



## Original article

# Pattern and dynamics of biomass stock in old growth forests: The role of habitat and tree size



Zuoqiang Yuan<sup>a</sup>, Antonio Gazol<sup>b</sup>, Xugao Wang<sup>a</sup>, Fei Lin<sup>a,\*</sup>, Ji Ye<sup>a</sup>, Zhaochen Zhang<sup>a,c</sup>, YanYan Suo<sup>a,c</sup>, Xu Kuang<sup>a,c</sup>, Yunyun Wang<sup>a,c</sup>, Shihong Jia<sup>a,c</sup>, Zhanqing Hao<sup>a</sup>

<sup>a</sup> Key Laboratory of Forest Ecology and Management, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, 110164, PR China

<sup>b</sup> Instituto Pirenaico de Ecología, IPE-CSIC, Avenida Montañana, 1005, Zaragoza, Spain

<sup>c</sup> University of Chinese Academy of Science, Beijing 100049, PR China

## ARTICLE INFO

## Article history:

Received 14 December 2015

Received in revised form

12 June 2016

Accepted 15 June 2016

## Keywords:

Forest dynamics

Carbon sequestration

Tree size

Growth

Mortality

Spatial variation

## ABSTRACT

Forest ecosystems play a fundamental role in the global carbon cycle. However, how stand-level changes in tree age and structure influence biomass stock and dynamics in old-growth forests is a question that remains unclear.

In this study, we quantified the aboveground biomass (AGB) standing stock, the coarse woody productivity (CWP), and the change in biomass over ten years (2004–2014) in a 25 ha unmanaged broad-leaved Korean pine mixed forest in northeastern China. In addition, we quantified how AGB stock and change (tree growth, recruitment and mortality) estimations are influenced by the variation in habitat heterogeneity, tree size structure and subplot size.

Our analysis indicated that Changbai forest had AGB of 265.4 Mg ha<sup>-1</sup> in 2004, and gained 1.36 Mg ha<sup>-1</sup> y<sup>-1</sup> between 2004 and 2014. Despite recruitment having better performance in nutrient rich habitat, we found that there is a directional tree growth trend independent of habitat heterogeneity for available nutrients in this old growth forest. The observed increases in AGB stock (~70%) are mainly attributed to the growth of intermediate size trees (30–70 cm DBH), indicating that this forest is still reaching its mature stage. Meanwhile, we indicated that biomass loss due to mortality reduces living biomass, not increment, may be the primary factor to affect forest biomass dynamics in this area.

Also, spatial variation in forest dynamics is large for small sizes (i.e. coefficient of variation in 20 × 20 m subplots is 53.2%), and more than 90 percent of the inherent variability of these coefficients was predicted by a simple model including plot size. Our result provides a mean by which to estimate within-plot variability at a local scale before inferring any directional change in forest dynamics at a regional scale, and information about the variability of forest structure and dynamics are fundamental to design effective sampling strategies in future study.

© 2016 Elsevier Masson SAS. All rights reserved.

## 1. Introduction

Forest ecosystems play a major role in the global carbon budget since they harbor important above- and below ground biomass stocks and have a strong carbon sequestration potential (Dixon et al., 1994; Pan et al., 2011; Fang et al., 2014). Whether or not forests will be able to continue to sequester additional carbon is a key concern in an era of global change (McMahon et al., 2010; Dai

et al., 2013; Anderson-Teixeira et al., 2015). Recent studies have shown growth enhancement over the past several decades across many forest types due to environmental changes, such as elevated CO<sub>2</sub> and nitrogen deposition (Silk et al., 2013; McMahon et al., 2010; Hember et al., 2012; Fang et al., 2014; Wu et al., 2014). For example, Fang et al. (2014) demonstrated that about 8.4–21.6% of biomass carbon sink in Japan's forests was induced by climatic changes from 1980 to 2005, and simultaneously reported that the growth enhancement differs among forest types, age classes, and regions.

Yet, despite significant effect of environmental changes on forest growth at the regional and global scale (Phillips et al., 1998; Malhi et al., 2006; Chave et al., 2008; Toledo et al., 2011), soil nutrients

\* Corresponding author: Fei Lin.

E-mail address: [linfei@iae.ac.cn](mailto:linfei@iae.ac.cn) (F. Lin).

and water availability may be the stronger driver of spatial variation in biomass increment at local scales (Oren et al., 2001; DeWalt and Chave, 2004; Paoli et al., 2008). From an ecological perspective, nutrient rich soil will support a greater growth than poor soils in accordance with the idea that soil nutrient supply was the main limiting factor for primary production (Chase and Leibold, 2003). But, higher soil nutrients could lead to lower biomass with faster rates of turnover on rich sites because mortality rates could increase faster than growth rates on rich soils (Russo et al., 2005; Paoli et al., 2008). Because stand biomass accumulation is the sum of gain and loss, the relative importance of two processes will have contrasting implications for the magnitude and trend of forest biomass storage changes (Chao et al., 2009; Holzwarth et al., 2013). For example, long-term studies in several old growth forests have indicated that biomass accumulation is close to zero or negative as a result of biomass loss due to mortality is roughly equal to or higher than production of surviving trees (DeBell and Franklin, 1987; Chave et al., 2003; Taylor and MacLean, 2005; Feeley et al., 2007; Xu et al., 2012). Alternatively, Eisen and Barker Plotkin (2015) showed that biomass increase in northeastern U.S. forests was due to the increase in size and low disturbance of large dominant trees. Despite these efforts, more empirical studies are needed to examine whether forests exhibit dramatic difference in growth and/or mortality rates across local habitats, and these eventually lead to differences in forest directional change trend at local scale (Chave et al., 2003; McMahon et al., 2010; Wang et al., 2011; Xu et al., 2012).

Moreover, it is generally accepted that the ability of forests to sequester carbon decreases with size (or age), and that old-growth forests become carbon neutral (Carey et al., 2012). However, empirical studies have proved that large, “old” trees do not act simply as senescent carbon reservoirs but actively fix larger fraction of carbon compared to smaller trees (Zhou et al., 2006; Luysaert et al., 2008; Silk et al., 2013; Stephenson et al., 2014). For instance, a literature review by Luysaert et al. (2008) reported that forests older than 200 years sequestered on average  $2.4 \text{ Mg C ha}^{-1} \text{ yr}^{-1}$  in AGB though about 20% variation existed. Large trees have recently started to attract the attention of ecologists not simply because they are becoming increasing rare (Lindenmayer et al., 2012), but because they contribute to forest carbon storage and the accumulation rates increases continuously with tree size (Zhou et al., 2006; Luysaert et al., 2008; Silk et al., 2013; Stephenson et al., 2014). In a recent study, Slik et al. (2013) showed that large trees were responsible for the great amount of biomass variation across the tropics. Chave et al. (2003) suggested that stems commonly defined as large, that is above 70 cm in diameter (Clark and Clark, 1996), only accounted for 0.22% of overall and contributed over 13% of the AGB increment on Barro Colorado Island (BCI) plot. In particular, small trees (e.g.  $\text{DBH} < 10 \text{ cm}$ ) are generally excluded from some studies, or a few small stems are directly measured in very small proportion of larger plots (Zhou et al., 2011; Vincent et al., 2015). Thus, it remains unclear the relative importance of tree size class in shaping forest carbon accumulation over time, which is critical for predicting future carbon sequestration in a given forest ecosystem (Silk et al., 2013).

Much of our knowledge about forest structure, dynamics and demography has come from observations of permanent plots (Gilbert et al., 2010; McMahon et al., 2010; Wagner et al., 2010; Anderson-Teixeira et al., 2015). These plots are the empirical basis for the current debate on forest dynamics that has been focused on the detection of recent changes in AGB fluxes and stocks (Lewis et al., 2014; Malhi et al., 2006; Chave et al., 2008). Unlike standing stock, it will need considerably more sampling effort to obtain a reliable estimate of AGB dynamics (e.g. tree growth, mortality and

recruitment) as it represents the intersection and difference of two measurements (Chave et al., 2003; Wagner et al., 2010). Subtle changes (e.g. growth, recruitment and mortality) may be missed by insufficient sample size resulting from ignoring great local spatial variation (Fox, 2001; Valencia et al., 2009). Thus, large-scale permanent plots may be required to decipher unambiguous trends in natural forest dynamics.

In the present study, we used a 25 ha fully mapped forest plot where all trees with a  $\text{DBH} \geq 1 \text{ cm}$  have been tagged, identified, measured in 2004 and re-surveyed in 2014. We investigate the spatial variation and short-term dynamics (2004–2014) of AGB in 25 ha old-growth temperate forest plot in northeastern China. Specifically, we aim to answer the following questions: (1) Do the forest in different habitats have similar directional change (growth, recruitment and mortality) in this old growth forest? We expected significant differences in AGB change because trees growing in nutrient rich habitat area expected to have better performance. (2) Do large trees contribute more carbon sequestration than medium or smaller trees? We expected the AGB gaining mainly come from the big trees due to its great AGB stock. (3) Are more sampling efforts needed to estimate the forest AGB dynamics than stock? In other words, whether the inherent spatial variations of forest AGB dynamics larger than stock?

## 2. Materials and methods

### 2.1. Study site

The Changbai Mountain Nature Reserve (CMNR) in northeastern China is the largest protected temperate forest in the world (Hao et al., 2007; Yang et al., 1985, Fig. 1). Our study site is located in a core zone of broad-leaved Korean pine mixed forest ( $42^{\circ}23' \text{N}$  and  $128^{\circ}05' \text{E}$ ), with mean canopy tree age of 280 years (Yuan et al., 2012; Hao et al., 2007). This area has a temperate continental climate with long, cold winters and warm summers. Rainfall averages  $700 \text{ mm yr}^{-1}$ , most of which occurs from June to September ( $480\text{--}500 \text{ mm}$ ). Mean annual temperature is  $2.8^{\circ} \text{C}$ , with a January mean of  $-13.7^{\circ} \text{C}$ , and a July mean of  $19.6^{\circ} \text{C}$  (Liu, 1997; Yang et al., 1985).

This area was rarely disturbed by fire due to the humid climate environment and steady protection policy by local government. The natural disturbance comes from the strong wind in spring and winter season (Zhou et al., 2011).

### 2.2. Plot survey and biomass calculation

The broad-leaved Korean pine (*Pinus koraiensis*) mixed forest is the dominant vegetation type in northeastern China, which is well-known for high species richness and a unique species composition for temperate forests (Stone, 2006). In the summer of 2004, a 25-ha ( $500 \times 500 \text{ m}$ ) plot was established, henceforth referred to as the CBS (Changbaishan) plot, representative of forests in the area, in the core zone of the CMNR to avoid the influence of human activities. All free-standing woody stems  $\geq 1 \text{ cm}$  in trunk diameter were mapped, measured and identified to species. The first plot census started in July 2004 and ended in September 2004, and the second census was carried out in July and August of 2014. The first census found 36,907 individuals (not including branches) belonging to 52 species to 32 genera and 18 families while 30,543 individuals belonging to 51 species were surveyed in 2014. This work was conducted based on Forestry Standards “Observation Methodology for Long-term Forest Ecosystem Research” of People’s Republic of China (LY/T 1952–2011). Our previous studies have shown that the forest species composition and structure of CBS plot is similar with results from other forests in this area (Song et al., 2014; Zhao et al.,

Download English Version:

<https://daneshyari.com/en/article/6297324>

Download Persian Version:

<https://daneshyari.com/article/6297324>

[Daneshyari.com](https://daneshyari.com)