BIOMASS ESTIMATION METHODOLOGY FOR FOREST IN BULGAN PROVINCE, MONGOLIA

Tsolmon Altanchimeg(1)(2), Tsolmon Renchin (2), Bayanjargal Darkhijav (2)(4), Philippe De Maeyer(3), Batchuluun Tseveen(4), Bayanmunkh Norovsuren(5)

[1, 3] Ghent University, Krijgslaan 281, Gent, 9000, Belgium
[2, 4] National University of Mongolia, Ikh surguuliin gudamj, Sukhbaatar district, Ulaanbaatar, 14201, Mongolia
[5] Mongolian National University, Ulaanbaatar, Mongolia
Email: tsolmon.altanchimeg@ugent.be; bayanjargal@seas.num.edu.mn; tsolmon@num.edu.mn; philippe.demaeyer@ugent.be; batchuluun@num.edu.mn; n.bayanmunkh@mnun.edu.mn

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ABSTRACT: Forest biomass is plays an important role for the global carbon stock and climate change. Forest carbon storage depends on forest biomass dynamics. The objective of this research is to estimate forest biomass in the Bulgan province, Mongolia. Allometric equations calculate biomass estimates from tree measurements such as diameter at breast height (DBH), height. Backscatter coefficients for vertical transmit and vertical receive (VV), for vertical transmit and horizontal receive (VH) from Sentinel data were used in the study area. We used biomass estimation methodology using ground truth data. The output map from the methodology was compared with VV and VH data. Output map and the relationship between VH data shows a positive result R2=0.65 for birch wood and R2=0.52 for larch wood. The results of our study for improved allometric equations for more accurate forest biomass estimation.

INTRODUCTION

Mongolia is situated in the central and semi-arid north-eastern part of Asia (Choimaa, et al. 2010). The forested area approximately to 8 percent of the total territory of Mongolia (FRDC 2017). The northern part of Mongolia has taiga forest covers, which extend to Siberia in Russia in the North (Sata, Kimura and Kitoh 2007). The Mongolian forests are mainly coniferous, mixed with some broadleaf trees (UN-REDD 2018). Mongolia's dominant tree species is Siberian larch (Larix sibirica Ledeb), which covers 80 % of the country’s forested area (Jamsran 2004). The Mongolian forests have a low productivity and growth and vulnerable. These forests could easily lose their ecological balance with the lowest natural regrowth rate. The boreal forests located in the northern hemisphere, with a harsh continental climate (Altanchimeg, et al. 2019, UN-REDD 2018).

Therefore, science-based advanced technology should be applied to use it in a sustainable way of the forest ecosystems. The current state of the forest (or trees outside forests) can be described in terms of the physical conditions and the factors that have affected the forest in the past, leading to the current state (FAO 2019). The soil moisture plays a considerably important role in ecology and the forest ecosystem (Wen, Lu and Li 2015). The investigation of the soil moisture in different contexts, such as in agriculture, hydrology, meteorology, forestry and natural disaster management is important (Hosseini and Saradjan 2011). The forest biomass is one of the most important parameters for the global carbon stock modeling, yet it can only be estimated with great uncertainty (Mette, et al. 2002). The global forest inventory and an accurate forest (above-ground) biomass estimation still are the critical missing parts in the global climate change discussion (FAO, 2001). However, the Institute of General and Experimental Biology (IGEB) of the Mongolian Academy of Sciences (MAS) has carried out a biomass field survey on the main tree species of Mongolia (Chimidnyam 2017, MET 2016).

Many studies used the remote sensing technique to estimate the forest biomass. Gerylo (2000) developed empirical modes based on Landsat TM reflectance, vegetation indices and collected 106 plots from Fort Simpson, NWT. The retrieval of the forest biomass using science-based satellite image processing and analyzing and has received increasing attention for several reasons during the last decades. Several researchers applied the synthetic aperture radar (SAR) images in order to estimate the forest biomass. Satellite radar is often proposed as the best tool remarkably to overcome the substantial spatial frequency (Woodhouse, et al. 2012).

A study by (Renchin, Ryutaro et Sri Sumantyo 2002) focused on the use of the JERS-1 SAR data to measure various properties, such as the total tree biomass, age and height, by means of a least-square method. This technique included both the modeling approach and empirical estimations of the forest biomass (based on the ground data). In another research, one looked into the models based on a large set of different vegetation indices and the multivariable models. The spectral satellite data include the medium spatial-resolution ranges from 10 to 100 m. More recently, the high spatial resolution data (IKONOS, QuickBird, WordView 2) have shown a high increase in availability. The improved accuracy in biomass estimation is reached when compared with the former two spatial resolutions. The main disadvantage is derived from their spatial resolution, which makes the data processing more time-consuming and thus better suited for local or regional scales (Lu 2006). The biomass estimation equations and models are used to estimate the biomass or the volume of the aboveground tree ingredients based on a diameter at breast height (DBH) and the height data (Kebede et Soromessa 2018). The generality of the allometric equations can be evaluated either by comparing species within a region or by comparing the same species appearing on various sites (Keith, Barrett et Keenan 2000). Most of the allometric models were based on the relation between the aboveground biomass (AGB) and diameter at breast height (DBH) and the total height of the tree (H) measurements. The biomass is found allometrically, generally on a species level, using the DBH alone or where available and generally more accurately, the DBH and height (Goetz et Dubayah 2011).

In this researches objectives are (1) to estimate the forest biomass which is modified from the general equation using ground truth measurements in which the species' specific coefficients of various trees (DBH, height and soil moisture) can be found, (2) a need exists to correlate between the forest biomass and the VV, VH backscattering respectively.

STUDY AREA

The study area Bulgan is one of the northern provinces of Mongolia, located between the latitude 47° 14'-50° 23'N and longitude 101°37'-104° 45'E, in the territory of the Khangai mountain forest steppe zone. The north part (of this province) is characterized by alpine forests, gradually blending in the arid steppe plains of the central Mongolian highlands. Temperatures fluctuate between +38 °C in summer and -49 °C during winter. The average annual temperature amounts to -2.4°C, and the average precipitation ranges from 200 to 350 mm with a discontinuous permafrost. The soil type is sandy with semi desert features in the southern part, while fertile land mainly appears in the north for crop cultivation. According to the Holdridge life zones' system of bioclimatic classification, Bulgan is situated in the boreal dry scrub biome (larch, birch and shrub), where larch measures 86,12 % and birch 13,88 % (FRDC 2016). The Ministry of Environment and Tourism (MET) forest report records 5 species of trees and bushes in the Bulgan province forests and 3 main forest types: Larch (Larix sibirica), Pine (Pinus silvestris), Cedar (Pinus cembra), Birch (Betula) and Poplar (Populus diversifolia).

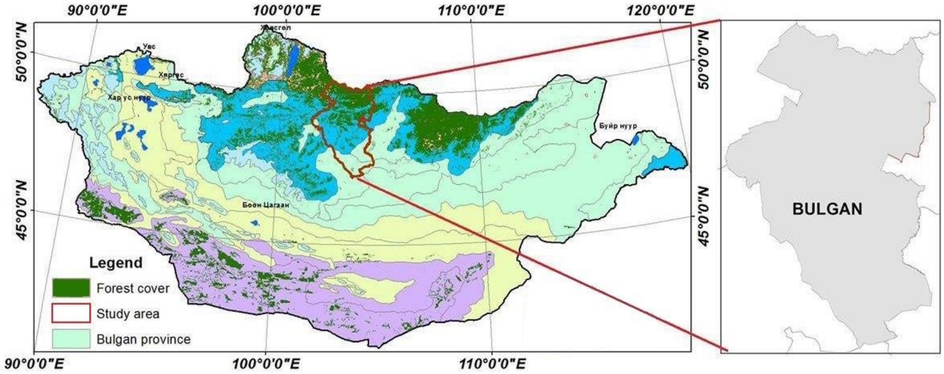

Figure 1. Study area Bulgan province

DATASETS

Ground truth data have been collected 150 samples, which are the soil moisture data, diameter at breast (DBH) and height of the Larch and Birch at Bulgan province in July and August, 2018 year. We collected the wood sampling for leaf presence and type of field plots (size, shape and number) and measured the DBH and height from the Larch and Birch. In Mongolia the forest biomass growth is high in July and August. We used the soil moisture data in this study and measured the soil samples from all the corresponding different types of larch and birch wood loam soil. We used Sentinel-1 C-band SAR data acquired at VV and VH polarisation at 2018 year.

METHODOLOGY

The forest biomass can be estimated using allometric equations. Generally, most of researcher calculating tree biomass used in equation 1 to 3. We selected equation 3 in order to assess the tree trunk biomass in this study area. Where the $\widehat{Y}$ is predicted biomass, D and H represent the diameter (cm) and height (m).

$$\widehat{Y} = aD^2 \quad (1)$$

$$\widehat{Y} = a(D^2H)^2 \quad (2)$$

$$\widehat{Y} = aD^2H^c \quad (3)$$

We assume that tree volume can be calculated following the equation (2), where α, β, ɣ and δ represent the coefficients for the general tree trunk volume, DBH, H, and M (soil moisture), respectively. The value of α varies across the forest types. Therefore, this equation can be used for volume estimation for various tree types.

This study involved the application of the least-squares approach. The resultant tree coefficients can be utilized in the estimation of the total tree biomass. We assumed the following regression model for the tree trunk biomass calculations during this research:

$$\widehat{Y} = \alpha D^{\beta} H^{\gamma} M^{\delta} \quad (4)$$

A logarithm function and least squares approach was used to find the coefficients α, β, ɣ, δ needed to solve the following unconstrained minimization Equation 3. Here we indicate the functions as follows: $\ln\widehat{Y} = Y'$, $\ln\alpha = \alpha'$, $\ln D = D'$, $\ln H = H'$, $\ln M = M'$, F is a convex function reaching its minimum point in equation 3 developed by (Altanchimeg, et al. 2019).

$$F(\alpha', \beta, \gamma, \delta) = \sum_{i=1}^{n}\left[\alpha' + \beta D_i' + \gamma H_i' + \delta M_i' - \widehat{Y}_i'\right]^2 \rightarrow \min \quad (5)$$

The ground truth data was applied the respective coefficients and equations were derived. Table 1 presents the α, β, δ, ɣ coefficients for different trees using the model approach. The total biomass for the forest types, namely larch, and birch, was estimated by using the above equation. In order to incorporate the environmental factors, such as the moisture content of various trees, the equation (4) can be modified using this approach.

ANALYSIS

Most of the allometric models are based on breast height and the total height of the tree measurements. However, this study developed algorithms to estimate the total stand biomass for different shapes of the considered tree trunks. A least-squares method was applied in order to establish the tree trunk shape coefficients, which were then used to assess the total stand biomass by means of ground data. Additionally, the soil moisture was enhanced by supplementary factors. Both figures 2 and figure 3 show a good correlation (R^2 =0.52 and r^2 =0.65) for VH and larch and birch biomass respectively. Therefore, the VH backscatter coefficient for birch biomass is higher than the VH backscatter coefficient for the larch biomass.

RESULTS AND DISCUSSION

In this research, we selected the boreal forested area which is located in the northern part of Mongolia. All four α, β, ɣ, δ coefficients estimated dry weights of the stem and branch biomass in this study. Our study area's predominant forests are characterized by the Siberian larch (Larix sibirica) and birch (Betula platyphylla). This study focused on the total tree biomass, diameter, height and soil moisture content, using a least-squares approach. This model approach (Table1) included both allometric modelling and the empirical estimations of the forest biomass based on the ground data. The allometric equation presented in this study was used to calculate the biomass. Regression models were also approach for larch and birch, the Mongolian dominant trees, with DBH, height, and soil moisture as variables. This model can also be applied to investigate the relationship between trunk biomass and soil moisture content in other forest stands. The tree shape coefficients α, β, δ and ɣ will allow a refinement of the simple approach from former biomass studies. Most of the dependent variables DBH (D in equations), H, M, and variables are obtained through calculations and measurements. These regression equations are related to AGB with the DBH, height (H) and wood density (D) both individually and in combination. Our results show that species-specific tree biomass approach is very important for accurate estimation of the biomass in the northern forest region of Mongolia. We used the backscatter coefficients for vertical transmit and vertical receive (VV), for vertical transmit and horizontal receive (VH) of the SAR images for the validation of the forest biomass in this research. The Sentinel-1B SAR data are very useful for the forest biomass study. The backscatter is determined by a variety of vegetation structural properties that may or may not, correlate with the AGB (in addition to the possible perturbations of the signal from the soil moisture, slope and surface roughness characteristics). The biomass scatter plot from the model and backscattering coefficient VH from the Sentinel-1B satellite is shown in Figure 2 with (R^2=0.65) for birch wood and R^2=0.52 for larch wood. Figure 2 and 3 describe the relation between the VH and VV backscatter larch biomass and birch biomass. From the analysis, we can conclude that there is a high biomass for the samples where the heights measure 20 m or more concerning the larch and birch wood. This method is suitable to evaluate the forest biomass in the region. Overall, the Sentinel-1B SAR imagery relationship showed reasonable results, while the model provides good outcomes for the biomass.

Table 1. Coefficients and volume equations for the forests in the study area

Forest type	α	β	ɣ	δ	Equations
Larch	0.18	1.74	1.05	0.25	$V=0.18D^{1.74}H^{1.05}M^{0.25}$
Birch	0.17	1.81	1.22	-0.33	$V=0.17D^{1.81}H^{1.22}M^{-0.33}$

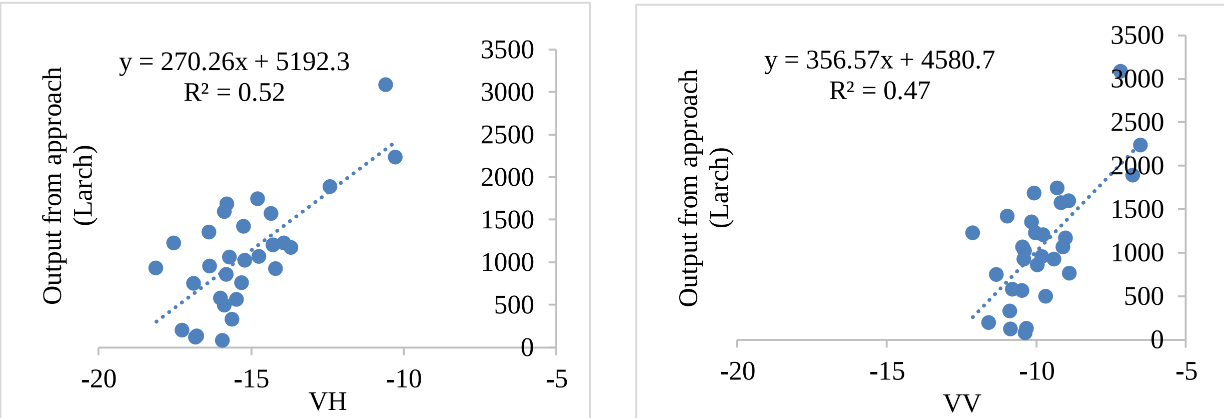

Figure 2. Figure 2 relationship between the Larch biomass and the backscattering coefficient VH and VV. The backscattering coefficient VH result was R^2=0.52.

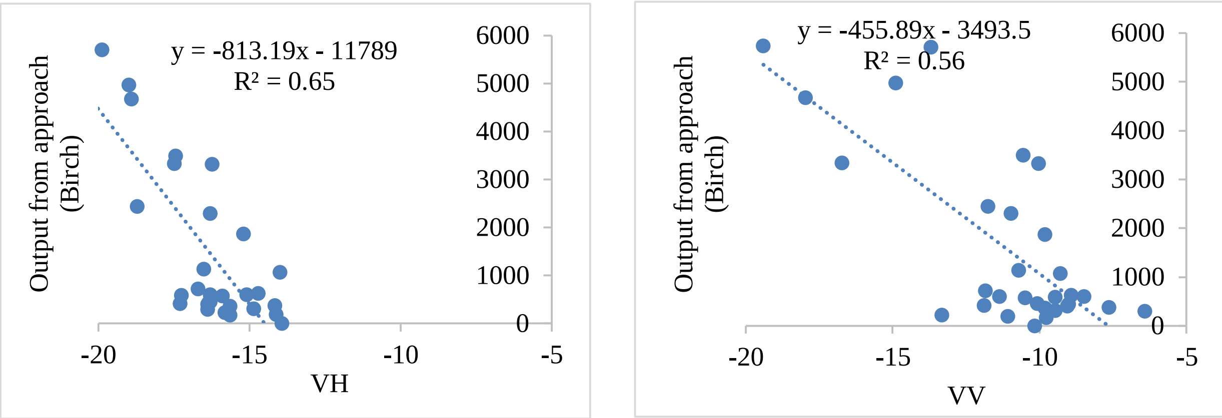

Figure 3. Figure 3 relationship between output from model approach for Birch and VV and VH from Sentinel SAR data. Result was good R^2=0.65, VH and output from model approach for Birch wood.

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