

# Cover as a simple predictor of biomass for two shrubs in Tibet



Lin Zhang<sup>a,b,\*</sup>, Guangshuai Cui<sup>a,c</sup>, Wei Shen<sup>a</sup>, Xinsheng Liu<sup>d</sup>

<sup>a</sup> Key Laboratory of Alpine Ecology and Biodiversity, Institute of Tibetan Plateau Research of Chinese Academy of Sciences, Beijing 100101, China

<sup>b</sup> CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing 100101, China

<sup>c</sup> University of Chinese Academy of Sciences, Beijing 100039, China

<sup>d</sup> College of Tourism and Territorial Resources, Jiujiang University, Jiujiang, Jiangxi 332005, China

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## ABSTRACT

Knowledge of the quantitative relationship between plant cover and its corresponding biomass for shrubs is not well known, especially for those on the Tibetan Plateau. Based on investigations of 35 sites, 90 plots and 95 standard individuals for two typical shrub species (*Rhododendron nivale* Hook. f. and *Sophora moorcroftiana* (Benth.) Baker) across Tibet, we developed allometric models for biomass estimation from measurements of crown diameter and/or height. We found that the parameters of crown projection area (CPA), height and their product (volume) were all significantly ( $p < 0.01$ ) correlated with dry mass of different organs for both species at individual level. The CPA rather than volume best predicted aboveground dry mass. This is because that the bulk density declined significantly with increasing plant height, leading to the inappropriateness for plant height itself being employed as a parameter in biomass estimation, especially for shrubs in smaller size groups. At community level, cover was tightly correlated with the aboveground, belowground and total biomass ( $R^2 = 0.97\text{--}0.99$ ). Therefore, biomass for the two shrubs can be simply estimated by measuring plant cover, which enables rapid estimation of shrubland carbon stock at large scales by using satellite data and repeated experiments over time. This non-destructive method using cover to estimate shrub biomass can be applied not only in arid ecosystems but also in alpine or subalpine environment.

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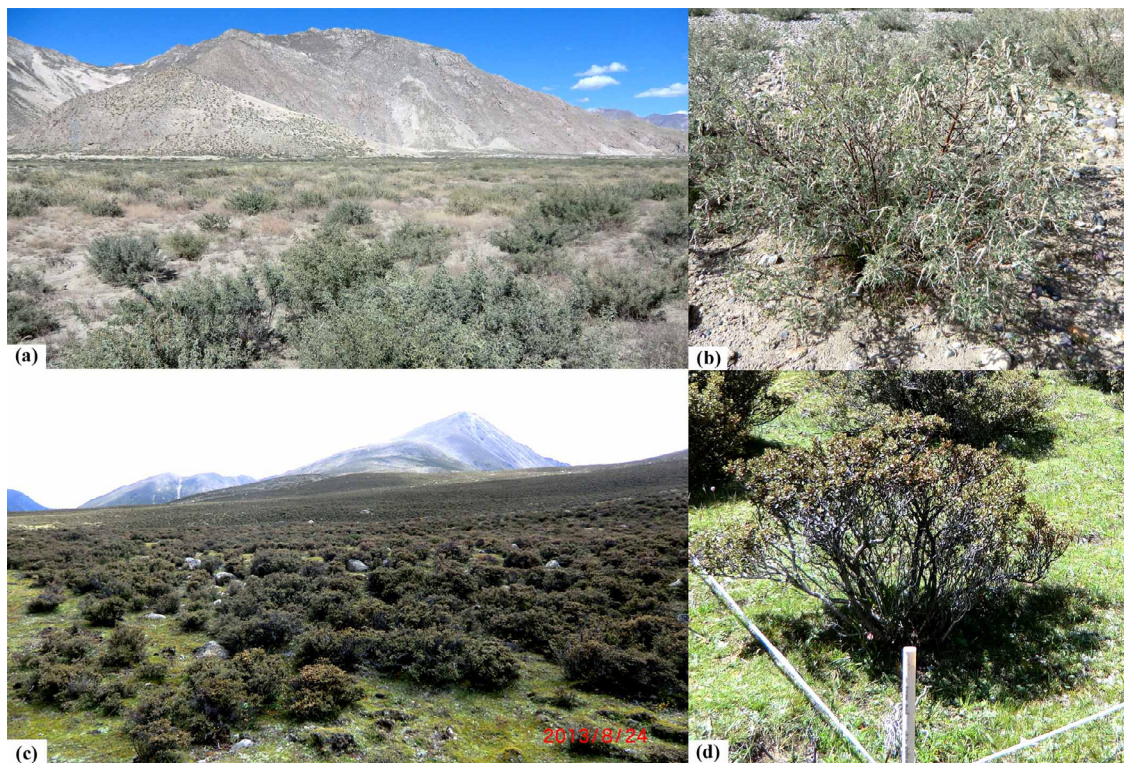
## 1. Introduction

Terrestrial vegetation biomass has been being extensively explored across tropical rain forests to arctic tundra throughout the world since 1960s (e.g., Lieth and Whittaker, 1975; Luo et al., 2002; Hudson and Henry, 2009; Lv et al., 2010), and the accurate estimation of biomass is still regarded as a key issue in the study of ecosystem carbon cycle. Classical biomass investigation generally encompasses the measurements of stem diameter (diameter at breast height or basal diameter) and height, allowing us to estimate biomass for different organs and the sum by using allometric equations for each individual within a representative plot (Kimura, 1981; Clark et al., 2001). However, this method is only appropriate for woody species with evident upright main stems and is not the case applicable for shrubs or scrubs without main stems. Instead, plant cover, calculated via measurement of

crown diameter rather than stem diameter, is usually employed as an important parameter to estimate biomass or dry matter production (e.g., Wang, 1994; Montès et al., 2004; Zeng et al., 2006, 2007; Flombaum and Sala, 2007; Elzein et al., 2011; He et al., 2011; Hasen-Yusuf et al., 2013; Ruiz-Peinado et al., 2013; Liu et al., 2015). Among these studies, many applied plant volume, i.e. the product of plant cover and height to deduce biomass at individual level (Zeng et al., 2006; He et al., 2011; Hasen-Yusuf et al., 2013). But only a few took cover as a single variable to predict biomass at community level. For example, Montès et al. (2004) founded regression equations between aboveground dry mass and plant cover for 3 Mediterranean woody species at individual level and then estimated aboveground biomass using plot coverage derived from photographing systems while Flombaum and Sala (2007) directly employed coverage to predict aboveground biomass for shrubs and grasses on Patagonian steppe at community level. Flombaum and Sala (2009) further emphasized that plant cover could be a good predictor of aboveground biomass in arid ecosystems. However, we are still unaware whether plant cover can be used to deduce biomass for typical shrubs on the Tibetan Plateau because the shrubs there suffer from the combined effect of low temperature and rainfall that is quite different

\* Corresponding author at: Institute of Tibetan Plateau Research, Chinese Academy of Sciences, 16 Lincui Road, Chaoyang District, Beijing 100101, China. Tel.: +86 10 84097055.

E-mail address: [zhanglin@itpcas.ac.cn](mailto:zhanglin@itpcas.ac.cn) (L. Zhang).



**Fig. 1.** The physiognomy and representative individuals of (a, b) *Sophora moorcroftiana* and (c, d) *Rhododendron nivale*.

from the above situations. Further, the available data about shrub biomass on the plateau are scarce (Hu et al., 2006; Gao et al., 2014), especially those contained information of both aboveground and belowground measurements.

Shrub is distributed widely across almost the whole Tibet, and covers a large area of about  $13 \times 10^6$  ha (The Editorial Committee of China Vegetation of the Chinese Academy of Sciences, 2000). From a viewpoint of landscape, the shrubs in Tibet mainly consist of alpine shrubs and arid-valley shrubs. Among these, *Rhododendron nivale* is the most common alpine shrub generally occurring above 4300 m a.s.l. in east and south of Tibet, while *Sophora moorcroftiana* mainly dominates in the arid valley of the Yarlung Zangbo River in centre Tibet. As the most representative alpine shrub and xerophytic shrub on the plateau, they generally form typical single woody-dominant communities and add up to cover above 60% of the total area for shrub ecosystems in Tibet. In view of their large distribution area and slow growth rate under low temperature and arid conditions, it is of great importance and necessity to set up species-specific allometric relationships between plant dry mass and some easy-measured parameters like crown diameter and/or height so as to estimate plant biomass accurately by non-destructive measurements. However, according to our knowledge so far, no allometric models have been reported for these species on the plateau.

Recently, study on spring vegetation phenology on Tibetan Plateau during 2000–2011 by Shen et al. (2014) indicated that the growing season length tends to extend where shrub ecosystems exactly dominate, i.e., the growth potential for shrubs is assumed to increase in a warming future. Therefore, understanding the current situation and pattern of shrub biomass on the plateau is of great necessity under scenarios of climate change. In this paper, based on investigation of 90 plots and measurements of biomass allocation for 95 individuals for the two shrub species across Tibet, we aimed to (1) develop allometric models to estimate foliage, stem, root, and aboveground and total biomass from measurements of

crown diameter and/or height at individual level, and consequently disclose which parameter is the best indicator of shrub biomass; (2) estimate aboveground and belowground biomass at community level.

## 2. Data and methods

### 2.1. Study sites and species

This study was conducted in centre and east Tibet. *S. moorcroftiana* (SM) dominates in arid valleys of the upper and middle reaches of Yaluzanbu River in centre Tibet where the climate is warm and dry, with a mean annual air temperature of 4–9 °C and annual precipitation of 250–450 mm. *R. nivale* (RN) is distributed widely with alpine meadow, forming a typical alpine shrub-meadow landscape in east Tibet where the climate is relative cold and humid, with a mean annual air temperature of –4–6 °C and annual precipitation of 350–900 mm.

SM is a deciduous thorny shrub belonging to Leguminosae. Usually 10–30 aboveground stems may sprout from a same rootstock, forming a hemispherical clump with height ranging between 10 and 60 cm (Fig. 1a and b), and occasionally reaching 100 cm or more. As a deep-rooted woody species, SM plays an important role in determining the dynamics of the herbaceous layer facilitating their growth in its understory. RN, generally 10–45 cm tall, is an alpine evergreen shrub with quite irregular and ramified stems (Fig. 1c and d). In relatively humid regions like the Sergyma Mountains in southeastern Tibet, individuals of RN can be as tall as 70–90 cm. Both species flower during May to June.

### 2.2. Plots investigation and sampling methods

During August of 2011 and 2012, we selected 15 sites (28.05–31.64° N, 91.25–98.46° E, 4300–4900 m a.s.l.) along the highways in the south and east of Tibet and another 15 sites

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