

34

Nanjenshan Forest Dynamics Plot, Taiwan

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Site Location, Administration, and Scientific Infrastructure

The Nanjenshan Forest Dynamics Plot is located in the Nanjenshan Nature Reserve of Ken-Ting National Park on the Heng-Chun peninsula at the southern end of Taiwan (fig. 34.1). The reserve is 450 km south of Taipei. The Nanjenshan Nature Reserve comprises more than 2400 ha of forest and is located in the north-eastern corner of the park. The reserve was established in 1984 when the Ken-Ting National Park was established and is managed under the authority of Ken-Ting National Park. A 3-ha Forest Dynamics Plot was established in 1989 on the east ridge of Wan-li-te Mountain. In 1998, the plot was expanded to 6 ha. In this chapter, we report only on the first 3 ha.

Four other permanent plots were established in the nature reserve from 1992–99 following the Forest Dynamics Plot methodology: (1) The 2.8-ha Creek Plot located in the foothills of Mt. Nanjenshan; (2) the 1-ha Nanjen Transect (40 × 250 m) extending up an altitudinal gradient from the stream valley to the top of Mt. Nanjenshan; (3) the 2-ha Nanjen Lake Plot located near Nanjen Lake; and (4) the 5-ha Secondary Forest Plot located along the bank of Basajaru Creek. All five permanent plots were designated as one of Taiwan's Long-Term Ecological Research (LTER) sites in 1995.

A field station located at the entrance of the nature reserve is equipped with modern amenities, such as a kitchen and dining facilities, bunk beds, laundry machine, and a small laboratory. The nearest town, Man-Chou, is about 15 km away and is connected to the station by a well-maintained, paved road.

Climate

An automated weather station located inside the plot showed that annual rainfall averages 3582 mm (1996–99), with a maximum of 4240 mm and a minimum of 2536 mm. While there are no distinct dry months (months averaging less than 100 mm rainfall), rainfall is distinctly seasonal. Almost half the annual rainfall occurs during summer (June–August), with more than 70% falling between June and October. The mean annual temperature is 23.5°C, with mean daily temperature ranging from 16.3°C (January) to 30.7°C (July). See table 34.1.

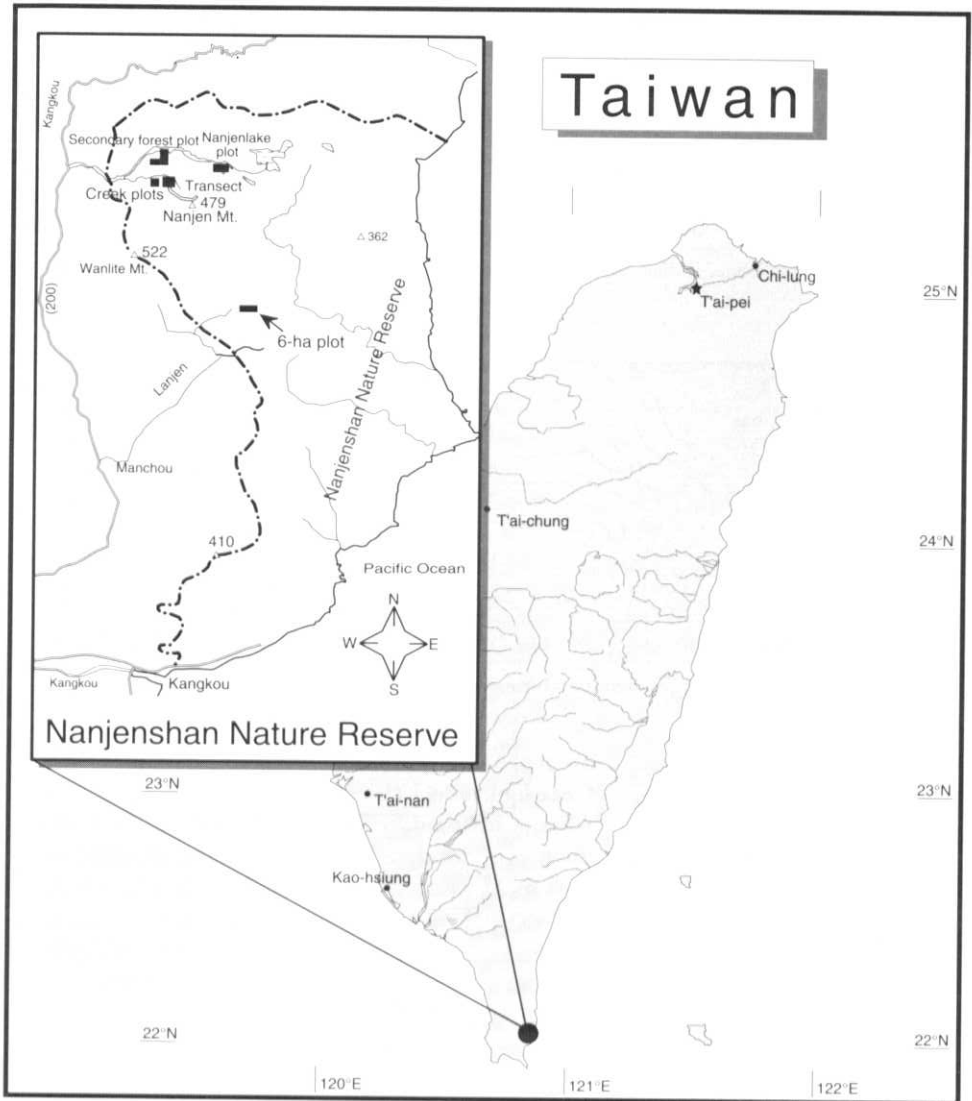


Fig. 34.1. Location of the 6-ha Nanjenshan Forest Dynamics Plot.

Topography and Soil

The terrain of Nanjenshan Nature Reserve is rugged. Several rivers originate in this area, and they dissect the landscape into deep gorges and ravines. The plot has strong relief with slopes typically varying between 30 and 50% grade. Elevation ranges from 300 m above sea level in the protected creek bottom to 340 m atop the most exposed slopes facing the northeastern monsoon winds. A small creek

Table 34.1. Nanjenshan Climate Data

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/ Averages
Rain (mm)	111	107	116	130	206	681	568	463	321	523	206	150	3582
ADTMx (°C)	22.3	22.4	25.9	28.2	28.6	27.7	30.7	30.0	28.3	26.6	24.7	23.2	26.8
ADTMn (°C)	16.3	16.4	18.6	19.3	21.9	23.2	23.8	23.7	22.3	21.7	19.9	18.0	20.3

Notes: Average daily temperatures (maximum and minimum) were recorded from December 1996 to April 1999 (<http://lter.npust.edu.tw/>).

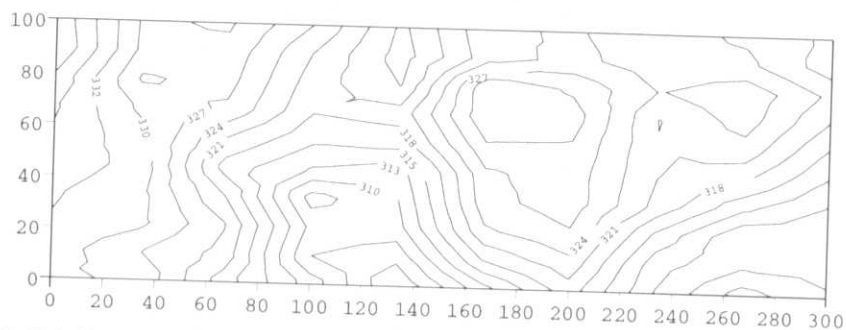


Fig. 34.2. Topographic map of the 3-ha Nanjenshan Forest Dynamics Plot with 3-m contour intervals.

runs north-south through the plot in a steep ravine, dividing the plot into distinct windward and leeward slopes. See figures 34.2 and 34.3.

The exposed bedrock consists of interbedded strata of sandstone and shale of the Miocene. The soils consist of more than 45% clay, and are classified as paleudults or hapludalfs with advanced weathering and pedogenesis (Chen et al. 1997). The soil is strongly acidic with pH values between 4 and 5, and its organic carbon content and cation exchange capacity are low (Chen et al. 1997). Soil depth is relatively shallow, ranging from 40 to 60 cm to bedrock (Sun et al. 1998).

Forest Type and Characteristics

The Nanjenshan forest contains a broad mixture of temperate and tropical species that is attributed to the geography and landscape of the region. The higher altitudinal limit of tropical rainforest on the sides of larger tropical mountains has been reported from all parts of the tropics. Called the Massenerhebung effect, this phenomenon is hypothesized to be the result of the increased heating of larger mountain massifs, which enables lowland plants to extend the range of their altitudinal distribution. In small, isolated mountains and coastal ranges, the opposite tendency has been witnessed; temperate species descend beyond their

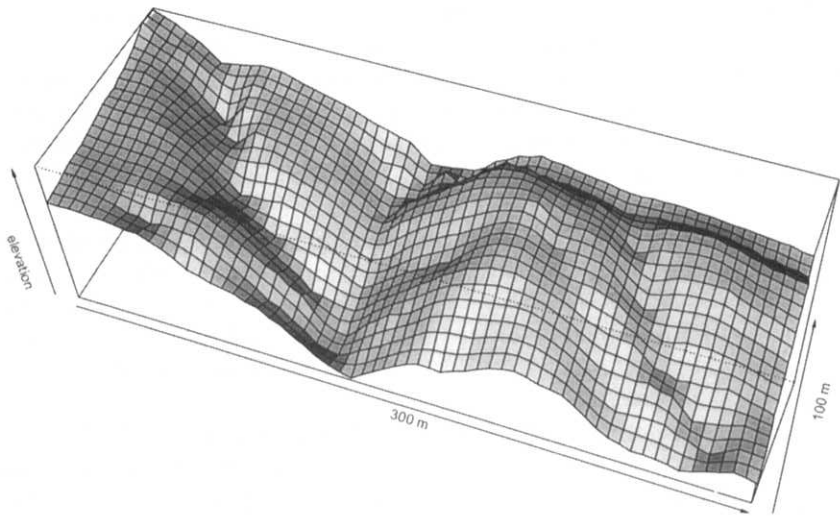


Fig. 34.3. Perspective map of the 3-ha Nanjenshan Forest Dynamics Plot.

typical lower elevation limit. Because the Nanjenshan Forest Dynamics Plot is located on a small, isolated mountain at the southern end of the Central Ridge of Taiwan, which is a large mountain massif, the broad mixture of both temperate and tropical species in the forest may be an indication of the Massenerhebung effect. In addition, the northeasterly monsoon winds are particularly strong and persistent in the Nanjenshan forest area because of a topographic funneling effect. This further decreases air temperatures, thus allowing temperate species to descend to even lower elevations.

Nanjenshan forest is highly differentiated into zones, characterized by abrupt changes in species composition, due to the existence of varying degrees of specialization and generalization to microsite conditions along the stress gradient (Sun 1993). Most species are associated with either the windward or leeward slopes. The 3-ha Nanjenshan Forest Dynamics Plot can be divided into four habitats: windward (0.72 ha), leeward (0.82 ha), intermediate (1.23 ha), and creek (0.23 ha).

The forest on windward slopes tends to be short in stature (3–5 m), unstratified, high in stem density (20,065 trees/ha), and low in per-stem species richness. Leaves are small and thick, and litter fall rates are low (Sun 1993). Dominant species at these sites comprise trees from Fagaceae, Aquifoliaceae, Theaceae, and Winteraceae, such as *Quercus championii* (Fagaceae), *Ilex cochinchinensis* (Aquifoliaceae), and *Eurya hayatai* (Theaceae).

In the intermediate habitat, trees are not directly exposed to strong winds, though they still suffer moderate wind damage. The average canopy height is between 5 and 8 m with minimal forest stratification, similar to the forest structure of the windward habitat. The intermediate habitat has the lowest species richness per area of the four habitats. Dominant species includes *Ilex cochinchinensis* (Aquifoliaceae), *Castanopsis carlesii* (Fagaceae), and *Illicium arborescens* (Illiciaceae).

In the leeward habitat, the forest grows on protected slopes and is relatively tall (10–15 m), stratified, relatively low in stem density (7505 trees/ha), and much higher in per-stem species richness. Litter fall rates are much higher and leaves are larger and thinner (Sun 1993). Dominant species found in this habitat include *Schefflera octophylla* (Araliaceae), *Psychotria rubra* (Rubiaceae), and *Beilschmiedia erythrophloia* (Lauraceae).

In the creek habitat, trees reach up to 15–20 m. Stem density is the lowest of the four habitats, averaging 4257 trees/ha. Compared to other habitats, the creek habitat has many fewer individuals but each individual grows much larger. This habitat is very similar to the leeward habitat. However, the species composition is quite different. Dominant species at this habitat include *Schefflera octophylla* (Araliaceae), *Astronia ferruginea* (Melastomataceae), and *Wendlandia formosana* (Rubiaceae). For census data and rankings, see tables 34.2–34.7.

Table 34.2. Nanjenshan Plot Census History

Census	Dates	Number of Trees (≥1 cm dbh)	Number of Species (≥1 cm dbh)	Number of Trees (≥10 cm dbh)	Number of Species (≥10 cm dbh)
First	July 1989–February 1991	36,629	118	3162	79
Second	July 1996–February 1997	36,383	125	3272	82

Notes: Two censuses have been completed of 3 ha, the next census is expected to begin in 2004.

Table 34.3. Nanjenshan Summary Tally

Size Class (cm dbh)	Average per Hectare							3-ha Plot				
	BA	N	S	G	F	H'	α	S	G	F	H'	α
≥1	36.3	12,209	104	68	37	1.64	15.6	118	79	41	1.68	15.15
≥10	23.9	1,054	61	44	24	1.49	14.0	79	55	30	1.55	14.69
≥30	5.2	46	13	11	7	0.94	5.5	26	21	14	1.17	5.32
≥60	0.3	1	1	1	1	—	—	2	2	1	0.28	—

Notes: BA represents basal area in m², N is the number of individual trees, S is number of species, G is number of genera, F is number of families, H' is Shannon–Wiener diversity index using log₁₀, and α is Fisher's α. Basal area includes all multiple stems for each individual. Individuals are counted using their largest stem. All species were identified. Data are from first census.

Table 34.4. Nanjenshan Rankings by Family

3-ha Forest Dynamics Plot									
Rank	Family	Basal Area (m ²)	% BA	% Trees	Family	Trees	% Trees	Family	Species
1	Fagaceae	11.7	32.3	8.3	Aquifoliaceae	4910	13.4	Lauraceae	11
2	Theaceae	3.4	9.4	8.6	Illiciaceae	4421	12.1	Fagaceae	10
3	Aquifoliaceae	2.7	7.5	13.4	Lauraceae	3254	8.9	Rubiaceae	10
4	Illiciaceae	2.1	5.9	12.1	Theaceae	3145	8.6	Euphorbiaceae	8
5	Lauraceae	1.9	5.3	8.9	Fagaceae	3058	8.3	Theaceae	8
6	Myrtaceae	1.8	5.0	4.7	Rubiaceae	3008	8.2	Moraceae	5
7	Daphniphyllaceae	1.8	5.0	3.3	Euphorbiaceae	2075	5.6	Aquifoliaceae	5
8	Araliaceae	1.7	4.6	1.2	Myrtaceae	1724	4.7	Myrtaceae	4
9	Oleaceae	1.5	4.2	3.0	Celastraceae	1388	3.8	Myrsinaceae	4
10	Euphorbiaceae	1.2	3.4	5.6	Symplocaceae	1328	3.6	Rutaceae	4

Notes: The top 10 families for trees ≥ 1 cm dbh are ranked in terms of basal area, number of individual trees, and number of species, with the percentage of trees in the plot. Data are from the first census.

Fauna

Nanjenshan has 14 species of mammals, including 6 species of bats, all of which are insectivores. The only large mammal in the nature reserve is the Taiwanese macaque (*Macaca cyclopis*), which mainly feeds on leaves and fruits. There are 45 species of birds, a figure significantly lower than other tropical forests. Other taxa include 19 species of amphibians and 28 species of reptiles (Hou and Huang 1999). Insects are more abundant and diverse, representing at least 464 species and 85 families. Fungi are another diverse group found in this area; over 368 species have been identified.

Natural Disturbance

The north-easterly winter monsoon is the major environmental factor in this region, which starts in the middle of October and lasts until late February. The monsoon winds are particularly strong and persistent in this area because Nanjenshan Nature Reserve is located at the first break in the central mountain massif that runs the length of Taiwan. Average wind speed is greater than 5 m/sec in the windward slope and less than 2.5 m/sec in the leeward slope during monsoon season. During nonmonsoon season (March to September), average wind speed is less than 2 m/sec.

Typhoons are also very common in this region. They can arrive as early as May or as late as November. When a typhoon directly hits the forest, it strips away many trees and creates landslides and huge gaps. Due to the destructive nature of typhoons, they greatly affect the regeneration processes of the forest. In contrast, monsoon winds do not cause massive and direct destructive damage to the forest.

Table 34.5. Nanjenshan Rankings by Genus

Rank	Basal Area (m ²)		% Trees		3-ha Forest Dynamics Plot		Trees	% Trees	Genus	Species
	Genus	BA	%	Genus	Genus					
1	<i>Castanopsis</i> (Fagaceae)	15.9	14.6	2.8	<i>Ilex</i> (Aquifoliaceae)	<i>Ilex</i> (Aquifoliaceae)	4910	13.4	<i>Ficus</i> (Moraceae)	6
2	<i>Quercus</i> (Fagaceae)	12.8	11.8	3.9	<i>Illicium</i> (Illiciaceae)	<i>Illicium</i> (Illiciaceae)	4421	12.1	<i>Ilex</i> (Aquifoliaceae)	5
3	<i>Ilex</i> (Aquifoliaceae)	8.2	7.5	13.4	<i>Psychotria</i> (Rubiaceae)	<i>Psychotria</i> (Rubiaceae)	2029	5.5	<i>Lastanthus</i> (Rubiaceae)	5
4	<i>Illicium</i> (Illiciaceae)	6.4	5.9	12.1	<i>Eurya</i> (Theaceae)	<i>Eurya</i> (Theaceae)	1461	4.0	<i>Castanopsis</i> (Fagaceae)	4
5	<i>Daphniphyllum</i> (Daphniphyllaceae)	5.5	5.0	3.3	<i>Syzygium</i> (Myrtaceae)	<i>Syzygium</i> (Myrtaceae)	1423	3.9	<i>Persca</i> (Lauraceae)	4
6	<i>Schefflera</i> (Araliaceae)	5.0	4.6	1.2	<i>Quercus</i> (Fagaceae)	<i>Quercus</i> (Fagaceae)	1417	3.9	<i>Syzygium</i> (Myrtaceae)	4
7	<i>Osmanthus</i> (Oleaceae)	4.6	4.2	3.0	<i>Auridesmia</i> (Euphorbiaceae)	<i>Auridesmia</i> (Euphorbiaceae)	1349	3.7	<i>Quercus</i> (Fagaceae)	3
8	<i>Syzygium</i> (Myrtaceae)	4.3	3.9	3.9	<i>Symplocos</i> (Symplocaceae)	<i>Symplocos</i> (Symplocaceae)	1328	3.6	<i>Neolitsea</i> (Lauraceae)	3
9	<i>Lithocarpus</i> (Fagaceae)	3.6	3.3	1.1	<i>Daphniphyllum</i> (Daphniphyllaceae)	<i>Daphniphyllum</i> (Daphniphyllaceae)	1192	3.3	<i>Ardisia</i> (Myrsinaceae)	3
10	<i>Pasania</i> (Fagaceae)	2.8	2.5	0.5	<i>Microtropis</i> (Celastraceae)	<i>Microtropis</i> (Celastraceae)	1172	3.2	<i>Glochidion</i> (Euphorbiaceae)	3

Notes: Top 10 tree genera for trees ≥ 1 cm dbh. Data are from the first census.

Table 34.6. Nanjenshan Rankings by Species

Rank	Species	Number Trees	% Trees	Species	Basal Area (m ²)	% BA	% Stems
1	<i>Illicium arborescens</i> (Illiciaceae)	4421	12.1	<i>Castanopsis carlesii</i> (Fagaceae)	14.5	13.3	2.5
2	<i>Ilex cochinchinensis</i> (Aquifoliaceae)	2248	6.1	<i>Illicium arborescens</i> (Illiciaceae)	6.4	5.9	12.1
3	<i>Psychotria rubra</i> (Rubiaceae)	2029	5.5	<i>Quercus longinux</i> (Fagaceae)	6.3	5.8	2.5
4	<i>Eurya hayatai</i> (Theaceae)	1385	3.8	<i>Daphniphyllum glaucescens</i> (Daphniphyllaceae)	5.5	5	3.3
5	<i>Antidesma hiiranense</i> (Euphorbiaceae)	1349	3.7	<i>Schefflera octophylla</i> (Araliaceae)	5.0	4.6	1.2
6	<i>Daphniphyllum glaucescens</i> (Euphorbiaceae)	1192	3.3	<i>Quercus championii</i> (Fagaceae)	4.8	4.4	0.7
7	<i>Microtropis japonica</i> (Celastraceae)	1172	3.2	<i>Osmanthus marginatus</i> (Oleaceae)	4.6	4.2	3.0
8	<i>Ilex matsudai</i> (Aquifoliaceae)	1170	3.2	<i>Lithocarpus amygdliifolius</i> (Fagaceae)	3.6	3.3	1.1
9	<i>Osmanthus marginatus</i> (Oleaceae)	1090	3.0	<i>Schima superba</i> (Theaceae)	3.1	2.8	1.1
10	<i>Ilex uraiensis</i> (Aquifoliaceae)	1085	2.9	<i>Elaeocarpus sylvestris</i> (Elaeocarpaceae)	2.8	2.6	0.5

Notes: The top 10 tree species for trees ≥ 1 cm dbh are ranked by number of trees and basal area. Data are from the first census.

Table 34.7. Nanjenshan Tree Demographic Dynamics for 1991–97

Size Class (cm dbh)	Growth Rate (mm/yr) 1991–1997	Mortality Rate (%/yr) 1991–1997	Recruitment Rate (%/yr) 1991–1997	BA Losses (m ² /ha/yr) 1991–1997	BA gains (m ² /ha/yr) 1991–1997
1–9.9	1.14	1.77	2.0	0.20	0.58
10–29.9	1.62	1.38	3.0	0.29	0.48
≥ 30	2.74	2.03	4.1	0.11	0.15

The monsoon winds blow continuously, 24 hours a day, 7 days a week, and exert a chronic stress on the forest that may have a different and a potentially greater cumulative effect on forest structure and dynamics than typhoons.

Human Disturbance

Human activities in this area date back to 1000–1500 years ago. Several archeological sites have been excavated at the northern part of the reserve. Evidence of human activities that occurred 50 to 60 years ago includes extraction of *Cinnamomum* (Lauraceae), the collection of forest orchids, and the creation of betel palm (*Areca catechu*, Palmae) plantations. However, most human activities were

restricted to the northern part of the nature reserve, or below 250 m elevation. At higher elevations, where the permanent plot is located, the area's remoteness ensured little anthropogenic disturbance of the reserve prior to its designation as a national park. After the establishment of the park, all hunting, poaching, and illegal land use were forbidden. However, hunters are occasionally seen inside the reserve. To what extent their activities affect the forest dynamics is unknown.

The permanent plot is situated in the center of the nature reserve, which is composed of more than 2000 ha of continuous forest. The forest edge nearest to the plot is about 2 km away. The reserve is surrounded primarily by secondary forest, betel palm plantations, coconut plantations, and rice fields.

Plot Size and Location

Nanjenshan is a 3-ha, 300 × 100 m plot, whose long axis lies east-west. The north-west corner of the plot is at 22°03'34.1" N and 120°51'09.1" E. The southeast corner is at 22°03'30.8" N and 120°51'19.6" E.

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