Abstract: The Tibetan forest is one of the most important national forest zones in China. Despite the potentially important role that Tibetan forest will play in the Earth’s future carbon balance and climate regulation, few allometric equations exist for accurately estimating biomass and carbon budgets of this forest. In the present study, allometric equations, both species-specific and generic, were developed relating component biomass (DW) to diameter at breast height (DBH) and tree height (H) for six most common tree species in Tibetan forest. The 6 species were Abies georgei Orr., Picea spinulosa (Griff.) Henry, Pinus densata Mast., Pinus yunnanensis Franch., Cypresses funebris Endl. and Quercus semecarpifilia Smith. The results showed that, both DBH-only and DBH-H based species-specific equations showed a significant fit ($P<0.05$) for all tree species and biomass components. The DBH-only equations explained more than 80% variability of the component biomass and total biomass, adding H as a second independent variable increased the goodness of fit, while incorporating H into the term DBH-H decreased the goodness of fit. However, not all DBH-H combined equations showed a significant fit ($P<0.05$) for all tree species and biomass components. Hence, the suggested species-specific allometric equations for the six most common tree species are of the form $\ln(DW) = c + a \ln(DBH)$. The generalized equations of mixed coniferous component biomass against DBH, DBH-H and DBH-H also showed a significant fit ($P<0.05$) for all biomass components. However, due to significant species effect, the relative errors of the estimates were very high. Hence, generalized equations should only be used when there are too many different tree species, or there is no species-specific model of the same species or similar growth form in adjacent area.

Keywords: Tibetan forest; Allometric models; Species-specific; Mixed coniferous forest; Model evaluation

Introduction

As there are about 40% of belowground carbon (C) and 80% of all aboveground terrestrial C stored in forest biomass (Dixon et al. 1994; Goodale et al.
2002), forests are considered an important sink for atmospheric CO$_2$ and provide a great potential for temporarily storing atmospheric CO$_2$ in terrestrial ecosystems (Peichl and Arain 2007). Hence, estimation, reporting and accounting of forest biomass and C stock is of great importance for climate change researches (Alves et al. 2010; Chave et al. 2005, 2014; Joseph et al. 2013; Sandeep et al. 2016).

It has been widely reported that allometry is the most common and reliable method for estimating biomass, net primary production and biogeochemical budgets in forest ecosystems (Gower et al. 1999; Liu et al. 2015; Wang 2006). Site-and-species-specific equations are more accurate for site-based predictions (Liu et al. 2015; Paul et al. 2013) while generalized models have a great potential for large-scale carbon budgets derived from inventory data (Anitha et al. 2015; Chave et al. 2005, 2014; Wang 2006; Sandeep et al. 2016). The most commonly used method for developing allometric models is to relate total tree biomass or its components such as foliage, branch, stem and root to diameter at breast height (DBH) or both DBH and tree height (H) using log-transformed data through least squares regression (Bi et al. 2004; Chave et al. 2005; Gower et al. 1999; Ketterings et al. 2001; Nelson et al. 1999; Wang 2006). However, as H is much more difficult and time-consuming but less accurate to be determined than DBH (Gower et al. 1999; Wang 2006), tree height is rarely used in practice (Bond-Lamberty et al. 2002; Martin et al. 1998; Wang 2006). It was suggested that H should only be included as a driving variable if it is accurately measured and only when using the species-specific models (Nelson et al. 1999). As for the generalized regression models, wood densities (WD) and forest type were two most important predictive variables other than DBH (Chave et al. 2005), ignoring variations in wood density would result in poor overall prediction of the stand aboveground biomass (Baker et al. 2004; Chave et al. 2005). Furthermore, other site-specific factors such as stand age, tree density, soil moisture, nutrients, light, topography, and disturbance may also affect tree allometry (Peichl and Arain 2007). A number of literatures have sought to find the ‘best’ biomass regression model, but most of these studies constructed complex models with too many fitted parameters, which disobeyed the principle of parsimony (Chave et al. 2005).

The Tibetan forest, one of the most important national forest zones in China, is not only important in protecting local eco-environment, but also playing an important role in national carbon budgets (Wang et al. 2014). Despite the potentially important role that Tibetan forest will play in the Earth’s future C sinks, C balance and climate regulation, the carbon pools and fluxes of this forest have not been accurately quantified from ecosystem process-based data (Fang et al. 2001). Few biomass allometric equations exist for tree species in Tibetan forest (Luo 1996), the relative errors in biomass estimates among these allometric equations are unknown for Tibetan forest tree species. The quantification of these errors will facilitate to choose proper allometric equations for various ecological researches and silvicultural objectives. In the present study, species-specific allometric equations of 6 most common tree species were developed for biomass estimation. Relationships were tested for biomasses such as foliage, branch, stem, root and total biomass against DBH, DBH-H and DBH-H. Three hundred and eighty one sample trees from five coniferous species were then combined to develop a set of generalized allometric equations for mixed coniferous trees in Tibetan forest ecosystems. Hence, the objective of this study was (1) to develop species-specific allometric equations for six most common tree species and the generic allometric equations for the mixed coniferous species in Tibetan forest; (2) to quantify and compare the predicted errors and (or) precision of the models, hence to select proper allometric equations for accurately quantifying the carbon pools and fluxes of Tibetan forest.

1 Materials and Methods

1.1 Site description

This study was conducted in the Nyingchi and Qamdo regions, which are located on the southeastern Tibetan Plateau. The two regions are adjacent, with an area of $23.48 \times 10^4$ km$^2$ and a forest coverage of 25.70% (Wang et al. 2014). This area is characterized by a semi-humid climate,