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The impact of *Amomum villosum* cultivation on seasonal rainforest in Xishuangbanna, Southwest China

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Abstract. Integrating conservation goals with the sustainable use of tropical rain forests has received much attention in recent decades. *Amomum villosum*, a traditional Chinese medicinal herb, has been cultivated in the understory of seasonal rain forest for 40 years in Xishuangbanna, Southwest China. Cultivated area has reached 58.11 km^2 much of which is distributed within nature reserves. This practice has caused controversy on whether *A. villosum* cultivation would alter the structure and function of the primary forest. This study examined the effects of medicinal plant cultivation on seasonal rain forest by comparing plant diversity, biomass, litterfall and soil nutrients of primary rain forest with disturbed areas where *A. villosum* is cultivated. The results indicate that plant diversity, tree biomass, litter production and soil nutrients are significantly lower in the disturbed than in the primary rain forest. These results suggest that the cultivation of *A. villosum* affects the structure and function of the seasonal rain forest in Xishuangbanna.

Introduction

Tropical forests are richer in biodiversity than any other terrestrial ecosystem on earth. Although covering only 7% of the world's surface, tropical forests contain about 50% of the world's species (Burgess 1993). Despite increasing concern over the loss of tropical forests and significant local and international efforts to find solutions to the problem, the current annual rate of deforestation in the tropics is around 0.9% (Burgess 1993), compared to 0.8% during 1980–1990, and 0.6% during 1976–1980 (Food and Agriculture Organization 1993). The deforestation of tropical rainforests has resulted in an estimated loss of 10,000 species each year (Rowe et al. 1992). The search for sustainable solutions to the high rates of forest and species loss has focused on various forms of natural forest management (Center for International Forestry Research 1993; Boot and Gullison 1995; Lanly 1995; Lugo 1995; Bruenig 1996; Bawa and Seilder 1997; Bouman and Brand 1997).

Xishuangbanna is located in southern Yunnan Province, in southwest China (24°10′ to 22°40′ N, 99°55′ to 101°50′ E) bordered by Laos in the south and southeast and Burma in the southwest. It is a famous region in China for its diverse flora, fauna and beautiful landscape. It is estimated that about 5000 species of higher plants (16% of those in China) exist in this area of 19,200 km^2 (0.2% of that in China), of which nearly 1000 species of wild plants can be directly utilized by the people. This area has one of the greatest diversities of species in China and is of great importance in the maintenance of regional biodiversity (Cao and Zhang 1997; Shanmughavel et al. 2001). In the early 1950s, about 60% of the total area of Xishuangbanna was covered by forest (Xu 1985). Recent investigation has revealed that this has declined greatly due to the rapid expansion of the local population and irrational exploitation of local forest cover has declined to 27% at the beginning of 1990s (Shanmughavel et al. 2001). Like other tropical areas of the world, Xishuangbanna is inhabited by many indigenous minority groups who have only recently started to develop economically. Managing conflicting interests between tropical rain forest conservation and economic development has attracted attention in recent years.

Amomum villosum was introduced into South and Southwest Yunnan in 1963 as a traditional Chinese medicine used for treating gastritis, stomachache and digestive troubles (Zou 1993). *A. villosum* is a sciophyte and it can grow well in the tropical forest or subtropical forest. Because it can growth new ramets by rhizoma, the farmers always plant rhizoma underground in tropical forest. *A. villosum* is a perennial grass, and it can produce new ramets every year. So, the management of farmers is only removing old ramets and other seedlings of other plants are by hands every year (Zou 1993).

But now, planting *A. villosum* under the tropical forest has brought a series of ecological questions; especially in nature reserves the bio-diversity loss is very distinct because of *A. villosum* cultivation. Moreover, the effects to biodiversity after planting *A. villosum* have attached attention of local government (Gao et al. 2002). Although there are studies on the structure and composition of topical rainforests (Yin 1993; Liu 1996, 1998; Su et al. 1997; Wang et al. 1997; Zheng et al. 2001, 2003; Meng et al. 2003), there is still short on information of ecosystem processes associated with *A. villosum* cultivation in the rainforest. The area of *A. villosum* cultivation had reached 58.11 km^2 by 1998 (Gao et al. 2002), and was mainly planted in the understory of seasonal rain forest. Farmers in nearby countries such as Laos and Burma are now learning the technique and are also cultivating *A. villosum* in the areas of tropical rain forest (Figure 1).

The main objectives of this investigation were to assess the effects of *A. villosum* cultivation on the plant diversity, biomass, litter production, and soil water and nutrient contents in the seasonal rain forest of Xishuangbanna.

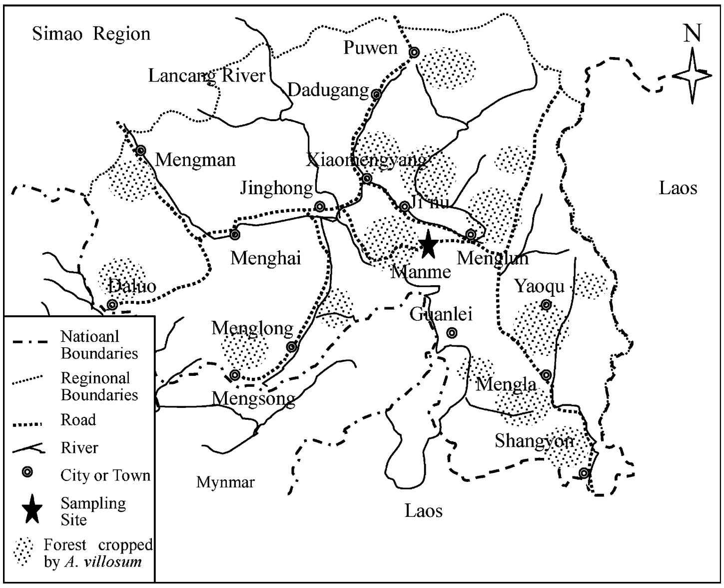

Figure 1. Sketch showing Xishuangbanna, border on Laos and Burma. Shade area means with dots mainland of *A. villosum*, but all of them are in rainforest, or in nature reserve. Sampling site indicated by five-pointed star in black shade, Manme village.

Sampling methods and data analysis

The study was conducted in the Menglun Nature Reserve, which Menglun Nature Reserve is part of the Xishuangbanna National Nature Reserve covering 1242 ha. The Xishuangbanna National Nature Reserve was first established in 1958 after being named as a Provincial Reserve of Yunnan. In 1986 Xishuangbanna was promoted to National Nature Reserve status. In 1993, the nature reserve joined the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Man and Biosphere Reserve network, with the primary objective to conserve the forest ecosystems including rare plant and animal species. Human activities are prohibited within the nature reserve, however, local indigenous people occasionally enter the reserve for hunting and gathering or harvesting fruit, medicinal plants, and fuelwood.

Three 50 m × 50 m plots (21°56′ N to 21°59′ N, 101°08′ E to 101°12′ E, 650–850 m elevation) were located in undisturbed seasonal rain forest within the nature reserve (Figure 2). In these sites, there have not cropped *A. villosum* due to steep gradient, and the vegetation in these sites were dominated by *Pomentia tomentosa* and *Terminalia myriocarpa*. Forest soil is a yellow latosol developed from purple sandstone. The height of the forest canopy is about 45–48 m. In order to compare the vertical distribution of plant diversity in the forest community, forest structure was divided into five layers: tree layer A (over 30 m), tree layer B (16–30 m), tree layer C (below 16 m), shrub layer

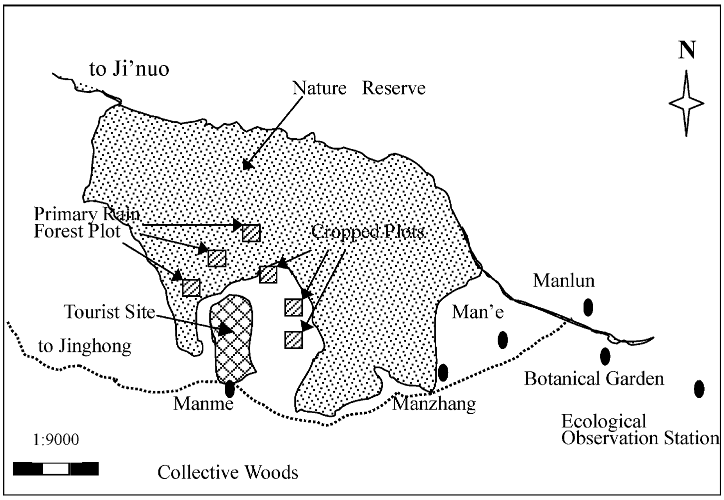

Figure 2. Sampling plots was located as sketch. Six plots (in incline lines) have been cropped with *A. villosum*, which three plots in nature reserve (shade area with dots) and three plots in collective woods (open area).

(3–15 m) and herb layer (below 3 m) (Cao et al. 1996, 1997; Zhu 1997). Three 50 m×50 m plots were also established in disturbed seasonal rain forest. The disturbed site is adjacent to the nature reserve, and is a communal area where the local village is allowed to lightly harvest some timber under a nature reserve station permit. In the 1980s local people cultivated *A. villosum* in the communal forest and on the fringe of the nature reserve. Farmers maintained some overstory trees to provide shade in the understory for *A. villosum* but cleared shrub and herb layer plants. Before starting our survey, we have rented the disturbed forest plots from local households in order to exclude further human disturbance since from1998.

Plant diversity and biomass were measured in each 50 m × 50 m plot in the disturbed and undisturbed sites. All trees with DBH ≥5 cm and woody lianas with DBH ≥2 cm were identified and measured for height and diameter. Shrubs and herbs were surveyed in five 5 m×5 m subplots located at the four corners and center of each large plot. Shrub and herb species were identified and individuals counted. Following the survey, all shrubs and herbs in the subplots were harvested to determine biomass.

The dry weight biomass of tree species was calculated from existing allometric equations (Xiao 1992; Wen et al. 1997; Zheng et al. 2000). Shannon-Wiener index was used to calculate plant diversity of the forest layers in each plot, and herb diversity in subplots was calculated using the Simpson index (Magurran 1988).

Litterfall was collected every two weeks from April 2000 to May 2001 in the primary and disturbed seasonal rain forest sites. Ten 0.25 m^2 litter traps (Yi et al. 1994) were located randomly in each 50×50 m plot under the tree canopy and leaves, fruits and twigs were collected. Litter samples were dried at 60 °C for 48 h and weighed(Ren et al. 1999). The total of twice litterfall in a month were calculated as the sum of monthly collections.

Soil nutrients and water content were measured by collecting soil samples at 0–10, 10–20 and 20–30 cm depths at 10 random locations in each plot. Soil samples were taken three times during the dry season (March, April and May). Samples were kept in plastic bags and transported to the laboratory for analyses. Samples for soil water content were weighed, dried at 105 °C for 24 h, and reweighed. Soil samples were further analyzed for organic matter (OM), total N, P, and K, and available N, P and K. Chemical analyses were done at the Soil Laboratory of Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences.

Soil samples collected from the field were first air dried and then ground in a ceramic mortar using a ceramic pestle. Ground samples were then passed through a 2-mm sieve and retained for further laboratory analyses. Organic matter was measured using the Walkley–Black technique (Allison 1975) and total nitrogen was measured using a semi-Micro-Kjeldahl method (Bremner and Mulvaney 1982). Available nitrogen content was measured following Hawkers et al. (1997) which determines plant-available nitrate and ammonium before and after aerobic incubation. Available phosphorus was extracted using the Bray-1 method (Bray and Kurtz 1945) and concentrations were determined colorimetrically using the molybdenum blue method of Murphy and Riley (1962). Due to the trace amounts of P determined by this method, extractable P was also measured by extraction with aqua regia. Potassium was determined by an Atomic Absorption Spectrophotometer after extraction of a 10 g soil sample with 1 M aqueous ammonium acetate for 2 h (Chapman 1965). Available potassium was extracted using an acetic ammonium method (Lodhiyal and Singh 1995).

The *t*-test was used for pair-wise comparison of the diversity values, biomass, soil water and nutrient content for disturbed rainforest and undisturbed rainforest (Bailey 1968; Parker 1976). For annual litterfall analysis, we employed the repeated-measurement two-way ANOVA to analyze for the difference between disturbed rainforest and undisturbed rainforest.

Results

Plant diversity

The cultivation of *A. villosum* significantly affected plant diversity of the seasonal rainforest (Figure 3). The decrease in plant diversity of different forest layers tended to follow the pattern: lianas > shrubs > tree layers > herbs. In the tree layers, many species exceeding about 20 m, such as *Terminalia Myriocarpa* and *Pometia tomentosa*, were thinned with some individuals left standing as shade trees to achieve the 30–40% light intensity favorable for the growth and

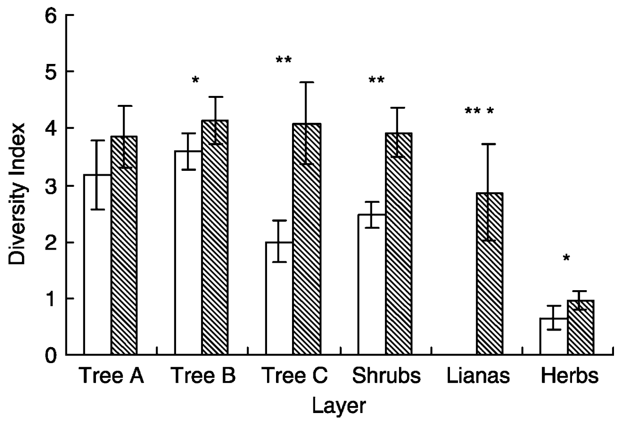

Figure 3. Plant diversity indexes of every layer of disturbed rainforest (open bars) and undisturbed rainforest (solid bars). Values are Means ± SE. Means differed significantly between disturbed rainforest and undisturbed rainforest (*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$, orthogonal contrast after *t*-test).

yield of *A. villosum*. Trees in the lower layers, shrubs and lianas were cleared to prepare space for *A. villosum*, and plant diversity in these layers decreased dramatically. Ground layer plants were also cleared and *A. villosum* seedlings or cuttings were planted in conditioned soil with a spacing of approximately 1 m × 1 m. *A. villosum* grows rapidly by the extension of stolons and rapidly covers most of the ground. The plants begin to flower and fruit by the end of the third year after planting. Every year, farmers weeded young trees, shrubs and herbs to increase the yield of *A. villosum*. A lot of trees, especially arbor layer C, and almost all the shrubs and lianas were lost. Some typical species of tropical rain forest, such as *Myristica yunnanensis, Pouteria grandifolia, Pometia tomentosa, Girronera subaequalis, Terminlia myriocarpa, Horsfieldia tetratepala, Drypetes cuminghii, and Celtis cinnamomea* are not exist in *A. villosum* field (Table 1), more of these species are the dominant trees, but they were slashed by farmers at seedling stage.

The cultivation of the medicinal plant *A. villosum* affected not only the species diversity but also the spatial distribution of plant diversity and community structure of the seasonal rain forest. In the undisturbed forest plots, the forest could easily be divided into five layers according to height. More than 75% of the plant species and 82% of the individuals occurred in the tree layer C and shrub layer. These layers were reduced by 36.8 and 48.3% in species respectively, in the disturbed rain forest site.

Biomass and litterfall

For the reason of local farmers' 'management' to *A. villosum*, there was a significant decrease in the tree, shrub, and liana biomass of the seasonal rain

Table 1. List of plants in the sites.

Latin name	*A. villosum* site	Rain forest
Actinodaphne henryi		+
Adina pilulifera		+
Aglaia abbreviata		+
Aglaia parviridia	+	+
Aglaonema pierreanum	+	+
Alstonia scholaris		+
Antiaris toxicaria		+
Aphananthe cuspidata		+
Aporusa yunnanensis	+	+
Baccaurea ramiflora		+
Barringtonia macrostachya	+	+
Bauhinia erythropoda		
Bauhinia touranensis	+	
Bauhinia variegata var.candida		
Belosynapsis ciliata	+	+
Boehmeria zollingeriana		
Caesalpinia cucullata		+
Calamus nambariensis var.xishuangbannaensis		+
Canarium album		
Canarium strictum		+
Canthium parvifoliam	+	+
Capparis fohaiensis		+
Castanopsis indica		+
Cayratia japonica var. ferruginea		+
Celastrus monospermus		+
Celtis timorensis		
Chesalia curviflora	+	+
Chukrasia tabularis var.velutina	+	+
Cinnamomum pathenoxylum		+
Combretum latifolium		
Craspedolobium schonchii	+	
Croton argyratus	+	+
Cyanotis vaga		+
Cyclobalanopsis austrocochinchienensis		+
Dalbergia pinnata		+
Desmodium gangeticum		
Diospyros nigrocartex		+
Dolichandrone stipulata var.velutina		
Dracaena angustifolia		+
Drypetes indica		
Elaeocarpus varunua		+
Euodia lepta		+
Ficus semicordata		
Ficus tinctoria subsp.gibbosa		+
Ficus variegata var.chlorocarpa		
Fissistigma polyanthoides		
Garcinia cowa		
Gomphostemma microdon		+
Goniothalamus cheliensis		+
Grewia celtidifolia		

Table 1. Continued

Latin name	*A. villosum* site	Rain forest
Gutzlaffia henryi	+	+
Horsfieldia amygdalina	+	+
Horsfieldia tetratepala		+
Knema globularia		+
Lasianthus hookeri		+
Leea crispa		
Leea guineensis		+
Ligustrum rugolosum		+
Lithocarpus fohaiensis		+
Litsea monopetala		+
Lygodium conforme	+	+
Mayodendron igneum		
Measa permollis		+
Melia toosanden		+
Melodinus tenuicaudatus		+
Memecylon polyanthum		+
Micromelum tntegerrimum		
Millettia eurybotrya		+
Millettia leptobotrya		+
Millettia oosperma		+
Millettia pachycarpa		+
Millettia reticulata		+
Millingtonia hortensis		+
Mitrephora maingayi		+
Morinda angustifolia		+
Munronia henryi	+	
Mycetia glandulosa		+
Mycetia gracilis		
Nauclea tsaiana		+
Phaphidosperma vagabunda		+
Phoebe lanceolata		
Phyllanthus leptoclados		
Piper longum	+	+
Pittosporopsis kerrii	+	+
Polyalthia cheliensis		+
Pometia tomentosa	+	+
Pseudoranthemum malaccense		
Psychotria calocarpa		
Psychotria henryi		
Psychotria yunnanensis		+
Pteridium excelsum		+
Pterospermum menglunense		+
Rhodomyrtus tomentosa	+	
Salacia polysperma		+
Saprosma ternatum		+
Schizandra plena		
Scleropylum wallichianum		+
Stixis suaviolens		
Strychnos wallichiana	+	+
Syzygium cumini		+

Table 1. Continued

Latin name	*A. villosum* site	Rain forest
Syzygium szemaoense	+	+
Tetrastigma planicaulum		
Thunbergia grandiflora	+	+
Trewia nudiflora		+
Turpinia montana		
Walsura robusta		+
Xanthophyllum yunnanensis		+
Total	22	76

+, species exist in the site.

forest (Table 2). Average biomass of the primary seasonal rain forest plots was 597.73 t ha^{-1}, similar to values reported for tropical rain forest in Karnataka, India and rain forest dominated by *Partocapus* in Malaysia, which were 420–649 and 423.9–647.6 t ha^{-1}, respectively (Kato et al. 1978; Rai and Proctor 1986a, b). In the disturbed rain forest site, biomass averaged 279.73 t ha^{-1} indicating a 46.8% reduction due to the use of the forest over the past 30 years. The biomass reduction in this study is higher than the biomass loss resulted from logging in a tropical rain forest in Malaysia (Brown et al. 1991). In our results, the biomass of herbs increased significantly due to the extensive cover of *A. villosum*.

Total annual litterfall production in the primary and disturbed seasonal rain forest was 9.859 and 7.949 t ha^{-1} year^{-1}, respectively. Litterfall production values for both sites were higher than the global average of 7.22 t ha^{-1} y^{-1} estimated for tropical forests (Bray and Gorham 1964). However, there was a significant decrease in total litterfall production between the primary and disturbed sites. Differences in litterfall mainly occurred in the dry season (Figure 4). During the dry season litterfall production was 5.023 t ha^{-1} accounting for 50.95% of the annual total in primary rain forest. In the disturbed rain forest dry season litterfall production was 3.663 t ha^{-1}, 46.08% of total annual litterfall. The differences in litterfall production between the two sites were apparently caused by the removal of plants in the tree and shrub layers. The annual distribution of litterfall was also changed due to the forest disturbance. In primary forest two peaks in litterfall production occurred over March, April and May, and again in July. In the distributed rain forest site,

Table 2. Biomass (t ha^{-1}) of vegetation in undisturbed and disturbed tropical seasonal rain forests in Xishuangbanna, Southwest China.

	Trees	Shrubs	Woody lianas	Herbs
Primary forest	588.80 ± 66.81	4.86 ± 0.25	3.59 ± 0.42	0.48 ± 0.1
Disturbed forest	272.45 ± 40.31	0.26 ± 0.04	0.06 ± 0.03	6.90 ± 2.7
p-Value	**	***	***	*

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$, orthogonal contrast after *t*-test.

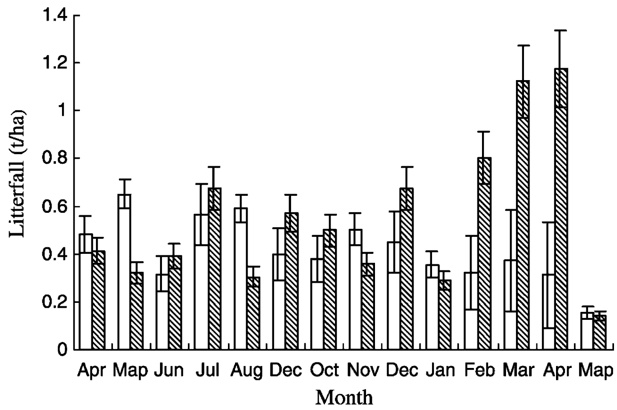

Figure 4. Seasonal allocation of litterfall in disturbed rainforest (open bars) and undisturbed rainforest (solid bars) from April of 2000 to May 2001. Values are Means ± SE. Means differed significantly between disturbed rainforest and undisturbed rainforest (*$p < 0.05$, orthogonal contrast after ANOVA).

only one peak occurred during February, March and April. Peak litterfall production in the disturbed site occurred one month earlier than in the undisturbed site.

Soil water and nutrient content

In rainy season, the soil water content of *A. villosum* land is not significant different from the tropical rain forest (Table 3). But in the dry season, soil water was reduced in the disturbed forest site compared to the undisturbed site. And also, because the roots of *A. villosum* all distribute in the depth from 10 to 30 cm, the soil water content of *A. villosum* land descended nearly linearly from surface layer to 30 cm depths, but for the tropical rain forest it descended slowly.

In the nine soil nutrient indexes, the O.M, T.N, T.P, T.K and A.N content of *A. villosum* land is not higher than of tropical rain forest soil in the same depth. (Table 3). Two mechanisms may explain these results. First, nutrient harvest during the preparation and cultivation of *A. villosum*, and the subsequent decrease in litterfall production, may have reduced the amount of nutrients stored in plant tissues and returned to the soil as detritus. Second, nutrient uptake and assimilation in *A. villosum* proliferating in the understory may have led to reduced nutrient availability in the soil.

A reasonable proportion of soil nutrient elements is an important pre-condition for increasing *A. villosum* fruit production, especially reasonable contents of N, P and K. *A. villosum* needs a high K content, especially in the bloom and fruit set period, the N and K proportion must be 1:1.2 at least. *A. villosum* strongly gathers K element in the soil, which we can see clearly

Table 3. Soil water and nutrient content in disturbed and undisturbed seasonal tropical rain forest in Xishuangbanna, Southwest China.

Variable	Depth(cm)	Means ± SE		*p*-Value
		Distributed forest	Undistributed forest	
pH	0–10	5.91 ± 0.731	4.97 ± 0.158	*
	10–20	5.47 ± 0.833	4.76 ± 0.133	
	20–30	5.09 ± 0.491	4.74 ± 0.080	
Water content (%)	0–10	14.03 ± 0.325	14.80 ± 0.469	
	10–20	13.35 ± 0.500	14.54 ± 0.493	*
	20–30	12.33 ± 0.280	14.25 ± 0.500	**
SOM (%)	0–10	2.960 ± 0.713	4.670 ± 0.209	**
	10–20	0.780 ± 0.102	1.370 ± 0.127	**
	20–30	0.590 ± 0.042	0.850 ± 0.084	*
Total N (%)	0–10	0.180 ± 0.037	0.252 ± 0.007	**
	10–20	0.055 ± 0.003	0.099 ± 0.010	**
	20–30	0.049 ± 0.002	0.080 ± 0.005	**
Total P (%)	0–10	0.031 ± 0.006	0.041 ± 0.002	*
	10–20	0.025 ± 0.002	0.035 ± 0.002	*
	20–30	0.025 ± 0.051	0.025 ± 0.003	
Total K (%)	0–10	0.527 ± 0.031	0.674 ± 0.033	**
	10–20	0.635 ± 0.125	0.786 ± 0.120	
	20–30	0.806 ± 0.044	0.935 ± 0.115	*
Available N ($\mu g\ g^{-1}$)	0–10	150.960 ± 12.413	205.230 ± 6.058	***
	10–20	49.440 ± 2.364	77.320 ± 3.336	***
	20–30	42.560 ± 0.553	47.180 ± 2.116	**
Available P ($\mu g\ g^{-1}$)	0–10	12.520 ± 4.760	10.500 ± 0.793	
	10–20	3.990 ± 2.147	1.130 ± 0.147	
	20–30	1.270 ± 0.311	0.890 ± 0.040	
Available K ($\mu g\ g^{-1}$)	0–10	193.970 ± 23.87	90.930 ± 35.087	**
	10–20	86.330 ± 11.16	33.450 ± 15.569	**
	20–30	29.530 ± 8.980	28.470 ± 6.11	

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$, orthogonal contrast after *t*-test.

from Table 3. The soil's T.K content decreased from the deep layer to the surface in *A. villosum* land. This indicated that kalium in the surface was absorbed and utilized. But the soil A.K content increased from deep to surface, this indicated that kalium was mineralized and absorbed by *A. villosum*, so it appeared that K+ was enriched in the surface layer. K+ was absorbed to the surface by the planting of *A. villosum*, but K+ easily run off by rain, so this aggravated the kalium element's run-off. But there were no significant differences in available P between *A. villosum* land and rain forest. More research is needed on this.

Discussion

A. villosum cropped in Xishuangbanna tropical rainforest significantly decreased the plant diversity, especially decreased rare plants. The compact unitary population of *A. villosum* inhabits most part of space, and for this reason, the seedlings' restoration of arbor layers could not accomplish successfully. From a certain degree, it will baffle the natural succession of tropical rainforests. Generally, the top trees in tropical rain forest can live about 200 years (Richards 1952). However, with the reduction of plant diversity and simplification of community structure, the microclimate in the rain forest may also have changed, which could affect the growth of dominant trees. The ecology of the forest may also be significantly altered if *A. villosum* persists in the understory and hinders the natural regeneration of tree species that contribute to the complex forest structure.

After cropped *A. villosum* in the tropical rainforest, the biomass of tropical rainforest decreased significantly, and also, the distribution of biomass in very layer of forest has changed greatly. In total biomass of tropical rainforest, the arbor layers' quotient reduced. In primary rainforest, the biomass proportion of arbor layers is 98.51%, but in *A. villosum* land, the proportion is 97.40%. On the contrary, to the biomass of herbage, it has increased from 0.08% in primary rainforest to 2.47% in *A. villosum* land (Table 2).

Differences in annual litterfall distribution could be due to changes in the microclimate and soil water content resulting from the simplification of forest community structure. The changes of litterfall after cultivated *A. villosum* may effect the nutrient cycle of tropical rainforest. It has reduced the income of soil nutrient. The productivity of soil may become more and more sterile, and it is disadvantage to restoration of arbores seedlings.

Soil water and nutrient contents are important factors that affect forest productivity. This shows that the tropical rain forest has good capacity of containing water. Because that the dense roots of *A. villosum* in the surface layer prevent rainwater from saturating down to the deep soil layer, and the leaves of *A. villosum* can transpire a great amount of water, the soil water content decreased and the structure of soil changed with bad ventilation property. Also, the roots of *A. villosum* mainly distribute in the upper layer of soil, lead to the soil elements be transferred to surface layer along the soil solution, and easily flow away with rainwater. Abundance soil water is useful to *A. villosum* flower bud differentiation and reproductive growth in dry season. But for the land in which people have been planting *A. villosum* for many years, its capacity to retain water has decreased greatly, and cannot offer enough water for *A. villosum*'s normal physiological action when the dry season comes. Some research indicated that *A. villosum* fruit contains N 1.166%, P 0.192% and K 3.29% (He and He 1984; Xiong 1987; Guan 1995). According to the harvest of dry fruit of 150 kg ha^{-1} every year, that amounts to N 1.749 kg P 0.288 kg K 4.935 kg which will be taken away.

The mosaic of tropical and subtropical vegetation produced by the unique geographic location and climate of Xishuangbanna, forms tropical rain forest ecosystems that are biodiverse and sensitive to disturbance. *A. villosum* is mainly planted under seasonal rain forest within the Xishuangbanna nature reserve, and the area of such forest only occupies 4.8% of the total protected area (Xu 1985). Cultivation of *A. villosum* under tropical seasonal rain forest has been considered as an important way for local minorities in Xishuangbanna to expand their marketable goods and improve their economic situation. Therefore, *A. villosum* cultivation has expanded to 5811 ha of understory in the seasonal tropical rain forest. The cultivation of *A. villosum* has a large impact on the forest ecosystem because the maintenance of high species diversity and biomass of this forest relies on a complex forest structure, and lower layers of vegetation are drastically reduced or cleared for cultivation. In the disturbed rain forest, plant diversity, community structure, biomass, litterfall and soil nutrients were affected. The results from this study question if *A. villosum* cultivation is a sustainable way to use tropical rain forest, because it does not integrate conservation of biodiversity and economic development. Therefore, finding alternatives to the cultivation of *A. villosum* will be the most important measure to protect the diversity, structure, and function of the seasonal rain forests in this region. However, it will also be a challenge to stabilize and recover the plant diversity and ecological function of the tropical seasonal rain forest because *A. villosum* persists in the seasonal rain forest understory as an invasive species.

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