

主 論 文 の 要 約

論文題目 : **Distribution patterns and aboveground net primary productivity of bamboos in northern Laos**
(ラオス北部におけるタケ類の分布様式と地上部純一次生産速度)

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Bamboos (Bambusoideae, Poaceae) are highly prevalent plants and 1642 species are distributed worldwide. They have been closely associated with the daily lives of local people and used in various ways (Figure 1). Due to recent development of engineering technology and commercial uses of bamboos, the global market is rapidly growing. As bamboos also have important functions such as soil erosion control, high carbon sequestration ability, rehabilitation of degraded lands, and preservation of biodiversity, they are attracting increasing attention. Despite such socioeconomic and ecological importance and keen interest in bamboos, taxonomic studies on bamboos remain insufficient and the difficulty of bamboo species identification has caused a confused species classification and thus hindered further ecological research including distribution patterns, its associated environmental factors, and the estimation of biomass and net primary productivity (NPP). Since northern Laos includes areas with a wide range of altitude and is located near the bamboo diversity hotspot of southern China (Figure 2), high species richness of bamboos is expected. However, taxonomic information of bamboos is extremely limited in the region and inventory research has not been carried out yet in six of eight provinces of northern Laos. On the other hand, bamboos are one of dominant plants in fallows, which are major land-use type in the region. Northern Laos is an optimum study site to examine distribution patterns and to estimate carbon sequestration potential of bamboos.

The objectives of this study were to improve the bamboo taxonomic information and to examine whether bamboos make a significant contribution to carbon sequestration in northern Laos, focusing on aboveground parts as a first step. In Chapter II, I listed up bamboo species that are distributed in northern Laos and examined the distribution patterns of the bamboo species and its associated environmental factors. In Chapter III, I developed species-specific allometric equations to estimate aboveground biomass for 11 common and widely distributed

bamboos in northern Laos. In addition, given the difficulty in identifying bamboo species and coexistence of multiple bamboo species in fallows, multi-species allometric equation, which is applicable for biomass estimation irrespective of bamboo species, was also developed. In Chapter IV, using the allometric equations developed in Chapter III and previous study, I estimated aboveground biomass (AGB) and aboveground NPP of five major bamboo species in northern Laos. To explore the factors that influence potential carbon sequestration rates, monthly variation in aboveground NPP and its components were also assessed. In conclusions, I discussed the significance of bamboo inventory in northern Laos in Chapter V. I also estimated aboveground carbon stock and sequestration rate in the entire northern Laos. Lastly, I addressed several points to be challenged in future studies of bamboos in the region.

In Chapter II, a total of 63 bamboo species or morpho-species including 17 genera were identified among the specimens. Eight of these species were newly recorded in Laos. Thirteen bamboo species were classified as unidentified species. The interview survey generated 914 records, representing 42 species of wild bamboos and 30 species of planted bamboos. Five wild, and one planted bamboo species were widely distributed; numerous bamboo species were rarely recorded and some showed specific distribution patterns. Elevation had a negative effect on wild bamboo species richness and the species composition of wild bamboos was significantly correlated with elevation and air temperature. My results indicate high bamboo species richness in northern Laos, and the utility of a combination of interview surveys and specimen sampling to elucidate the distribution patterns of wild bamboos. The environmental factors associated with bamboo species richness and composition identified here corresponds in part to those of trees in tropical and subtropical regions.

Most species-specific allometric regressions developed for 11 common bamboo species showed significant correlations in Chapter III. In addition, the multi-species allometric relationships for culm biomass and AGB showed particularly high correlations (Figure 3), indicating the usefulness of multi-species allometric equations to estimate bamboo biomass in mixed-species bamboo forests with unknown bamboos and bamboos without species-specific allometric equations. The generally small differences in the fitness of AGB estimates between DBH (diameter at breast height) and DBH^2H indicate that DBH is a practical explanatory variable for biomass estimation.

In Chapter IV, I found large variations in the AGB and it was highest in *Indosasa sinica* (59.87 Mg ha⁻¹) and lowest in *Cephalostachyum virgatum* (11.54

Mg ha⁻¹) among the five bamboo species examined. The sympatric distribution of multiple bamboo species at the study sites may have suppressed the AGB in four of the five studied species. The aboveground NPP estimates were between 3.43 and 14.25 Mg ha⁻¹ yr⁻¹; those for *Dendrocalamus membranaceus* (8.20 Mg ha⁻¹ yr⁻¹) and *I. sinica* (14.25 Mg ha⁻¹ yr⁻¹) were comparable to mean global estimates for temperate evergreen forests (8.78 Mg ha⁻¹ yr⁻¹) and tropical moist forests (10.56 Mg ha⁻¹ yr⁻¹). High culm recruitment rates (15.20–23.39% yr⁻¹) were major contributors to aboveground NPP estimates. Seasonal patterns of aboveground NPP were largely influenced by the phenology of the new culms. In the four sympodial bamboo species, new culms began to emerge following the onset of persistent rainfall, mainly in July and August. However, the sprouting of new culms in the monopodial species *I. sinica* followed a trend of increasing temperatures, mainly in March and April. Thus, my results indicate that bamboos have considerable potential for sequestering carbon in northern Laos, but that this potential may be impacted by climate change.

The high species richness of bamboos in northern Laos is likely due to the emergence of both paleotropical and temperate woody bamboos. Combining my bamboo list with previous ones, I found that Laos has the fourth highest in bamboo species richness among countries in the Asia-Pacific region in Chapter V (Figure 4). However, considering that inventory studies of bamboos has not been carried out yet in some districts in northern Laos and several provinces in central and southern Laos and that numerous bamboos remain morpho-species or unidentified species, the continuous improvement of bamboo taxonomy is still needed in Laos. Estimated aboveground carbon stock of bamboos in northern Laos, using results in Chapter III and IV and previous estimates, was a total of 120.24 TgC (41.44 TgC in fallows and 78.79 TgC in conservation forests). The estimate for aboveground NPP of bamboos in fallows in northern Laos was 20.42 TgC yr⁻¹. Compared to the estimate of Moso bamboos in China (27.53 TgC yr⁻¹), carbon sequestration capability in fallows of northern Laos is smaller than that in Moso bamboo forests of China, while substantial amount of carbon seems to be fixed in the region. Further studies on aboveground NPP quantification are required to evaluate the carbon sequestration function of bamboos and compare its potential among bamboo species and regions. I focused on aboveground biomass and NPP in this study, however, belowground parts should be also examined to comprehensively quantify the carbon sequestration rate of bamboos, which allocate considerable amount of biomass to roots and rhizomes.



Figure 1 Pictures of bamboo uses by local people. Culms are used for house construction (a), traditional musical instrument (b), furniture (c), and various daily containers (d). Some edible bamboo shoots are sold in a local market (e) and bamboos are sometimes planted as ornamental plants (f).

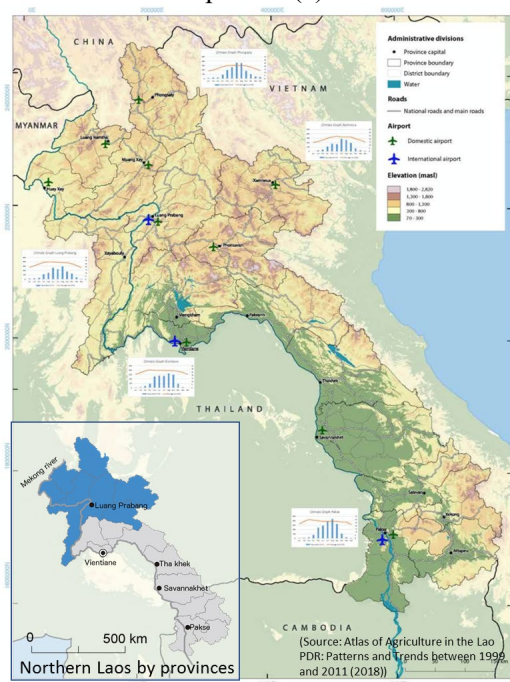


Figure 2 Location of Laos and northern Laos.

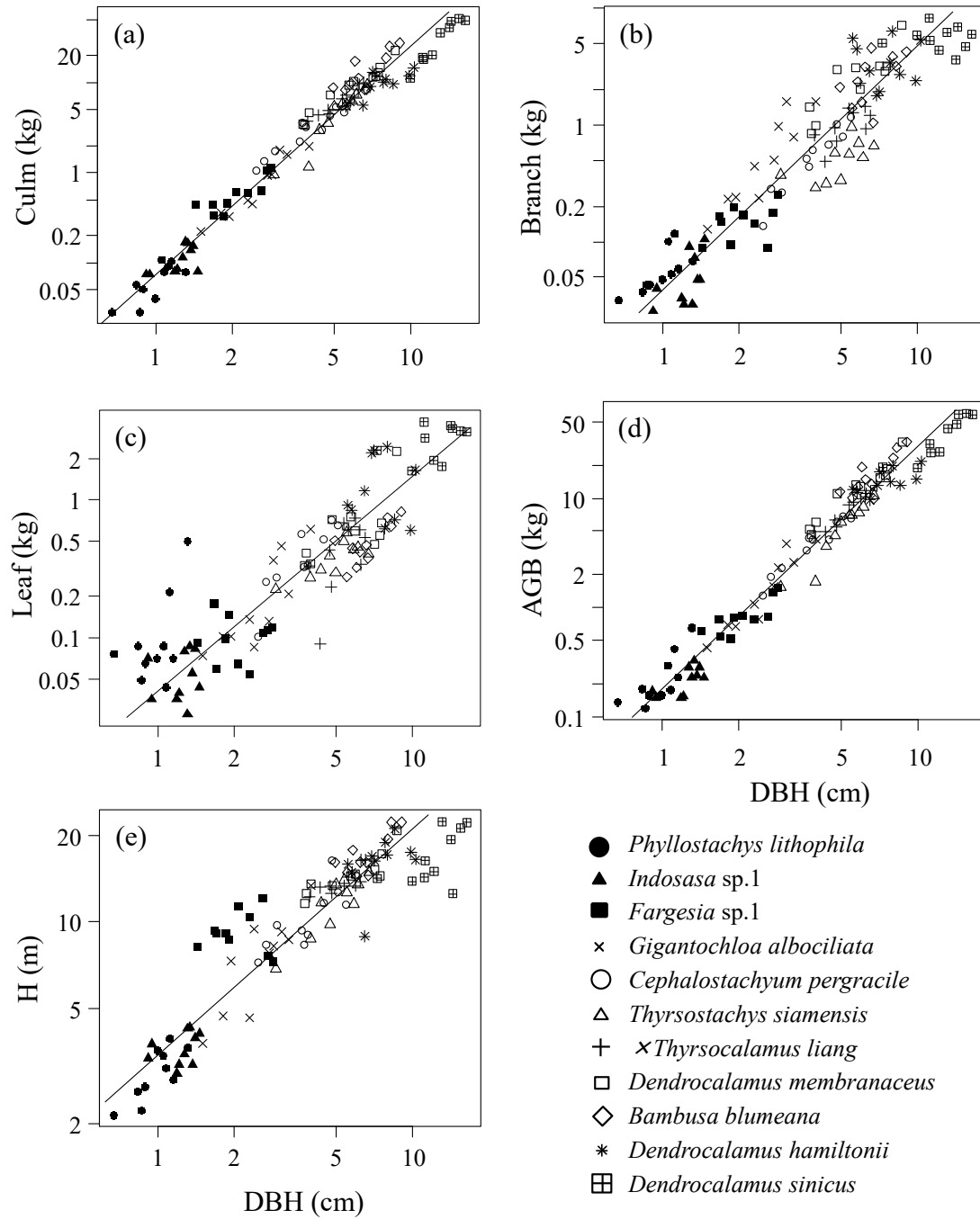


Figure 3 Allometric relationships between diameter at breast height (DBH) and (a) culm biomass, (b) branch biomass, (c) leaf biomass, (d) aboveground biomass (AGB), and (e) culm length (H) for 11 bamboo species in northern Laos. The regression lines for the pooled data are shown (Xayalath et al. 2019).

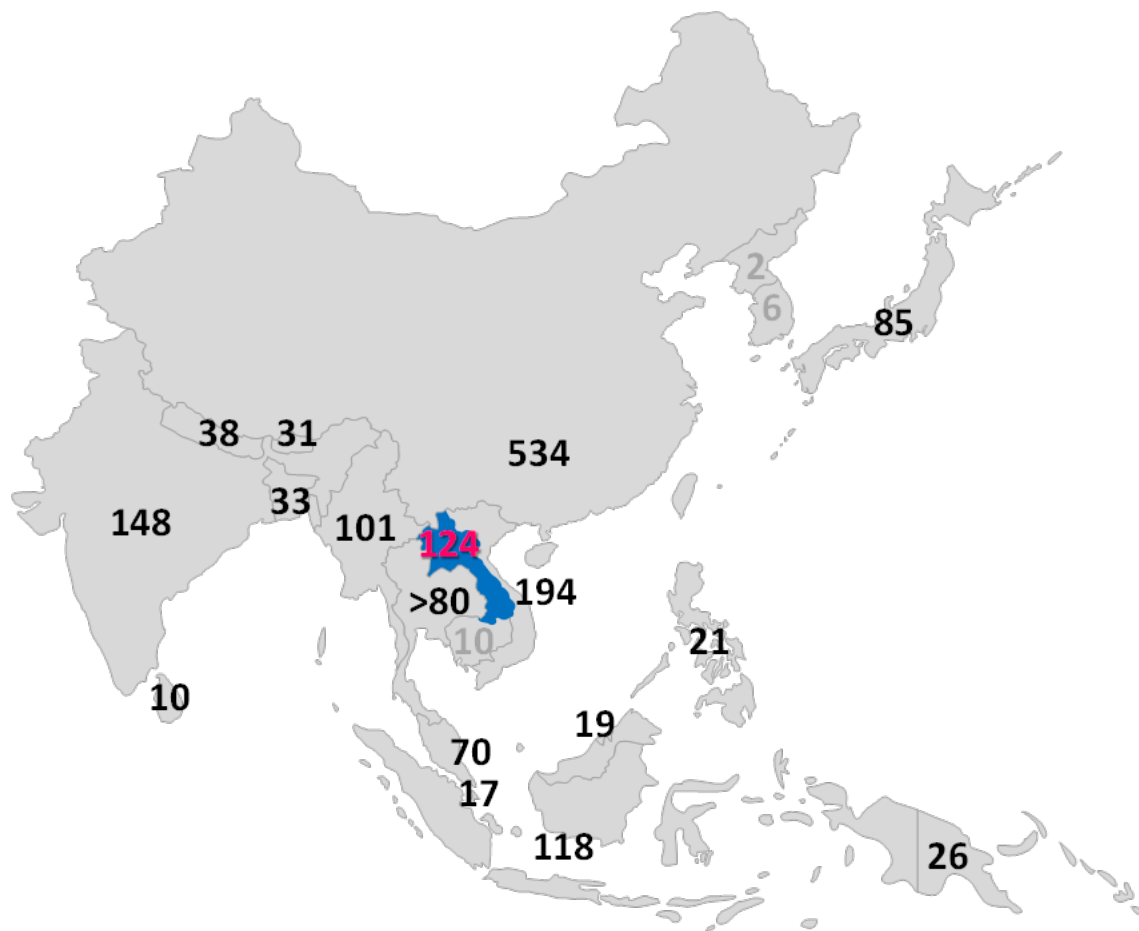


Figure 4 Map showing the number of bamboo species recorded in each country in the Asia-Pacific region. The numbers in grey indicate insufficient bamboo taxonomic information. Data are from the following studies: Bangladesh (Banik 1998); Bhutan (Stapleton 1994); Brunei (FD 2020); China (Wu et al. 2006); Cambodia (Monyrak 1998); India (Sharma & Nirmala 2015); Indonesia (Widjaja 1998); Japan (Uchimura 2005); Laos (This study); Malaysia (Mohamed & Appanah 1998); Myanmar (Htun 1998); Nepal (Shrestha 1998); North Korea (Bystriakova et al. 2003); Papua New Guinea (Holttum 1967); Philippines (Roxas 1998); Singapore (RMBR 2020); South Korea (Bystriakova et al. 2003); Sri Lanka (Kariyawasam 1998); Thailand (Dieter 2018); Vietnam (Nguyen 2006).