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Underground biomass accumulation of two economically important non-timber forest products is influenced by ecological settings and swiddeners' management in the Bago Mountains, Myanmar

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ABSTRACT

Diverse tree species, understory bamboos, shrubs, and herbs in mixed deciduous forests (MDFs) provide not only timber, but also non-timber forest products (NTFPs) in terms of fuel, food, and medicinal plants. Sustainability and the economic value of commercially extracted NTFPs have been studied mainly for the aboveground vegetative components of plants. However, such important knowledge of the underground parts of the plants is limited because of difficulties observing them and lesser consideration of the lower value of NTFPs, compared with timber, in forest management. Here we established allometric models to predict the root and corm biomasses of two plants, *Rauvolfia serpentina* and *Amorphophallus bulbifer*, in relation to their aboveground, vegetative parts. Estimated underground biomasses of the two species were compared among three habitat types: a swidden field, a fallow forest after cultivation, and a ridge forest that was not subjected to swidden agriculture. The length of the longest leaf of each individual plant explained the accumulation of the underground biomass of *R. serpentina* ($R^2 = 0.64$, $P < 0.001$) in a positive, linear relationship, and stem diameter at ground level did the same for *A. bulbifer* ($R^2 = 0.92$, $P < 0.001$). The largest biomass accumulation of *R. serpentina* was found in swidden fields because of its light demanding nature, which was supported by a significant, negative correlation between canopy cover and leaf length (Pearson's correlation = -0.612, $P < 0.05$). Because *A. bulbifer* was cut during weeding time, we could not measure its biomass accumulation in swidden fields; however, its occurrence in swidden fields was confirmed by farmers and field observations. No difference in the biomass accumulation of *A. bulbifer* was observed between the fallow and ridge forests. The promising growth of both species in the same year that a fire occurred during swidden cultivation suggests that the underground regeneration source provides advantages related to the harvesting of NTFPs and allows them to co-exist with slashing and burning in a swidden system, as well as surface fires in an MDF. Establishment of the two species in fallow vegetation was possibly facilitated by ecological and anthropogenic factors such as the reproductive bulbils of *A. bulbifer* and the broken root fragments of *R. serpentina* left after the harvest, as well as the dormancy period of these species during the dry season. This study revealed the cultivation potential of NTFPs that are suitable for community and agroforest plantations using a swidden system in an MDF that experiences fires.

1. Introduction

Swiddening, also known as slash-and-burn cultivation, is a common practice of subsistence agriculture for forest dwellers in hilly regions. In the Bago Mountains in Myanmar, the Karen people have lived on swidden agriculture since before British colonial times (Bryant, 1994b). The Bago Mountains are a range of undulating hills covered with mixed deciduous forests (MDFs) that are characterized by valuable tree species such as teak (*Tectona grandis*), *Xylia xylocarpa*, and *Pterocarpus macrocarpus* (Blasco et al., 1996; Bullock et al., 2009), and they have experienced a long history of teak forest management since the time of the British colonial government. Because vegetation is diverse in terms of tree species, as well as understory bamboos, shrubs, and herbs (Whitmore, 1984), MDFs provide non-timber forest products (NTFPs) in the form of fuel, food, and medicinal plants that aid the subsistence of swidden communities. In line with the recent, growing influence of the cash economy, the Karen people have come to rely on harvesting NTFPs, such as *Rauvolfia serpentina* (Apocynaceae) and *Amorphophallus bulbifer* (Araceae) that grow with other forest floor species in swidden fields and surrounding forests, for cash income.

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Rauvolfia serpentina (bonma-yaza in Burmese), which is known as Sarpagandha in Ayurvedic medicine, is a prominent medicinal plant from which alkaloid contents are extracted from its roots to treat hypertension (Soe et al., 2004; Monachino, 1954; Sheldon et al., 1997). Increasing demand and the overexploitation and loss of *R. serpentina* habitats after excessive deforestation resulted in its resource exhaustion in wild populations, for example, those in India, Java, and Indonesia (Cai et al., 2009; Dey and De, 2010; Sheldon et al., 1997), and the species has been included in the Convention on International Trade in Endangered Species of Wild Fauna and Flora Appendix II since 1990 (Sheldon et al., 1997). *Amorphophallus bulbifer* (wa-u in Burmese), commonly known as konjac, is famous for the glucomannan in its corms, which is valued as a low-calorie, high-fiber food, and used as a straight-chain polymeric material (Wang et al., 2011).

Because of the increasing demand for medicinal and herbal species, forest degradation, and the conversion of forests into other land uses, source of NTFPs have decreased worldwide (Shackleton et al., 2011). It may not be possible to prevent the overexploitation and extinction of plant resources unless NTFPs and land use systems are included in forest management strategies. Formulations of management interventions to sustainably use plant resources critically require the evaluation of NTFP extraction by local people. In Myanmar, underground NTFPs are less studied because of the difficulties associated with directly measuring their harvestable parts, compared with their aboveground vegetative parts, and because NTFPs extracted from undergrowth have a comparatively smaller biomass and lower value than timber products and they are less considered in forest management. However, forest management in Myanmar has focused recently on local livelihoods and biodiversity conservation by encouraging agroforestry and community forestry in degraded secondary forests near human settlements. Logging has also been suspended for at least a decade in the Bago Mountains to accelerate forest rehabilitation, and, thus, NTFPs have become prominent because of their productive value in the forests in this area. Furthermore, the demand for NTFPs seems to have been increased by current political changes of the country, which has resulted in increased economic investments and trade from foreign countries. A lack of information on small plants with economic value in swidden systems may lead to less recognition of the importance of local resource management, as well as the cultivation potential of marketable plant species in community-based agroforestry programs. The objectives of this study were (i) to understand the botanical characteristics and swiddeners' harvest practices of *R. serpentina* and *A. bulbifer*; (ii) to estimate and compare their underground biomasses among swidden fields, fallow forests, and ridge forests; and (iii) to analyze the influences of both ecological and anthropogenic factors on their biomass accumulation to improve the sustainable management of NTFPs in an MDF.

2. Materials and methods

2.1. Study site

The Bago Mountains (Fig. 1a), located between N 16°50′34″ and 19°29′34″, E 94°41′19″ and 97°13′27″, comprise undulating hills with average elevation of 600 m. They experience distinct rainy and dry seasons from May to October and November to April, respectively, because of the tropical monsoon climate. The mean annual temperature is 26 °C, and the mean annual rainfall is 2300 mm, with variations along the mountain range running from north to south. Forest vegetation, which is typical of tropical monsoon forests (Bullock et al., 2009; Whitmore, 1984), is supplied with rain water during the monsoon and seasonally deciduous during the dry season, and surface fires and swidden burning occur annually. Secondary forests at the study site are the mixed deciduous type and are dominated by tree species of *T. grandis*, *X. xylocarpa*, *P. macrocarpus*, *Dalbergia* spp., and *Dipterocarpus* spp., which are associated with a large proportion, approximately 30% of the basal area density, of bamboos (Thein et al., 2007). The Bago Mountains are regarded as home to *T. grandis*, and the forests here have been managed for more than one century to produce timber, which is an important part of Myanmar's economy. Reserved forests (Fig. 1b), which are divided into compartments, are the fundamental management units of the forest territory, and they were formed at the time of forest management by the British colonial government. Human access for tree felling and logging is prohibited in reserved forests (Bryant, 1994a).

The Karen people, who live in these hills, were recognized by the colonial government as participating in the formation of teak plantations using an agroforestry system that was based on traditional Karen swiddening (Bryant, 1994b; Maung and Yamamoto, 2008; Win and Kumazaki, 1998). Therefore, they have been regarded as indigenous swiddeners with a long history of residence in the study area. During the British colonial period, some of the reserved forest area, approximately 4000–6000 ha, was granted to each community for customary land use (the Karen area), and it was placed under forest management by the government to support the local livelihoods of swiddeners. Local swiddeners subsist on traditional swidden cultivation and forest products within the designated Karen area. For swidden agriculture, farmers slash and burn secondary forests, preferably vegetation comprising a mixture of trees and bamboos (Chan et al., 2013), to prepare well-burnt fields enriched with ashes. They cultivate crops, including upland rice (*Oryza sativa*), cotton (*Gossypium hirsutum*), sesames (*Sesamum indicum*), chilis (*Capsicum frutessens*) and vegetables, for 1 year and repeat the same process at a different place the following year. After cultivation, swidden fields are abandoned as fallows during a vegetation recovery period as long as 12–18 years (Chan et al., 2013; Fukushima et al., 2007); however, some fallows that are easily accessible (in terms of distance) are opened frequently, thereby reducing the length of the fallow period to approximately 8 years (Chan et al., 2013). Connections to lowland areas have been improved within the last few decades, and, currently, the cash economy has become important for local livelihoods, for example, people sell cash crops and forest products to middlemen and buy household commodities from peddlers.

We studied two Karen areas, the KC and ST villages (Fig. 1b), where the people conduct traditional swidden agriculture. The settlement in the ST village was relocated to the roadside by the government one decade ago because of civil unrest in the eastern part of the Bago region. However, ST villagers are still conducting swidden agriculture around the old settlement, which is far from the new settlement. The landscape of the study site is characterized by swidden fields, fallow forests on slopes and remnant forests and conservation forests that have cultural importance on the ridges between the swidden fields.

2.2. Allometric model establishment

An allometric model was established by simple linear regression based on the assumption that the aboveground plant growth of *R. serpentina* and *A. bulbifer* is related to the masses of roots and corms. A regression analysis is used commonly to predict the response variable, especially for estimating plant biomass and finding the relationship between the measurements of plant parts by establishing allometric models (Budiman, 2012; Chamberlain et al., 2013; Li et al., 2008). In this study, to predict the dependent variable (the fresh weights of roots or corms), the explanatory variables of stem diameter at ground level, stem height, and the length of the longest leaf were tested in a simple linear regression analysis, using 69 individual plant samples each of *R. serpentina* and *A. bulbifer*. A natural log transformation was applied to the measured variables to meet a normal distribution assumption in the linear regression analysis. For each species, the best-fit model was validated by the correlation coefficient and used to estimate underground biomass.