DETERMINATION OF TREE STEM VOLUME: A CASE STUDY OF *CINNAMOMUM*

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ABSTRACT

DETERMINATION OF TREE STEM VOLUME: A CASE STUDY OF *Cinnamomum*

Modelling of trees has attracted scientific research in various fields and disciplines since trees and forests play very important roles in the global system. It helps in the proper decision makings and implementation of policies. Hence, this research is designed such that the idea of determining the best models and solving their parameters that give the best estimates are conceptualized. The significant factors and their relationships are identified through a modelling approach. A modeling approach is developed which focuses on the phases in the model-building procedures, effects of interactions variables on the model, minimizing the effects of multicollinearity on the variables and recommending remedial techniques to overcome them, identification of the significant variables by removing insignificant variables, selecting the best model using the eight selection criteria (8SCs), and finally using the residual analysis to validate the chosen best model. Illustrations and algorithms are incorporated into the procedures. Non-normal and nonlinear data variables are addressed, hence data characterization is presented. A data transformation approach is introduced, based on the different data characteristics using the maximum coefficient of determination (R^2) and maximum p-value approaches. Transformations are numerically optimized for linearity and normality of models. The three stem biomass equations adopted are namely, the Newton, Huber and Smalian's formulae, based on the multiple regression (MR) and polynomial regression (PR) techniques. Relevant mathematical models are identified from the 684 models obtained in estimating the volume and the biomass equations used. The best MR model is model M52.5.5 Newton, however, the best PR model (P57.14.6 Newton) is found to give an improved estimation. Comparisons between the MR and PR models of the case studies are analyzed based on the eight selection criteria (8SCs). Factors contributing to the stem volume estimation are identified as tree height (*T*) and diameter at base (*Db*) as main contributors, while diameter at the middle (*Dm*), breast height (*Dbh*) and top (*Dt*) are significant contributors. Simulations of the best models are done using the Maple software.

ABSTRAK

Pemodelan tentang pokok telah menarik kajian saintifik dalam berbagai bidang dan disiplin, lebih-lebih lagi pokok dan hutan memainkan peranan penting dalam sistem global. Ia di perlukan dalam pembuat keputusan dan mengimplementasikan polisi-polisi yang telah ditetapkan. Justru, kajian ini telah dibentuk agar konsep untuk menentukan model terbaik dan menyelesaikan nilai parameter yang memberi penganggaran terbaik dapat diketengahkan. Faktor-faktor signifikan dan hubungannya dikenalpasti melalui satu pendekatan pemodelan. Pendekatan pemodelan ini memfokuskan kepada fasa-fasa dalam pembentukan model, kesan interaksi pada pembolehubah untuk penganggaran, meminimakan kesan multikollinearan dan mencadangkan teknik untuk mengatasinya, mengenalpastikan pembolehubah yang tidak signifikan dengan proses penyingkiran, pemilihan model terbaik berdasarkan lapan kriteria pemilihan (8SC), dan akhir sekali, menentukan kewajaran pemilihan model dengan analisis reja. Illustrasi dan algoritma yang berkaitan dipersembahkan untuk menunjukkan teknik penyingkiran pembolehubah multikolinearan dan yang tidak signifikan. Ketidak normalan dan kelinearan data telah ditangani dengan pencirian data. Untuk kelinearan dan kenormalan, transformasi data dilakukan dengan perhatian diberikan kepada sifat kekalutan pembolehubah. Satu pendekatan transformasi dibentuk dengan menggunakan pendekatan kaedah pekali penentuan (R^2) dan nilai-p. Kekalutan model dikenali dengan penggunaan transformasi yang sesuai dan dioptimumkan untuk meningkatkan darjah kepersisan model pilihan secara statistik. Tiga persamaan batang pokok telah digunakan iaitu, Newton, Huber dan Smalian. Pemodelan ini dibangunkan bersandarkan kaedah regresi berganda dan polinomial. Model matematik dan persamaan yang digunakan telah dikenalpastikan untuk menganggar isipadu batang pokok daripada 684 model yang terbentuk . Model regresi berganda terbaik adalah M52.5.5 Newton. Satu penganggaran yang lebih baik didapati dengan model P57.14.6. Perbandingan model regresi berganda dengan model polinomial telah dibuat berdasarkan lapan kriteria pemilihan (8SC). Faktor-faktor utama yang mempengaruhi penganggaran isipadu adalah tinggi pokok (T) dan diameter bawah (Db) sementara faktor-faktor signifikan adalah diameter paras dada (Dbh), tengah (Dm) dan atas (Dt). Simulasi model terbaik juga dilakukan dengan menggunakan perisian Maple.

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LIST OF ABBREVIATIONS

Ab	Area at the base
Am	Area at the middle
ASEAN	Association of South-East Asian Nations
At	Area at the top
BH	Breast Height
Db	Diameter at the base
Dbh	Diameter at breast height
Dm	Diameter at the middle
Dt	Diameter at the top
MR	Multiple Regression
PR	Polynomial Regression
RWEDP	Regional Wood Energy Development Programme
8SC	8 Selection Criteria

CHAPTER 1

INTRODUCTION

1.0 Background

Tree stem biomasses have stimulated economic and scientific interests, especially, where trees with medicinal values, industrial and economic benefits are concerned. Tree wood and biomass attributes from chemical and physical structures have made them valuable for a given end use. An example would be deciding the time for tree cropping and harvesting that would have benefitted many sectors, especially in forestry and agriculture. Innovative forest management practices can capture commercial opportunities and deliver environmental outcomes in waste water re-use, biofuels, carbon sequestration, fodder crops and timber (Gillison *et al.*, 2004).

The forest inventory and timber volume estimation are needed for forest management by all forest inventories and timber companies. The measurement of sample trees is a costly process, and at times impossible for logs in standing trees. Any difference in volume estimation will affect accuracy. Since majority of the saw log sales are still on a volume basis, hence, any changes in the estimation will indirectly produce huge changes in profits or revenues. Hence, it is necessary to obtain a good estimation tool which can give accurate qualitative and quantitative evaluation and yet reduce costs.

Since the advent of the new millennium, there is an increasing need to find alternatives to fossil fuel and consequently, biomass and bioenergy have started to give significant contributions to global fuel production and consumption. Biomass can be derived from the carbonaceous wastes of various human and natural activities, including such from the forestry plantations and wastes from the timber industry, agricultural residues, raw materials from the forest, major parts of household waste for example, sewage and municipal solid waste (MSW), agro-industrial wastes such as rice husks and palm oil residues, and wood from natural

forests and woodlands (Salman Zafar, 2009). In developing countries, biomass energy usually originates from fuel wood, animal wastes, and agricultural residues, and is primarily utilized for activities which are essential for survival. In Malaysia, the types of biomass potential for use in generating biomass energy have been identified to have come primarily from agricultural activities (Nerenberg, 2011; Koh and Hoi, 2003). Hence there is a need of the correct parameter chosen for biomass estimation and prediction.

In other words, the growth of trees would contribute significantly, directly or indirectly in various fields of multiple-objectives, besides balancing water, air as well as wind of the Earth's ecosystem. Hence, this has incurred interest in looking at the optimised production of tree stem biomasses of multi-purposes and utilities. Thus, tree species which have multiple usages will be of the primal choice, as such, contributions of modelling the tree stem biomass in the various disciplines can be realised. In this research, an indigenous tree species, *Cinnamomum iners* is chosen whereby the volumes of the tree stem biomasses are modelled, and can be shown to contribute in the various fields stipulated in the following sections.

1.1 Importance of Study: Why Cinnamon trees?

The choice of tree in this particular study would make a difference in terms of its significance and potential contributions to the country's economic revenue besides the identification of new value-added innovative products into the world market for export. Besides that, new mathematical concepts can be derived while undergoing these modelling processes.

Hence, in this chapter, the uses and potentials of Cinnamon is preliminary introduced, followed by some examples in modern researches using the Cinnamon species that can still be explored, and finally its value-added significance and economic contributions towards the world economic model.

1.2 Uses and Economic Potentials of Cinnamon

In Malaysia, *Cinnamomum iners,* or in short, *C. iners,* is one of the cinnamon tree species grown. It is not just being environmentally friendly, but also being used in

landscaping with an aesthetic quality as well as planted in recreational parks and as shade trees to parking cars (Bruner *et al*., 2001; Nowak *et al*., 2006). Besides that, it also can be manufactured into products that have commercial benefits. For example, the bark can be used as a medicine, which is sometimes traded, and is called *mesni* in Sarawak (Lemmens *et al*., 1995). The wood is used as *medang*, as in for example, house building and cabinet work. Besides that, the oils from the leaves are used for flavouring sweets and confectionery. The bark is sometimes used together with the leaves in brewing tea, and also as a substitute for cinnamon. Furthermore, the mucilage has found technical applications, for example, in the manufacture of mosquito coils, fragrant joss-sticks, plastic products, formica, glue, inner layering of tyres, coating of high-quality paper products, paints and fibre glass (Babu *et al*., 2004).

Even though cinnamon oil is of very high value, yet, there is no international standard for it. The increased price would depend on the higher *cinnamaldehyde* content which possesses antimicrobial, antibacterial, antioxidant and antifungal properties. It inhibits aflatoxin production, that is, by causing complete inhibition of *Candida albicans*, *A.fumigatus*, *A.niger*, *Penicillium frequentans*, *P.decumbens* and *Cladosporium bantiannum* at 0.33mm concentration (Babu *et al*., 2004). However, cinnamon oil has to be used with caution during pregnancy because it has been reported to have caused miscarriages, since it is an irritant and narcotic poison in large doses.

Cinnamon had also been widely used in culinary and as food additives (Samy, 2005). There are many species of cinnamon that produce oils through the process of distillation. Researches had shown that the various types of cinnamon can be used for different purposes, such as, antimicrobial, antifungal and anti-pest. An example would be *Cinnamomum iners*, being used in traditional therapy for illnesses such as to relieve fever (Lin *et al*., 2007), and are found to have antifungal and amylase inhibitor properties.

In terms of medicinal properties, *C. iners*' bark, also called *cassia*, is found to help in relieving those who have Type 2 diabetes melitus. The effects of brewing