SPECIES DIVERSITY, FLORISTIC COMPOSITION AND PHYSIOGNOMY CHANGES IN A RAINFOREST REMNANT IN SOUTHERN YUNNAN, CHINA AFTER 48 YEARS

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ZHU H, WANG H & ZHOU SS. 2010. Species diversity, floristic composition and physiognomy changes in a rainforest remnant in southern Yunnan, China after 48 years. In order to investigate the effects of tropical forest fragmentation, a comparative study on floristic composition, plant life forms and ecological species groups in a 13.9 ha remnant tropical rainforest was conducted over 48 years (1959/1960–2008) in southern Yunnan, China. A total of 258, 292 and 332 native seed plant species were present in the remnant in 1959/60, 1997 and 2008 respectively. A total of 407 species were recorded in the remnant from the three inventories, of which 188 species were common. Species diversity did not reduce with diminution and further isolation of the remnant. Species could condense with the limited natural habitats of the remnant with the loss of surrounding natural vegetation. There was a significant shift in floristic composition with 27.1% species of the original forest absent in the inventory in 2008 and 43.4% of the present species were new migrants. The species shift was greatly accelerated in the recent 10 years in the remnant with changes of surrounding vegetation into rubber plantations. There was a conspicuous shift in the relative representation of mature-forest and light-demanding species: the former decreased. However, plant life forms did not show significant change in the remnant over 48 years. Species loss was balanced by new migrants across life forms. Although species diversity was maintained and physiognomy (life forms) of the remnant did not change significantly, the floristic composition and ecological species groups were conspicuously changed through time. This implies that the essential flora of the tropical rainforest could not be actually maintained in the remnant. It is suggested that the flora of tropical rainforest cannot be protected from impoverishment even if the fragmented forests are conserved.

Keywords: Tropical rainforest, fragmentation, species richness, floristic shifts, implications for conservation

ZHU H, WANG H & ZHOU SS. 2010. Perubahan kepelbagaian spesies, komposisi flora dan fisiognomi saki-baki hutan hujan di selatan Yunnan, China selepas 48 tahun. Kajian perbandingan komposisi flora, bentuk hidup tumbuhan dan kumpulan spesies ekologi di dalam saki-baki hutan hujan tropika seluas 13.9 ha di selatan Yunnan, China dijalankan selama 48 tahun (1959/60–2008) bagi menyiasat kesan pemecahan hutan tropika. Sebanyak 258, 292 dan 332 spesies tumbuhan berbiji asli terdapat di dalam saki-baki hutan masing-masing pada tahun 1959/60, 1997 dan 2008. Sejumlah 407 spesies direkodkan dalam ketiga-tiga inventori. Daripada jumlah ini, 188 spesies ialah spesies yang sama. Kepelbagaian spesies tidak merosot dengan pengecilan dan pemencilan saki-baki hutan. Spesies di dalam saki-baki hutan boleh mengecut apabila habitat semula jadinya menjadi terhad akibat kehilangan vegetasi asli sekeliling. Terdapat perubahan signifikan dalam komposisi flora—27.1% daripada spesies di dalam hutan asal hilang dalam inventori tahun 2008 dan 43.4% daripada spesies semasa merupakan hijrahan baru. Perubahan spesies di dalam saki-baki hutan dipercepat dengan banyak dalam masa 10 tahun kebelakangan ini akibat perubahan vegetasi sekeliling kepada ladang getah. Terdapat perubahan ketara dalam perwakilan spesies hutan matang dan spesies pemerlu cahaya—spesies hutan matang berkurangan. Bagaimanapun, bentuk hidup tumbuhan tidak menunjukkan perubahan signifikan di dalam saki-baki hutan selama tempoh 48 tahun. Kehilangan spesies diimbangi dengan hijrahan baru semua bentuk hidup tumbuhan. Walaupun kepelbagaian spesies dikekalkan dan fisiognomi (bentuk hidup) saki-baki hutan tidak berubah dengan signifikan, komposisi flora dan kumpulan spesies ekologi berubah dengan masa. Ini menunjukkan bahawa flora yang penting di dalam hutan hujan tropika sebenarnya tidak dapat dikekalkan di dalam saki-baki hutan. Dicadangkan bahawa flora hutan hujan tropika tidak dapat dilindungi dan dijangka akan hilang walaupun saki-baki hutan dipulihara.

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INTRODUCTION

Tropical rainforest fragmentation and its effects on biodiversity change have been of major concern in tropical ecology and biodiversity conservation (Turner 1996, Laurance & Bierregaard 1997). For example, the prospects for species survival in fragmented landscapes were recently reviewed (Henle *et al.* 2004). Many studies of tropical rainforest fragmentation and biodiversity changes have been done in Manaus in Brazil (Lovejoy *et al.* 1986, Klein 1989, Bierregaard *et al.* 1992, Malcom 1994, Fonseca de Souza & Brown 1994, Camargo & Kapos 1995, Ferreira & Laurance 1997, Benitez-Malvido 1998, Laurance *et al.* 1998a, b) and other tropical areas (Diamond *et al.* 1987, Newmark 1991, Kattan *et al.* 1994, Laurance 1994, Daily & Ehrlich 1995, Murcia 1995, Cadotte *et al.* 2002, Williams-Linera 2002, Zhu *et al.* 2004). Some consistent patterns have been recognised, such as reduced total species richness with the fragmentation of tropical forests (Lovejoy *et al.* 1986, Bierregaard *et al.* 1992, Chittibabu & Parthasarathy 2000), and less species rich in smaller fragments (Newmark 1991, Leigh *et al.* 1993, Laurance 1994, Daily & Ehrlich 1995), as well as conspicuous floristic drift in fragments (Tabarelli *et al.* 1999, Arroyo-Rodriguez & Mandujano 2006, Santos *et al.* 2008). Most studies of plants related to tropical forest fragments have focused on comparisons between currently existing fragments of different sizes or histories (Leigh *et al.* 1993, Turner *et al.* 1996, Turner & Corlett 1996, Ferreira & Laurance 1997, Fox *et al.* 1997, Oliveira-Filho *et al.* 1997, Benitez-Malvido 1998, Laurance *et al.* 1998a, Cadotte *et al.* 2002, Pither & Kellman 2002, Williams-Linera 2002, Zhu *et al.* 2004), or comparisons between fragments and large protected forests (Santos *et al.* 2008). Only a few studies have investigated species development with time based on comparisons between historical records and the present inventories of the same fragments, for example studies of avifauna (Willis 1974, Diamond *et al.* 1987, Kattan *et al.* 1994) and plants (Turner *et al.* 1996, Venkateswaran & Parthasarathy 2005).

In southern Yunnan, China, some natural tropical rain forest remnants are conserved near local villages and usually are less disturbed for religious reasons (Liu *et al.* 2002). Local people generally call them 'holy hills'. One of such remnants, which was part of a natural tropical seasonal rainforest in a former nature reserve became isolated in the late 1950s with rescission of the nature reserve for farms run by local government under the influence of the so-called 'great leap in industry', a nation-wide movement initiated by the Chinese government. However, the remnant has been less disturbed since 1960 due to its attribution as a 'holy hill' although it has been continually reduced in size. The remnant was floristically inventoried in 1959/1960. In 1997 and 2008, we made intensive inventories on the remnant again. Having historical and current data on the forest offers an excellent opportunity to investigate changes in species composition with time due to fragmentation. Thus, comparative studies on species richness, floristic composition, plant life form groups and ecological species groups in the remnant of tropical rainforest were made by comparing the historical records (1959/1960) with the inventories in 1997 and 2008 in this study so as to investigate floristic and physiognomic changes in the remnant over time.

MATERIALS AND METHODS

Study site

The study site is in a remnant of tropical seasonal rainforest on a holy hill near the village of Mangyangguan, which is located at 21° 35' N and 100° 40' E, at an altitude of 630 m, in Xishuangbanna, southern Yunnan (Figure 1). The remnant was part of a large forest patch in the early 1950s, isolated soon after and became completely isolated as a small patch in the late 1950s (tracing from references). From available Landsat Thematic Mapper (TM) images, which were used to create the land covers, the remnant was part of a large natural forest in 1950, but became isolated and was reduced to 30.04 ha in 1988, 18.37 ha in 1999 and 13.85 ha in 2007 and is surrounded by rubber plantations (Figure 2). The remnant in 2008 was still 13.85 ha in size.

The region is influenced by a typical tropical monsoon climate. From the records of a local climate station, which is 15 km away from the study site and at the same altitude, the annual mean temperature is 21.3 °C and the annual temperature accumulation (the sum of daily temperature means of > 10 °C) is 7752.5 °C. Frost has never been recorded. The mean annual precipitation is 1426.9 mm. More than 80% of

the precipitation falls during the rainy season between May and the end of October. The annual mean relative humidity is 85%.

The soil is laterite, developed from siliceous rocks with a deep solum but a thin humus horizon. The pH is between 4.5 and 5.0.

Inventories and data analyses

The remnant of tropical seasonal rainforest on the holy hill was surrounded by primary forests in a former nature reserve. After Chinese–Russia expedition to the region in the late 1950s, an ecological research station of the Chinese Academy of Sciences was initiated and established at the foot of the holy hill in 1959. The tropical seasonal rainforest on the holy hill was fully inventoried by repeated transect walks, and plant specimens for all encountered species (except epiphytic plants on high branches and crowns of big trees, which were identified and evaluated by binoculars) were collected from 1959 till 1960. A 0.25 ha sampling plot was also laid out in the forest for phytosociological study. A primary plant list with 246 species from the inventory was compiled for reference. The plot data were published in an article on population structure of the tropical seasonal rainforest (Xiang 1981). The plant list from the inventory in 1959/1960 was revised by authors of the present article for verification of plant names based on herbarium specimens and floristic data accumulated from the region. The species in the remnant in 1959/1960 were identified and confirmed. We made intensive floristic inventories in the remnant in 1997 and 2008 by repeated transect walks. Voucher plant specimens were collected and identified. Complete plant lists of 1997 and 2008 were compiled. The floristic inventories of 1959/1960, 1997 and 2008 were compared to investigate species change over time. Plant life forms suggested by Raunkiaer (1934) and ecological species groups suggested by Whitmore (1989) were also compared based on these inventories to investigate physiognomic changes over 48 years. Voucher specimens were kept in the herbarium of Xishuangbanna Tropical Botanical Garden (HITBC). Species authorities follow *Flora Reipublicae Popularis Sinicae* (*Flora of China*).

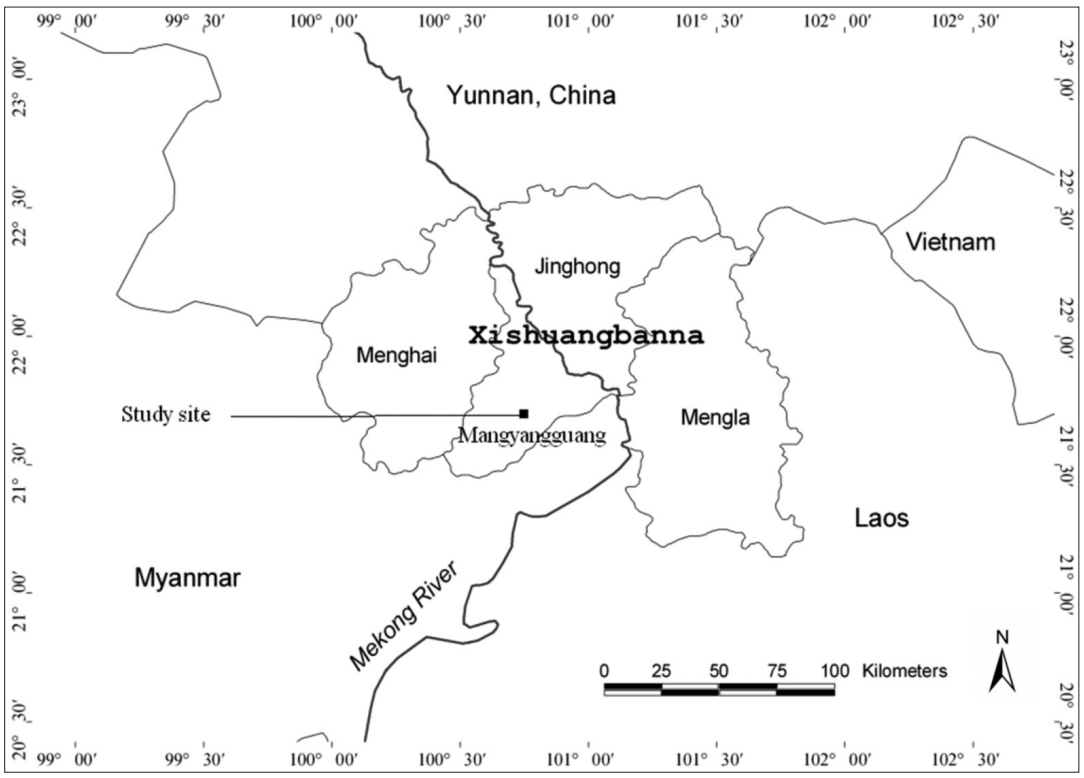


Figure 1 Locality of the study site

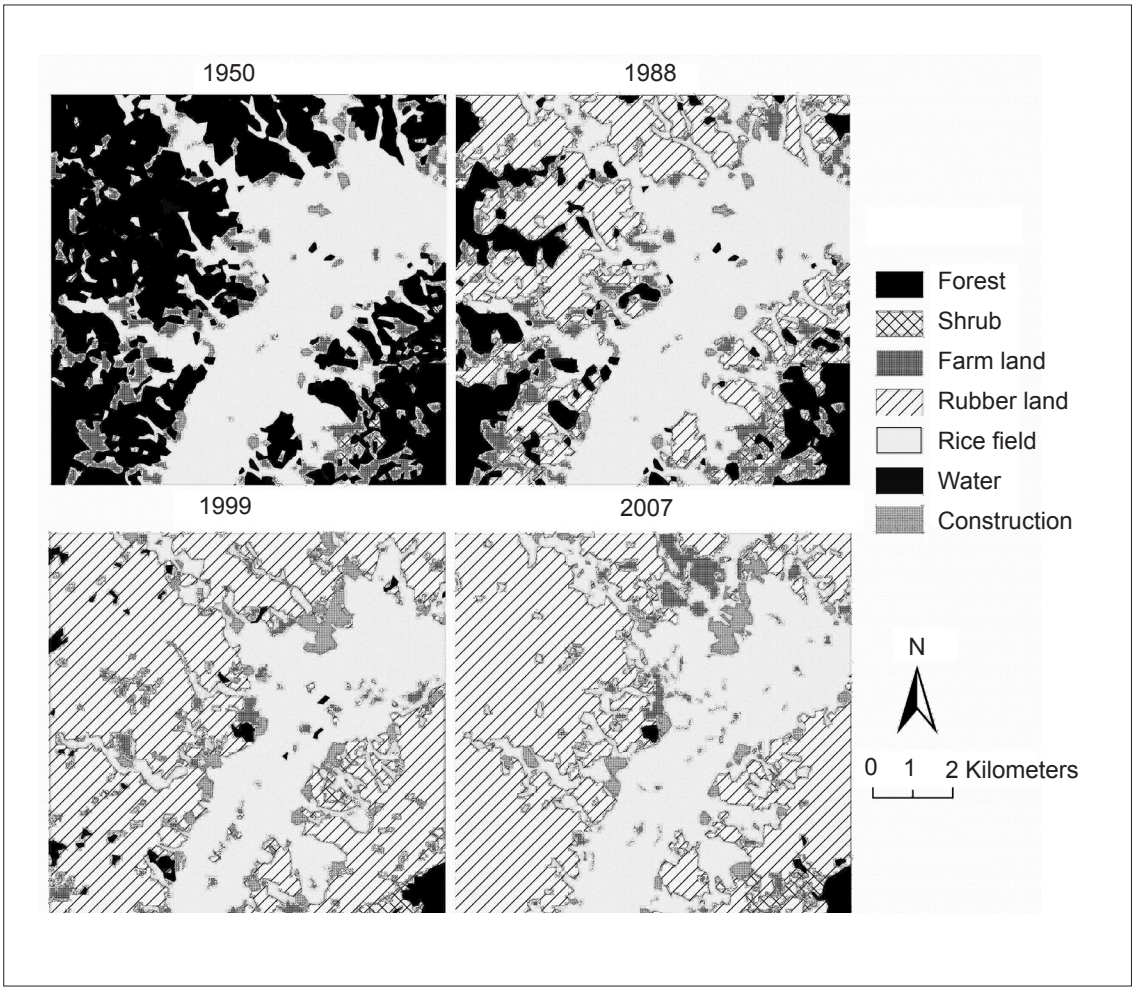


Figure 2 Trends in forest cover between 1950 and 2007 in the study region. Source: GIS Laboratory of Xishuangbanna Tropical Botanical Garden.

RESULTS

Change in overall species diversity and composition

In 1959/60, 258 species of seed plants were identified from the remnant (Table 1). In 1997 and 2008, 292 and 332 species of seed plants respectively were present in the same remnant. Of the 258 original species, 47 species were not found in 1997 and 70 were not found in 2008. Of the species in 1997, 81 were new migrants compared with the list of 1959/60. Of the species in 2008, 68 species were new migrants compared with the list of 1997, but 144 species were new migrants compared with the original list in 1959/60. Of all 407 species recorded from the remnant in the three inventories in 48 years, 188 species were common (Table 1).

Changes in plant life forms and ecological species groups

Plant life forms and ecological species groups from the lists in 1959/1960, 1997 and 2008 were compared (Figures 3 and 4). Life forms did not show statistically significant change over 48 years, except that megaphanerophytes, mesophanerophytes and epiphytes were more diverse in 1959/60, while lianas were more diverse in 1997 and 2008. Among the 70 species that were present in 1959/60 but absent in 2008, 35 species were trees, 6 shrubs, 14 lianas, 3 epiphytes and 12 herbaceous plants. Among the 144 species new to the remnant in 2008, 54 species were trees, 18 shrubs, 39 lianas and 33 herbaceous plants. The missing species were similar to the new migrants across life forms, i.e. tree species > liana species > herbaceous species > shrub species. Although

Table 1 Species list for inventories in 1959/1960, 1997 and 2008 in the remnant tropical rainforest

Species	Life form	1959/1960	1997	2008
Ageratum conyzoides	TH	+	+	+
Arthraxon lanceolatus	TH	+	+	+
Chrysopogon aciculatus	TH	+	+	+
Cyathula prostrata	TH	+	+	+
Geophila herbacea	TH	+	+	+
Hedyotis capitellata var. *mollissima*	TH	+	+	D
Hedyotis verticillata	TH	+	+	+
Oplismenus compositus	TH	+	+	+
Panicum cordatum	TH	+	+	+
Panicum repens	TH	+	+	+
Paspalum conjugatum	TH	+	+	+
Scleria chinensis	TH	+	+	+
Scurrula ferruginea	PARA	+	+	+
Ardisia villosa	NA	+	+	+
Ardisia virens	NA	+	+	+
Callicarpa longifolia	NA	+	+	+
Capparis sabiaefolia	NA	+	+	+
Capparis tenera	NA	+	+	+
Capsicum frutescens	NA	+	+	+
Chassalia curviflora	NA	+	+	+
Clerodendrum japonicum	NA	+	+	+
Clerodendrum villosum	NA	+	+	+
Daphniphyllum paxianum	NA	+	D	D
Datura stramonium	NA	+	+	D
Elaeagnus conferta	NA	+	+	+
Ervatamia officinalis	NA	+	+	+
Evodia lepta	NA	+	+	+
Helicteres viscida	NA	+	+	+
Lasianthus hookeri var. *dunniana*	NA	+	+	+
Leea indica	NA	+	D	D
Maesa indica	NA	+	+	+
Maesa macilentoides	NA	+	+	+
Melastoma imbricatum	NA	+	+	+
Oreocnide rubescens	NA	+	D	D
Pandanus furcatus	NA	+	+	+
Pavetta hongkongensis	NA	+	+	+
Prismatomeris tetrandra	NA	+	+	+
Psychotria henryi	NA	+	D	D
Psychotria siamica	NA	+	D	D
Solanum indicum	NA	+	+	+
Solanum spirale	NA	+	+	+
Urena lobata	NA	+	+	+
Aidia yunnanensis	MI	+	+	+
Antidesma fordii	MI	+	+	D
Antidesma montanum	MI	+	+	+

(continued)

Table 1 (continued)

Species	Life form	1959/1960	1997	2008
Antidesma sootepense	MI	+	+	+
Aporusa dioica	MI	+	+	+
Aporusa yunnanensis	MI	+	+	+
Aralia armata	MI	+	+	+
Ardisia arborescens	MI	+	D	D
Arytera littoralis	MI	+	+	+
Canthium horridum	MI	+	+	+
Cipadessa baccifera	MI	+	+	+
Clausena dentata var. *dunniana*	MI	+	+	D
Clausena excavata	MI	+	+	+
Cocculus orbiculatus var. *mollis*	MI	+	D	D
Croton argyratus	MI	+	+	+
Dalbergia pinnata	MI	+	+	+
Dalbergia rimosa	MI	+	+	+
Dalbergia stipulacea	MI	+	+	+
Decaspermum fruticosum	MI	+	+	+
Decaspermum gracilentum	MI	+	+	+
Dendrocnide sinuata	MI	+	D	D
Ficus esquiroliana	MI	+	+	+
Ficus hookeri	MI	+	D	D
Ficus langkokensis	MI	+	+	+
Flacourtia rukam	MI	+	+	D
Garcinia lancilimba	MI	+	+	+
Helicia cochinchinensis	MI	+	+	+
Knema erratica	MI	+	+	+
Macaranga denticulata	MI	+	+	D
Macropanax dispermus	MI	+	+	+
Mallotus barbatus	MI	+	+	+
Mallotus paniculatus	MI	+	+	+
Meliosma arnottiana	MI	+	+	+
Memecylon polyanthum	MI	+	+	D
Miliusa sinensis	MI	+	D	D
Millettia leptobotrya	MI	+	+	+
Mischocarpus pentapetalus	MI	+	D	D
Ormosia fordiana	MI	+	+	+
Ostodes paniculata	MI	+	+	+
Phoebe lanceolata	MI	+	+	+
Phyllanthus emblica	MI	+	+	D
Phyllostachys sp.	MI	+	+	D
Premna fulva	MI	+	D	D
Saprosma ternata	MI	+	+	+
Schefflera octophylla	MI	+	+	+
Stereospermum colais	MI	+	+	+
Sumbaviopsis albicans	MI	+	+	D
Suregada glomerulata	MI	+	+	+
Symplocos cochinchinensis	MI	+	+	+

(continued)

Table 1 (continued)

Species	Life form	1959/1960	1997	2008
Symplocos hookeri	MI	+	+	D
Syzygium polypetaloideum	MI	+	D	D
Syzygium latilimbum	MI	+	+	+
Syzygium oblatum	MI	+	+	+
Syzygium tetragonum	MI	+	+	+
Tarenna yunnanensis	MI	+	+	D
Turpinia cochinchinensis	MI	+	+	+
Vitex quinata var. *puberula*	MI	+	+	+
Amoora dasyclada	MG	+	+	+
Antiaris toxicaria	MG	+	+	+
Aphananthe cuspidata	MG	+	+	+
Beilschmiedia linocieroides	MG	+	+	+
Canarium tonkinense	MG	+	+	+
Chukrasia tabularis var. *velutina*	MG	+	+	+
Cinnamomum austroyunnanense	MG	+	+	+
Garuga floribunda var. *gamblei*	MG	+	D	D
Gironniera subaequalis	MG	+	+	+
Ixonanthes cochinchinensis	MG	+	+	+
Pometia tomentosa	MG	+	D	D
Pouteria grandifolia	MG	+	+	+
Pterospermum lanceifolium	MG	+	+	+
Semecarpus reticulata	MG	+	+	+
Sloanea dasycarpa	MG	+	D	D
Acronychia pedunculata	ME	+	+	+
Actinodaphne henryi	ME	+	D	D
Adenanthera pavonina var. *microsperma*	ME	+	+	+
Ailanthus giraldii	ME	+	+	+
Alangium kurzii	ME	+	+	+
Albizia lucidior	ME	+	+	+
Alstonia rostrata	ME	+	+	+
Aphanamixis polystachya	ME	+	D	D
Artocarpus lakoocha	ME	+	D	D
Baccaurea ramiflora	ME	+	+	+
Barringtonia macrostachya	ME	+	D	D
Caryota monostachys	ME	+	+	+
Castanopsis indica	ME	+	+	+
Chisocheton siamensis	ME	+	+	+
Choerospondias axillaris	ME	+	D	D
Colona floribunda	ME	+	+	D
Dasymaschalon rostratum	ME	+	D	D
Dillenia indica	ME	+	D	D
Elaeocarpus prunifolioides	ME	+	+	+
Evodia austrosinensis	ME	+	+	+
Ficus altissima	ME	+	+	+
Ficus geniculata	ME	+	+	+
Ficus glaberrima	ME	+	D	D

(continued)

Table 1 (continued)

Species	Life form	1959/1960	1997	2008
Ficus orthoneura	ME	+	+	D
Garcinia cowa	ME	+	+	+
Garcinia xanthochymus	ME	+	+	+
Garuga pinnata	ME	+	+	+
Harpullia cupanioides	ME	+	+	+
Homalium ceylanicum var. *laoticum*	ME	+	+	+
Horsfieldia glabra	ME	+	+	+
Ilex godajam	ME	+	+	+
Knema furfuracea	ME	+	+	+
Knema globularia	ME	+	+	+
Litsea glutinosa	ME	+	+	+
Litsea liyuyingi	ME	+	+	+
Litsea umbellata	ME	+	+	D
Mangifera siamensis	ME	+	+	+
Mangifera sylvatica	ME	+	+	+
Manglietia forrestii	ME	+	+	+
Microcos paniculata	ME	+	+	+
Mitrephora maingayi	ME	+	+	+
Myrsine seguinii	ME	+	+	+
Nephelium lappaceum	ME	+	+	+
Phoebe puwenensis	ME	+	+	+
Phoebe macrocarpa	ME	+	D	D
Pithecolobium clypearia	ME	+	+	+
Polyalthia simiarum subsp. *cheliensis*	ME	+	+	+
Radermachera microcalyx	ME	+	+	+
Sapindus rarak	ME	+	+	+
Spondias pinnata	ME	+	D	D
Sterculia lanceolata	ME	+	+	+
Streblus indicus	ME	+	+	+
Toona ciliata	ME	+	+	D
Trewia nudiflora	ME	+	+	+
Wrightia pubescens	ME	+	+	+
Xanthophyllum siamense	ME	+	+	+
Adenia parviflora	LPH	+	D	D
Aspidocarya uvifera	LPH	+	D	D
Aspidopterys obcordata	LPH	+	+	+
Atylosia barbata	LPH	+	+	+
Caesalpinia cucullata	LPH	+	+	+
Caesalpinia millettii	LPH	+	+	+
Celastrus hindsii	LPH	+	+	D
Celastrus paniculata	LPH	+	+	+
Cissus glaberrima	LPH	+	+	+
Cissus javana	LPH	+	+	+
Combretum latifolium	LPH	+	+	+
Connarus yunnanensis	LPH	+	+	+
Dioscorea garrettii	LPH	+	D	D

(continued)

Table 1 (continued)

Species	Life form	1959/1960	1997	2008
Dioscorea glabra	LPH	+	+	+
Embelia undulata	LPH	+	+	+
Entada phaseoloides	LPH	+	+	+
Fissistigma polyanthum	LPH	+	+	+
Gnetum montanum	LPH	+	+	+
Heterostemma wallichii	LPH	+	D	D
Hiptage acuminata	LPH	+	+	+
Hodgsonia macrocarpa	LPH	+	+	+
Ichnocarpus polyanthus	LPH	+	+	+
Illigera parviflora	LPH	+	D	D
Iodes cirrhosa	LPH	+	+	+
Iodes vitiginea	LPH	+	+	+
Ipomoea pileata	LPH	+	+	+
Morinda cochinchinensis	LPH	+	+	+
Mucuna macrocarpa	LPH	+	+	+
Mussaenda hossei	LPH	+	+	+
Mussaenda sessilifolia	LPH	+	+	D
Neuropeltis racemosa	LPH	+	+	+
Parabarium spireanum	LPH	+	+	+
Parameria laevigata	LPH	+	D	D
Passiflora foetida	LPH	+	+	+
Poikilosperma lanceolatum	LPH	+	D	D
Pristimera arborea	LPH	+	+	D
Pueraria alopecuroides	LPH	+	+	+
Randia bispinosa	LPH	+	+	+
Rourea minor	LPH	+	+	+
Salacia polysperma	LPH	+	+	+
Santaloides roxburghii	LPH	+	+	D
Smilax glabra	LPH	+	+	+
Smilax hemsleyana	LPH	+	+	+
Spatholobus pulcher	LPH	+	+	+
Stephania dolichopoda	LPH	+	+	+
Stixis suaveolens	LPH	+	+	+
Strychnos nitida	LPH	+	+	+
Tetracera scandens	LPH	+	D	D
Tetrastigma obovatum	LPH	+	D	D
Thunbergia grandiflora	LPH	+	+	+
Tinomiscium petiolare	LPH	+	+	+
Trachelospermum cordatum	LPH	+	D	D
Uncaria laevigata	LPH	+	+	+
Uncaria sinensis	LPH	+	+	+
Urceola rosea	LPH	+	+	+
Ventilago calyculata	LPH	+	+	+
Arundina graminifolia	HPH	+	D	D
Asystasia gangetica	HPH	+	+	D
Lepidagathis incurva	HPH	+	+	+

(continued)

Table 1 (continued)

Species	Life form	1959/1960	1997	2008
Munronia henryi	HPH	+	D	D
Murdannia macrocarpa	HPH	+	D	D
Piper boehmeriifolium	HPH	+	+	+
Piper sarmentosum	HPH	+	+	+
Polygonum chinense	HPH	+	+	+
Amorphophallus virosus	G	+	+	+
Colocasia esculenta	G	+	D	D
Cyperus iria	G	+	+	+
Aerides multiflorum	EP	+	+	+
Aeschynanthus acuminatus	EP	+	D	D
Dendrobium primulinum	EP	+	+	+
Dischidia tonkinensis	EP	+	+	+
Epipermnum pinnatum	EP	+	D	D
Ficus gibbosa var. *cuspidifera*	EP	+	D	D
Ficus sagittata	EP	+	+	+
Hoya pottsii	EP	+	+	+
Pholidota imbricata	EP	+	+	+
Piper mullesua	EP	+	+	+
Pothos chinensis	EP	+	+	+
Pothos scandens	EP	+	+	+
Rhaphidophora megaphylla	EP	+	+	+
Begonia sp.	CH	+	D	D
Belosynapsis ciliata	CH	+	D	D
Bredia velutina	CH	+	D	D
Commelina diffusa	CH	+	D	D
Eurysolen gracilis Prain	CH	+	+	D
Pseudechinolaena polystachya	CH	+	+	+
Rottboellia exaltata	CH	+	+	D
Tadehagi triquetrum	CH	+	+	+
Bidens pilosa	TH	-	-	NM
Blumea balsamifera	TH	-	-	NM
Borreria latifolia	TH	-	-	NM
Breynia fruticosa	TH	-	-	NM
Carex baccans	TH	-	NM	+
Conyza canadensis	TH	-	-	NM
Crassocephalum crepidioides	TH	-	-	NM
Hedyotis costata	TH	-	-	NM
Hedyotis scandens	TH	-	-	NM
Laggera alata	TH	-	-	NM
Vernonia cinerea	TH	-	-	NM
Alchornea tiliifolia	NA	-	NM	+
Allophylus hirsutus	NA	-	NM	+
Ardisia solanacea	NA	-	NM	+
Cajanus grandiflorus	NA	-	-	NM
Clerodendrum bungei	NA	-	-	NM
Clerodendrum henryi	NA	-	-	NM

(continued)

Table 1 (continued)

Species	Life form	1959/1960	1997	2008
Glochidion eriocarpum	NA	-	NM	+
Ixora yunnanensis	NA	-	-	NM
Leea compactiflora	NA	-	-	NM
Melastoma affine	NA	-	-	NM
Psychotria yunnanensis	NA	-	-	NM
Rauvolfia verticillata	NA	-	NM	+
Sida acuta	NA	-	-	NM
Solanum erianthum	NA	-	-	NM
Solanum photeinocarpum	NA	-	-	NM
Solanum torvum	NA	-	NM	+
Sterculia brevissima	NA	-	-	NM
Zanthoxylum dissitum	NA	-	NM	+
Camellia assamica var. *assamica*	MI	-	NM	+
Amoora yunnanensis	MI	-	-	NM
Antidesma acidum	MI	-	-	NM
Apodytes dimidiata	MI	-	NM	+
Artocarpus nitidus subsp. *lingnanensis*	MI	-	-	NM
Bridelia insulana	MI	-	NM	+
Celtis biondii	MI	-	NM	+
Cerasus cerasoides	MI	-	NM	D
Cylindrokelupha kerrii	MI	-	NM	+
Elaeocarpus braceanus	MI	-	-	NM
Evodia simplicifolia	MI	-	NM	+
Ficus callosa	MI	-	NM	+
Ficus hirta	MI	-	NM	+
Ficus hispida	MI	-	-	NM
Ficus vasculosa	MI	-	NM	+
Glochidion arborescens	MI	-	NM	+
Glycosmis pentaphylla	MI	-	NM	+
Hyptianthera stricta	MI	-	NM	+
Idesia polycarpa	MI	-	-	NM
Lepionurus sylvestris	MI	-	-	NM
Litsea cubeba	MI	-	-	NM
Litsea garrettii	MI	-	-	NM
Mallotus millietii	MI	-	-	NM
Mallotus philippinensis	MI	-	NM	+
Mallotus repandus	MI	-	-	NM
Manihot esculenta	MI	-	-	NM
Mayodendron igneum	MI	-	NM	+
Meliosma rigida	MI	-	-	NM
Micromelum integerrimum	MI	-	-	NM
Millettia dorwardii	MI	-	NM	+
Millettia pulchra	MI	-	NM	D
Morinda angustifolia	MI	-	NM	+
Ormosia yunnanensis	MI	-	NM	+
Oroxylum indicum	MI	-	NM	D

(continued)

Table 1 (continued)

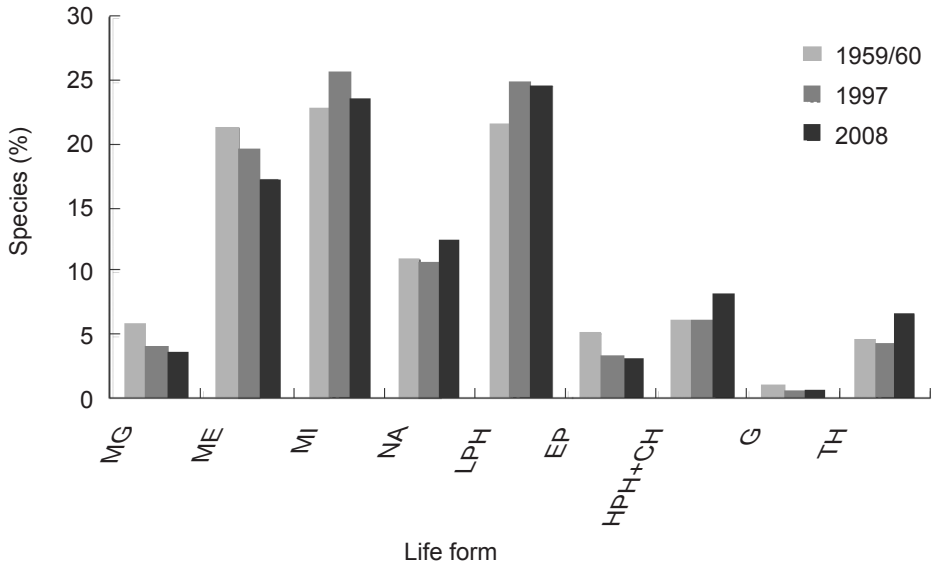
Species	Life form	1959/1960	1997	2008
Phyllanthus flexuosus	MI	-	NM	+
Pittosporopsis kerrii	MI	-	-	NM
Polyalthia cerasoides	MI	-	NM	D
Psidium guajava	MI	-	-	NM
Scleropyrum wallichianum	MI	-	NM	+
Streblus asper	MI	-	-	NM
Trema orientalis	MI	-	NM	+
Trichilia connaroides	MI	-	NM	+
Vernonia volkameriifolia	MI	-	NM	+
Canthium simile	ME	-	NM	+
Celtis timorensis	ME	-	NM	+
Dolichandrone stipulata	ME	-	NM	+
Dysoxylum binectariferum	ME	-	NM	+
Dysoxylum densiflorum	ME	-	-	NM
Elaeocarpus sphaerocarpus	ME	-	NM	+
Engelhardia spicata	ME	-	NM	+
Ficus benjamina	ME	-	NM	+
Heteropanax fragrans	ME	-	NM	+
Lagerstroemia tomentosa	ME	-	NM	+
Litsea panamanja	ME	-	NM	+
Melia toosendan	ME	-	-	NM
Pygeum topengii Merr.	ME	-	-	NM
Tarennoidea wallichii	ME	-	NM	+
Wrightia laevis	ME	-	NM	+
Dioscorea alata	LPH	-	-	NM
Dioscorea bulbifera	LPH	-	-	NM
Acacia pennata	LPH	-	NM	+
Amalocalyx microlobus	LPH	-	NM	+
Aristolochia tagala	LPH	-	-	NM
Bauhinia touranensis	LPH	-	-	NM
Cayratia trifolia	LPH	-	NM	+
Cissus subtetragona	LPH	-	NM	+
Craspedolobium schochii	LPH	-	-	NM
Cryptolepis sinensis	LPH	-	NM	+
Cynanchum corymbosum	LPH	-	NM	+
Embelia parviflora	LPH	-	NM	+
Erythropalum scandens	LPH	-	NM	+
Gouania leptostachya	LPH	-	NM	+
Gymnema sylvestre	LPH	-	NM	+
Hypserpa nitida	LPH	-	NM	+
Jasminum nervosum	LPH	-	NM	+
Maclura cochinchinensis	LPH	-	NM	+
Maclura pubescens	LPH	-	NM	+
Mappianthus iodoides	LPH	-	-	NM
Morinda umbellata	LPH	-	NM	D

(continued)

Table 1 (continued)

Species	Life form	1959/1960	1997	2008
Mucuna pruriens	LPH	-	-	NM
Mussaenda macrophylla	LPH	-	-	NM
Paederia cavaleriei	LPH	-	NM	+
Pericampylus glaucus	LPH	-	NM	+
Passiflora edulis	LPH			NM
Peripterygium quinquelobum	LPH	-	-	NM
Poranopsis discifera	LPH	-	NM	+
Rubus alceifolius	LPH	-	NM	+
Rubus pirifolius var. *cordatus*	LPH	-	-	NM
Sabia limoniacea	LPH	-	-	NM
Securidaca inappendiculata	LPH	-	NM	+
Smilax bracteata	LPH	-	-	NM
Strophanthus wallichii	LPH	-	NM	+
Tetrastigma cruciatum	LPH	-	NM	+
Thunbergia lacei	LPH	-	-	NM
Toxocarpus villosus	LPH	-	NM	+
Ventilago madaraspatana	LPH	-	NM	+
Zehneria indica	LPH	-	-	NM
Ziziphus fungii	LPH	-	NM	+
Ziziphus oenopolia	LPH	-	NM	+
Colebrookea oppositifolia	HPH	-	NM	+
Indosasa hispida	HPH	-	-	NM
Musa acuminata	HPH	-	-	NM
Zingiber xishuangbannaense	HPH	-	-	NM
Amomum villosum	HCH	-	-	NM
Chroesthes pubiflora	CH	-	NM	+
Dicliptera roxburghiana	CH	-	NM	+
Eupatorium coelestinum	CH	-	-	NM
Eupatorium odoratum	CH	-	NM	+
Malvastrum coromandelianum	CH	-	-	NM
Microstegium ciliatum	CH	-	-	NM
Phaulopsis dorsiflora	CH	-	NM	+
Pseuderanthemum polyanthum	CH	-	NM	+
Rhaphidospora vagabunda	CH	-	NM	+
Scoparia dulcis	CH	-	-	NM
Setaria palmifolia	CH	-	-	NM
Siegesbeckia orientalis	CH	-	-	NM
Synedrella nodiflora	CH	-	-	NM
Synotis cappa	CH	-	NM	+
Thysanolaena maxima	CH	-	NM	+
Tithonia diversifolia	CH	-	-	NM

MG = megaphanerophyte, ME = mesophanerophyte, MI = microphanerophyte, NA = nanophanerophyte, LPH = liana phanerophyte, HPH = herbaceous phanerophyte, CH = chamaephyte, EP = epiphyte, G = geophyte, TH = therophyte, PARA = parasitic plants; + = present, - = not present, D = disappeared, NM = new migrant



MG = megaphanerophyte, ME = mesophanerophyte, MI = microphanerophyte, NA = nanophanerophyte, LPH = liana phanerophyte, HPH = herbaceous phanerophyte, CH = chamaephyte, EP = epiphyte, G = geophyte, TH = therophyte

Figure 3 Comparison of plant life form groups between the historical records in 1959/60 and the inventories in 1997 and 2008 in the remnant of the tropical rain forest on holy hill

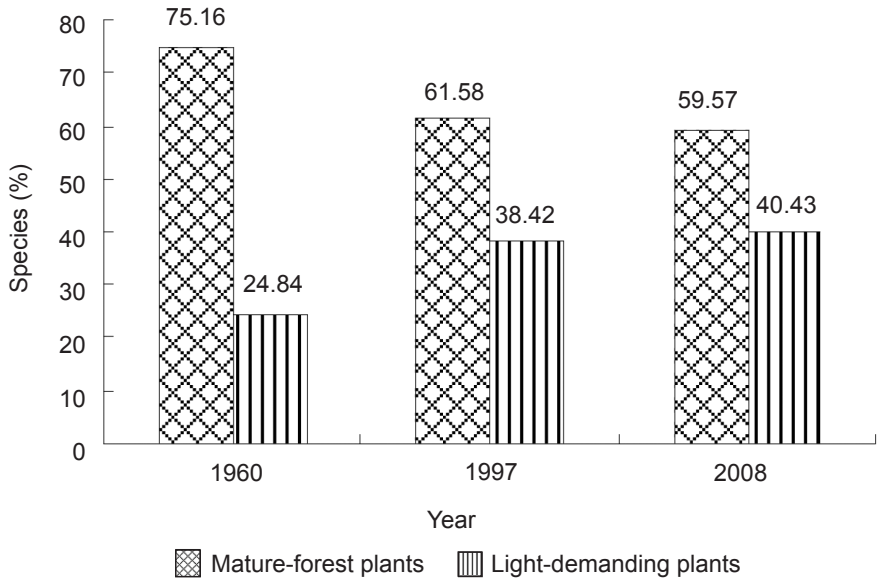


Figure 4 Ecological species groups of woody plants between the historical records in 1959/60 and the inventories in 1997 and 2008 in the remnant tropical rainforest on holy hill

life forms did not show statistically significant change, there is an obvious trend towards the reduction of primary forest features.

For ecological species groups (regeneration strategy), the mature-forest woody plants (climax plus shade-tolerant) were more diverse in 1959/60, while the light-demanding plants (pioneers plus heliophiles) were relatively more diverse in 1997 and 2008. One of the conspicuous changes in ecological groups is an increase in ruderal species, especially after 1997. Among the total of 407 species recorded from the three inventories in 48 years, four ruderal species such as *Ageratum conyzoides, Capsicum frutescens, Chrysopogon aciculatus* and *Cyathula prostrate* were common through the time. A

total of three ruderal species such as *Solanum torvum, Synotis cappa* and *Thysanolaena maxima* were present in 1997 and another 16 ruderal species such as *Blumea balsamifera, Laggera alata, Malvastrum coromandelianum* and *Siegesbeckia orientalis* appeared in 2008 (Table 1). Except for the these ruderal species, four local invasive species were found in the remnant—*Eupatorium odoratum* was present in 1997 and thereafter; *Eupatorium coelestinum, Tithonia diversifolia* and *Synedrella nodiflora* appeared only in 2008.

DISCUSSION

In 1959/60, 258 species of seed plants were recorded from the remnant, whereas in 2008, 332 species of seed plants were present in the same remnant, although it had reduced in size. The total number of species did not reduce with diminution and further isolation of the remnant.

Species diversity at any one location is maintained because local extinction is balanced by immigration, even though the abundance of each species changes from one generation to the next (Primack & Hall 1992). In this study, species diversity was maintained but the total species richness increased over 48 years of forest fragmentation. The increase in the total species richness suggests that species could condense to the limited natural habitats of the remnant even when the surrounding natural forests were lost. However, there was a significant shift in the floristic composition in the remnant. A total of 70 species recorded in the remnant in 1959/1960 were not seen in 2008. The missing 70 species made up 27.1% species of the 1959/1960 records. In contrast, there were 144 new species in 2008 not represented in 1959/1960, contributing 43.4% of the total present species in the remnant. A shift in species composition took place in the forest remnant during the 48 years' fragmentation.

If we look at species shifts between 1959/1969 and 1997, and between 1997 and 2008, the following were observed: 47 original species were missing in 1997, which made up 18.2% of the original flora, while 81 new migrants were recorded in 1997, which contributed to 27.7% of the flora in 1997. In contrast, 28 species in the flora of 1997 were missing in 2008, which made up 9.6% of the flora of 1997, while 68 new migrants were recorded, which made up 20.5% of the flora of 2008. From 1959/1960 till 1997, the rate of loss of species was 18.2% of the original flora and the new migrant rate was 27.7% of the flora. From 1997 to 2008 the species loss rate was 9.6% and the new migrant rate was 20.5% of the flora. It is clear that species shift was greatly accelerated in the recent 10 years in the remnant.

From the landuse and land cover data in 1976, 1988 and 2003 (Li *et al.* 2007), the tropical rainforests cover of 10.9% of the total area of the region in Xishuangbanna in 1976 dropped to 8.0% in 1988 and 3.6% in 2003. The high price of rubber promotes the expansion of rubber plantations in Xishuangbanna. The accelerated species shift in the recent 10 years corresponds to the rapid loss of tropical rainforest in the region. The study of surrounding vegetation on edge-related tree mortality in Amazonian forest fragments revealed that edge effects in forest fragments are significantly influenced by the structure of surrounding vegetation (Mesquita 1999). This study in southern Yunnan also revealed that species shift in the remnant was significantly influenced by the change of surrounding vegetation into rubber plantations.

Species shifts also occur in large protected forests. Tropical rainforest is considered to be a mosaic of gap, building and mature facies and is always in compositional flux in space and time. This is explained as 'mosaic or cyclical of regeneration' (Richards 1952, Brokaw 1989, Whitmore 1989, 1990). However, species shifts in forest fragments are evidently faster and bigger.

Studies on changes in species richness and floristic diversity between fragments and large protected forest patches in Mexico revealed that there was no significant difference in total species richness between fragments and large protected forest patches. However, changes were observed in the secondary or the early successional species and non-secondary or the mature-forest species (Arroyo-Rodriguez & Mandujano 2006), for example, a rise in the relative importance of ruderal species (Tabarelli *et al.* 1999). Studies on the functional attributes of tree assemblages in forest fragments of north-eastern Brazil revealed that a striking floristic drift took place in these edge-effected habitats (Santos *et al.* 2008). Our study also revealed that ecological species groups changed significantly in the

fragment with floristic shifts. The mature-forest (climax and shade-tolerant) species declined and early successional species became more important. One of the distinct changes is an increase in ruderal species. During the 48 years' fragmentation, three ruderal species appeared in 1997 and thereafter, while 16 ruderal species appeared in 2008. These findings are similar to Tabarelli's study in Atlantic fragment forests in Brazil. There were four most invasive species in the region, of which *E. odoratum* was present in 1997 and thereafter, while *E. coelestinum, T. diversifolia* and *S. nodiflora* appeared in 2008 in the remnant. Invasion of these species in the remnant corresponds to the quick change of surrounding vegetation into rubber plantations.

Turner *et al.* (1996) made a comparison between the historical records (herbarium specimens) and extant plant list from a 4 ha remnant of tropical rainforest in Singapore following more than 100 years' fragmentation. He concluded that 50.9% species from herbarium records were lost from the forest, but 94 native species in the extant plant list were not in herbarium records. Venkateswaran and Parthasarathy (2005) made a comparison on changes in species composition and density of trees ≥10 cm girth in a 1 ha plot in a tropical dry evergreen forest of temple forest (similar to our holy hill forest in Yunnan) over a decade. They found that the total number of tree species rose by 21% (from 24 to 29 species), but about 11% of the total number of species within the plot was lost over the period. Immigration accounted for an increase of 27.6% of the species recorded. These examples, including our case, showed that the floristic shifts took place in fragmented forests over time.

Life forms in the remnant did not change significantly except for slight reduction of megaphanerophytes, mesophanerophytes and epiphytes, and slight increase of liana phanerophytes. Species loss was balanced by new migrants across life forms to some extent. This feature could explain that life forms did not show statistically significant change in the remnant. However, in the fragment of lowland tropical rainforest isolated more than a century in Singapore, 85.7% of herbaceous plant species, 73.3% of shrubs, 66.7% of epiphytes, 60.0% of lianas and 42.3% trees species were lost (Turner *et al.* 1996). In our study, 27.1% of tree species, 21.4% of shrubs, 25.0% of lianas, 23.0% of epiphytes and 38.7% of herbaceous plants were lost from the original flora in the remnant. The species loss was almost similar across life forms except for herbaceous plants with relatively higher ratio in the remnant in southern Yunnan, and was lower than the case in Singapore. The loss of herbaceous plants was balanced by distinct increase of ruderal species in some extent, so that life forms in the remnant in southern Yunnan did not change significantly. Our study also revealed that 9.6% of species was lost from 1997 till 2008, which was similar to a study in India by Venkateswaran and Parthasarathy (2005) with extinction within the plot accounting for 11% of tree species of the original inventory in a decade.

The microclimates in the remnant of our study site and the large protected forest of the same type were observed by Ma *et al.* (1998). The microclimatic disparity between the interior and exterior of the forest is less in the remnant compared with the large protected (primary) forest. For example, the differences in maximum air temperature, maximum soil temperature and relative air humidity between the interior and exterior of the forest were 6.1 °C, 28.2 °C and 37% respectively in the large protected forest, and 4.9 °C, 19.6 °C and 6% respectively in the remnant on the holy hill. Studies on edge effects of soil revealed that the differences of soil moisture and pH between the edges and the interiors were larger in the large protected forest than in the remnant. The differences in organic matter and extractable N between the edges and the interiors were distinctly greater in the protected forest than in the remnant. The extractable K was higher in the protected forest than in the remnant (Zhu *et al.* 2004). Floristic shifts in the remnant in southern Yunnan are strongly influenced by the edge effects of microclimate and soil.

In summary, the species diversity was maintained. Even though total species richness increased, the floristic composition and ecological species groups were distinctly changed in the remnant in 48 years of fragmentation. The maintenance of species richness does not mean that the flora of the rainforest can be maintained in the fragmented forest. Our results support the suggestions of Santos *et al.* (2008) that conservation policy guidelines will fail to protect ageing, hyper-fragmented landscapes from drastic impoverishment if the remaining forest patches are heavily dominated by edge habitat.

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