ABOVEGROUND BIOMASS ALLOMETRIC EQUATIONS AND FUELWOOD PROPERTIES OF SIX SPECIES GROWN IN ETHIOPIA

By

WOLDEYOHANES FANTU

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

March 2005

To my wife, Meselech Mettete and

Children, Brooke and Nephtalem

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

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Chairman: Associate Professor Ahmad Ainuddin Nuruddin, Ph.D.

Faculty: Forestry

In Ethiopia, plantations of fast growing species are being established to increase the supply of wood; especially for the biomass fuel consumption. In order to better inventory the supply of biomass, allometric equations and fuel properties need to be determined. The objectives of this study were i) to develop regression equations of tree component from six species ii) to determine fuel properties and fuel value index (FVI) of the six tree species and iii) to compare combustion characteristics of tree component of the six species using thermogravimetric analysis (TGA).

The selected exotic species were *Eucalyptus globulus, Eucalyptus grandis* and *Eucalyptus saligna;* and the indigenous were *Acacia abyssinica, Acacia seyal* and *Acacia tortilis*. For each species, 24 sample trees (20 for regression and four for validation test) were randomly selected from respective forest stands located in central, western and southern part of Ethiopia.

Biometrical data were obtained by felling representative trees stratified into diameter at breast height (DBH) classes. The ANOVA and prediction equations were analyzed by using base-10 log-transformed dry weights (kg) of aboveground

biomass (AGB) components and their corresponding log-transformed DBH, squared diameter at breast height (DBH^2), and DBH^2*height (H). For data analysis, Microsoft Excel 2002 and SPSS 11.5 were used. To determine fuelwood properties of components of the six tree species such as moisture content (MC), basic density (D), volatile matter (VM), fixed carbon (FC), ash (As), gross heat value (GHV) and combustion characteristics, experimental samples were collected by random sampling method. All the test samples were replicated three times. These studies were conducted at the Faculty of Forestry, Universiti Putra Malaysia.

The allometric equation with DBH^2 as predictor variable showed better results (higher R^2 and lower SE) than other growth parameters. The improvement in R^2 and SE was very little when H was included as predictor variable (up to 6 and 2.5% respectively). Since DBH can easily be measured with higher accuracy and provided better estimates, it was recommended as an adequate growth parameter for AGB estimation.

The GHV of stem wood and branch component did not show significant variation ($p>0.05$) between species. For foliage biomass the variation between species was highly significant ($p<0.001$). It was observed that, GHV alone does not indicate the merits of desirable fuelwood qualities; therefore, FVI was calculated considering GHV, MC, D and As. The results revealed that FVI constitutes an adequate criterion for selecting and ranking fuelwood species. The species investigated in current study were ranked according to FVI in descending order of desirable fuelwood properties; i.e. *E.globulus, E.grandis, E.saligna, A. tortilis, A.seyal* and *A. abyssinica*.

Results from TGA showed that stem wood and branch components in all species exhibited to have similar burning profile; and comparable burning characteristics. Generally, ignition temperature of burning samples increased with increasing volatile matter content. It was also observed that ignition requirement for foliage biomass was lower compared to stem wood and branch component.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PERSAMAAN ALLOMETRIC BIOJISIM ATAS TANAH DAN SIFAT BAHAN API BAGI ENAM SPESIES DI ETHIOPIA

Oleh

WOLDEYOHANES FANTU

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Di Ethiopia, penanaman species cepat tumbuh telah dimulakan bertujuan untuk meningkatkan bekalan kayu; terutamanya penggunaan bahan api biojisim. Bagi menentukan inventori bekalan biojisim yang terbaik, persamaan 'allometric' dan sifat bahan api perlu ditentukan terlebih dahulu. Objektif kajian ini adalah i) untuk membentuk model regresi komponen bagi enam spesies kayu ii) untuk menentukan sifat bahan api dan indeks nilai bahan api (FVI) bagi enam spesies dan iii) untuk membandingkan ciri-ciri pembakaran komponen bagi enam spesies kayu dengan menggunakan analisis 'thermogravimetrik' (TGA).

Spesies eksotik yang telah dipilih adalah *E.globulus, E.grandis* dan *E. saligna;* dan spesies tempatan adalah *A. abyssinica, A.seyal* dan *A.tortilis.* Bagi setiap spesies, 24 sampel pokok (20 untuk regresi dan empat untuk ujian validasi) dipilih secara rawak dari pada kawasan hutan di bahagian tengah, barat dan selatan Ethiopia.

Data biometrik diperolehi dari pokok yang ditebang mengikut pengkelasan perepang paras dada (DBH). ANOVA dan persamaan yang diramalkan dianalisa

menggunakan “Base-10 log-transformed” berat kering (kg) komponen pokok dan perkaitan “log-transformed” diameter paras dada (DBH), diameter paras dada kuasa dua (DBH^2) dan DBH^2 * H. Bagi menganalisis data, Microsoft Excel 2002 and SPSS 11.5 telah digunakan. Untuk menentukan sifat bahan api setiap komponen bagi enam spesies seperti kandungan lembapan (MC), ketumpatan asas (D), bahan volatil meruap (VM), karbon tetap (FC), abu kayu (As), nilai kepanasan kasar (GHV) dan ciri-ciri pembakaran, sampel-sampel percubaan telah dikutip dengan kaedah persampelan secara rawak. Kesemua sampel ujian direplikasi sebanyak tiga kali. Kajian ini telah dijalankan di Universiti Putra Malaysia.

Persamaan ‘allometric’ dengan kuasadua DBH sebagai pembolehubah ramalan menunjukkan keputusan lebih baik di mana (R^2 yang tinggi dan SE yang rendah) daripada parameter tumbesaran yang lain. Pembaikan dalam R^2 dan SE adalah terlalu kecil apabila H dimasukkan sebagai pembolehubah ramalan (sehingga 6 dan 2.5%). Memandangkan DBH mudah diukur dengan ketepatan yang tinggi dan memberikan anggaran yang baik, maka adalah disyorkan ianya dijadikan parameter tumbesaran kepada penganggaran AGB.

GHV komponen batang dan dahan berkayu tidak menunjukkan variasi yang signifikan ($p>0.05$) diantara spesies. Bagi variasi biojisim daun diantara spesies adalah sangat siknifikan ($p<0.001$). Melalui pemerhatian, jika hanya GHV sahaja yang digunakan ia tidak menunjukan merit kualiti bahan api yang menarik; justeru itu, FVI telah diukur dengan mengambilkira GHV, MC, D dan As. Keputusan menunjukkan bahawa FVI mempunyai criteria yang mencukupi dalam memilih dan menyusun bahan api spesies. Spesies yang telah dikaji dalam kajian semasa disusun

mengikut FVI dalam susunan menurun bagi ciri-ciri bahan api yang menarik iaitu *E. globulus, E.grandis, E. saligna, A.tortilis, A.seyal* dan *A. abyssinica.*

Keputusan daripada TGA menunjukkan komponen batang dan dahan kayu dalam kesemua spesies yang diuji mempunyai profail dan ciri-ciri pembakaran yang sama. Secara amnya, suhu penyalaan bagi pembakaran sampel-sampel akan meningkat apabila terjadi peningkatan kandungan bahan mudah meruap. Ia juga diperhatikan bahawa keperluan penyalaan bagi biojisim daun adalah rendah berbanding dengan komponen batang dan dahan kayu.

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I certify that an Examination Committee met on March 3, 2005 to conduct final examination of Woldeyohanes Fantu Ewnetu on his Doctor of Philosophy thesis entitled "Aboveground Biomass Allometric Equations and Fuelwood Properties of Six Species Grown in Ethiopia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

WOLDEYOHANES FANTU EWNETU

Date:

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