Allometric modeling for biomass estimation in remote sensing

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Abstract

This research develops an allometric model for estimation of biomass based on the height and DBH of trees in the forests of Iran. Without an accurate allometric model, we can't estimate true biomass from SAR images. After extensive field investigations, 124 trees are selected from the 4 different dominant tree species for the development of an allometric model covering the wide range of DBH and height classes. Twelve commonly used allometric models, three generic models and a proposed model are tested and the most suitable model is selected based on some of the commonly measured statistical parameters (coefficient of determination (R^2), RMSE, Mean Error, Underestimated Error, and Overestimated Error). We show that the biomass estimation accuracy is improved in a multilayer perceptron neural network (MLPNN) when the density of woods and the tree measurements are used in combination compared to estimating the biomass by classic allometric models.

1.Introduction

The most suitable method for biomass estimation is remote sensing, as this technique is usually better than traditional field-based methods when considering time, costs, and feasibility (Brown et al, 1989, Calama et al, 2008), although it is probably less accurate (Ketterings et al, 2001, Zianis and Mencuccini 2004). However, the problem of the remote sensing-based biomass estimation is that remotely sensed data do not directly estimate the amount of biomass present in a forest (Mette et al, 2004). Field AGB is necessary for comparing the result of remotely sensed methods in biomass estimation. In general, field AGB is calculated using the allometric equations based on the measured DBH and/or height or from the conversion of forest stocking volume. Regression models have commonly been used to relate field measurements to remotely sensed observations obtained via optical and radar sensors (Brown et al, 1989, Mette et al, 2004). Thus, field measurement of forest biomass remains necessary for remote sensing of biomass estimation, and the accuracy of remote sensing techniques largely depends on the accuracy of ground data (Brown et al, 1989).

The method of field based biomass measurement can be divided into two groups i.e. direct and indirect (Overman et al, 1994). The direct method involves the complete harvesting of sample plots and subsequent extrapolation to an area unit (Araujo et al, 1999, Charru et al, 2010). The indirect method aims to construct a functional relationship between tree biomass and other tree dimensions, such as stem diameter, height and wood density, by means of regression analysis (Brown et al, 1989, Henry et al, 2010, Knapic, 2011). Since the direct method is very time consuming, costly and completely destructive, and biomass expansion factors (BEFs) are complex in nature, field observations of biomass are normally based on allometric models that approximate the biomass of the tree component or the total biomass of single trees according to easily measured variables, such as diameter at breast height (DBH) or height (Ketterings et al, 2001, Pilli et al, 2006).

2.Modeling

The relationship between the physical parameters (DHB or/and height) and the AGB of all harvested sample trees needed to be established in order to estimate the AGB of non-harvested trees. Although there are several empirical methods available, this study established this relationship using allometric equations because an allometric model is a useful tool which can approximate the AGB of single trees according to easily measured variables, such as diameter at breast height (DBH) or height (H) (Overman et al, 1994, Brown, 1997, Araujo et al, 1999, Ketterings et al, 2001, Montagu et al, 2005, Pilli et al, 2006(.

The most common allometric model in biomass studies takes the form of the power function (Brown, 1997, Ketterings et al, 2001, Zianis and Mencuccini, 2004, Pilli et al, 2006) as follows:

$$AGB = a. (DBH)^b \qquad (1)$$

Where *AGB* is the total above-ground biomass, *DBH* is the diameter at breast height, *a* and *b* are the scaling coefficient and scaling exponent, respectively. In most cases, the variability of *AGB* is largely explained by the variability of *DBH*. However, the values of *a* and *b* are reported to vary with species, stand age, site quality, climate, and stocking of stands (Ketterings et al, 2001, Zianis and Mencuccini, 2004), and the most common problem with allometric equations as that the raw data are non-linear and tend to be heteroscedastic.

As such, the equation 1 cannot satisfy the relationship between AGB and the DBH. Hence, the standard method for obtaining estimates for the coefficients *a* and *b* ns by the least-squares regression for *D* and *M* measured from destructively sampled trees which represent the diameter range within the stands under investigation (Zianis and Mencuccini, 2004, Pilli et al, 2006), and the form of the model will be as follows (2):

ln (AGB) = In (a) + b. In (DBH) (2)

This transformation is appropriate when the standard deviation of *AGB* at and *DBH* increases in proportion to the value of *DBH* in many cases, log-transformation of real data results in homoscedasticity of the dependent variable *AGB*, a prerequisite for regression methods. However, even though the linear relationship of equation 2 mathematically equivalent to equation 1, they are not identical in a statistical sense (Zianis and Mencuccini, 2004) and this transformation introduces a systematic bias that is generally corrected using a correction factor estimated from the standard error, but it has become conventional practice in allometric studies (Niklas, 2006).

Different types of regression models and combinations of parameters have been used including ordinary least squares on log-transformed data (Overman et al, 1994, Montagu et al, 2005, Pilli et al, 2006, Arevalo et al, 2007), weighted least-squares regression on log-transformed variables (Arevalo et al, 2007), and non-Iinear regression (Saint-Andre et al, 2004, Murali et al, 2005, Arevalo et al, 2007). However, apparently there is no single optimal regression model that can give a good calibration function for the estimation of AGB because the values of coefficients are varied based on many factors (Ketterings et al, 2001 and Zianis and Mencuccini, 2004). Considering this situation, this paper tested different types of regression models for North of Iran including linear and non-linear, but most emphasis was placed on the methods of Brown et al, (1989), Brown et al, (1997) and Chave et al, (2005) as the work of these three researchers used in recently remote sensing researches for estimation of biomass from SAR images (Amini and Sumantyo, 2009, Englhart et al, 2011, Saatchi et al, 2011, Carreiras et al, 2012, Englhart et al, 2012). Finally, proposed method was done with an MLPNN. A multilayer neural network is made up of sets of neurons assembled in a logical way and constituting several layers.

Refernces

Brown, S, Gillespie, A J R, and Lugo, A E, (1989), Biomass Estimation Methods for Tropical Forests with Applications to Forest Inventory Data, Forest Science, 35, pp 881-902.

Calama, R., Barbeito, I., Pardos, M., del Río, M. and Montero, G. 2008. Adapting a model for even-aged Pinus pinea L. stands to complex multi-aged structures. For. Ecol. Manag., 256(6): 1390–1399.

Ketterings, Q M, Coe, R, van Noordwijk, M, Ambagau, Y, and Palm, C A, (2001), Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass an maxed secondary forests, *Forest Ecology and Management*, 146, pp 199-209.

Zianis, D and Mencuccini, M, (2004), On simplifying allometric analyses of forest biomass, *Forest Ecology and Management*, 187, pp 311-332.

Mette, T, Papathanassiou, K, Hajnsek, I, Pretzsch, H and Biber, P, (2004), Applying a common allometric equation to convert forest height from Pol-InSAR data to forest biomass, *Geoscience and Remote Sensing Symposium, 2004 IGARSS 2004 Proceedings 2004 IEEE International*, 1, pp 269-272.

Overman, J P M, Watt, H J L, and Saldarriaga, J G, (1994), Evaluation of Regression Models for Above-Ground Biomass Determination an Amazon Rainforest, *Journal of Tropical Ecology*, 10, pp 207-218.

Araujo, T M, Hnguchn, N, and Junior J Ade C, (1999), Comparison of formulae for biomass content determination in a tropical ram forest site in the state of Para, Brazil Forest Ecology and Management, 117, pp 43-52.

Niklas, K J, (2006), A phyletic perspective on the algometry of plant biomass partitioning patterns and functionally equivalent organ-categories, *New Phytol*, 171, pp 27-40.