The Zawita plantation forest needs more information on yield models using volume equations for *P. brutia* growing under the conditions of the Kurdistan Region of Iraq which will contribute to providing valuable information in the planning and sustainable management of the forest plantations in the region. Hence, this work has been carried out to apply volume equations for *P. brutia* that can explicitly state the relationship between tree volume and diameter and provide more information for the development of more systematic forest management prescriptions at the Zawita region in future. This study consists of four parts. For the first part, a large number of mathematical models, which have been used by various authors in the development of volume-tables and volume equation construction, were analyzed in searching for suitable volume equations for *P. brutia* plantations. Overall, we have used eight unweighted volume equations including two logarithmic transformed equations and seven weighted forms of volume equations for volume data of a 25 – 30 year old *P. brutia* plantation. In the second part, the study used the method of least squares for the construction of volume equations, because the most common problem in volume table construction has been the variation in tree forms or commonly referred to as heteroscedasticity of residuals. This is because the larger tree volumes tend to deviate from the regression line more than the smaller ones, and therefore the weighted least squares was used to correct the heteroscedasticity in volume table construction. The least squares method was used to fit the construction of volume equations for both over bark and under bark volumes. The third part discussed the statistical method to find the best-fit equation. A more suitable index for comparing regression equations

has been devised by Furnival, which is based on the concept of maximum likelihood. The index was used to determine the best-fit equation, in choosing the final equations for both over and under bark equations. Finally, the study conducted validation to compare the true volume calculated using Newton's formula with the predicated volume derived from the equation. The actual and estimated volume per hectare was compared and tested using the t-test.

In conclusion, the study developed the following equations for estimating under bark (VI) and over bark (VO) volume, equations:

$VI = 0.0003378 * D^{1.21342} * H^{1.18863}$, $VO = 0.0002722 * D^{1.40425} * H^{1.06470}$, where VI and VO are (merchantable tree volumes m3 up to 10 cm) breast height diameter (cm), and H is the total log length (m). The equations were found to estimate merchantable tree volumes. As usual, a test of applicability of these equations is needed if they are to be applied elsewhere.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PERSAMAAN ISIPADU P*inus brutia* SEPULUH DI HUTAN ZAWITA, DAERAH DUHOK, IRAQ

Oleh

SAGVAN MOHAMMED HAJI

November 2016

Pengerusi : Profesor Madya Shamsudin Ibrahim, PhD
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Perancangan untuk pengurusan hutan bergantung kepada dinamik hutan, termasuklah integrasi dalam semua disiplin hutan dan memahami ciri-ciri sumber hutan termasuk dinamik pertumbuhannya. Pertumbuhan hutan dan model hasil boleh memberikan maklumat berharga mengenai perhutanan, yang boleh digunakan untuk menentukan tahap tuaian atau pemotongan yang dibenarkan dan untuk menganalisis rawatan alternatif kelompok pokok. Kekurangan maklumat teknikal mengenai hutan di kawasan Zawita adalah salah satu halangan utama terhadap pembangunan dan pertumbuhan hasil, dasar alam sekitar dan petunjuk penilaian hutan. Hutan ladang Zawita memerlukan maklumat lanjut mengenai model hasil menggunakan persamaan isipadu untuk P. brutia yang tumbuh di bawah keadaan kawasan Kurdistan di Iraq yang akan menyumbang kepada penyediaan maklumat berharga dalam perancangan dan pengurusan mampan ladang hutan di kawasan tersebut. Oleh itu, kajian ini telah dijalankan untuk mengguna pakai persamaan isipadu untuk P. brutia yang boleh secara jelas menyatakan hubungan antara isipadu pokok dan diameter serta memberi maklumat lanjut untuk pembangunan preskripsi pengurusan hutan yang lebih sistematik di kawasan Zawita pada masa depan. Kajian ini terdiri dari empat bahagian. Untuk bahagian pertama, sejumlah besar model matematik, yang telah digunakan oleh pelbagai penulis dalam pembangunan jadual-isipadu dan pembinaan persamaan isipadu, dianalisis dalam usaha mencari persamaan isipadu yang sesuai untuk ladang P. brutia. Secara keseluruhan, kami telah menggunakan lapan persamaan tanpa pemberat termasuk dua persamaan terjelma logaritma dan tujuh bentuk persamaan isipadu dengan pemberat untuk data isipadu suatu ladang P. brutia berumur 25-30 tahun. Di bahagian kedua, kajian ini menggunakan kaedah kuasa dua terkecil bagi pembinaan persamaan isipadu, kerana masalah yang paling biasa dalam pembinaan jadual isipadu ialah variasi dalam bentuk pokok atau biasanya dirujuk sebagai heteroskedastisiti reja. Ini kerana isipadu pokok yang lebih besar cenderung menyimpang dari garis regresi lebih daripada yang lebih kecil, dan oleh itu kuasa dua terkecil dengan pemberat telah digunakan untuk membetulkan heteroskedastisiti dalam pembinaan jadual isipadu. Kaedah kuasa dua terkecil digunakan untuk

memuatkan pembinaan persamaan-persamaan isipadu untuk kedua-dua isipadu luar kulit dan di dalam kulit kayu. Bahagian ketiga membincangkan kaedah statistik untuk mencari persamaan penyuaian terbaik. Indeks yang lebih sesuai untuk membandingkan persamaan-persamaan regresi telah direka oleh Furnival, yang berdasarkan kepada konsep kebolehjadian maksima. Indeks itu adalah digunakan untuk menentukan persamaan yang penyuaian terbaik, dalam memilih persamaan-persamaan akhir bagi kedua-dua persamaan di luar dan di dalam kulit kayu. Akhir sekali, pengesahan dilakukan untuk membandingkan isipadu sebenar yang diperolehi menggunakan formula Newton dengan anggaran isipadu yang diperolehi daripada persamaan yang dibentuk. Isipadu sehektar sebenar dan anggaran telah dibandingkan dan diuji menggunakan ujian-t. Kesimpulannya, kajian ini membangunkan persamaan berikut untuk menganggarkan isipadu di bawah kulit kayu (VI) dan di atas kulit kayu (VO); persamaan: $VI = 0.0003378 * D^{1.21342} * H^{1.18863}$, $VO = 0.0002722 * D^{1.40425} * H^{1.06470}$, di mana VI dan VO adalah isipadu pokok yang boleh diperdagangkan (m^3) sehingga 10 cm diameter di paras dada (cm), dan H adalah panjang balak (m). Persamaan tersebut didapati menganggarkan isipadu pokok yang boleh diperdagangkan.Seperti biasa, ujian berkenaan persamaan ini dikehendaki jika perlu untuk digunakan di tempat lain.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

ANOVA	Analyses of variance
a.s.l	Above sea level
Bt	Bark thickness
Bt_1	Bark thickness at the large end of the log section
Bt_m	Bark thickness at the mid-point of the log section
Bt_s	Bark thickness at the small end of the log section
°C	Degree centigrade
dbh	Diameter at breast height
dub	Diameter under bark
dob	Diameter over bark
D_1	Diameter at the large end of the log section
D_m	Diameter at the mid-point of the log section
D_s	Diameter at the small end of the log section
f	Correction factors
FI	Furnival's index
V	Volume of tree
V_1	Volume under bark
V_2	Volume over bark
$ß_{i\,(1,\,2\ldots)}$	Coefficient
R^2	Coefficient of determination
Bias	Mean residual
SEE	The standard error of estimate
SDR	The standard deviation of residual

S_{ei}	Standard error of estimate
SSE	Sum of square
SST	Total sum of square
SPSS	Statistical Package for Social Science

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Forests are considered as important assets in the economy of any country, they provide a variety of natural resources such as food, raw material, fuel wood and fodder (Sattout *et al*., 2007) .Other benefits of forests include the provision of landscape for recreational opportunities, protection of soil against erosion, purification of water, production of oxygen, consumption of carbon dioxide, regulation of micro climate and provision of biological diversity. The industrial revolution and high demand of forest products during the 19th century resulted in a substantial deforestation that caused a reduction in the extent of the world total forest area from 50% to 30 % (Kataria *et al*., 2013). A common approach in trying to increase the forest cover is to reforest new areas through forest plantations establishment either managed for timber, fuel wood or – pulp and paper production. The existing natural forests are managed mainly for conservation and protection purposes (Kataria *et al*., 2013). As a result, fast-growing tree species such as, Acacia, Pinus and Eucalyptus have been a popular choice of species planted in forest plantation worldwide (Borras *et al*., 2012).

According to Yasodha *et al*., (2004), about 48% of the overall forest plantation worldwide is used to industrial use; 26% for agro forestry, fuel wood, soil and water conservation and the remaining 26% to other purposes that have not been specified.

Thus, there is an increasing demand for forest plantation to fulfill the increasing demand for forest products (Kröger, 2012). In the recent years, due to high demand for forest products resulting from rapid development in technology, the focus of governments and private sectors have been on mass reforestation programmers with fast-growing industrial tree species with the intention to shorten the rotation cycle and fulfilling the increasing demand of the timber market (FAO, 2012).

Tree volume equation is useful for forestry practices in estimating the volume to be harvested based on certain parameters like tree diameter and height that can easily be measured. Such method has been used for more than a hundred years (West, 2009).

However, the information from commercial tree plantation is lacking in most developing nations for example modeling equation or developing volume equation. There exist simple tools and methods, which can be utilized to estimate either individual tree volume or the volume of the whole forest plantation stands. Volume equations have been studied for many years and the study continuously attracting many researchers in the field of forestry. It is being researched and studied widely because there are no single volume equations, which can be satisfactorily utilized for

all tree species (Clutter *et al*., 1983; Muhairwe, 1999), and no single is model suitable for all purposes (Cao *et al*., 1980; McClure & Czaplewski, 1986).

The volume of a stem is a function of the basal area, bark thickness, shape and height of a tree (Holmgren, 2004). Measuring stem volume is a herculean task because inaccurate estimation of any of the aforementioned factors will compromise the accurate estimation of stem volume. The measurement, elucidation and application of stem volume are premised on the standard of use, measurement units and other stipulations (West, 2009).

According to the FAO, (2009), 1.9% or about 822,000 hectares of Iraq is forested, of this**,** Iraq had 15,000 hectares of planted forest. Between 1990 and 2000, the average annual gain of planted forest and average annual reforestation rate were 1,400 hectares and 0.17% respectively. Between 2000 and 2005, the deforestation rate was 0.10%, which account for about 43.8% decrease per year.

Forest in Iraq is linked to Turkish and Mediterranean forests, through the dominance of Turkish red pine (*P. brutia. - P. brutia* sub). The species is naturally distributed mainly in the Mediterranean and Aegean regions of Turkey, including east Aegean Islands, Crete in Greece, Cyprus, Syria, and northern Iraq (Fikret & Lee,1999).

In 1988, the Iraqi Ministry of Agriculture had planted about 30 hectares of *P. brutia* in the mountainous region of Zawita using a planting space of 3x3 m. *P. brutia* is a natural species to Zawita area, which is located in the northwestern part of Kurdistan region, and extending to far north of Iraq. The region ranges between 800 to 1600 meters in altitude. The species has a considerably tolerance to poor soils, frost and draught. This species is planted not only in Kurdistan region, but also in other parts of Iraq. The species is easily adapted to different climates and conditions of the region. The species was selected for the study because it has an economic importance. Its wood is used for fuel wood, pulp and charcoal. This species is considered a light-demanding. The lack of the technical information on forests in the Zawita region is one of the main obstacles to the development of forest management standards and environmental policy in the area. The forest plantation evaluation in Zawita needs more scientific work on the development of yield models (Zeki, 2012). The development of yield models for this species growing in Kurdistan region will contribute towards providing valuable information in planning and sustainable management of forest plantations in the region, as cited by the Kurdistan Regional Government. Hence, this work was carried out to develop volume functions for *P. brutia* that can demonstrate the relationship between tree volume and diameter and provide a useful tool in managing the forest in Zawita in the future.

1.2 Reasons of modeling *Pinus brutia*

The forest ecosystem provides a number of goods and services to meet the increasing demands of the society. The demands are the major thrust determining the practices and objectives of forest management. Therefore, there is a pressing need to manage forest to ensure unhindered supply of wood and non-wood forest products, bio energy supply, biodiversity conservation, preservation of water resources, carbon sequestration and storage, the prevention of deforestation and forest degradation. Precisely, the management of the forest should be done by considering it as an intricate adaptive systems influenced by socioeconomic and ecological changes (Messier *et al*., 2013). Considering the multi functionality and complexity of *P. brutia* trees, there exist a need for effective forest management systems premised on scientific knowledge to guarantee the provision of various resources and ecosystem services in a dynamic world. This scenario justifies the need for science-based tools and decision support schemes to aid and enhance adaptive forest management to meet the dynamic socio-economic and environmental conditions (EFI, 2010).

Nonetheless, there is paucity of such science-based tools for many forest ecosystems in many countries. This has been the case for *P. brutia* trees. In spite of the economic and ecological importance of *P. brutia*, the scientific knowledge regarding its stand dynamics and yield prediction is meager. In addition, there is a paucity of information for predicting the stand dynamics in stand structures of light-demanding species naturally tending to form even-aged stands, typical of Mediterranean Pine forests. Albeit, the prediction of carbon and forest biomass is crucial for myriad uses like fuel wood production, fire risk management and carbon balance calculations, there is little information on the effect of stand structure and forest management on the allocation of forest biomass in eastern Mediterranean pine forests. A topical issue in forest science is the accurate prediction of carbon stock estimation, forest-level biomass and tree-stand on large spatial scales (Jenkins *et al*., 2003; Muukkonen, 2007). Moreover, the consequences of ecological interactions between stand dynamics and diverse features of *P. brutia* ecosystems e.g., wood and non-wood forest products and pests remain obscure.

1.3 Problem Statement

The basic tool in quantifying volume and value of forest stands is the tree volume equations. It's also important for growth and yield studies and for estimating response silvicultural treatment. These tools can be used in assessing the standing volume of instrument in forest organization and management practices (Berhe, 2009)

The lack of technical information on forests in the Zawita region is one of the main obstacles to the development of growth and yield, environmental policy and forest evaluation indicators. Zawita plantation forest needs more information on yield models (Zeki, 2012). Hence, this work has been carried out to apply volume equations for *P. brutia* that can explicitly stated the relationship between tree volume and diameter and provide more information in the development of more systematic forest management prescriptions at Zawita region in future.

1.4 Study objectives

The main objective of this study is to find reliable techniques for estimating tree volume for *P. brutia*, and is important to minority groups in the mountainous regions of in northern Iraq.

The specific objectives of this research were:

1. To apply volume equation for *P. brutia* that can overtly describe the relationship between tree volume and dbh, and among the tree volume, height and dbh, and by fitting regression equations to sample trees;
2. To compare the goodness-of-fit of potential volume equation of *P. brutia* using Furnival's index (FI).
3. To recommend the best fit over- underbark volume equations of *P. brutia* for Zawita region in Kurdistan.

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