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CONSTRUCTION OF A CANOPY OBSERVATION SYSTEM IN A TROPICAL RAINFOREST OF SARAWAK

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ABSTRACT. We constructed a canopy observation system, comprised of two tree towers at heights ≥50 m above the ground and 9 spans of aerial walkway with the total length of 300 m, in a lowland mixed dipterocarp forest in Lambir Hills National Park, Sarawak, Malaysia in 1992–1993. This paper illustrates the construction procedures and discusses methodology for studies of the rainforest canopy.

In the early 1980s, pioneer works in tropical rainforests revealed that the canopy of tropical rainforests was the center of most plant productivity and reproduction (Sutton *et al.* 1983; Whitmore 1984), and animal abundance (Erwin 1983, 1988; Stork 1987a, 1987b, 1988a, 1988b; Rees 1983), varying with distribution of food and shelter resources. These findings stimulate the development of techniques to access the canopy, which reaches 40 to 70 m above ground. Several access methods have been developed, e. g. ropes and ascenders (Mitchell 1982; Perry 1978, 1984; Dial & Tobin 1994), raft (Halle & Pascal 1992), crane (Joyce 1991; Illueca & Smith 1993), tower and walkway (Mitchell 1982). Each method has advantages and disadvantages, and must be selected to fit the purposes of a study.

The Canopy Biology Program in Sarawak (CBPS) started in 1991 to study plant phenology, seasonal changes in insect abundance and interactions between plants and animals in canopy layers (Inoue & Hamid 1994).

Rainfall in the Southeast Asian tropics changes greatly from month to month with varying periodicity (Inoue & Nakamura 1990; Inoue *et al.* 1993). Of these periods, the most predominant occurs every 4 to 6 years and is caused by the El Niño and Southern Oscillation, (and the drought which follows lasts for up to 10 months). The drought triggers a general flowering of mixed dipterocarp forests in this region (Ashton *et al.* 1988; Ashton 1993; Appanah 1993). To understand patterns of plant phenology in such a changing environment, we need to monitor plant phenology and insect abundance for at least one episode of the "season". CBPS plans to conduct bimonthly censuses of both plants and insects along a fixed route in the canopy for at least one episode.

We have employed the combination of tree towers and aerial walkways as the best access method for the long-term observations described above. Rafts cannot be set in the same location for long periods due to potential harmful effects on trees. And, due to existence of emergent trees, rafts are difficult to land on the irregular canopy surface in Southeast Asian rainforests. A crane cannot cover an area greater than its boom length, and its construction disturbs the forest during the transportation of materials and construction of base plates. Single rope techniques are inconvenient for routine censuses.

Tree towers and aerial walkways had already been constructed in various places in Southeast Asia (Pasoh, Peninsular Malaya; Poring, Sabah; Semengoh, Sarawak among others). We have modified previous methods to fit our long-term use and have integrated methods to cover a wide area of canopy. We have constructed two tree towers extending ≥50 m and connected by 9 spans of aerial walkway that pass through various

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canopy layers. The total length of walkways is 300 m and this total system is reputed to be the biggest in the world.

This paper aims to explain the construction of the tree towers and walkways and discuss our canopy access system.

Location

We marked out a canopy biology plot (200 × 400 m, 8 ha) on a clayey soil site near the headquarters of Lambir Hills National Park, Sarawak, Malaysia (4°20′N, 113°50′E, altitude 60 m, FIGURE 1) in 1992. The plot is covered by intact mixed dipterocarp forests at altitudes of 100 to 200 m above the sea level. The height of emergent trees exceeds 70 m. In the central part we made two tree towers on neighboring ridges and connected them by walkways as described below.

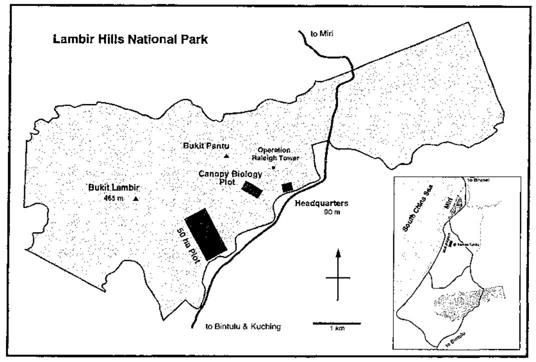

FIGURE 1. The site of the canopy biology plot in Lambir Hills National Park (inset: Miri and surrounding areas).

Construction Procedure

Tree Towers

Tree tower 1 (T1) was constructed around an emergent tree of *Dryobalanops lanceolata* (Dipterocarpaceae), tree code B1, on a gentle ridge (FIGURES 2, 3). The height of B1 is 70 m and DBH is 1.52 m.

Eleven wooden platforms and 11 flights are set around the trunk of B1 and observers can walk spirally up to the top wooden platform. The distance between two consecutive platforms is 3.0 m and the height of the top platform is 33 m above the ground. These platforms are supported by four pillars (5 × 5 inches) set in a square of 4.88 m. Pillars are made with iron wood (*Eusideroxyron zwageri,* Lauraceae). Only one brace is set in each unit of flight, not a crossed pair, to allow free swing of the tree tower in response to wind. At the middle of T1, pillars are pulled by supporting cables (ϕ=16 mm) in 4 directions. The bases of the four pillars are set in concrete.

Wooden handrails (height, 0.92 m) are set on both sides of platforms and wooden flights for the security of observers and so there is no necessity to use safety belts on T1. Capacity of T1 is limited to 10 people.

Above the top platform of T1 we constructed two emergent platforms among the branches at 45 and 55 m above ground to which aluminum ladders were connected. Independent safety cables are fixed directly to tree trunk. The aluminum ladders are not connected to the top platform of T1 to permit independent movement in wind.

It took about 2 months starting from the middle of July 1992 for construction of T1. The emergent platforms and aluminum ladders were constructed in 2 weeks in January 1993.

Tree tower 2 (T2) was constructed on one side of a canopy tree, *Dipterocarpus pachyphyllus* (Dipterocarpaceae), tree code B129 (FIGURES 4, 5). The height and DBH are 48 m and 1.36 m, respectively. The square size (2.44 m) of T2 is 50 % of that of T1 but the height (48.6 m) of the top platform of T2 is 16 m higher than T1. The top platform is higher than the height of B129 and outlook is clear in all directions. There are 14 wooden platforms, including the top. Except for the 4 full cover platforms, the other 10 are 0.61 × 0.61 m square. The difference in height between two platforms is about 3.5 m and is determined by the length of an aluminum ladder (4.6 m). To reduce the total weight of the tower we used aluminum ladders to climb from a platform to the next platform, instead of wooden steps.

The size of the pillar wood is 6x6 inches in the lower half of T2 and 5 × 5 in the upper half. Braces were crossed and four supporting cables were attached to the middle of the tower. As pillars were attached to the main branches of B129, T2 is more stable than T1 in wind. Capacity of T2 is limited to 5 people.

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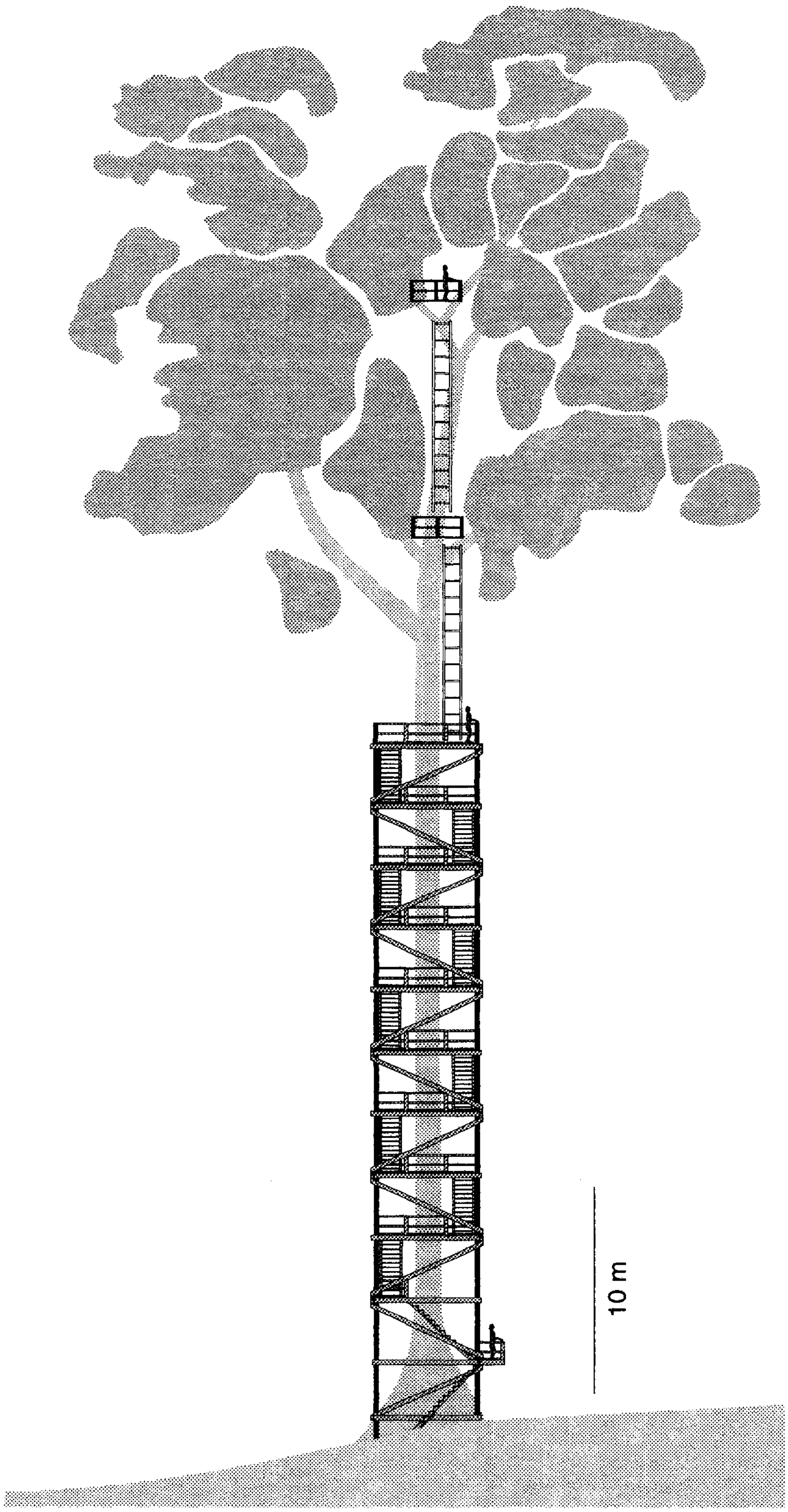
FIGURE 2. A profile of Tree Tower 1 (T1) from viewpoint of the east side (p. 26).

FIGURE 3. Tree Tower 1 (T1). (a) a total view, (b) the first stage of construction in August 1992, (c) an inner view, supporting cables from Walkway 1 seen at the middle, (d) supporting cable for T1 at the middle of T1 (p. 27).


10 m

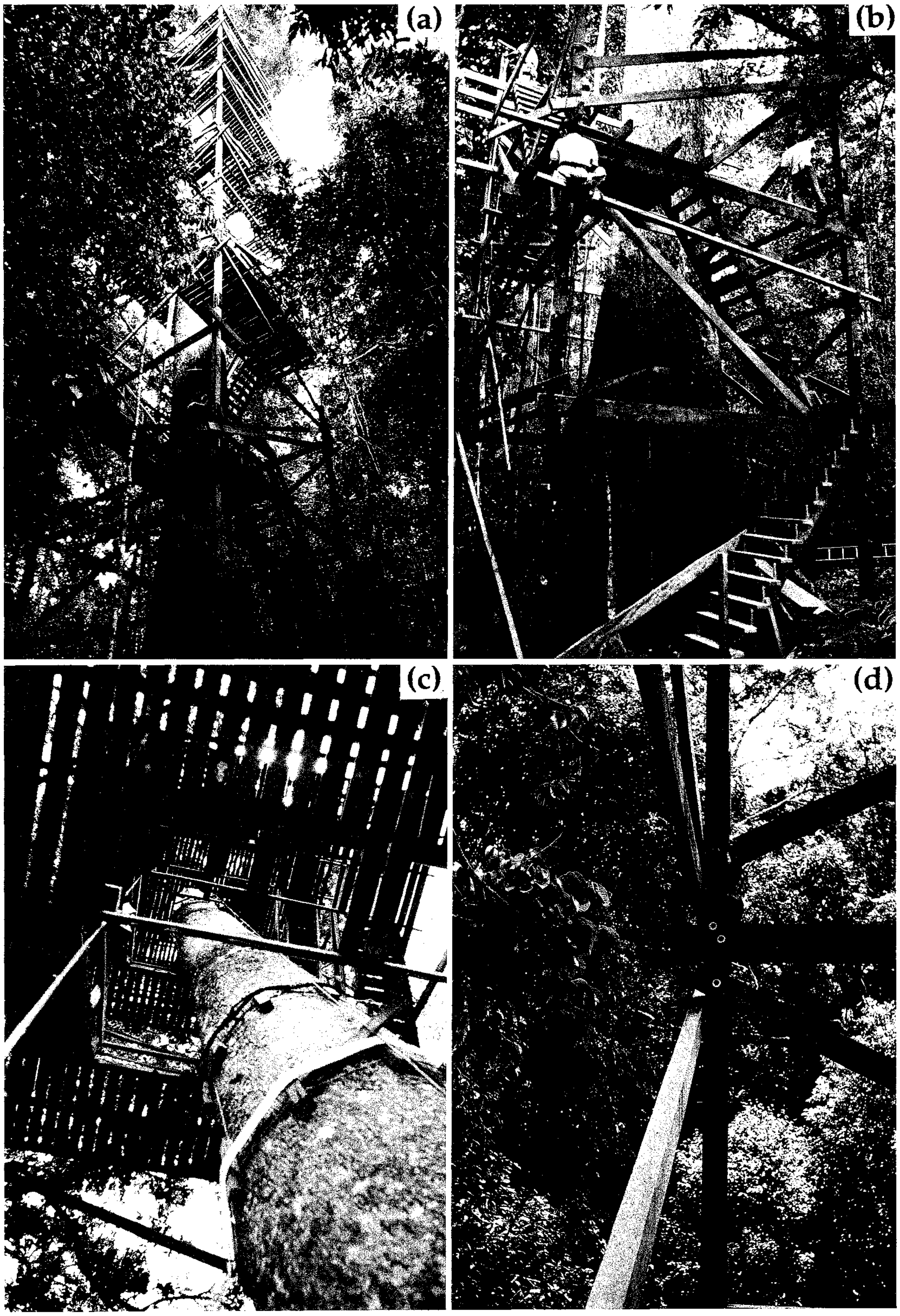

(a)
(b)
(c)
(d)

FIGURE 3 (continued). (e) The two emergent platforms and aluminum ladders to access them, (f) climb to the top emergent platform, (g) the top platform of T1 and the basement of the emergent ladder system.

We constructed T2 in 3 months starting in January 1993.

Walkways

The two tree towers were connected by 9 spans of aerial walkway (FIGURES 6–8). We used trunks of emergent or canopy trees as piers. The length of a span ranged from 25 to 54 m, depending on the distribution of pier trees. We tried to make one span shorter than 30 m. Spans pass through canopy layers from 15 to 35 m above the ground.

Structure of one span of a standard-sized walkway with a length of 30 m is shown in FIGURE

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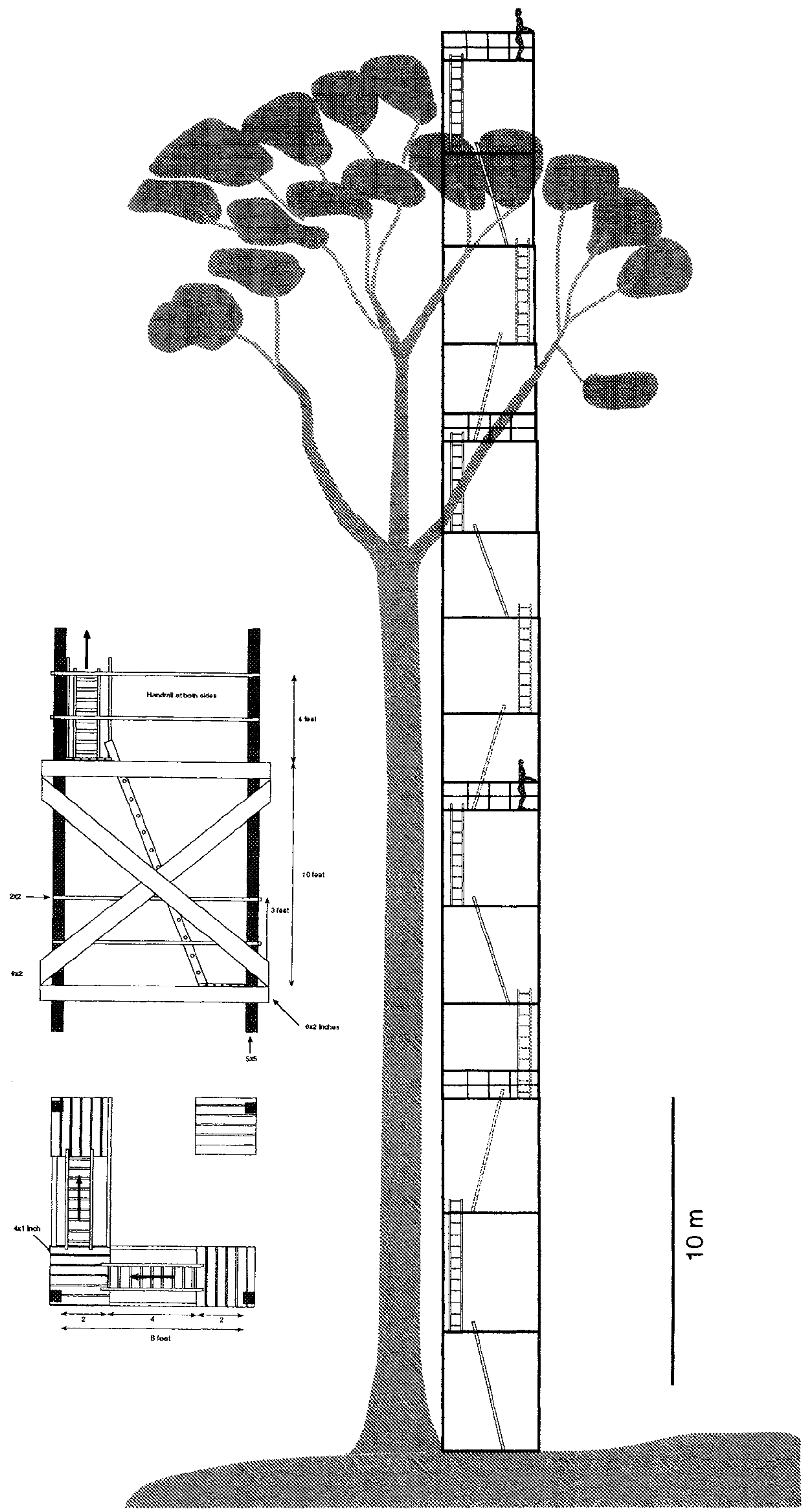
FIGURE 4. (a) A profile of Tree Tower 2 from the east side, (b) the detail design of T2 (p. 29).


Handrail at both sides
4 feet
10 feet
3 feet
2x2
6x2
6x2 inches
5x5
4x1 inch
2
4
2
8 feet
10 m

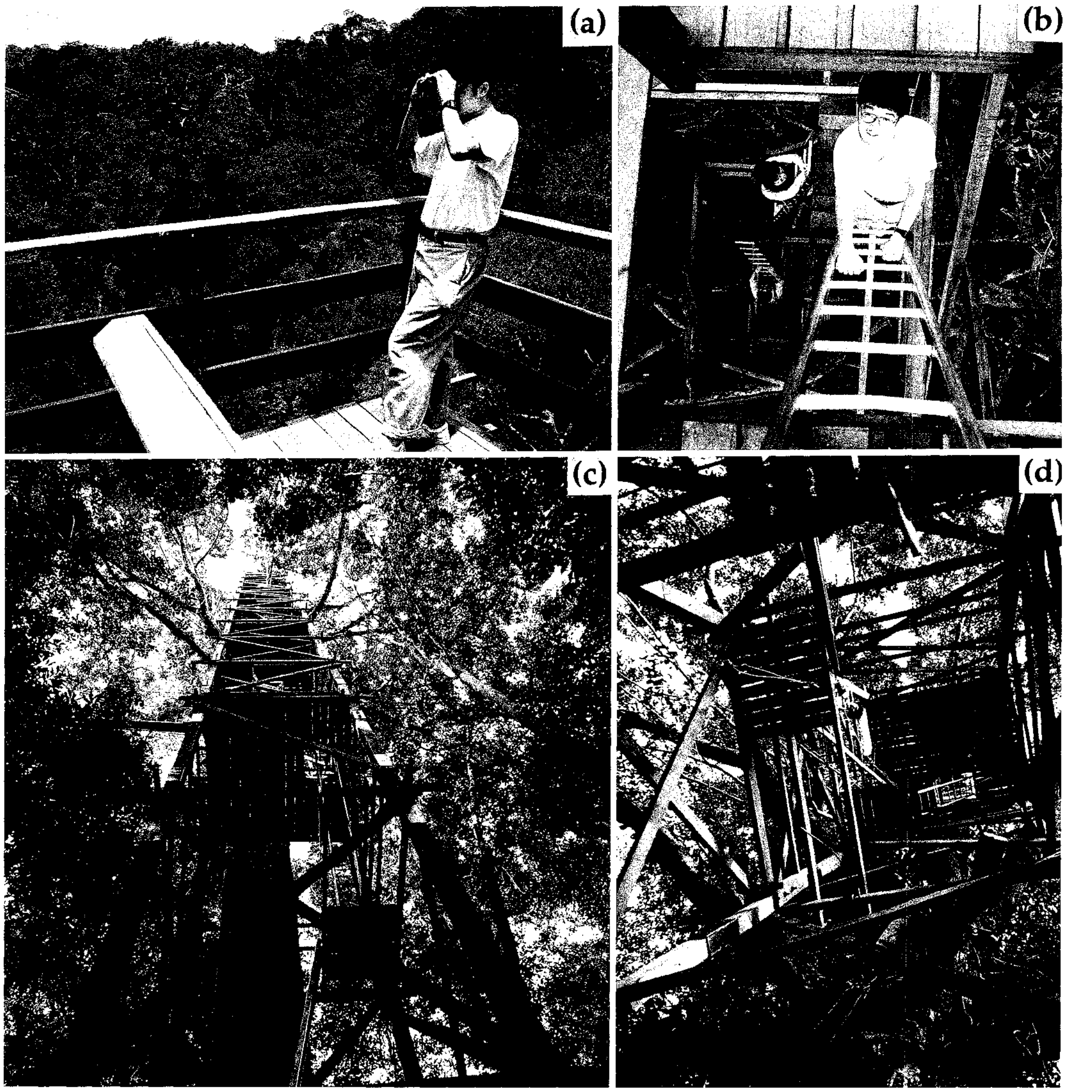


FIGURE 5. Tree Tower 2 (T2). (a) the top platform, (b) climbing up to the top platform, looking down from there, (c) a total view of T2, (e) an inner view of T2.

7. Observers walk on wooden plates set on aluminum ladders. Aluminum ladders are suspended by suspension cables (ϕ=3.5 mm with plastic cover) at intervals of 61 cm (every two holes of aluminum ladders) from the two carrying cables (ϕ=16 mm, 2000 kg test). The two handrail cables (ϕ=16 mm with plastic cover) are also connected to aluminum ladders. Aluminum ladders are connected to each other with iron plates. The width between handrails is 0.6 m for easy movement and safety. A safety cable (ϕ=8 mm, 500 kg test) is fixed on one side of the handrails at

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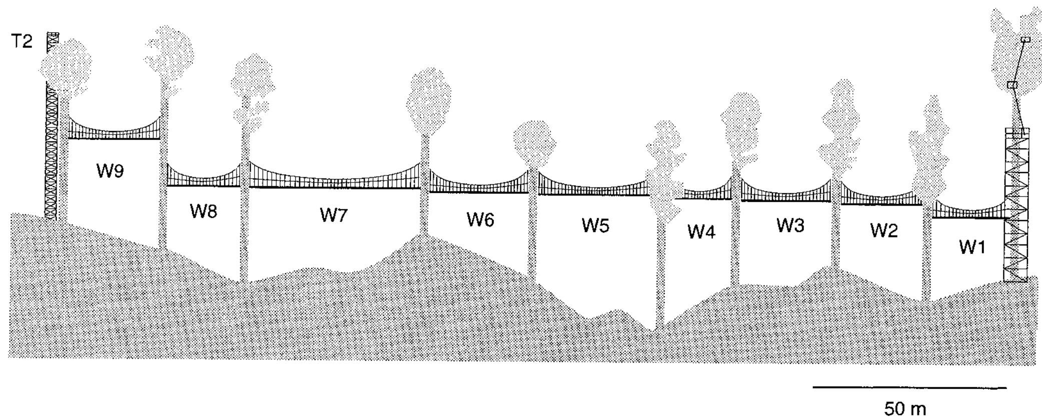
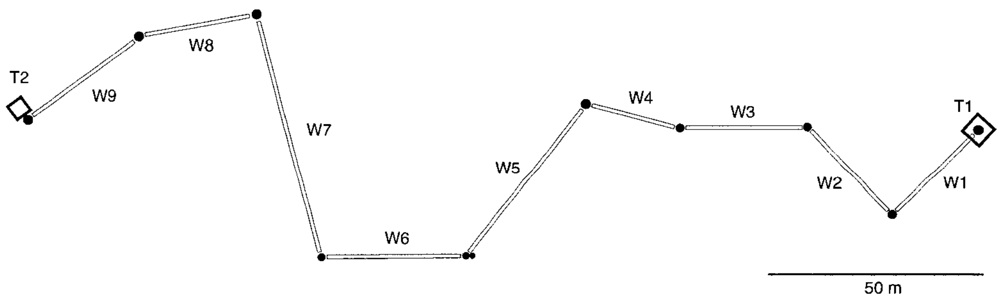
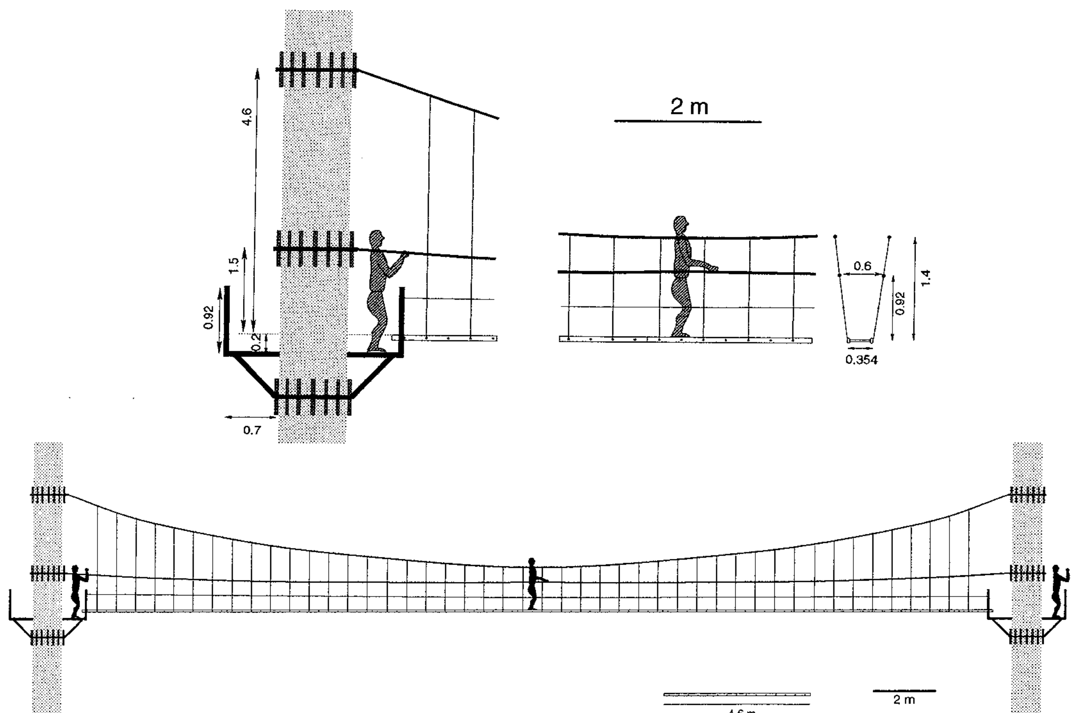
FIGURE 6. (a) A profile of the canopy observation system from the south view, (b) a top view of 9 spans of walkways (W1 to W9) (p. 31, top half).

FIGURE 7. A profile of the standard of walkway. The length of walkway changes depending the distance of supporting trees. (a) the total profile, (b) detailed design (p. 31, bottom half).


T2
T1
W9
W8
W7
W6
W5
W4
W3
W2
W1
50 m


T2
W9
W8
W7
W6
W5
W4
W3
W2
W1
T1
50 m


4.6
1.5
0.92
0.2
0.7
2 m
0.6
0.92
1.4
0.354
4.6 m
2 m

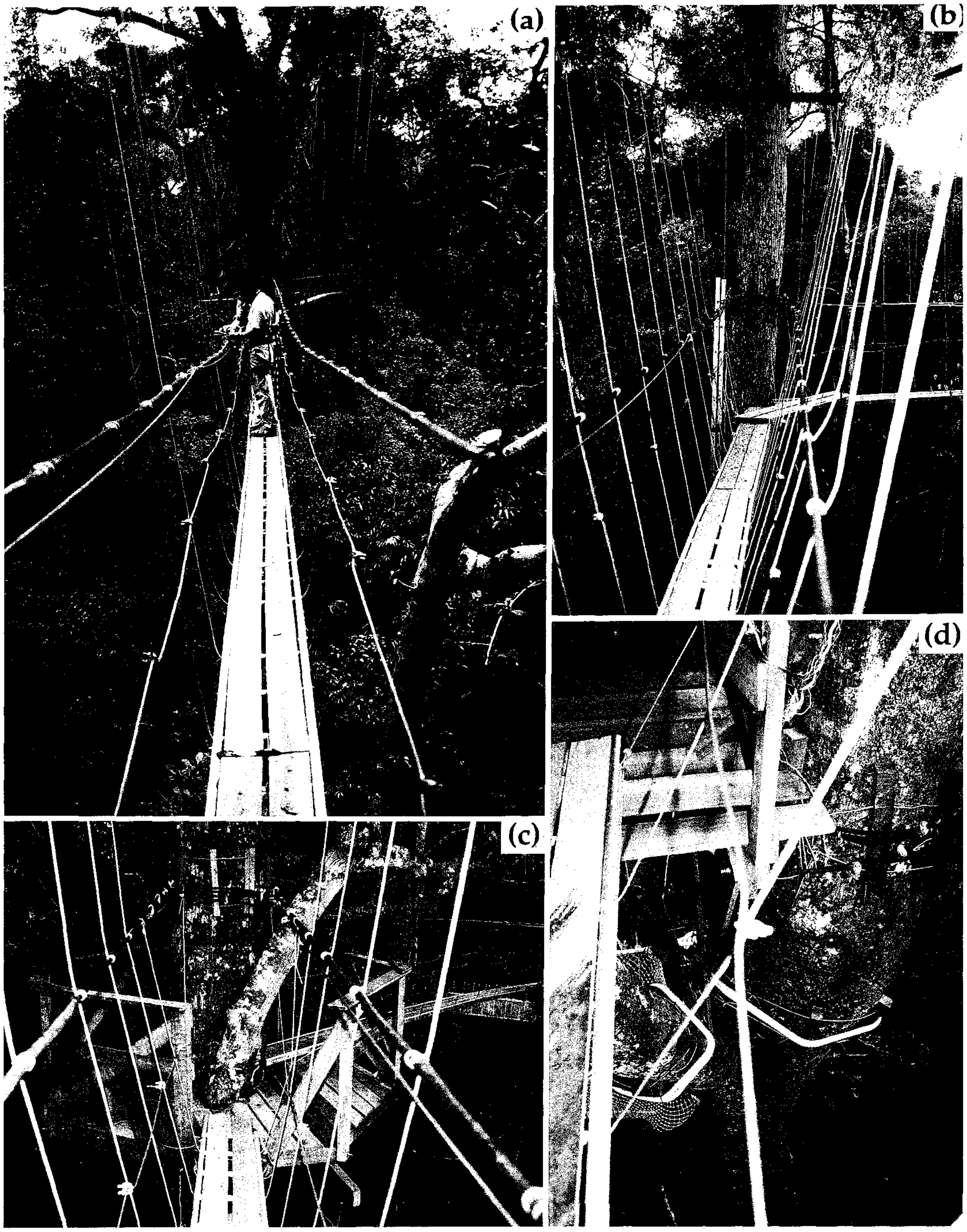


FIGURE 8. Walkways. (a) walkway 3, (b) walkways 6 and 7 and an aluminum ladder set on the pier trees of W6 and W7, (c) the platform on the pier tree of W2 and W3, looking from W3, (d) the supporting woods for the platform on the pier tree of W1 and W2.

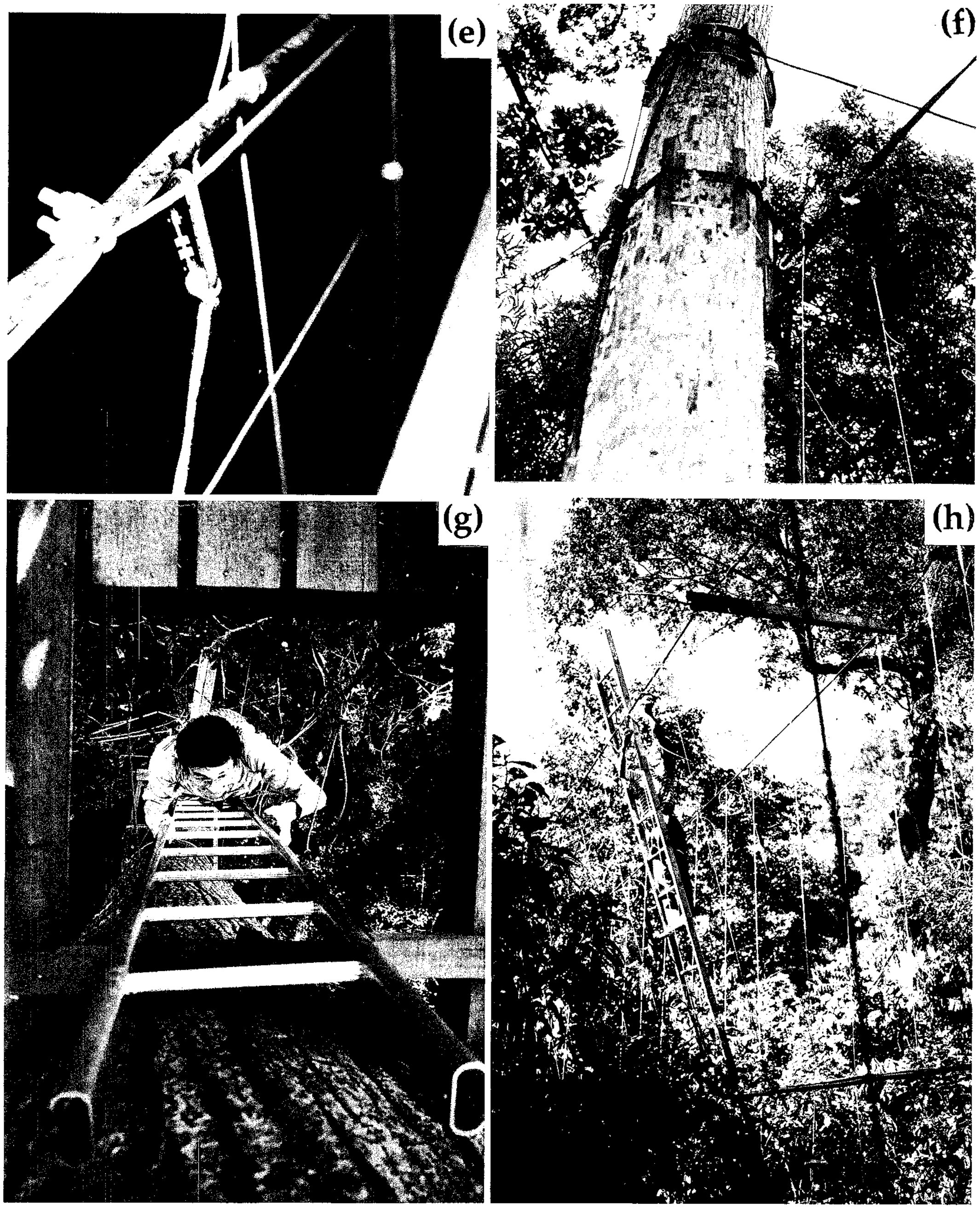


FIGURE 8 (continued). (e) a safety cable, (f) supporting cables on the pier tree of W7 and W8, (g) climbing the aluminum ladder from W8 to W9, (h) construction of W7.

intervals of 4.6 m and an observer connects at least one safety belt out of the two to this safety cable at all times on the walkways.

Carrying and handrail cables are anchored, not directly on tree trunks, but on shock absorbing wooden buttresses (5 × 5 × 50 cm) set at intervals of 30 cm around the trunk, to reduce harmful effects on trees. The heights of anchoring points of the carrying cables and handrail cables are 4.6 m and 1.5 m respectively from the level of the aluminum ladders. Platforms were made on pier trees to allow movement from the walkway to the next walkway.

When the two consecutive walkways do not run in a straight line, we pull the pier tree by cables to balance the stress.

Walkway 1 was constructed from September to November, 1992 and the remaining 8 from January to April 1993.

Problems and Improvements

The canopy observation system has worked reasonably well for two years since the completion of construction of the whole system in 1993 and we have obtained various information about the canopy, most of which is new to science.

The most serious problem in construction of tree towers is transportation of heavy iron woods into the forest. This limits sites of tree towers to areas not far from roads. To reduce the total weight of materials, we used aluminum ladders. The climbing system that was constructed above the top platform of Tree Tower 1 (T1) can be modified to a complete system in which aluminum ladders and wooden platforms are connected together from the ground.

One limitation to the use of walkways is the risk of tree fall. In October 1993, a tree trunk (ϕ=0.4, l=10 m, the total estimated weight=5 tons) hit Walkway 6. Fortunately the part that touched W6 was the tip of the trunk and only loosened some cables. If bigger trunks hit a walkway, the whole walkway system could collapse. There are two ways to reduce risk of tree fall; one is to develop a safety system that activates when walkways are struck by a heavy object, and the second is to construct each walkway independently. We suggest that a hub system with one aluminum central tower and a few walkways radiating from the central tower would be the best design.

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Literature Cited

Appanah S. 1993. Mass flowering of dipterocarp forests in the aseasonal tropics. J. Bioscience 18: 457–474.

Ashton P. S. 1993. The community ecology of Asian rain forests, in relation to catastrophic events. J. Bioscience 18: 501–514.

——— T. J. Givnish, and S. Appanah. 1988. Staggered flowering in the Dipterocarpacae: new insights into floral induction and the evolution of mast fruiting in the aseasonal tropics. Am. Nat. 132: 44–66.

Dial R. and S. C. Tobin. 1994. Description of arborist methods for forest canopy access and movement. Selbyana 15(2): 24–37.

Erwin T. L. 1983. Beetles and other insects of tropical forest canopies at Manaus, Brazil, sampled by insecticidal fogging. Pp. 59–75 *in* S. L. Sutton, T. C. Whitmore and A. C. Chadwick, eds., Tropical rain forest: ecology and management. Blackwell Scientific Publications, Oxford.

———. 1988. The tropical forest canopy-The heart of biotic diversity. Pp. 123–129 *in* E. O. Wilson and F. M. Peter, eds., Biodiversity. National Academy Press, Washington, D.C.

Hallé F. and O. Pascal, eds. 1992. Biologie une canopee de foret equatoriale II Rapport de mission: radeau des cimes Octobre Novembre 1991, reserve de Canpo, Cameroon. Foundation Elf, Paris.

Illueca J. E. and A. P. Smith. 1993. Exploring the upper tropical forest canopy. Our Planet 5: 12–13.

Inoue T. and A. A. Hamid, eds. 1994. Plant reproductive systems and animal seasonal dynamics: long-term study of dipterocarp forests in Sarawak. The Report of Monbusho International Scientific Research, Center for Ecological Research, Kyoto University, Otsu.

——— and K. Nakamura. 1990. Physical and biological background for insect studies in Sumatra. Pp. 1–11 *in* S. F. Sakagami, R. Ohgushi and D. W. Roubik, eds. Natural History of social wasps and bees in equatorial Sumatra. Hokkaido University Press, Sapporo.

———, ———, S. Salmah, and I. Abbas. 1993. Population dynamics of animals in unpredictably-changing tropical environments. J. Bioscience 18: 425–455.

Joyce C. 1991. A crane's eye view of tropical forests. New Scientist 21: 30–31.

Mitchell A. W. 1982. Reaching the rain forest roof—a handbook on technique of access and study in the canopy. UNEP.

Perry D. R. 1978. A method of access into the crowns of emergent and canopy trees. Biotropica 6: 155–157.

———. 1984. The canopy of the tropical rain forest. Scientific American 251: 114–122.

Rees C. J. C. 1983. Microclimate and the flying Hemiptera fauna of a primary lowland rain forest in Sulawesi. Pp. 121–136 *in* S. L. Sutton, T. C. Whitmore and A. C. Chadwick, eds. Tropical rain forest: ecology and management. Blackwell Scientific Publications, Oxford.

Stork N. E. 1987a. Canopy fogging, a method of collecting living insects for investigations of life history strategies. Journal of Natural History 21: 563–566.

———. 1987b. Guild structure of arthropods from Bornean rain forest trees. Ecological Entomology 12: 69–80.

———. 1988a. Insect diversity: facts, fiction and speculation. Biological Journal of the Linnean Society 35: 321–337.

———. 1988b. Species number, species abundance and body length relationships of arboreal beetles in Bornean lowland rain forest trees. Ecological Entomology 13: 25–37.

Sutton S. L., T. C. Whitmore and Chadwick A. C., eds. 1983. Tropical rain forest: ecology and management. Blackwell Scientific Publications, Oxford.

Whitmore T. C. 1984. Tropical rain forests of the Far East (2nd edition). Clarendon, Oxford.