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Species Composition and Vegetation Pattern of a Lowland Rain Forest at the Nanjenshan LTER Site, Southern Taiwan

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ABSTRACT: This study focused on a remnant of lowland rain forest in the Nanjenshan Reserve of southern Taiwan. During 1989-1994, two long-term plots of 2.1 and 3 ha were set up at Lanjenchi (hill) and Nanjenshan (valley) sites, and forest composition, structure and species diversity were compared between the two plots. In the Lanjenchi plot, the most important families (sum of basal areas of all species within that family) were Fagaceae, Theaceae, Aquifoliaceae, Illiciaceae, Lauraceae and Myrtaceae, while in the Nanjenshan plot, the most important families were Euphorbiaceae, following by Moraceae, Meliaceae, Lauraceae, Aquifoilaceae, Urticaceae and Lythraceae, which bore some similarities to the tropical rain forests both in physiognomy and structure. Both TWINSPAN classification and DCA ordination separated the windward forest from the leeward forest stands in the Lanjenchi plot, but no such pattern could be recognized for the Nanjenshan plot. In the Lanjenchi plot, both species composition and forest structure changed dramatically with exposure due to chronic monsoon wind-stress. As wind stress increased, canopy height decreased from 15-20 m in the creek bottom to 3-5 m in the most exposed windward habitat. Stem density increased steadily with increasing exposure, and mean similarity among quadrats become higher as well. Total basal areas were comparable between the plots and forest stands. Dominance-diversity curve for each of the forests conformed to a lognormal distribution. There was a strong tendency for species diversity to be higher in the less exposed forests.

KEY WORDS: Evergreen broad-leaved forest, Classification, Ordination, Forest types, Dominance-diversity curve, Species-area curve, Monsoon wind.

INTRODUCTION

The Nanjenshan Nature Reserve on the southern tip of Taiwan harbors some of the best examples of lowland rain forest in Taiwan. The Nanjenshan forests are particularly noteworthy biogeographically because of the admixture of both holarctic and tropical elements in flora (Li and Keng, 1950; Huang *et al.,* 1980), and ecologically because of the importance of chronic monsoon wind-stress in organizing the communities (Sun *et al.*, 1998). Although previous studies of the lowland rain forests in this area have examined forest composition (Liu and Liu, 1978; Chen and Huang, 1986; Su and Su, 1988), data on patterns of tree species composition, diversity and structure for areas greater than 0.1 ha are scarce.

The objective of this paper is to describe the results of the first census of two long-term plots (2.1 and 3 ha in area) established between 1989 and 1994. The information provided here will also serve as a basic source to facilitate comparison with biodiversity monitoring plots in Taiwan and other parts of the world.

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Study area

The Nanjenshan Reserve, centered approximately at 22°3' N and 120°51' E, is part of the Kenting National Park. It is situated at the east side of a mountain range near the coast of the Pacific Ocean in the Hengchun peninsula of southern Taiwan (Fig. 1). The topography is rugged with steep slopes, ridges and valleys. Elevation ranges from 260 to 460 m. The exposed geologic strata consist of interbedded strata of sandstone and shale of Miocene age. The soils are clay loam to sandy clay loam, and are classified as fine, mixed, hyperthermic, Typic paleudults with highly weathering and pedogensis. Soil depth ranges from 40 to 60 cm to bedrock. The soils are acid (pH 4.7-5.0) and generally infertile.

The climate is hot, humid and coastal with prevailing northeasterly monsoon winds during October and May. Typhoons sweeping the reserve between July and September usually bring heavy rains. Climate data from the weather stations located within the plots (1992-1994, 1997-1998) indicate that the annual rainfall varies from 2144 to 4395 mm with ca. 76% of the total falling between June and October (Fig. 2). However, the rainy events are well spread throughout the year. The mean annual temperature at 325 m asl. is 22.6°C and monthly means range from 17.7°C in January to 27.4°C in August. For the five months of record (between October 1994 and February 1995), the frequency of winds from the north, north-east and east totalled 67 percent. The mean daily average wind velocity was 6.1 m/s, and the mean maximum was 9.3 m/s.

The Nanjenshan reserve supports two recognizable forest zones (Su, 1984). Of these, the *Machilus-Castanopsis* zone occupies the upper windward slopes and ridgetops (above 250 m asl.), and is now the most prevalent and collectively constitutes ca. 95% of the forest. The remaining 5% is the *Ficus-Machilus* zone usually occupying the valley sites (below 250 m).

METHODS

For research purposes, two long-term plots (Fig. 1) were demarcated at the Lanjenchi hill (*Machilus-Castanopsis* zone) and Nanjenshan valley sites (*Ficus-Machilus* zone) during 1989-1994. The hill site was a 3 ha (300 m × 100 m) plot with the long dimension spanning the wind-stress gradient. The elevation in the plot ranges from 300 m in the sheltered creek bottom to 340 m on the most exposed slopes facing into the northeasterly monsoon winds. The valley plot, 2.1 ha (150 m × 140 m) in extent, is on a gentle slope with a small creek in the northeastern corner. Elevation ranges from 225 to 275 m.

Each plot was divided into 10 × 10 m quadrats, and all free-standing woody plants ≥ 1 cm dbh were tagged, measured, mapped, and identified. Botanical nomenclature followed Flora of Taiwan (Huang, 1993-1998) throughout.

For data analyses, plants with multiple stems were considered as one for density calculation, and for basal area, sum of basal areas of all stems was used. A primary matrix of species RB (relative basal area) by quadrats (164 species × 510 quadrats) was subjected to TWINSPAN classification (Hill, 1979a) and DCA ordination (Hill, 1979b).

Species richness was evaluated at the site scale using rarefaction method (Hurlbert, 1971). This method estimates the number of species expected in a random sample of individuals taken from a collection. Mean similarity for all pairs of quadrats within each plot or forest type was calculated using percentage similarity (Goodall, 1978).

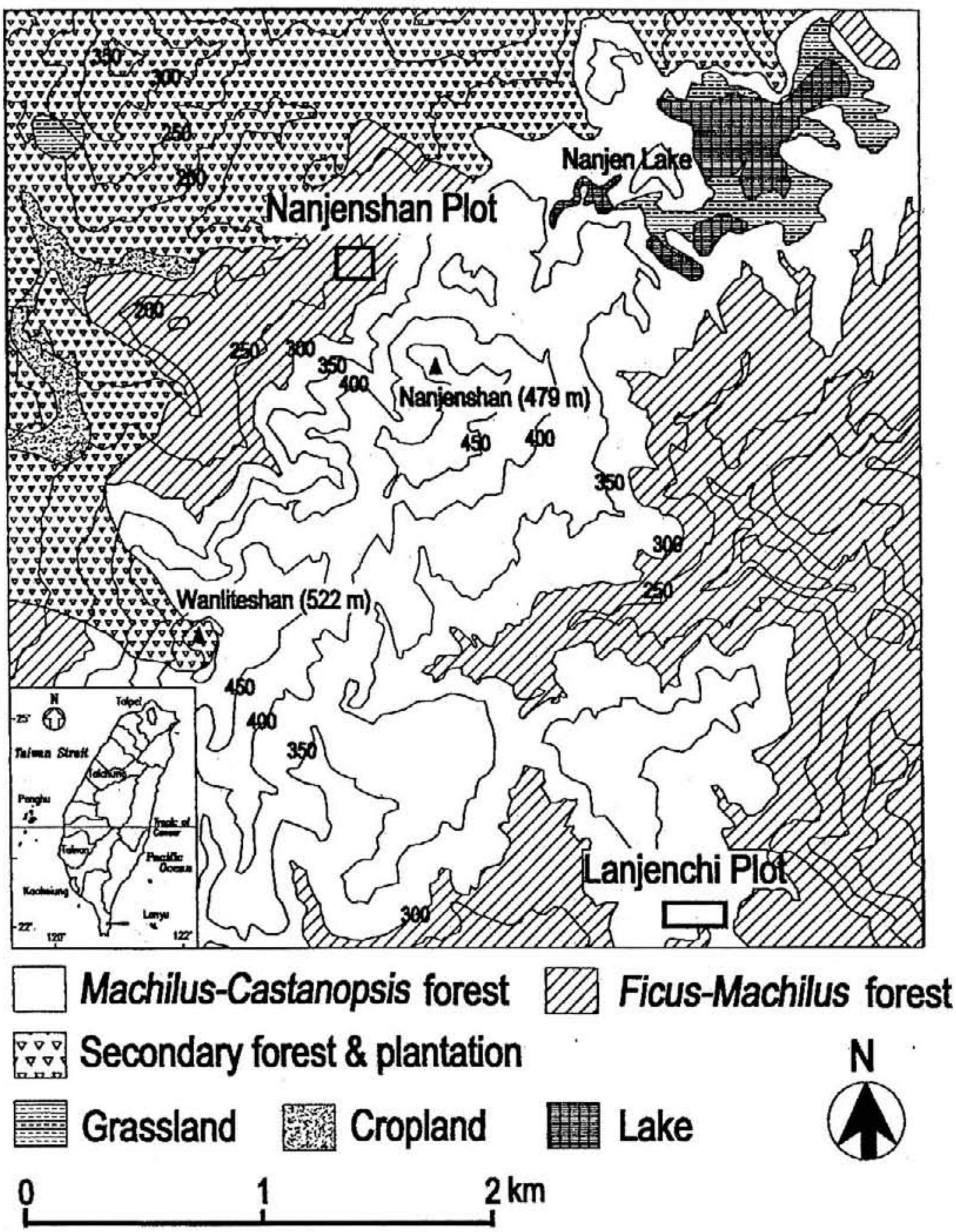

Fig. 1. Vegetation map of Nanjenshan area showing the location of the Lanjenchi plot (3 ha) and Nanjenshan plot (2.1 ha).

RESULTS

Floristics

The vascular flora of the Lanjenchi plot was composed of 120 species in 80 genera and 41 families. Free-standing woody species in quadrats of 0.01-ha varied from 11 to 50 with an average of 34. Families with the most abundant species were Lauraceae, Fagaceae, Rubiaceae, Theaceae, Euphorbiaceae and Moraceae (Fig. 3).

Within the Nanjenshan plot, there were 44 families, 78 genera and 108 species. The number of species in each quadrat varied from 6 to 30 with an average of 17. The best-represented families were Euphorbiaceae, Moraceae, Rubiaceae and Lauraceae (Fig. 3).

Forest composition

Lanjenchi plot

A total of 36,706 stems (12,235 stems/ha) was recorded in the census. Number of individuals per quadrat of 0.01 ha varied from 15 to 381 (average = 122). The canopy reached heights of 10-15 m on the leeward slopes and creek bottoms, but only 3-5 m on the windward slopes and ridges.

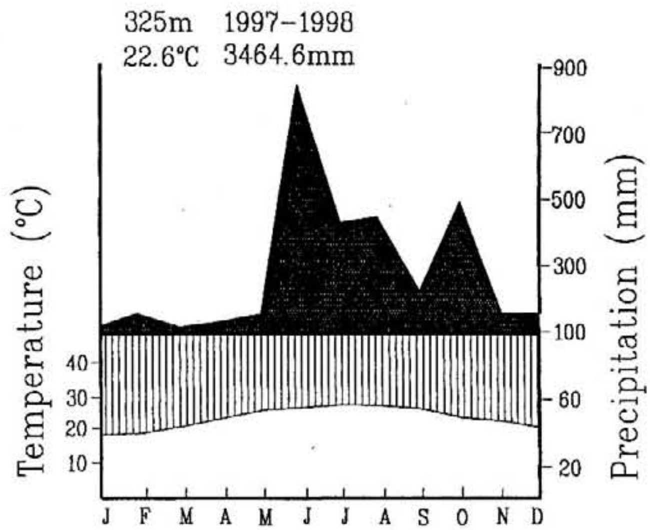

Fig. 2. Climate diagram representative of the Nanjenshan area.

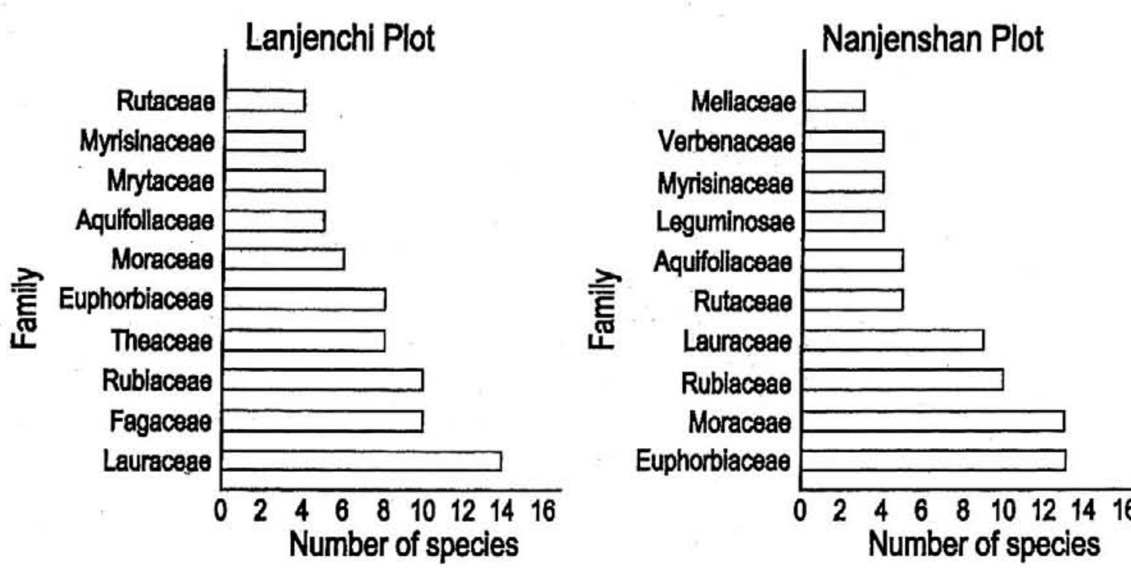

Fig. 3. Families with the most abundant species in the Lanjenchi and Nanjenshan plots.

The mean basal area was 41.1 m^2/ha. The families with the largest basal areas were Fagaceae, Theaceae, Aquifoliaceae, Illiciaceae, Lauraceae, Myrtaceae, Daphniphyllaceae and Araliaceae (Fig. 4). The most important species, as indicated by basal areas (≥ 1 m^2/ha), were *Castanopsis cuspidata* var. *carlesii, Illicium arborescens, Cyclobalanopsis longinux,* *Cyclobalanopsis championii, Daphniphyllum glaucescens* ssp. *oldhamii, Schefflera octophylla, Osmanthus marginatus, Lithocarpus amygdalifolius, Schima superba* var. *kankoensis and Eurya nitida* var. *nanjenshanensis* (Table 1). These ten species accounted 52.1% of the total basal area. Although *Illicium arborescens* (usually a subcanopy tree) did not attain large diameter (generally < 20 cm dbh), it occurred at a high density, which accounted for its high importance value. The thirty largest trees with dbh ≥ 44.7 cm were mainly contributed by *Cyclobalanopsis championii* (9 individuals), *Castanopsis cuspidata* var. *carlesii* (6) and *Cyclobalanopsis longinux* (5).

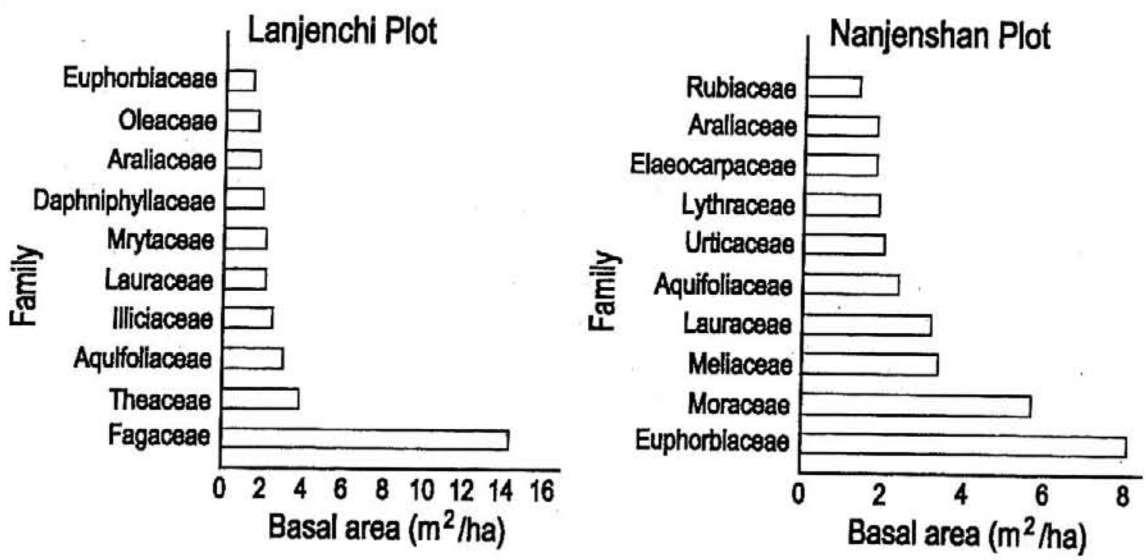

Fig. 4. Dominant families in the Lanjenchi and Nanjenshan plots.

Nanjenshan plot

Total abundance of all woody species was 7,062 stems (3,363 stems/ha) in the plot. Number of individuals per quadrat ranged from 7 to 114 with an average of 43. The canopy of this forest was very irregular with scattered individuals of canopy species attained heights of 15-20 m. The forest bore some similarities to the tropical rain forests both in physiognomy and structure. It was rich in thick-lianas and epiphytes. In addition, some species showed buttresses and silt roots.

Basal area of all stems was 38.75 m^2/ha. The six most important families in descending order of basal areas were Euphorbiaceae, Moraceae, Meliaceae, Lauraceae, Aquifoliaceae and Urticaceae (Fig. 4). The ten most dominant species with a basal area of 1 m^2/ha or more were *Bischofia javanica, Ficus benjamina, Dysoxylum kuskusense, Ilex rotunda, Dendrocnide meyeniana, Lagerstroemia subcostata, Sloanea formosana, Schefflera octophylla, Machilus japonica* var. *kusanoi* and *Castanopsis indica* (Table 1). Their total basal area accounted for 66.1% of all species. The largest tree recorded was an individual of *Bischofia javanica* which was 138 cm dbh. The thirty large trees with 63 cm dbh or more were mainly contributed by *Bischofia javanica* (10 individuals), *Ilex rotunda* (5) and *Machilus japonica* var. *kusanoi* (4).

Table 1. Composition and structure for the forests in the Lanjenchi and Nanjenshan plots. Only species with basal areas ≥ 0.3 m^2/ha are included. Species order is based on species scores along the first axis of DCA ordination. BA = basal area, IV = (relative density + relative basal area)/2.

Species	Lanjenchi plot				Nanjenshan plot			
	Density (ha)	BA (m^2/ha)	%BA	IV	Density (ha)	BA (m^2/ha)	%BA	IV
Rhaphiolepis indica var. *hiiranensis*	101	0.48	1.16	0.99	0	0.00	0.00	0.00
Cyclobalanopsis championii	88	1.91	4.66	2.69	0	0.00	0.00	0.00
Syzygium buxifolium	327	0.68	1.66	2.17	0	0.00	0.00	0.00
Eurya nitida var. *nanjenshanensis*	469	1.00	2.45	3.14	0	0.00	0.00	0.00
Ilex maximowicziana	131	0.48	1.17	1.12	0	0.00	0.01	0.01
Podocarpus macrophyllus	138	0.30	0.72	0.93	0	0.00	0.00	0.00
Pasania formosana	35	0.73	1.77	1.03	0	0.00	0.00	0.00
Ilex lonicerifolia var. *matsudai*	390	0.75	1.84	2.51	0	0.00	0.00	0.00
Gordonia axillaris	159	0.85	2.07	1.69	0	0.00	0.00	0.00
Microtropis japonica	391	0.33	0.80	2.00	0	0.00	0.00	0.01
Illicium arborescens	1479	2.33	5.68	8.88	0	0.00	0.00	0.00
Osmanthus marginatus	365	1.68	4.09	3.53	4	0.00	0.01	0.06
Castanopsis cuspidata var. *carlesii*	306	6.16	14.98	8.74	0	0.00	0.00	0.00
Lithocarpus amygdalifolius	136	1.29	3.13	2.12	1	0.10	0.25	0.15
Decaspermum gracilentum	101	0.40	0.98	0.90	0	0.00	0.01	0.01
Cyclobalanopsis pachyloma	75	0.69	1.67	1.14	0	0.00	0.00	0.00
Symplocos theophrastaefolia	176	0.41	1.01	1.22	0	0.00	0.00	0.00
Magnolia kachirachirai	107	0.36	0.87	0.87	0	0.00	0.00	0.00
Daphniphyllum glaucescens ssp. *oldhamii*	398	1.88	4.58	3.91	3	0.03	0.07	0.08
Cyclobalanopsis longinux	309	2.29	5.56	4.04	0	0.00	0.00	0.00
Elaeocarpus sylvestris	62	0.96	2.32	1.42	0	0.00	0.00	0.00
Ilex cochinchinensis	752	0.95	2.31	4.23	1	0.00	0.01	0.03
Adinandra formosana	97	0.47	1.15	0.97	1	0.00	0.01	0.02
Syzygium euphlebium	80	0.54	1.32	0.99	0	0.00	0.00	0.01
Beilschmiedia tsangii	237	0.37	0.90	1.42	0	0.00	0.00	0.00
Sapium discolor	45	0.77	1.88	1.12	0	0.00	0.00	0.00
Schima superba var. *kankoensis*	140	1.08	2.63	1.88	7	0.27	0.69	0.44
Castanopsis fabri	42	0.57	1.39	0.87	0	0.00	0.00	0.00
Astronia formosana	67	0.71	1.74	1.14	0	0.00	0.00	0.00
Machilus thunbergii	90	0.41	0.99	0.86	2	0.05	0.12	0.09
Pasania harlandii	28	0.65	1.58	0.91	6	0.05	0.13	0.16
Ilex uraiensis	363	0.84	2.05	2.51	39	0.21	0.55	0.85
Syzygium kusukusense	67	0.48	1.16	0.86	17	0.09	0.24	0.37
Schefflera octophylla	153	1.79	4.35	2.80	49	1.73	4.48	2.97
Beilschmiedia erythrophloia	133	0.29	0.71	0.90	24	0.53	1.38	1.05
Neonauclea reticulata	3	0.05	0.11	0.07	7	0.43	1.12	0.66
Machilus zuihoensis	28	0.14	0.34	0.28	6	0.36	0.93	0.55
Psychotria rubra	678	0.23	0.56	3.05	600	0.67	1.73	9.78
Ardisia sieboldii	36	0.18	0.44	0.37	47	0.84	2.16	1.78
Michelia compressa	24	0.07	0.18	0.19	22	0.71	1.84	1.24
Sloanea formosana	29	0.14	0.34	0.29	68	1.75	4.53	3.28
Ficus fistulosa	37	0.05	0.13	0.22	107	0.55	1.43	2.30
Reevesia formosana	2	0.00	0.01	0.01	34	0.30	0.78	0.90
Machilus japonica var. *kusanoi*	4	0.00	0.00	0.02	32	1.51	3.91	2.43
Castanopsis indica	2	0.04	0.09	0.05	26	1.10	2.84	1.81
Ilex rotunda	5	0.01	0.02	0.03	22	2.18	5.62	3.14
Drypetes hieranensis	2	0.00	0.01	0.02	121	0.34	0.87	2.23
Lagerstroemia subcostata	0	0.00	0.00	0.00	30	1.85	4.77	2.82
Cryptocarya concinna	0	0.00	0.00	0.00	27	0.63	1.63	1.21
Ficus benjamina	2	0.00	0.01	0.01	67	3.81	9.82	5.91
Turpinia ternata	0	0.00	0.00	0.00	180	0.72	1.85	3.61
Dysoxylum kuskusense	0	0.00	0.00	0.00	325	3.11	8.04	8.85
Bischofia javanica	0	0.00	0.00	0.00	42	6.52	16.83	9.04
Macaranga tanarius	0	0.00	0.00	0.00	32	0.38	0.99	0.98
Ficus ampelas	0	0.00	0.00	0.00	31	0.91	2.35	1.64
Dendrocnide meyeniana	0	0.00	0.00	0.00	162	2.03	5.25	5.04
Trema orientalis	0	0.00	0.00	0.00	9	0.32	0.82	0.54
Ehretia thyrsiflora	0	0.00	0.00	0.00	4	0.43	1.12	0.62
Sapindus mukorossii	0	0.00	0.00	0.00	8	0.78	2.01	1.12
Subtotal	8889	36.79	89.57	81.11	2163	35.29	91.20	77.79
Total	12235	41.10	100.00	100.00	3363	38.75	100.00	100.00

ORDINATION AND CLASSIFICATION

The results of DCA ordination and TWINSPAN classification are shown in Fig. 5. The eigenvalues for the first four DCA axes were 0.82, 0.43, 0.32 and 0.28, and the corresponding gradient lengths were 6.39, 3.73, 3.00 and 3.00, respectively. As expected, the quadrats of the Nanjenshan plot are readily segregated from the quadrats of the Lanjenchi plot along the first axis at a score of 3.5. Further inspection of the configuration shows that the Lanjenchi samples in the left half of Fig. 5 spread out almost linearly on a single gradient. Topographic positions (creek, leeward slope, windward slope and ridge) are well represented from right to the left of the diagram. For the sake of simplicity, two segments were delineated at a score of about 2 and labeled windward and leeward forest types. Vegetation characteristics varied markedly between the two plots and the windward and leeward forest types in the Lanjenchi plot (Table 2). Total density was great in the windward forest type. Species composition of the two forest types also varied. The windward forest type was dominated by *Castanopsis cuspidata* var. *carlesii*, *Illicium arborescens*, *Cyclobalanopsis championii*, *Osmanthus marginatus*, *Cyclobalanopsis longinux*, *Daphniphyllum glaucescens* ssp. *oldhamii*, *Lithocarpus amygdalifolius*, *Eurya nitida* var. *nanjenshanensis*, *Gordonia axillaris*, *Schima superba* var. *kankoensis*, *Ilex lonicerifolia* var. *matsudai* and *Syzygium buxifolium* (Table 3). The principal canopy species of the leeward forest type were *Castanopsis cuspidata* var. *carlesii*, *Schefflera octophylla*, *Cyclobalanopsis longinux*, *Daphniphyllum glaucescens* ssp. *oldhamii*, *Sapium discolor*, *Castanopsis fabri*, *Astronia formosana*, *Pasania harlandii*, *Ilex cochinchinensis*, *Elaeocarpus sylvestris* and *Ilex uraiensis* (Table 3). More extensive descriptions of the forest types can be found in Sun *et al.* (1998).

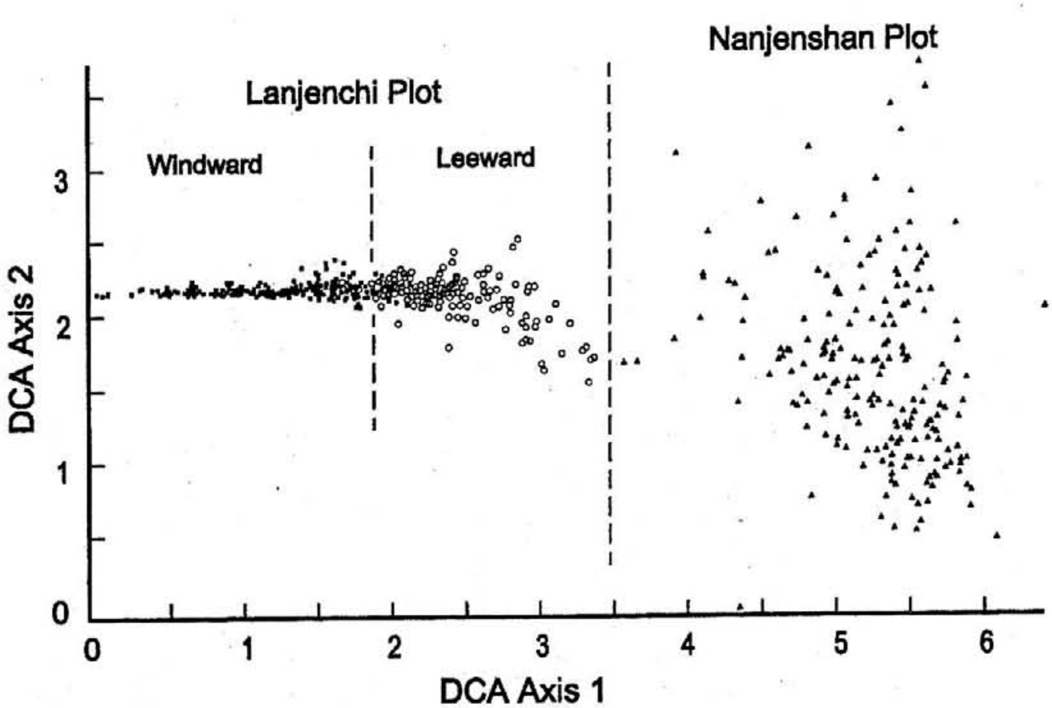

Fig. 5. DCA ordination (λ1=0.82, λ2=0.43) of the 510 quadrats from the Lanjenchi and Nanjenshan plots. The TWINSPAN groups are indicated by symbols.

Table 2. Density, basal area and diversity measures for the Lanjenchi and Nanjenshan plots and the windward and leeward forest types of the Lanjenchi plot.

Plot	Species	Species (0.01 ha)	Density (stems/ha)	Basal Area (m^2/ha)	Richness E(S5000)	Mean similarity
Lanjenchi:	120	34	12,235	41.10	100	-----
Windward	103	35	15,157	42.70	85	0.43
Leeward	96	28	6,809	38.12	94	0.37
Nanjenshan	108	17	3,363	38.75	101	0.34

Table 3. Composition and structure for the windward and leeward forest types in the Nanjenshan plots. Only species with basal areas ≥ 0.3 m^2/ha are included. Species order is based on species scores along the first axis of DCA ordination. BA = basal area, IV = (relative density + relative basal area)/2.

Species	Windward				Leeward			
	Density (ha)	BA (m^2/ha)	%BA	IV	Density (ha)	BA (m^2/ha)	%BA	IV
Rhaphiolepis indica var. *hiiranensis*	155	0.73	1.72	1.37	0	0.00	0.00	0.00
Cyclobalanopsis championii	134	2.94	6.87	3.88	3	0.02	0.05	0.05
Syzygium buxifolium	502	1.05	2.45	2.88	2	0.00	0.01	0.02
Eurya nitida var. *nanjenshanensis*	703	1.52	3.56	4.10	34	0.05	0.13	0.32
Ilex maximowicziana	197	0.70	1.64	1.47	8	0.08	0.20	0.16
Podocarpus macrophyllus	208	0.44	1.03	1.20	10	0.04	0.09	0.12
Pasania formosana	53	1.11	2.60	1.48	1	0.01	0.03	0.02
Ilex lonicerifolia var. *matsudai*	584	1.08	2.53	3.19	30	0.15	0.40	0.42
Gordonia axillaris	239	1.29	3.02	2.30	10	0.04	0.12	0.13
Microtropis japonica	576	0.47	1.11	2.46	48	0.06	0.15	0.42
Ternstroemia gymnanthera	147	0.37	0.87	0.92	12	0.05	0.13	0.15
Illicium arborescens	2158	3.20	7.49	10.86	217	0.73	1.92	2.55
Osmanthus marginatus	517	2.36	5.54	4.47	82	0.41	1.07	1.14
Castanopsis cuspidata var. *carlesii*	402	6.74	15.78	9.22	130	5.08	13.32	7.61
Lithocarpus amygdalifolius	191	1.71	4.00	2.63	34	0.50	1.31	0.91
Decaspermum gracilentum	135	0.49	1.15	1.02	36	0.24	0.64	0.58
Cyclobalanopsis pachyloma	94	0.73	1.70	1.16	40	0.61	1.60	1.09
Symplocos theophrastaefolia	229	0.46	1.09	1.30	77	0.32	0.83	0.98
Magnolia kachirachirai	142	0.31	0.73	0.83	44	0.44	1.16	0.90
Daphniphyllum glaucescens ssp. *oldhamii*	505	2.06	4.82	4.07	199	1.55	4.08	3.50
Cyclobalanopsis longinux	372	2.26	5.29	3.87	192	2.34	6.13	4.48
Machilus obovatifolia	113	0.31	0.72	0.73	35	0.19	0.49	0.50
Elaeocarpus sylvestris	77	0.91	2.13	1.32	34	1.04	2.74	1.62
Ilex cochinchinensis	852	0.90	2.12	3.87	565	1.03	2.71	5.50
Adinandra formosana	101	0.31	0.73	0.70	91	0.77	2.02	1.68
Syzygium euphlebium	76	0.39	0.90	0.70	89	0.83	2.18	1.74
Beilschmiedia tsangii	266	0.23	0.54	1.15	182	0.63	1.66	2.16
Litsea acuminata	182	0.11	0.25	0.73	250	0.34	0.90	2.28
Sapium discolor	46	0.40	0.93	0.62	45	1.46	3.84	2.25
Schima superba var. *kankoensis*	180	1.20	2.81	2.00	65	0.86	2.25	1.60
Neolitsea hiiranensis	98	0.07	0.16	0.41	188	0.52	1.36	2.06
Prunus phaeosticta	32	0.05	0.12	0.16	86	0.37	0.97	1.11
Castanopsis fabri	25	0.12	0.28	0.22	74	1.40	3.69	2.39
Astronia formosana	52	0.39	0.92	0.63	95	1.32	3.45	2.43
Machilus thunbergii	70	0.11	0.25	0.35	126	0.97	2.54	2.19
Pasania harlandii	29	0.37	0.87	0.53	28	1.17	3.06	1.73
Ilex uraiensis	432	0.74	1.72	2.29	234	1.04	2.73	3.09
Alniphyllum pterospermum	1	0.00	0.01	0.01	12	0.66	1.74	0.96
Syzygium kusukusense	56	0.36	0.85	0.61	87	0.70	1.82	1.55
Archidendron lucidum	3	0.01	0.03	0.02	85	0.59	1.54	1.39
Diospyros eriantha	90	0.07	0.17	0.38	92	0.36	0.94	1.15
Wendlandia formosana	11	0.01	0.03	0.05	140	0.45	1.19	1.62
Schefflera octophylla	130	0.62	1.44	1.15	194	3.96	10.40	6.63
Beilschmiedia erythrophloia	128	0.21	0.50	0.67	141	0.44	1.15	1.61
Machilus zuihoensis	19	0.02	0.04	0.08	44	0.37	0.97	0.80
Psychotria rubra	627	0.17	0.40	2.27	773	0.33	0.87	6.12
Ardisia sieboldii	23	0.08	0.19	0.17	61	0.37	0.98	0.94
Sloanea formosana	8	0.01	0.03	0.04	69	0.38	1.00	1.00
Subtotal	9812	40.19	94.13	86.54	5094	35.27	92.56	83.65
Total	15157	42.70	100.00	100.00	6809	38.12	100.00	100.00

Species diversity

Both species richness and diversity differed among the three forest types (Table 2). Species number per quadrat was consistently greater in the Lanjenchi plot. However, the expected species richness for a sample of 5000 individuals was higher in the Nanjenshan plot than in either forest type of the Lanjenchi plot. In contrast to the species diversity, mean similarity among quadrats was greater in the Lanjenchi plot, especially at the windward sites. Dominance-diversity curve for each of the forests seemed to conform to a lognormal distribution (Fig. 6). There were relatively few species with a high or a low basal area, many species with intermediate ones.

Species-area curves (Fig. 7) showed that the levels of accumulation were in the range of 93-103 species at the 1 ha scale. Each of the curves also showed that the number of species was approaching an asymptote, but was still increasing slowly.

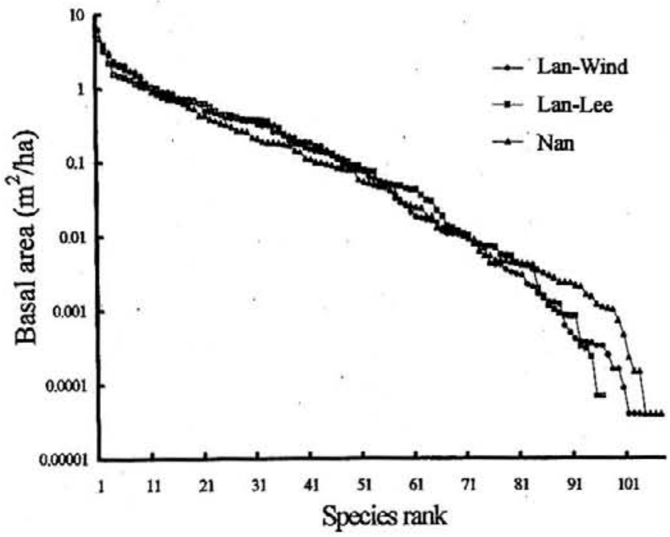

Fig. 6. Dominance-diversity curves for the Nanjenshan plot (Nan) and the windward (Lan-Wind) and leeward (Lan-Lee) forest types of the Lanjenchi plot.

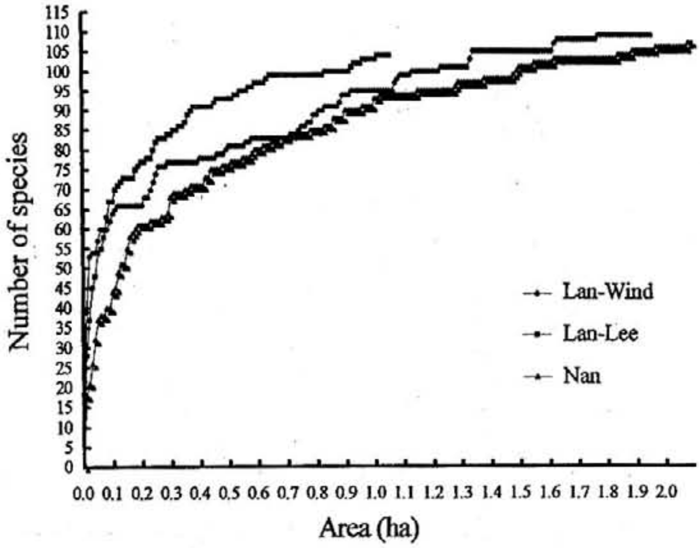

Fig. 7. Species-area curves for the Nanjenshan plot (Nan) and the windward (Lan-Wind) and leeward (Lan-Lee) forest types of the Lanjenchi plot.

DISCUSSIONS

The floristic affinities of the Lanjenchi forests clearly reflected the proximity to the Subtropical Forest Formation of East Asia which extends from Okinawa, Taiwan, South China to the northern half of Vietnam (Kira 1991). The reach of the forests to the southern tip of Taiwan corresponds approximately to the southeastern limit of the winter monsoon. Nevertheless, due to the effect of the foehn in winter season, precipitation decreases markedly toward the west part of the Hengchun Peninsula. As a result, the rain forests occur principally in the eastern and central parts of the peninsula.

Differences distinguishing the Lanjenchi plot from the Nanjenshan plot included floristic and structural factors. Of the 164 species, only 63 (38.4%) were found in both plots. However, the relatively minor inter-site floristic variation was highlighted by the percentage of species (80.5%) shared between the windward and leeward forests of the Lanjenchi plot. Structurally, the Nanjenshan valley plot was dominated by the stand of emergent big trees of *Bischofia javanica*, *Ilex rotunda* and *Ficus benjamina*. In contrast, the Lanjenchi forest was densely stocked, and had fairly level, apparently windclipped canopy. For trees $\geq$ 50 cm dbh, stems counts were 72 in the Nanjenshan plot, but only 10 in the Lanjenchi plot.

Although only a small percentage of the variance (7.1%) was accounted for by the first axis, the DCA analysis clearly pointed to a single underlying primary gradient for the Lanjenchi forest. However, the same analysis did not generate the same pattern for the Nanjenshan valley plot. The asymmetry in the floristic composition and physiognomic characteristics of vegetation at windward and leeward sites of the Lanjenchi plot seemed to be the results of interaction of wind stress and resource availability, particularly light and soil nitrogen (Sun *et al.*, 1998). Similar results were reported for the forests in the Caribbean, Central and northern South-America (Grubb *et al.*, 1963; Lawton and Dryer, 1980; Sugden, 1986).

When the DCA analyses were performed separately for the two plots, it appeared that the first axis explained less of the variance in the Nanjenshan data (5.1%) than the Lanjenchi data (10.5%). The results revealed more heterogeneity of the data from the Nanjenshan plot. It has been shown that, instead of monsoon effect, tree-fall regime, topography and human disturbance seemed to play a major role in species composition and vegetation structure of this area (Chan, 1994; Yang, 1994).

The basal areas of the forests studied are within the range of 38.12–42.7 m^2/ha. These are comparable to values obtained from a variety of evergreen broad-leaved forests in Taiwan (Chen 1993; Hsieh *et al.*, 1998). A relatively higher values of basal areas (53–80 m^2/ha) have been reported for the *Machilus-Castanopsis* and *Quercus* forests at middle altitudes (Hsieh, 1989; Song, 1996), where the forests were relatively protected from the strong monsoon winds and typhoons because of their sheltered topographic positions.

An increase in monsoon wind exposure not only affected plant composition and structure in these forests, but also plant diversity. It seemed that under a heavy wind stress, diversity tended to be lower at the site scale as estimated from the rarefaction algorithm. On the other hand, the mean similarity among quadrats was higher in more stressful environment. A high value of mean similarity indicated that the forest was not very diverse, and there was a high species overlap within the forest.

The richness of our plots, with 93-103 species/ha, compared favorably with the 99 species found in the Dinghushan 1-ha plot of southern China (Kong *et al.*, 1998), but lower than the 153 species (≥ 10 cm dbh) in the Jianfengling plot of Hainan Island (Li *et al.*, 1998). However, our plots showed higher basal areas (38.12-42.70 m^2/ha) in comparison to the Dinghushan plot (25.19 m^2/ha).

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台灣南部南仁山長期生態研究區低地雨林的組成及植被類型

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摘　要

為研究臺灣南部南仁山區的殘存低地雨林，於 1989-1994 年間在欖仁溪源頭及南仁山下的溪谷區分別設置 3 及 2.1 公頃的永久樣區，以比較兩區森林的物種歧異度、組成及結構。在欖仁溪樣區最優勢的科包含殼斗科、茶科、冬青科、八角茴香科、樟科及桃金孃科；在南仁山樣區最優勢的科則為大戟科、桑科、楝科、樟科，冬青科、蕁麻科、及千屈菜科，該樣區的森林在形相及結構上多少顯出熱帶雨林的特性。雙向列表比較法（TWINSPAN）及 DCA 排序法將欖仁溪樣區切分出兩種生育地類型，但南仁山溪谷樣區則無此現象。欖仁溪樣區生育地的分化主要緣自東北季風的吹襲。隨著風力梯度的增強，樹冠高度由溪谷區的 15-20 m 降至迎風坡面的 3-5 m；植株密度及樣區內的物種組成相似度則隨著暴露程度的加大而增高，但不同樣區間及生育地間樹幹的總胸高斷面積的差異不大。各森林的優勢度－歧異度曲線 均趨近於對數常態分佈曲線，物種歧異度則以隱避的溪谷及背風坡較高。

關鍵詞：常綠闊葉林，植群分類，排序分析，林型，優勢度－歧異度曲線，東北季風。

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