Taiwania, **52**(2): 127-144, 2007

Classification and Ordination of Evergreen Broad-Leaved Forest in the Middle and Upper Watershed of the Nan-Tze-Shian Stream in Southwestern Taiwan

Fu-shan Chou[(1)], Chun-kuei Liao[(2)] and Yuen-po Yang[(2,3)]

(Manuscript received 5 December, 2006; accepted 12 April, 2007)

ABSTRACT: A phytosociological survey was carried out in the middle and upper watershed of the Nan-Tze-Shian stream in southwestern Taiwan in order to determine the relationship between vegetation and environmental factors. Through the use of the tabular comparison method, a hierarchical vegetation classification was established. Detrended Correspondence Analysis (DCA) was applied to the data to clarify the variation of the 70 plots and search for a relationship with 5 environmental variables. The results show that the distribution of vegetation types is responding to the elevation and Whole Light Sky space (WLS). Three alliances and 9 associations were distinguished and described: (I) *Cyclobalanopsis stenophylloides* alliance, including *Neolitsea acuminatissima - Cyclobalanopsis morii*, *Vaccinium randaiense - Castanopsis cuspidata* and *Pasania kawakamii - Cyclobalanopsis stenophylloides* associations, (II) *Beilschmiedia erythrophloia* alliance, including *Camellia salicifolia - Beilschmiedia erythrophloia*, *Engelhardtia roxburghiana - Cyclobalanopsis longinux* and *Helicia formosana - Castanopsis kusanoi* associations, and (III) *Machilus kusanoi* alliance, including *Castanopsis formosana - Machilus philippinense*, *Machilus zuihoensis - Schefflera octophylla* and *Ficus irisana - Machilus kusanoi* associations.

KEY WORDS: Nan-Tze-Shian stream, Vegetation classification, Detrended Correspondence Analysis.

INTRODUCTION

The evergreen broad-leaved forest of Taiwan is distributed from sea level to ca. 2500 m in elevation, and covers ca. 32% of the island area (Hsieh et al., 1997). Evergreen broad-leaved forest is the most extensive landscape feature of Taiwan. Taiwan island is located within the Pacific monsoon zone and has a very complex topography, resulting in different of climatic regions and a diversity of mountainous vegetation types (Su, 1985). The floristic composition and structure of evergreen broad-leaved forest is complex. Although there are several hundreds papers discussing the study of vegetation in Taiwan, we are unable to completely comprehend the composition and structure of evergreen broad-leaved forest. Su (2002) pointed out that the diversification of vegetation classification in Taiwan is due to differences in vegetation schools and the technical details of algorithm. Therefore, the vegetation ecology of evergreen broad-leaved forest requires thorough research.

Excepting a few surveys by Suzuki (1941), Chen (1988) and Yang (2002, 2003), no comprehensive analysis has been made of vegetation research in the watershed of Nan-Tze-Shian stream in southwestern Taiwan. We selected the middle and upper watershed of Nan-Tze-Shian stream as our study area, because the primary forests in the lower area of Nan-Tze-Shian stream had been changed to road, village and cultivated land. Further, we only studied the evergreen broad-leaved forest, partly because the floristic composition of conifer forest is simple and partly because vegetation classification of conifer forest is relatively less debatable. Our aims in this paper were to elucidate how vegetation changes along the major environmental gradients by using a gradient analysis and a method distinguishing plant associations in the study area. It is hoped that the survey results will promote a greater level of knowledge and understanding of vegetation in the study area and provide data for vegetation mapping and environment monitoring.

1. Liukuei Research Center, Taiwan Forestry Research Institute, 198 Chungchuang, Chunghsing Village, Liukuei 844, Kaoshiung County, Taiwan.
2. Department of Biological Sciences, National Sun Yat-sen University, 70, Lien-hai Rd., Kaohsiung 804, Taiwan.
3. Corresponding Author. Tel: 886-7-5252000 ext. 3622; Fax: 886-7-5253622; Email: ypo@mail.nsysu.edu.tw

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METHODS

Site description

The origin of Nan-Tze-Shian stream is Southwestern of Yu-Shan Mountain, the highest peak (23˚47'N, 120˚46'E) in Eastern Asia. The study area is located in the middle and upper watershed of the Nan-Tze-Shian stream in southwestern Taiwan, where it flows through a narrow valley between watersheds of the Tzen-Wen stream and Lao-Nung stream (Fig. 1). It is a long and narrow rectangle whose altitude ranging from ca. 250 to 3952 m, gently sloping in a southwesterly direction from the Yu-Shan and Dung-Shuel-Shan towards the Kuo-Ting-Shan and Wu-Shan, respectively. According to Su (1984a), the climate of the study area belongs to the summer rain climate category. The summer rain, brought by SW monsoon winds from the South China Sea, is positively correlated with altitude. Drought causes noticeable deciduousness in the forests of lowland and low elevation southern and western Taiwan.

Data collection

Sampling was completed during 2002 and 2004, using the count-plot method designated by Mueller-Dombois and Ellenberg (1974). Plot locations were subjectively chosen in areas of homogenous vegetation, according to physiognomy and habitat topography. Seventy sampling plots were established in the study area and each plot was composed of twenty separate subplots (5 m × 5 m). Every woody individual with DBH $\geqq$ 1 cm was identified and its diameter at breast height (DBH) was also measured. In addition, epiphytic and herbaceous plants were identified and recorded for the description of vegetation types. The scientific names of vascular plants used followed Flora of Taiwan (Huang et al., 1993-2000). The plants not identified in the field were collected for later identification in the experiment and voucher specimens. The quantitative assessment of environmental factors is followed by method of Su (1987).

Statistical analysis

The analysis was based on a data matrix composed of 70 samples and 203 taxa. Importance values (IVI) were calculated for all tree species for each sampling plot as the sum of relative density + relative dominance + relative frequency (Curtis and McIntosh, 1950). The IVI data were transformed to integer values according to ordinal 1-9 octave scale (Gauch, 1982). Syntaxonomic tabular comparison (Mueller-Dombois and Ellenberg, 1974) was used to detect and clarify vegetation types in the data matrix. The naming of communities is done, using the characteristic species in front and dominant species behind. The characteristic species appears to be the most characteristic of the community and the most differential as compared to related communities. The dominant species appears in the canopy and has the higher IVI value. Hierarchical vegetation classification system is according to the U.S. National Vegetation Classification (USNVC) (Grossman et al., 1998). The upper levels of the classification hierarchy were delimited by the physiognomy of forest. The lowest two levels of the hierarchy, alliance and association, were based on floristic composition of plots. Detrend Correspondence Analysis (DCA) was conducted on plant species and environmental variable matrices using the PC-ORD package (McCune and Mefford, 1999). The relationships between the major gradient axis and environmental variables were calculated using Pearson correlation coefficients.

RESULTS

Vegetation classification

A hierarchy of forest vegetation system was developed by the tabular comparison method. Three alliances and nine associations were recognized in the synoptic table (Table 1), which represent the main plant communities in the study area. The relative values of major trees in each association are enumerated in Appendix 1. A description of major floristic composition and habitat type for all communities is given below.

Evergreen broad-leaved forest Formation

In Taiwan, evergreen broad-leaved forest is the most complex plant community, which is primarily composed of Lauraceae and Fagaceae trees. In this study, *Michelia compressa* var. *compressa*, *Beilschmiedia erythrophloia*, *Turpinia formosana* and *Elaeocarpus sylvestris* are common tree species of evergreen broad-leaved forest formation (Table 1).

I. Subtropical montane evergreen broad-leaved forest Subformation

Subtropical montane evergreen broad-leaved forests are distributed between 1200 and 2600 m in this study. Since these forests are often suffused in fog and cloud, they are also called fog forest. Two subzones are distinguishable depending on the altitude. The upper subzone is mixed with few conifers such as *Tsuga chinensis* and *Picea*

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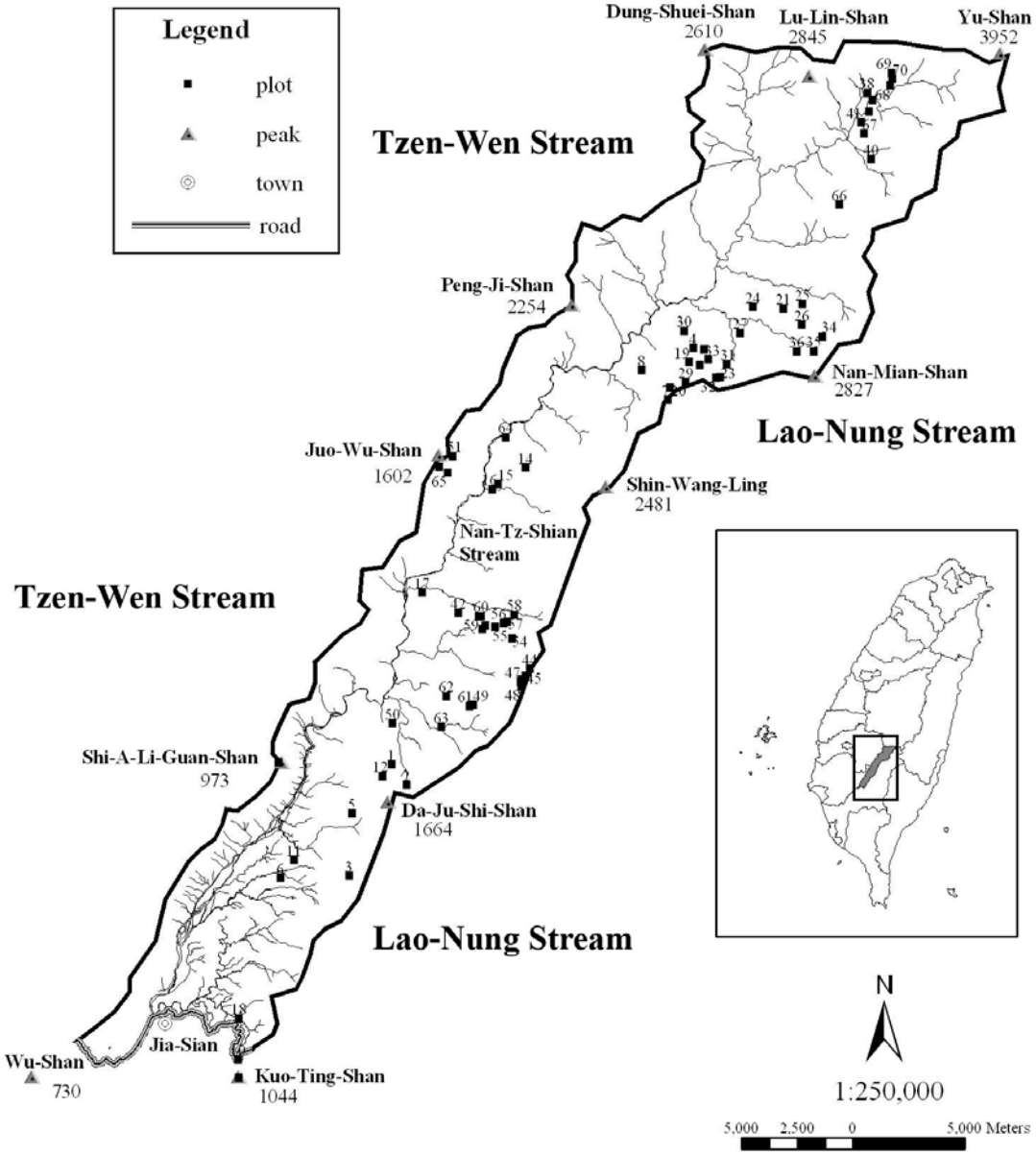


Fig. 1. Location of study area and plots.

morrisonicola, while the lower one is composed of large trees of the Lauraceae and Fagaceae families. This forest zone can be divided into *Cyclobalanopsis stenophylloides* alliance and *Beilschmiedia erythrophloia* alliance. In this study, *Castanopsis cuspidata*, *Eurya loquaiana*, *Daphniphyllum glaucescens*, *Gordonia axillaries*, *Neolitsea aciculata*, *Ilex ficoidea*, *Litsea acuminata*, *Machilus thunbergii* and *Eurya chinensis* are character species of montane temperate evergreen broad-leaved forest subformation (Table 1).

(I) *Cyclobalanopsis stenophylloides* Alliance

This alliance is distributed between 1800 and 2600 m in the study area. Viburnum parvifolium, Acer morrisonense, Cephalotaxus wilsoniana, Mahonia japonica, Callicarpa randaiensis, Eurya strigillosa and Symplocos konishii are character species of the alliance (Table 1). The alliance can be divided into Neolitsea acuminatissima - Cyclobalanopsis morii, Vaccinium randaiense - Castanopsis cuspidate and Pasania kawakamii - Cyclobalanopsis stenophylloides associations.

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Table 1. Synoptic table of the evergreen broad-leaved forests in the study area. The digits of columns contain the synoptic IVI value and constancy (1=5-20%; 2=21-40%; 3=41-60%; 4=61-80%; 5=81-100%) of species within each association.

Evergreen broad-leaved forest formation
I. Subtropical Montane evergreen broad-leaved forest (*Quercus* zone)
(I) *Cyclobalanopsis stenophylloides* alliance (upper *Quercus* zone)
A. *Neolitsea acuminatissima - Cyclobalanopsis morii* association
B. *Vaccinium randaiense - Castanopsis cuspidata* association
C. *Pasania kawakamii - Cyclobalanopsis stenophylloides* association
(II) *Beilschmiedia erythrophloia* alliance (lower *Quercus* zone)
D. *Camellia salicifolia - Beilschmiedia erythrophloia* association
E. *Engelhardtia roxburghiana - Cyclobalanopsis longinux* association
F. *Helicia formosana - Castanopsis kusanoi* association
II. Subtropical submontane evergreen broad-leaved forest (*Machilus-Castanopsis* zone)
(III) *Machilus kusanoi* alliance
G. *Castanopsis formosana- Machilus philippinense* association
H. *Machilus zuihoensis - Schefflera octophylla* association
I. *Ficus irisana - Machilus kusanoi* association

Alliance	(I)			(II)			(III)		
Association	A	B	C	D	E	F	G	H	I
Number of plots	5	15	7	12	11	6	4	5	5
Tsuga chinensis	1,1	-	-	-	-	-	-	-	-
Rhamnus chingshuiensis	1,1	-	-	-	-	-	-	-	-
Symplocos heishanensis	1,1	-	-	-	-	-	-	-	-
Sycopsis sinensis	1,1	-	-	-	-	-	-	-	-
Ligustrum morrisonense	1,2	-	-	-	-	-	-	-	-
Daphne arisanensis	1,1	-	-	-	-	-	-	-	-
Litsea morrisonensis	1,1	-	-	-	-	-	-	-	-
Elaeagnus formosana	1,1	-	-	-	-	-	-	-	-
Symplocos migoi	2,3	-	-	-	-	-	-	-	-
Neolitsea acuminatissima	5,5	-	1,1	-	-	-	-	-	-
Symplocos morrisonicola	5,5	1,1	-	-	1,1	-	-	-	-
Cyclobalanopsis morii	6,5	1,3	1,1	-	-	-	-	-	-
Viburnum integrifolium	1,1	2,3	-	-	1,1	-	-	-	-
Symplocos modesta	-	1,1	-	-	-	-	-	-	-
Trochodendron aralioides	-	1,1	-	-	-	-	-	-	-
Callicarpa remotiflora	-	1,1	-	-	-	-	-	-	-
Acer kawakamii	-	1,1	-	-	-	-	-	-	-
Rhododendron oldhamii	-	1,1	-	-	-	-	-	-	-
Symplocos arisanensis	-	1,1	-	-	-	-	-	-	-
Ilex pedunculosa	-	1,1	-	-	-	-	-	-	-
Prunus transarisanensis	-	1,1	-	-	-	-	-	-	-
Prunus campanulata	-	1,1	-	-	-	-	-	-	-
Picrasma quassioides	-	1,1	-	-	-	-	-	-	-
Viburnum formosanum	-	1,1	-	-	-	-	-	-	-
Damnacanthus indicus	-	1,1		-	-	-	-	-	-
Wikstroemia lanceolata	-	1,1	-	-	-	-	-	-	-
Symplocos sonoharae	-	1,2	-	-	-	-	-	-	-
Vaccinium randaiense	-	2,4	1,1	-	1,1	-	-	-	-
Alnus formosana	-	-	1,2	-	-	-	-	-	-
Embelia lenticellata	-	-	1,1	-	-	-	-	-	-
Pasania kawakamii		1,2	3,5	1,4					
Viburnum parvifolium	1,1	1,2	2,4	-	-	-	-	-	-
Acer morrisonense	1,2	1,1	1,1	-	-	-	-	-	-
Cephalotaxus wilsoniana	1,2	1,1	1,1	-	-	-	-	-	-
Mahonia japonica	1,1	1,1	1,1	-	-	-	-	-	-
Callicarpa randaiensis	1,2	1,1	1,1	-	-	-	-	-	-
Eurya strigillosa	3,4	1,3	1,2	-	-	1,2	-	-	-
Symplocos konishii	1,1	1,1	1,3	1,1	-	-	-	-	-

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Table 1. Continued.

Alliance	(I)			(II)			(III)		
Association	A	B	C	D	E	F	G	H	I
Number of plots	5	15	7	12	11	6	4	5	5
Picea morrisonicola	1,2	1,1	-	-	-	-	-	-	-
Symplocos glauca	1,1	1,1	-	-	-	-	-	-	-
Cleyera japonica	1,2	1,2	-	-	1,1	-	-	-	-
Dendropanax dentiger	1,1	1,1	-	-	1,1	-	-	-	-
Sinopanax formosana	-	1,1	1,1	-	-	-	-	-	-
Quercus tatakaensis	-	1,2	1,3	-	-	-	-	-	-
Ligustrum pricei	-	1,2	1,1	-	-	-	-	-	-
Ardisia chinensis	-	-	-	1,1	-	-	-	-	-
Symplocos theophrastifolia	-	-	-	1,1	-	-	-	-	-
Strobilanthes formosanus	-	-	-	1,1	-	-	-	-	-
Strobilanthes flexicaulis	-	-	-	1,1	-	-	-	-	-
Aucuba chinensis	-	-	-	1,1	-	-	-	-	-
Camellia salicifolia	-	-	-	1,1	-	-	-	-	-
Castanopsis kawakamii	-	-	-	1,1	-	-	-	-	-
Engelhardtia roxburghiana	-	1,1	-	-	5,5	1,2	-	-	-
Ilex goshiensis	-	-	-	-	1,2	-	-	-	-
Podocarpus macrophyllus	-	-	-	-	1,2	-	-	-	-
Cleyera japonica	-	-	-	-	1,1	-	-	-	-
Lasianthus microstachys	-	-	-	-	1,1	-	-	-	-
Euonymus tashiroi	-	-	-	-	1,1	-	-	-	-
Ilex rotunda	-	-	-	-	1,1	-	-	-	-
Litsea acutivena	-	-	-	-	1,1	-	-	-	-
Camellia sinensis	-	-	-	-	1,1	-	-	-	-
Symplocos caudata	-	-	-	-	1,1	-	-	-	-
Viburnum luzonicum	-	-	-	-	1,1	-	-	-	-
Helicia formosana	-	-	-	1,1	-	5,5	-	-	-
Castanopsis kusanoi	-	-	-	1,1	-	3,3	-	-	-
Machilus konishii	-	-	-	1,2	1,2	4,5	1,2	-	-
Helicia cochinchinensis	-	1,1	-	-	1,2	2,2	-	-	-
Prunus phaeosticta	-	-	-	-	1,2	2,3	-	-	-
Ternstroemia gymnanthera	-	1,3	-	1,1	2,3	1,1	-	-	-
Neolitsea parvigemma	-	-	-	1,2	2,3	2,3	-	-	-
Pasania brevicaudata	-	-	-	1,1	3,4	3,4	-	-	-
Machilus philippinense	-	-	-	1,1	1,1	1,1	1,2	-	-
Diospyros morrisiana	-	-	-	-	1,1	1,1	-	-	-
Ficus formosana	-	-	-	-	1,1	1,2	-	-	-
Alniphyllum pterospermum	-	-	-	-	1,1	1,2	1,2	-	-
Itea parviflora	-	-	-	1,1	1,2	-	-	-	-
Osmanthus enervius	1,1	-	-	1,1	1,1	-	-	-	-
Ardisia virens	-	-	-	1,1	-	1,1	1,2	-	-
Lindera communis	-	-	-	1,1	-	1,2	1,2	-	-
Diospyros morrisiana	-	-	-	-	1,1	1,1	-	-	-
Ficus formosana	-	-	-	-	1,1	1,2	-	-	-
Alniphyllum pterospermum	-	-	-	-	1,1	1,2	1,2	-	-
Cinnamomum subavenium	-	1,2	-	1,1	-	1,1	-	-	-
Elaeocarpus japonicus	-	2,4	-	1,1	2,3	-	-	-	-
Osmanthus heterophyllus	1,1	-	-	-	1,2	1,1	-	-	-
Eurya leptophylla	1,2	1,2	1,3	1,1	-	-	-	1,1	-
Lithocarpus lepidocarpus	1,2	3,4	1,2	1,2	1,2	-	-	-	-

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Table 1. Continued.

Alliance	(I)			(II)			(III)		
Association	A	B	C	D	E	F	G	H	I
Number of plots	5	15	7	12	11	6	4	5	5
Pittosporum illicioides	1,2	1,1	1,3	1,1	1,1	-	-	-	-
Cyclobalanopsis stenophylloides	3,4	1,3	6,5	3,4	1,2	-	-	-	-
Malus doumeri	-	1,1	1,3	1,1	1,1	-	-	-	-
Schima superba	-	1,2	1,1	1,2	1,1	-	-	-	-
Rhododendron leptosanthum	-	3,4	1,2	1,1	2,3	-	-	-	-
Machilus japonica	-	1,2	4,4	2,3	-	1,2	-	-	-
Machilus zuihoensis	-	1,1	1,1	1,1	-	-	-	-	-
Eriobotrya deflexa	-	1,2	1,3	1,2	2,3	-	-	1,3	-
Sloanea formosana	-	1,1	-	1,2	1,1	1,2	-	1,1	-
Cyclobalanopsis longinux	-	4,4	-	1,1	5,5	1,2	1,2	-	-
Castanopsis cuspidata	2,3	4,4	3,4	1,2	3,4	2,3	-	-	-
Eurya loquaiana	4,5	5,5	1,2	1,2	1,2	1,1	-	-	-
Daphniphyllum glaucescens	1,3	1,1	1,2	1,1	2,3	1,2	-	-	-
Gordonia axillaris	2,3	3,4	1,3	1,2	2,3	1,1	-	-	-
Neolitsea aciculata	1,1	2,3	4,5	2,3	1,1	1,1	-	-	-
Ilex ficoidea	1,1	3,4	-	2,3	1,1	1,2	-	-	-
Litsea acuminata	1,2	2,3	6,5	5,5	5,5	6,5	1,2	-	-
Machilus thunbergii	1,3	5,5	1,3	2,3	5,5	2,3	1,2	-	-
Eurya chinensis	1,2	1,2	1,2	1,2	1,2	2,4	-	1,1	-
Capparis acutifolia	-	-	-	-	-	-	1,2	-	-
Maclura cochinchinensis	-	-	-	-	-	-	1,2	-	-
Castanopsis formosana	-	-	-	1,1	-	-	6,5	1,1	1,1
Sapium discolor	-	-	-	-	-	-	-	1,1	-
Styrax suberifolia	-	-	-	-	-	-	-	1,1	-
Melicope pteleifolia	-	-	-	-	-	-	-	1,1	-
Aleurites montana	-	-	-	-	-	-	-	1,1	-
Cryptocarya chinensis	-	-	-	-	-	-	-	1,1	-
Saurauia tristyla	-	-	-	-	-	-	-	1,1	-
Bridelia tomentosa	-	-	-	-	-	-	-	1,1	-
Diospyros oldhamii	-	-	-	-	-	-	-	1,1	-
Euphoria longana	-	-	-	-	-	-	-	1,1	-
Ficus superba	-	-	-	-	-	-	-	1,2	-
Liquidambar formosana	-	-	-	-	-	-	-	1,2	-
Radermachia sinica	-	-	-	-	-	-	-	1,2	-
Champereia manillana	-	-	-	-	-	-	-	1,2	-
Styrax formosana	-	-	-	-	-	-	-	2,3	-
Wendlandia uvarufolia	-	-	-	-	-	-	-	2,3	1,2
Diospyros eriantha	-	-	-	-	-	-	-	2,4	1,1
Machilus zuihoensis	-	-	-	1,1	-	-	-	4,5	-
Ficus variegata	-	-	-	-	-	-	-	-	1,2
Leea guineensis	-	-	-	-	-	-	-	-	1,1
DeuTzeia pulchra	-	-	-	-	-	-	-	-	1,1
Glochidion philippicum	-	-	-	-	-	-	-	-	1,1
Melanolepis multiglandulosa	-	-	-	-	-	-	-	-	1,1
Crateva adansonii	-	-	-	-	-	-	-	-	1,1
Croton cascarilloides	-	-	-	-	-	-	-	-	1,1
Ilex asprella	-	-	-	-	-	-	-	-	1,1
Dendrocnide meyeniana	-	-	-	-	-	-	-	-	3,5
Glochidion zeylanicum	-	-	-	-	-	-	-	1,3	2,4
Ficus irisana	-	-	-	-	-	-	1,2	1,2	5,5

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Table 1. Continued.

Alliance	(I)			(II)			(III)		
Association	A	B	C	D	E	F	G	H	I
Number of plots	5	15	7	12	11	6	4	5	5
Machilus kusanoi	-	-	-	-	-	1,1	2,3	1,3	6,5
Mallotus paniculatus	-	-	-	-	-	1,1	1,2	2,4	1,3
Trema orientalis	-	-	-	-	-	1,1	1,2	1,2	1,3
Morus australis	-	-	-	-	-	-	1,2	1,2	1,2
Gardenia jasminoides	-	-	-	-	-	-	1,2	1,3	1,1
Cinnamomum camphora	-	-	-	-	-	-	1,2	1,3	1,1
Ehretia acuminata	-	-	-	-	-	-	1,2	1,3	1,2
Mallotus philippensis	-	-	-	-	-	-	1,2	2,4	2,4
Psychotria rubra	-	-	-	-	-	-	1,2	2,3	1,1
Sapindus mukorossii	-	-	-	-	-	-	1,2	4,5	3,4
Ficus erecta	-	-	-	-	-	-	1,2	1,1	1,1
Ficus nervosa	-	-	-	-	-	-	1,2	1,1	2,4
Koelreuteria henryi	-	-	-	-	-	-	1,2	1,1	2,4
Lagerstroemia subcostata	-	-	-	-	-	-	1,2	1,4	2,4
Neolitsea konishii	-	-	-	1,1	-	-	1,2	1,2	1,3
Fraxinus griffithii	-	-	1,1	-	-	-	1,2	2,3	-
Cyclobalanopsis glauca	-	-	-	-	-	-	1,2	1,1	-
Melia azedarach	-	-	-	-	-	-	1,2	1,3	-
Macaranga tanarius	-	-	-	-	-	-	1,2	-	1,1
Bischofia javanica	-	-	-	-	-	-	1,2	-	1,2
Prunus zippeliana	-	-	-	-	-	-	1,2	-	1,1
Murraya euchrestifolia	-	-	-	-	-	-	1,2	-	1,3
Ardisia sieboldii	-	-	-	-	1,1	-	1,2	-	1,1
Phoebe formosana	-	-	-	1,1	-	-	1,2	-	2,3
Vitex quinata	-	-	-	-	-	-	-	1,3	1,2
Aphananthe aspera	-	-	-	-	-	-	-	1,2	1,2
Ficus septica	-	-	-	-	-	-	-	1,2	1,2
Murraya paniculata	-	-	-	-	-	-	-	1,1	1,2
Ficus virgata	-	-	-	-	-	-	-	1,1	1,1
Photinia beauverdiana	1,2	1,3	2,4	1,1	-	-	-	1,1	-
Osmanthus matsumuranus	-	1,3	1,2	1,2	1,2	-	1,2	1,1	-
Ardisia cornudentata	-	1,1	-	1,1	1,3	1,2	-	1,2	1,2
Acer albopurpurascens	-	1,1	1,3	1,2	1,1	-	1,2	-	1,2
Michelia compressa	-	3,4	2,4	2,4	4,5	3,5	1,2	1,2	1,1
Beilschmiedia erythrophloia	-	1,2	3,4	6,5	4,5	5,5	3,3	1,1	1,1
Turpinia formosana	-	1,1	1,2	3,3	1,2	1,2	5,5	5,5	4,5
Elaeocarpus sylvestris	-	1,3	1,1	2,3	1,3	2,3	-	3,5	1,2
Cinnamomum insulari-montanum	-	1,2	2,4	1,2	1,1	-	1,2	2,3	-
Hydrangea chinensis	-	1,2	1,1	1,1	1,2	1,1	1,2	1,2	-
Litsea akoensis	-	-	2,4	1,1	-	1,1	1,3	1,1	1,2
Celtis formosana	-	-	1,1	1,2	-	-	2,3	4,5	3,4
Maesa perlaria	-	-	1,1	1,1	-	1,1	1,2	1,1	1,1
Schefflera octophylla	-	-	-	1,1	2,2	1,2	2,3	5,5	4,5
Glycosmis citrifolia	-	-	-	1,2	1,1	1,1	4,5	2,3	5,5
Syzygium formosanum	-	-	-	1,2	1,2	1,2	1,2	1,2	1,1
Pasania ternaticupula	-	-	-	1,1	1,1	1,2	1,2	-	1,2
Viburnum odoratissimum	-	-	-	1,2	1,2	-	2,3	1,1	1,1
Litsea hypophaea	-	-	-	-	1,1	1,1	1,2	2,4	1,2
Glochidion rubrum	-	-	-	-	1,1	1,1	1,2	1,2	1,2

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Table 1. Continued.

Alliance	(I)			(II)			(III)		
Association	A	B	C	D	E	F	G	H	I
Number of plots	5	15	7	12	11	6	4	5	5
Pasania cornea	-	-	-	-	1,2	1,2	1,2	-	1,1
Other species									
Microtropis fokienensis	1,1	-	-	-	1,1	-	-	-	-
Symplocos formosana	-	1,1	-	-	-	1,2	-	-	-
Cinnamomum kanehirae	-	1,1	-	1,2	-	-	-	-	-
Meliosma rhoifolia	-	1,1	-	-	1,1	-	-	-	-
Zelkova serrata	-	1,1	1,3	-	-	-	-	1,1	1,1
Ilex hayataiana	-	1,1	-	-	1,1	-	-	-	-
Adinandra formosana	-	1,2	-	-	1,1	-	-	-	-
Skimmia reevesiana	-	1,1	-	-	1,1	-	-	-	-
Callicarpa formosana	-	-	1,3	1,1	-	-	-	-	-
Semnostachya longespicata	-	-	-	1,1	-	-	1,2	-	-
Tetradium glabrifolium	-	-	1,1	-	-	1,2	-	1,1	-
Cinnamomum osmophloeum	-	-	-	1,1	-	-	-	1,1	-
Xylosma congesta	-	-	1,2	1,1	-	-	-	-	-
Castanopsis fargesii	-	-	-	1,1	-	1,1	-	-	-
Oreocnide pedunculata	-	-	1,3	1,3	-	-	-	-	1,1
Rhus succedanea	-	-	-	-	1,1	-	-	1,2	-
Trichodesma calycosum	-	-	-	1,1	-	-	-	-	1,1
Lasianthus fordii	-	-	-	-	-	1,1	-	-	1,1

A. *Neolitsea acuminatissima - Cyclobalanopsis morii* Association (Group A: 25, 26, 34, 35, 66 plots in Fig. 2).

Cyclobalanopsis stenophylloides - Cyclobalanopsis morii dominant community (Yang, 2002).

This association is confined to the upper part of hillsides or broad ridges, and altitudes from 2270 to 2600 m. This is mainly indicated by *Neolitsea acuminatissima*, *Symplocos morrisonicola* and *Symplocos migoi* (Table 1). The canopy is primarily formed by tall *Cyclobalanopsis morii*, with some *Cyclobalanopsis stenophylloides* and *Castanopsis cuspidata*. A few *Tsuga chinensis* and *Picea morrisonicola* are emergent trees. The subcanopy layer is dominated by *Neolitsea acuminatissima*, *Symplocos morrisonicola*, *Eurya loquaiana* and *Eurya strigillosa*. The ground layer contains many ferns like *Dryopteris formosana*, *Dryopteris lepidopoda*, *Polystichum parvipinnulum* and *Arachniodes rhomboids*.

B. *Vaccinium randaiense - Castanopsis cuspidata* Association (Group B: 4, 7, 20, 21, 22, 23, 28, 32, 36, 44, 45, 46, 47, 48, 56 plots in Fig. 2).

Castanopsis cuspidata subassociation (Suzuki, 1941)

This association is confined to upper part of hillsides or ridges, and altitude from 1650 to 2300 m. This is mainly indicated by *Vaccinium randaiense*, *Rhododendron leptosanthum*, *Viburnum integrifolium* and *Symplocos sonoharae* (Table 1). The canopy is primarily formed by tall *Castanopsis cuspidata*, *Cyclobalanopsis longinux*, *Gordonia axillaries*, *Machilus thunbergii* and *Lithocarpus lepidocarpus*. The subcanopy layer is dominated by *Vaccinium randaiense*, *Elaeocarpus japonicus*, *Litsea acuminata*, *Neolitsea aciculata*, *Ilex ficoidea* and *Ternstroemia gymnanthera*. The ground layer is mainly composed of *Dryopteris formosana*, *Athyrium erythropodum*, *Monachosorum henryi*, *Damnacanthus indicus* and *Plagiogyria euphlebia*.

C. *Pasania kawakamii - Cyclobalanopsis stenophylloides* Association (Group C: 19, 29, 33, 67, 68, 69, 70 plots in Fig. 2).

Machilus japonica association (Suzuki, 1941), *Cyclobalanopsis stenophylloides - Cinnamomun insulari-montanum - Beilschmiedia erythrophloia* type (Yang, 2002), *Cyclobalanopsis stenophylloides - Castanopsis cuspidate - Pasania kawakamii* type (Yang, 2002), *Cyclobalanopsis stenophylloides - Quercus tatakaensis - Pasania kawakamii* type (Yang, 2002).

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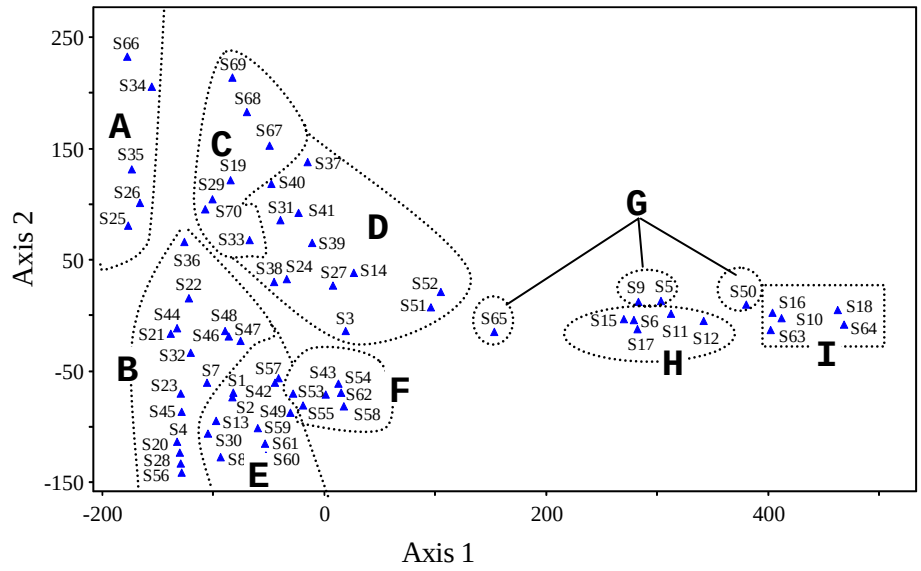


Fig. 2. Ordination of plots for the first two axes of DCA. A: *Neolitsea acuminatissima* - *Cyclobalanopsis morii* association. B: *Vaccinium randaiense* - *Castanopsis cuspidata* association. C: *Pasania kawakamii* - *Cyclobalanopsis stenophylloides* association. D: *Camellia salicifolia* - *Beilschmiedia erythrophloia* association, E: *Engelhardtia roxburghiana* - *Cyclobalanopsis longinux* association. F: *Helicia formosana* - *Castanopsis kusanoi* association. G: *Castanopsis formosana* - *Machilus philippinense* association. H: *Machilus zuihoensis* - *Schefflera octophylla* association. I: *Ficus irisana* - *Machilus kusanoi* association.

This association is confined to hillsides or ravines with altitudes ranging from 1970 to 2100 m. This is mainly indicated by *Pasania kawakamii*, *Machilus japonica*, *Viburnum parvifolium*, *Symplocos konishii* and *Callicarpa formosana* (Table 1). The canopy is primarily formed by tall *Cyclobalanopsis stenophylloides*, *Castanopsis cuspidata*, *Pasania kawakamii* and *Beilschmiedia erythrophloia*. The subcanopy layer is dominated by *Litsea acuminata*, *Neolitsea aciculata*, *Cinnamomum insulari-montanum* and *Litsea akoensis*. The ground layer is mainly composed of *Alpinia pricei*, *Damnacanthus indicus*, *Arachniodes pseudoaristata*, *Tetrastigma umbellatum*, *Pilea plataniflora*, *Polystichum hancockii* and *Embelia lenticellata*.

(II) *Beilschmiedia erythrophloia* Alliance

This alliance is distributed between 1200 and 1800 m in this study. *Beilschmiedia erythrophloia*, *Machilus konishii*, *Ternstroemia gymnanthera*, *Neolitsea parvigemma*, *Passania brevicaudata* and *Machilus philippinense* are character species of the alliance. The alliance can be divided into *Beilschmiedia erythrophloia*, *Engelhardtia roxburghiana* - *Cyclobalanopsis longinux* and *Helicia formosana* - *Machilus konishii* associations.

D. *Camellia salicifolia* - *Beilschmiedia erythrophloia* Association (Group D: 3, 14, 24, 27, 31, 37, 38, 39, 40, 41, 51, 52 plots in Fig. 2).

Castanopsis cuspidata - *Michelia compressa* - *Cyclobalanopsis stenophylloides* dominant community (Chen, 1988).

This association is confined to hillsides or ravines with altitudes ranging from 1370 to 1900 m. This is mainly indicated by *Ardisia chinensis*, *Symplocos theophrastifolia*, *Strobilanthes flexicaulis*, *Aucuba chinensis*, *Camellia salicifolia* and *Castanopsis kawakamii* (Table 1). The canopy is primarily formed by tall *Beilschmiedia erythrophloia*, *Cyclobalanopsis stenophylloides*, *Schima superba* var. *superba* and *Machilus japonica*. The subcanopy layer is dominated by *Litsea acuminata*, *Neolitsea aciculata*, *Michelia compressa* var. *compressa* and *Turpinia formosana*. The ground layer is mainly composed of *Apinia pricei*, *Arachniodes rhomboides*, *Tetrastigma umbellatum*, *Pilea plataniflora*, *Microlepia strigosa*, *Diplazium dilatatum* and *Elatostema lineolatum*.

E. *Engelhardtia roxburghiana* - *Cyclobalanopsis longinux* Association (Group E: 1, 2, 8, 13, 30, 42, 49, 57, 59, 60, 61 plots in Fig. 2).

Cyclobalanopsis longinux subassociation (Suzuki, 1941).

This association is confined to ridges with altitudes ranging from 1200 to 1780 m. This is mainly indicated by *Engelhardtia roxburghiana*, *Itea parviflora* and *Podocarpus macrophyllus* (Table 1). The canopy is primarily formed by tall *Cyclobalanopsis longinux*, *Engelhardtia*

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roxburghiana, *Machilus thunbergii* and *Michelia compressa* var. *compressa*. The subcanopy layer is dominated by *Litsea acuminata*, *Ilex ficoidea* and *Tricalysia dubia*. The ground layer is mainly composed of *Arachniodes pseudoaristata*, *Dryopteris formosana*, *Smilax lanceifolia*, *Asplenium normale*, *Polystichum biaristatum*, *Asplenium wrightii* and *Damnacanthus indicus*.

F. *Helicia formosana* - *Castanopsis kusanoi* Association (Group F: 43, 53, 54, 55, 58, 62 plots in Fig. 2).

This association is confined to hillsides with altitudes ranging from 1320 to 1560 m. This is mainly indicated by *Helicia formosana*, *Machilus konishii* and *Castanopsis kusanoi* (Table 1). The canopy is primarily formed by tall *Machilus konishii*, *Castanopsis kusanoi*, *Beilschmiedia erythrophloia* and *Pasania brevicaudata*. The subcanopy layer is dominated by *Litsea acuminata*, *Helicia formosana*, *Tricalysia dubia* and *Eurya chinensis*. The ground layer is mainly composed of *Diplazium dilatatum*, *Elatostema lineolatum*, *Monachosorum henryi*, *Asplenium normale*, *Microlepia strigosa*, *Microlepia obtusiloba*, *Ardisia cornudentatai* and *Calamus quiquesetinervius*.

II. Subtropical submontane evergreen broad-leaved forest Subformation

Subtropical submontane evergreen broad-leaved forests are distributed between 500 and 1200 m in this study. This is mainly indicated by *Machilus kusanoi*, *Mallotus paniculatus*, *Trema orientalis*, *Morus australis*, *Gardenia jasminoides*, *Cinnamomum camphora*, *Ehretia acuminate*, *Mallotus philippensis*, *Psychotria rubra*, *Sapindus mukorossii*, *Ficus erecta*, *Ficus irisana*, *Ficus nervosa*, *Koelreuteria henryi*, *Lagerstroemia subcostata* and *Neolitsea konishii* (Table 1). This forest zone only includes *Machilus kusanoi* alliance, which is composed of *Castanopsis formosana, Machilus zuihoensis - Schefflera octophylla and Ficus irisana - Machilus kusanoi associations.*

(III) *Machilus kusanoi* Alliance

G. *Castanopsis formosana* - *Machilus philippinense* Association (Group G: 5, 9, 50, 65, plots in Fig. 2).

This association is confined to hillsides or broad ridge with ranging altitudes from 900 to 1300 m. This is mainly indicated by *Castanopsis formosana* (Table 1). The canopy is primarily formed by tall *Castanopsis formosana*, *Machilus philippinense*, with some *Beilschmiedia erythrophloia* and *Machilus kusanoi*. The subcanopy layer is dominated by *Turpinia formosana*, *Glycosmis citrifolia* and *Viburnum odoratissimum*. The ground layer is mainly composed of *Elatostema lineolatum*, *Calamus quiquesetinervius, Arenga tremula, Bolbitis contaminans*, *Lepidagathis formosensis*, *Alocasia odora* and *Colysis wrightii*.

H. *Machilus zuihoensis* - *Schefflera octophylla* Association (Group H: 6, 11, 12, 15, 17 plots in Fig. 2).

This association is restricted to upper part of hillsides or ridges with altitudes ranging from 650 to 1000 m. This is mainly indicated by *Machilus zuihoensis*, *Styrax formosana*, *Diospyros eriantha* and *Wendlandia uvarufolia*. The canopy is primarily formed by tall *Schefflera octophylla*, *Machilus zuihoensis* and *Sapindus mukorossii*. The subcanopy layer is dominated by *Turpinia formosana*, *Celtis formosana* and *Litsea hypophaea*. The ground layer is mainly composed of *Arenga tremula*, *Liriope minor*, *Colysis pothifolia*, *Asplenium wrightii*, *Lygodium japonicum* and *Pteris longipes.*

I. *Ficus irisana* - *Machilus kusanoi* Association (Group I: 10, 16, 18, 63, 64 plots in Fig. 2).

This association is restricted to ravines with altitudes from 500 to 800 m. This is mainly indicated by *Ficus irisana*, *Dendrocnide meyeniana* and *Glochidion zeylanicum* (Table 1). The canopy is primarily formed by tall *Machilus kusanoi*, with some *Ficus irisana*, *Supindus mukorossii* and *Phoebe formosana*. The subcanopy layer is dominated by *Turpinia formosana*, *Schefflera octophylla*, *Glycosmis citrifolia* and *Dendrocnide meyeniana*. The ground layer is mainly composed of *Calamus quiquesetinervius*, *Alocasia odora*, *Arenga tremula*, *Colysis pothifolia*, *Colysis hemionitidea*, *Ctenitopsis fuscipes*, *Amischotolype hispida* and *Lepidagathis formosensis*.

Ordination

Figure 2 shows the ordination result of the DCA analysis. The eigenvalues for the DCA gradients were 0.770, 0.394 and 0.300 for the first, second and third axes, respectively, suggesting that three dimensions could explain in the major variation of vegetation. The plots are approximately evenly spread in DCA axis 1 and axis 2 space, and there is little discontinuity between groups A-I obtained from the synthetic table (Table 1). Pearson correlations between environmental variables and the three axes of DCA confirm that the major floristic gradient parallels the environmental gradient (Table 2). This

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Table 2. Pearson correlations between the environmental variables and the three axes of DCA ordination.

	Altitude	Slope	Aspect	SMI	WLS
Axis 1	- 0.912**	0.125	0.080	- 0.095	- 0.255
Axis 2	0.324	0.144	0.077	- 0.091	- 0.413*
Axis 3	0.008	- 0.136	- 0.116	- 0.057	0.056

Abbreviations for the environmental variables are SMI = Synthetic Moisture Index and WLS = Whole Light Sky space. (**significant at the 0.01 level, *significant at the 0.05 level).

floristic gradient is also a gradient of decreasing altitude, as the first DCA axis is negatively correlated with altitude. The second DCA axis is negatively correlated with whole light sky space.

The ordination diagrams obtained using DCA (Fig. 2) illustrate two main gradients. Axis 1 represents the altitude gradient, starting with the *Neolitsea acuminatissima - Cyclobalanopsis morii* association on the left hand side, followed by *Vaccinium randaiense - Castanopsis cuspidata*, *Pasania kawakamii - Cyclobalanopsis stenophylloides*, *Camellia salicifolia - Beilschmiedia erythrophloia*, *Engelhardtia roxburghiana - Cyclobalanopsis longinux*, *Helicia formosana - Castanopsis kusanoi*, *Castanopsis formosana - Machilus philippinense* and *Machilus zuihoensis - Schefflera octophylla* associations. At the end of the sequence is the *Ficus irisana - Machilus kusanoi* association. Figure 3 shows the altitudinal distribution of the nine plant associations, and estimated boundaries between forest zones. The altitudinal boundaries between upper *Quercus*, lower *Quercus* and *Machilus-Castanopsis* zones are ca. 1800 m and 1200 m, respectively. Therefore, altitude is a major environmental factor affecting the pattern of vegetation types and zones in this landscape. This result supports the finding that the division of Taiwanese vegetation zones by altitude is practicable (Su, 1984b). Furthermore, axis 2 of the DCA analysis shows a little significant correlation between vegetation pattern and the whole light sky space gradient. In fact, the whole light sky space is representative of the air moisture degree of a habitat. It is a major environmental factor affecting the diversification of vegetation types in the same forest zone.

DISCUSSION

The study area is located between watersheds of the Tzen-Wen stream and Lao-Nung stream. Among 70 plots, only 5 plots were located in the A-Li-Shan Range, which was defined as a nature reserve for aborigines. Through this range Cha-Shan roads (tea farm roads) passed in an earlier period, and caused the natural forest to be felled in most areas in this range. The primary forest in the area was quickly changed to tea plantation, bamboo grove and orchard. Now, it is only possible to find some residual natural forests at the ridges as well as on steep slopes. Only 11 plots were surveyed in the lower area below 1000 m altitude, and these forests have been disturbed by human activity. Anthropogenic disturbances influenced the vegetation structure and diversity significantly. O'Neill (2001) postulates that *Homo sapiens* is a keystone species that changes system stability by altering environmental constraints and biotic structures. Therefore, we must take into account human factors affecting managed forest ecosystems in this study area in the future.

Comparisons were made between these nine associations and the vegetation types outlined in previous publications that researched the watershed of Nan-Tze-Shian stream. Suzuki (1941) described *Machilus japonica*, *Cinnamomun camphora* and *Cyclobalanopsis longinux* associations in their report from a field survey at the upper Nan-Tze-Shian stream area. Further, the *Cyclobalanopsis longinux* association was divided into *Castanopsis cuspidata* and *Cyclobalanopsis longinux* subassociations by the limit of altitude from 1800 m to 2000 m. According to Suzuki's floristic compositions of forest types, the *Machilus japonica* association, *Castanopsis cuspidata* and *Cyclobalanopsis longinux* dominant subassociations are similar to the *Pasania kawakamii - Cyclobalanopsis stenophylloides*, *Vaccinium randaiense - Castanopsis cuspidata* and *Engelhardtia roxburghiana - Cyclobalanopsis longinux* associations in this study, respectively. In the case of the *Cinnamomun camphora* association, our results do not correspond with it. We hypothesize that the habitat niche of the *Cinnamomun camphora* association has been completely destroyed. Chen (1988) surveyed a permanent plot and named it as *Castanopsis cuspidata - Michelia compressa - Cyclobalanopsis stenophylloides* dominant community by the dominant species. Comparing this to our floristic compositions, the dominant community corresponds with the *Camellia salicifolia - Beilschmiedia erythrophloia* association of this study. Yang (2002) investigated 8 plots of evergreen broad-leaved forest using the Blaun - Blanquet method and named 8 dominant communities by the dominant species. The *Cyclobalanopsis stenophylloides - Cyclobalanopsis morii* dominant community is similar to the *Neolitsea acuminatissima - Cyclobalanopsis morii* association in this study. The *Cyclobalanopsis stenophylloides - Cinnamomun insulari - montanum - Beilschmiedia*

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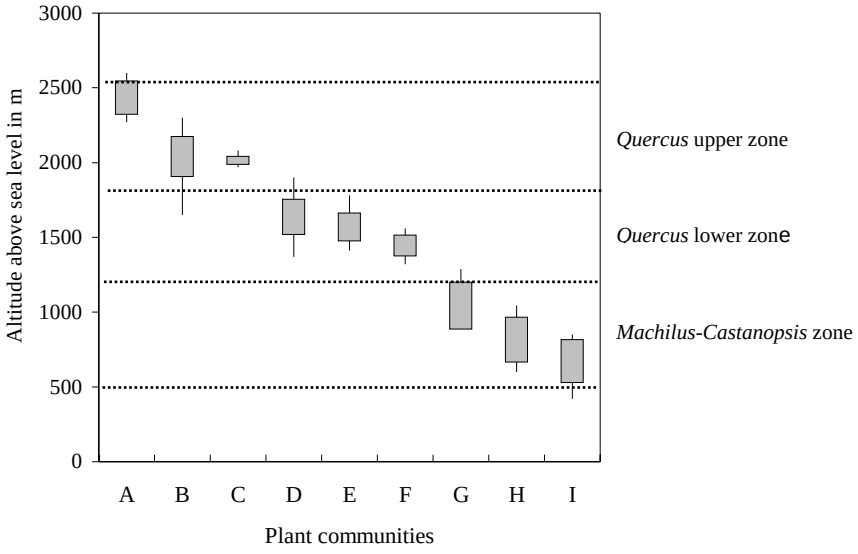


Fig. 3. Box plots showing the altitudinal distribution of the nine plant communities described, and estimated boundaries between *Quercus* upper, *Quercus* lower and *Machilus-Castanopsis* zones. A: *Neolitsea acuminatissima - Cyclobalanopsis morii* association. B: *Vaccinium randaiense - Castanopsis cuspidata* association. C: *Pasania kawakamii - Cyclobalanopsis stenophylloides* association. D: *Camellia salicifolia - Beilschmiedia erythrophloia* association. E. *Engelhardtia roxburghiana - Cyclobalanopsis longinux* association. F: *Helicia formosana - Castanopsis kusanoi* association. G: *Castanopsis formosana - Machilus philippinense* association. H: *Machilus zuihoensis - Schefflera octophylla* association. I: *Ficus irisana - Machilus kusanoi* association.

erythrophloia, *Cyclobalanopsis stenophylloides - Castanopsis formosana - Cyclobalanopsis globosa*, *Cyclobalanopsis stenophylloides - Castanopsis cuspidate - Pasania kawakamii*, *Cyclobalanopsis stenophylloides - Quercus tatakaensis - Pasania kawakamii*, *Cyclobalanopsis stenophylloides - Carpinus kawakamii* and *Machilus thunbergii - Pasania kawakamii* dominant communities are all similar to the *Pasania kawakamii - Cyclobalanopsis stenophylloides* association in this study. The *Machilus japonica - Castanopsis cuspidata* dominant community is similar to the *Camellia salicifolia - Beilschmiedia erythrophloia* association in this study. Yang (2003) surveyed a 1 hectare permanent plot. This unnamed plant community is similar to our *Vaccinium randaiense - Castanopsis cuspidata* and *Pasania kawakamii - Cyclobalanopsis stenophylloides* associations, according to its floristic composition. We surmise that the permanent plot contained the floristic composition of two separate associations, partly because its area was too large and partly because it was located on the boundary between the two associations.

According to Su (1984b), *Chamaecyparis* type, other coniferous type and mixed coniferous-broad leaved type are major vegetation types in the upper Quercus zone. In this study, the *Neolitsea acuminatissima - Cyclobalanopsis morii* association is belongs to mixed coniferous broad leaved type, which is dominated by *Cyclobalanopsis morii* in the canopy and a few *Tsuga chinensis* and *Picea morrisonicola* are emergent trees. We found many *Chamaecyparis* plantations along the Nan-Chi and Mei-Lan trials and few residual *Chamaecyparis* huge trees on the side of trials among survey period. We believe in the existence of *Chamaecyparis* forest type in the upper Quercus zone, and it has been destroyed completely by logging. A *Picea morrisonicola* stand on the side of Nan-Chi trail, but we only aim at evergreen broad-leaved forest of this study.

Woody vegetation in the study is responding directly or indirectly to important environmental gradients, including elevation and whole light sky space. The altitude is a major environmental factor affecting the pattern of vegetation types and zones in the landscape, a finding that supports the assertion that it is practicable to divide the vegetation zones of Taiwan by altitude (Su, 1984b). Furthermore, axis 2 of the DCA analysis shows a significant correlation between vegetation pattern and whole light sky space gradient. In fact, the whole light sky space is representative of the air moisture degree of the habitat. It is a major environmental factor affecting the diversification of vegetation types in the same forest zone.

Whittaker et al. (1973) and Ohsawa (1987) raised the concept of habitat niche to understand the relationship between pattern of community and environmental gradient. The vegetation zones distinguished in this analysis had some affinities with the zonal vegetation proposed for the Montane area

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of the central Taiwan (Su, 1984b). In this study, the *Neolitsea acuminatissima - Cyclobalanopsis morii*, *Vaccinium randaiense - Castanopsis cuspidate* and *Pasania kawakamii - Cyclobalanopsis stenophylloides* associations belong to the *Quercus* upper zone (Su, 1984b), and are majorly distributed in an altitudinal range from 1900 m to 2600 m. Its upper and lower boundary range is 100 m wider than the *Quercus* upper zone (Su, 1984b). The *Camellia salicifolia - Beilschmiedia erythrophloia*, *Engelhardtia roxburghiana - Cyclobalanopsis longinux* and *Helicia formosana - Castanopsis kusanoi* associations belong to the *Quercus* lower zone (Su, 1984b), and are majorly distributed in an altitudinal range from 1300 m to 1800 m. Their upper and lower boundary lines are 200 m lower than the *Quercus* upper zone of Su (1984b). The *Castanopsis formosana - Machilus philippinense*, *Machilus zuihoensis - Schefflera octophylla* and *Ficus irisana - Machilus kusanoi* associations belong to the majorly distributed in an altitudinal range from 500 m *Machilus - Castanopsis* zone (Su, 1984b), and are to1300 m. The upper boundary of the range is 300 m wider than the *Machilus - Castanopsis* zone (Su, 1984b). Therefore, the altitudinal ranges of vegetation zones in each of these two geographical climatic regions of Taiwan are unequal.

ACKNOWLEDGEMENTS

The authors thank Professor Horng-Jye Su, Department of Forestry, National Taiwan University, Professor Chang-Fu Hsieh, Institute of Ecology and Evolution, National Taiwan University, Dr. Ching-I Peng, Herbarium, Research Center for Biodiversity, Academia Sinica, and Dr. Ho-Yih Liu, Department of Biological Sciences, National Su Yat-sen University for their critical reading of the earlier manuscript and valuable suggestions. Thanks are due to Bing-Ling Shih, Tien-Tsai Chen, Tea-Chen Liu, Sheng-Sian Dai and Ting-Yi Tzi for help with some plants identification during the vegetation survey. We appreciate the criticism and suggestions that highly improved the quality of this manuscript provided by two anonymous reviewers.

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Appendix 1. The relative IVI values of major trees in each association of the evergreen broad-leaved forest in the middle and upper watershed of the Nan-tze-shian stream.

A. *Neolitsea acuminatissima - Cyclobalanopsis morii* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Cyclobalanopsis morii	25.50	6.13	11.15	14.97
Neolitsea acuminatissima	7.49	14.42	13.37	13.43
Symplocos morrisonicola	5.74	9.45	10.96	9.81
Castanopsis cuspidata	14.93	5.15	6.61	9.49
Cyclobalanopsis stenophylloides	10.76	4.57	4.29	7.28
Eurya loquaiana	2.73	6.65	6.76	6.15
Eurya chinensis	3.15	6.60	4.38	5.48
Gordonia axillaris	5.29	3.28	4.59	4.77
Picea morrisonicola	8.77	0.64	1.99	3.88
Eurya strigillosa	2.22	2.76	5.64	3.86
Cleyera japonica	3.48	3.24	2.94	3.59
Symplocos migoi	2.07	2.04	5.00	3.27
Daphniphyllum glaucescens	0.64	1.41	2.47	1.67
Lithocarpus lepidocarpus	1.50	0.52	1.31	1.17
Cephalotaxus wilsoniana	0.83	0.71	1.47	1.09
Eurya leptophylla	0.24	0.60	2.12	1.06
Litsea acuminata	0.29	0.80	1.76	1.04
Symplocos konishii	0.40	0.50	1.33	0.80
Pittosporum illicioides	0.46	26.27	1.09	0.70
Sycopsis sinensis	0.32	0.44	0.96	0.62
Others	3.19	3.82	9.81	5.86
Total	100	100	100	100

B. *Vaccinium randaiense - Castanopsis cuspidata* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Machilus thunbergii	11.81	10.81	8.79	10.54
Castanopsis cuspidata	13.77	6.02	5.78	8.61
Cyclobalanopsis longinux	14.25	4.43	5.35	8.02
Eurya loquaiana	4.71	10.47	7.84	7.70
Rhododendron leptosanthum	5.12	8.33	5.41	6.29
Viburnum integrifolium	1.78	8.05	4.06	4.62
Vaccinium randaiense	3.49	4.46	3.56	3.84
Lithocarpus lepidocarpus	6.08	2.14	3.16	3.83
Gordonia axillaris	3.61	3.00	4.44	3.70
Litsea acuminata	1.86	4.88	4.28	3.69
Michelia compressa	2.20	3.75	4.54	3.51
Elaeocarpus japonicus	2.10	1.99	2.65	2.25
Neolitsea aciculata	1.50	2.44	2.67	2.22
Cleyera japonica	1.71	2.30	2.48	2.17
Ternstroemia gymnanthera	1.78	2.09	2.55	2.14
Schima superba	3.17	1.00	1.40	1.86
Eurya strigillosa	1.52	1.91	2.02	1.83
Adinandra formosana	2.11	1.06	1.56	1.58
Beilschmiedia erythrophloia	1.45	1.41	1.56	1.47
Ilex ficoidea	0.78	1.47	1.89	1.38
Others	15.2	17.99	24.01	18.75
Total	100	100	100	100

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Appendix 1. Continued.

C. *Pasania kawakamii - Cyclobalanopsis stenophylloides* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Cyclobalanopsis stenophylloides	18.20	14.85	7.09	13.68
Litsea acuminata	10.74	14.28	13.68	13.16
Machilus japonica	10.44	11.72	8.79	11.60
Castanopsis cuspidata	8.64	6.10	4.40	6.43
Beilschmiedia erythrophloia	5.38	6.53	5.99	6.06
Pasania kawakamii	5.62	4.36	4.69	5.03
Neolitsea aciculata	3.51	4.02	7.06	5.01
Cinnamomum insulari-montanum	5.32	5.64	2.06	4.44
Litsea akoensis	1.58	3.95	4.21	3.36
Machilus thunbergii	5.09	4.04	3.02	3.03
Viburnum parvifolium	0.81	2.56	2.38	1.91
Eurya leptophylla	0.54	1.89	2.67	1.69
Michelia compressa	1.60	1.01	1.96	1.52
Gordonia axillaris	1.34	1.04	2.15	1.51
Eurya chinensis	0.61	1.79	1.75	1.38
Lithocarpus lepidocarpus	2.22	0.64	1.31	1.38
Photinia beauverdiana	0.67	1.16	2.20	1.37
Callicarpa formosana	0.55	1.34	2.02	1.32
Zelkova serrata	2.19	0.54	0.71	1.22
Eriobotrya deflexa	0.91	0.89	1.74	1.18
Others	14.04	11.65	20.12	13.70
Total	100	100	100	100

D. *Camellia salicifolia – Beilschmiedia erythrophloia* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Beilschmiedia erythrophloia	23.44	21.13	13.82	19.46
Litsea acuminata	9.26	11.81	11.71	10.93
Cyclobalanopsis stenophylloides	8.88	9.94	4.72	7.85
Turpinia formosana	3.67	5.88	5.73	5.09
Machilus thunbergii	5.30	3.50	3.70	4.17
Neolitsea aciculata	3.38	3.59	4.15	3.70
Machilus japonica	5.64	2.14	3.18	3.65
Glycosmis citrifolia	1.03	4.23	3.15	2.80
Tricalysia dubia	1.41	2.78	3.77	2.65
Castanopsis cuspidata	3.45	2.04	1.98	2.49
Viburnum odoratissimum	1.20	2.93	2.82	2.32
Schima superba	3.97	1.00	1.81	2.26
Michelia compressa	3.09	1.36	2.32	2.26
Machilus konishii	2.89	1.32	1.90	2.04
Neolitsea parvigemma	1.36	1.76	1.96	1.69
Sloanea formosana	1.77	1.34	1.68	1.60
Acer albopurpurascens	2.50	0.58	1.02	1.37
Elaeocarpus sylvestris	1.22	1.21	1.60	1.34
Castanopsis kusanoi	0.93	1.85	1.18	1.32
Osmanthus matsumuranus	0.53	1.35	2.08	1.32
Others	15.08	18.26	25.72	19.70
Total	100	100	100	100

E. *Engelhardtia roxburghiana – Cyclobalanopsis longinux* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Cyclobalanopsis longinux	16.98	7.51	6.90	10.46
Machilus thunbergii	12.65	8.33	7.13	9.37
Engelhardtia roxburghiana	11.74	7.89	6.53	8.72
Litsea acuminata	5.64	10.76	7.75	8.05
Castanopsis cuspidata	11.44	6.03	3.20	6.89
Beilschmiedia erythrophloia	1.54	5.13	5.23	3.97
Ilex ficoidea	2.17	3.86	4.49	3.50
Michelia compressa	2.31	3.05	3.96	3.11
Pasania brevicaudata	1.26	3.41	3.72	2.80
Schefflera octophylla	2.04	3.10	2.96	2.70
Tricalysia dubia	1.41	2.85	3.76	2.68
Elaeocarpus japonicus	3.26	2.27	2.47	2.67
Neolitsea parvigemma	1.41	3.27	3.08	2.59

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Appendix 1. Continued.

Species	Rdo %	Rde %	Rfi %	IVI %
Rhododendron leptosanthum	2.27	2.96	1.94	2.39
Ternstroemia gymnanthera	2.44	1.88	2.44	2.25
Lithocarpus lepidocarpus	2.70	1.15	1.68	1.84
Gordonia axillaris	2.40	1.23	1.61	1.75
Ardisia cornudentata	0.35	2.40	2.28	1.67
Osmanthus heterophyllus	1.26	1.84	1.73	1.61
Daphniphyllum glaucescens	1.08	1.60	1.87	1.51
Others	13.65	19.48	15.27	19.47
Total	100	100	100	100

F. *Helicia formosana – Castanopsis kusanoi* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Helicia formosana	12.12	21.31	14.39	16.09
Litsea acuminata	11.79	13.86	9.97	11.88
Beilschmiedia erythrophloia	9.82	6.76	7.76	8.14
Castanopsis kusanoi	11.94	6.23	6.04	8.12
Pasania brevicaudata	7.81	5.63	5.85	6.44
Engelhardtia roxburghiana	8.19	4.62	3.16	5.22
Machilus konishii	4.00	3.48	4.90	4.14
Schefflera octophylla	2.80	3.72	3.95	3.43
Tricalysia dubia	1.43	3.14	4.49	3.02
Helicia cochinchinensis	2.19	3.92	2.96	2.99
Michelia compressa	2.53	2.25	3.37	2.70
Cyclobalanopsis longinux	5.01	0.97	1.75	2.58
Elaeocarpus sylvestris	3.02	1.50	2.46	2.33
Machilus thunbergii	3.69	1.18	1.40	2.08
Neolitsea parvigemma	1.15	2.42	2.69	2.08
Castanopsis cuspidata	1.40	1.27	2.08	1.58
Prunus phaeosticta	0.74	1.36	1.94	1.35
Symplocos formosana	0.59	1.58	1.76	1.32
Eurya chinensis	0.53	1.69	1.55	1.25
Lindera communis	0.79	1.30	1.28	1.11
Others	8.46	11.81	16.25	13.15
Total	100	100	100	100

G. *Castanopsis formosana - Machilus philippinense* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Castanopsis formosana	22.37	23.73	13.36	19.82
Glycosmis citrifolia	2.58	10.62	10.15	7.78
Turpinia formosana	5.59	8.54	9.11	7.75
Cyclobalanopsis glauca	8.23	7.68	2.82	6.24
Beilschmiedia erythrophloia	4.78	3.67	4.48	4.31
Sapindus mukorossii	4.90	2.94	3.80	3.88
Machilus philippinense	6.18	2.02	2.56	3.59
Schefflera octophylla	4.48	2.09	3.74	3.44
Acer albopurpurascens	3.75	3.19	3.28	3.41
Pasania cornea	2.88	4.86	2.36	3.37
Machilus kusanoi	3.21	2.00	2.95	2.72
Neolitsea konishii	3.53	1.42	2.50	2.49
Celtis formosana	1.49	1.93	2.48	1.96
Phoebe formosana	2.67	1.72	1.48	1.96
Litsea hypophaea	1.30	1.69	1.55	1.51
Viburnum odoratissimum	0.64	1.37	2.45	1.48
Koelreuteria henryi	2.26	0.54	1.08	1.29
Psychotria rubra	0.22	1.27	2.39	1.29
Michelia compressa	1.89	0.65	1.14	1.23
Capparis acutifolia	0.42	1.57	1.56	1.18
Others	16.63	16.50	24.76	19.29
Total	100	100	100	100

H. *Machilus zuihoensis - Schefflera octophylla* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Schefflera octophylla	15.93	7.54	8.22	10.56
Turpinia formosana	8.07	13.81	8.75	10.21

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Appendix 1. Continued.

Species	Rdo %	Rde %	Rfi %	IVI %
Wendlandia uvarufolia	4.74	10.03	6.28	7.02
Sapindus mukorossii	7.71	4.19	5.25	5.72
Machilus kusanoi	7.71	3.54	2.63	4.63
Machilus thunbergii	6.94	2.62	3.48	4.34
Celtis formosana	2.66	2.89	4.05	3.20
Hydrangea chinensis	1.19	5.35	2.86	3.13
Diospyros eriantha	1.46	3.25	2.81	2.51
Glycosmis citrifolia	0.69	3.20	3.35	2.41
Elaeocarpus sylvestris	3.28	1.71	2.14	2.37
Mallotus philippensis	1.00	2.65	3.10	2.27
Champereia manillana	1.45	2.76	2.59	2.27
Cyclobalanopsis glauca	2.61	2.96	1.14	2.24
Fraxinus griffithii	3.35	1.63	1.65	2.21
Styrax suberifolia	2.08	2.52	1.64	2.08
Cinnamomum insulari-montanum	2.03	2.68	1.52	2.08
Styrax formosana	2.07	2.12	1.89	2.03
Psychotria rubra	0.41	2.45	3.20	2.02
Litsea hypophaea	1.06	2.08	2.24	1.80
Others	23.56	20.02	31.21	24.91
Total	100	100	100	100

I. *Ficus irisana - Machilus kusanoi* Association.

Species	Rdo %	Rde %	Rfi %	IVI %
Machilus kusanoi	22.14	11.78	9.74	14.55
Glycosmis citrifolia	6.78	21.26	13.27	13.77
Ficus irisana	11.02	9.16	9.24	9.80
Turpinia formosana	4.24	5.80	5.58	5.21
Schefflera octophylla	5.28	3.96	5.40	4.88
Dendrocnide meyeniana	4.45	4.17	4.85	4.49
Celtis formosana	2.47	3.54	5.11	3.71
Lagerstroemia subcostata	4.36	2.58	2.23	3.06
Sapindus mukorossii	3.64	1.77	3.34	2.92
Mallotus philippensis	1.80	3.35	3.01	2.72
Neolitsea konishii	1.52	3.33	2.78	2.54
Koelreuteria henryi	3.86	0.70	1.33	1.96
Phoebe formosana	2.65	1.51	1.45	1.87
Ficus nervosa	1.76	1.37	1.74	1.63
Ficus variegata	2.29	1.20	1.14	1.54
Ficus virgata	2.23	1.79	0.59	1.54
Diospyros eriantha	1.22	1.93	1.30	1.49
Glochidion zeylanicum	0.60	1.20	2.54	1.44
Murraya euchrestifolia	0.68	1.46	1.65	1.26
Ficus septica	0.89	1.27	1.24	1.14
Others	16.12	16.87	22.47	18.49
Total	100	100	100	100

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臺灣西南部楠梓仙溪中上游集水區常綠闊葉林植群生態之研究

周富三[(1)]、廖俊奎[(2)]、楊遠波[(2,3)]

(收搞日期：2006 年 12 月 5 日；接受日期：2007 年 4 月 12 日)

摘　　要

本研究主要目的是以多變數法分析楠梓仙溪中上游集水區的森林植群資料。使用降趨對應分析法來呈現 70 個樣區在空間上的分布情形，並與 5 項環境因子求相關。結果顯示本研究地區之植物組成與植被類型之空間分布明顯與海拔高及全天光空域有顯著的相關性。植被型之分類使用列表比較法將 70 個樣區分成 3 個群團與 9 個群叢，分別為 (I) 狹葉櫟群團：A.高山新木薑子-赤柯群叢、B.巒大越橘-長尾尖葉櫧群叢、C.大葉石櫟-狹葉櫟群叢、(II) 瓊楠群團：D.柳葉山茶-瓊楠群叢、E.黃杞-錐果櫟群叢、F.山龍眼-細刺苦櫧群叢、(III) 大葉楠群團：G.台灣苦櫧-菲律賓楠群叢、H.香楠-鵝掌柴群叢、I.澀葉榕-大葉楠群叢。

關鍵詞：楠梓仙溪、植被型、降趨對應分析法。

1. 林業試驗所六龜研究中心，844 高雄縣六龜鄉中興村中庄 198 號，臺灣。
2. 國立中山大學生物科學系，804 高雄市鼓山區蓮海路 70 號，臺灣。
3. 通信作者。Tel: 886-7-5252000 ext. 3622; Fax: 886-7-5253622; Email: ypo@mail.nsysu.edu.tw

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