

## Sinharaja Forest Dynamics Plot, Sri Lanka

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### Site Location, Administration, and Scientific Infrastructure

Located in the southwest region of Sri Lanka, the Sinharaja forest is the largest block of relatively undisturbed lowland evergreen rainforest on the island. Preservation of the Sinharaja forest goes back to 1907, when a 3200-ha area was demarcated as the result of a Forest Ordinance. In 1926, the ordinance was extended to cover 3724 ha. In 1978, after a short period of selective logging, the area was declared an 8800-ha International Man and Biosphere Reserve (de Zoysa and Raheem 1990). Subsequently, the forest, together with an eastern extension of 2450 ha, was declared a National Heritage Wilderness Area in 1988 and a UNESCO Natural World Heritage Site in 1989.

The 25-ha Sinharaja Forest Dynamics Plot was established in 1993 by the University of Peradeniya (Sri Lanka), the Forest Department of Sri Lanka, Harvard Institute of International Development (now the Center for International Development), and the Smithsonian Tropical Research Institute. The plot, which contains only undisturbed forest, is located in the southwestern portion of the reserve (fig. 37.1). The eastern, northern, and northwestern sides of the plot are surrounded by forests that are regenerating after they were selectively logged in the 1970s.

Between 1977 and 1981, 100 small plots, each 0.25-ha in extent, were set up in five different areas of the Sinharaja forest by I. A. U. N. Gunatilleke and C. V. S. Gunatilleke, to document the differences in floristic composition and community structure in this forest. In these plots, all trees above 10 cm dbh were enumerated. A recensus of these plots was conducted in 1999.

Site facilities include research vehicles, a building with accommodations for at least eight researchers, a basic field laboratory, shade houses, and facilities for cooking, dining, and bathing. The nearby Forest Department station at Kudawa can accommodate larger parties and student classes.

### Climate

Over a 17-year period from 1984 to 1999, annual rainfall ranged from 4087 to 5907 mm, and averaged 5016 mm. There is no distinct dry season (average

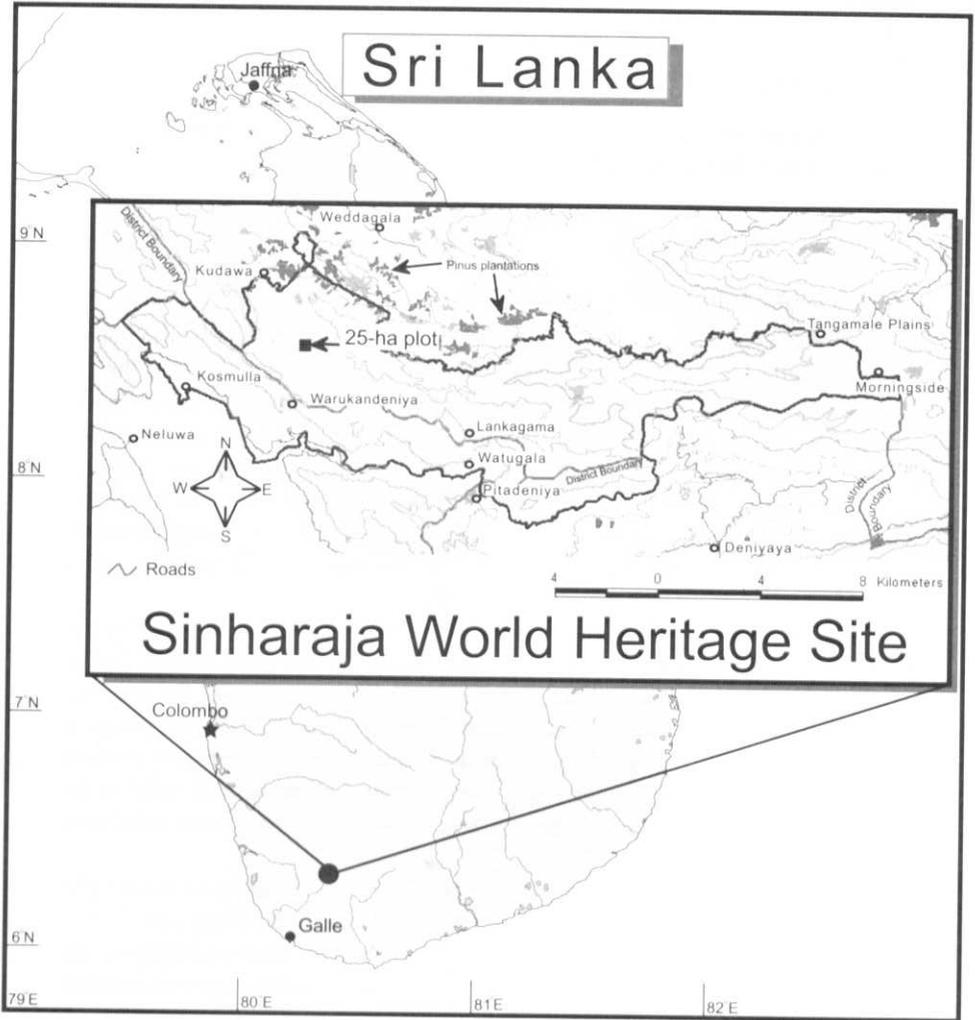


Fig. 37.1. Location of the 25-ha Sinharaja Forest Dynamics Plot.

monthly rainfall less than 100 mm). The forest receives rain from both the southwest monsoon, from May through July, and the northeast monsoon, from October through January (Munidasu et al. 2002). For climate data see table 37.1.

### Topography and Soil

The Sinharaja Forest Dynamics Plot lies between 424 and 575 m above sea level (figs. 37.2 and 37.3). It has a central valley bounded by two slopes, the steeper

Table 37.1. Sinharaja Climate Data

|           | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sep  | Oct  | Nov  | Dec  | Total/<br>Averages |
|-----------|------|------|------|------|------|------|------|------|------|------|------|------|--------------------|
| Rain (mm) | 191  | 171  | 237  | 434  | 695  | 610  | 390  | 424  | 553  | 562  | 471  | 274  | 5016               |
| ADTMx     | 24.4 | 25.5 | 26.8 | 26.1 | 25.0 | 24.0 | 23.7 | 23.9 | 24.1 | 23.9 | 24.1 | 24.5 | 24.7               |
| ADTMn     | 19.3 | 19.3 | 19.6 | 20.8 | 21.7 | 21.4 | 21.1 | 20.8 | 20.8 | 20.4 | 20.1 | 19.5 | 20.4               |

Notes: Rainfall data were collected in a large opening in the forest and temperature data were collected in the adjacent forest near the field station in Sinharaja at 520 m above sea level. Values given are rainfall averages taken over the period 1984–2002 and temperature averages over the period 1992–1999 from the understory of the forest.

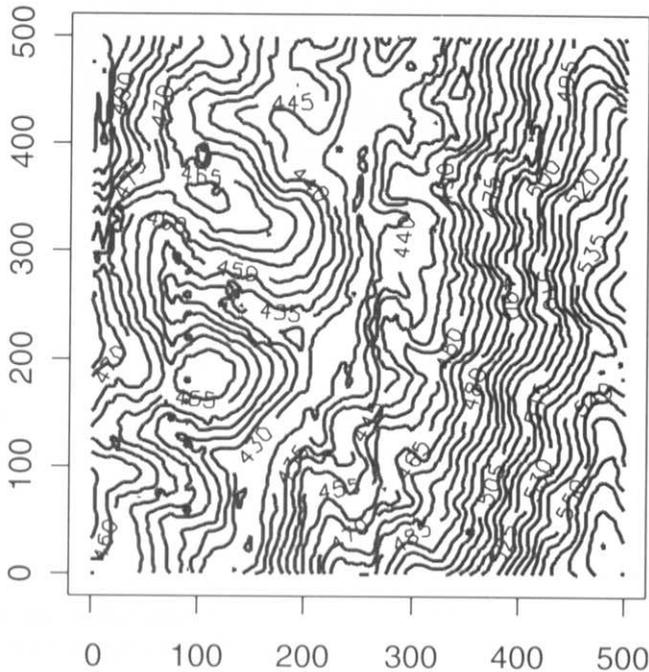


Fig. 37.2. Topographic map of the 25-ha Sinharaja Forest Dynamics Plot with 5-m contour intervals.

and higher slope faces the southwest, and the other faces the northeast. Seepage ways, spurs, and small hillocks cut across both slopes. Two perennial streams and several seasonal streamlets are present in the plot.

The geology of the area represents metamorphic rocks of Sri Lanka's Highland Series of the Precambrian Age (Cooray 1967). The more siliceous charnokite forms the prominent parallel crests; khondalite, rich in hornblende, underlies the fertile lower slopes and valleys. The soils overlying them are Ultisols (humults to udults) (Panabokke 1996). Soil physical–chemical characteristics for the Sinharaja forest in general are reported as follows: pH = 3.8–4.77; C = 1.44–4.73%; N =

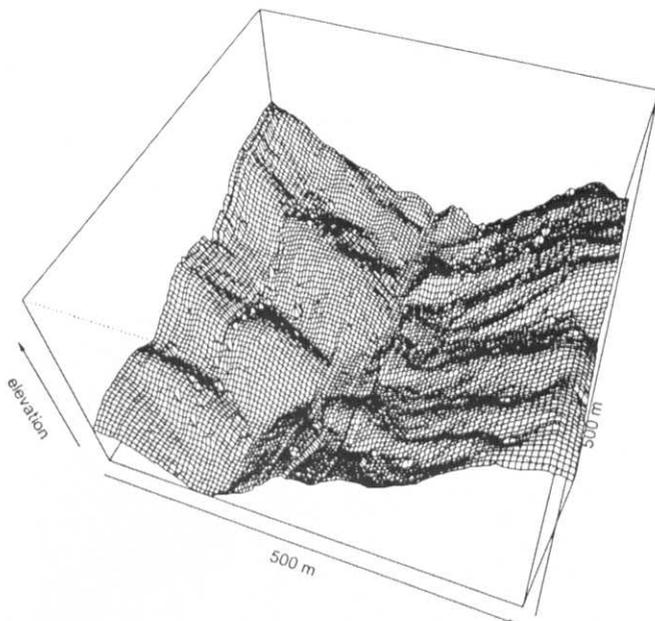


Fig. 37.3. Perspective map of the 25-ha Sinharaja Forest Dynamics Plot.

0.09–0.22%; P = 0.033–0.045%; K = 0.27–1.03%; Ca = 0.09–0.77%; Mg = 0.20–0.73% (Gunatilleke and Maheswaran 1988; Hafeel 1991; Gunatilleke et al. 1996).

### Forest Type and Characteristics

Although many species in the Sinharaja Forest Dynamics Plot are endemic to Sri Lanka (69%), the generic composition is strikingly similar to the lowland mixed dipterocarp forest of western Malesia. It is therefore categorized as mixed dipterocarp forest, though the south Asian endemic generic element differentiates it as a distinct regional type. Unlike other mixed dipterocarp forests, those of Sri Lanka's southwestern hills do not have an emergent layer of trees, possibly due to strong winds. Average canopy height in the plot is about 30 m. The forest structure is skewed toward small individuals.

Forest composition in the plot tends to change along an elevational gradient. As one ascends from the lower slopes at 430–459 m above sea level to the ridgetop above 520 m, the number of trees per hectare increases from 7272 to 11,278, the basal area per hectare increases from 39.2 to 59.4 m<sup>2</sup>, Fisher's alpha

Table 37.2. Sinharaja Plot Census History

| Dates |                        | Number of Trees ( $\geq 1$ cm dbh) | Number of Tree Species ( $\geq 1$ cm dbh) | Number of Lianas ( $\geq 1$ cm dbh) | Number of Liana Species ( $\geq 1$ cm dbh) | Number of Trees ( $\geq 10$ cm dbh) | Number of Tree Species ( $\geq 10$ cm dbh) |
|-------|------------------------|------------------------------------|---|-------------------------------------|--|-------------------------------------|--|
| First | August 1993–April 1996 | 205,373                            | 205                                       | 1128                                | 10*  | 16,937                              | 167  |

\* Number of liana species may increase as lianas are further identified.

Notes: One census has been completed. The second census was completed in 2002.

Table 37.3. Sinharaja Summary Tally

| Size Class (cm dbh) | Average per Hectare |      |     |    |    |      |          | 25-ha Plot |     |    |      |          |
|---------------------|---------------------|------|-----|----|----|------|----------|------------|-----|----|------|----------|
|                     | BA                  | N    | S   | G  | F  | H'   | $\alpha$ | S          | G   | F  | H'   | $\alpha$ |
| $\geq 1$            | 45.6                | 8215 | 142 | 81 | 38 | 1.53 | 24.4     | 205        | 116 | 46 | 1.71 | 22.5     |
| $\geq 10$           | 39.9                | 677  | 72  | 48 | 28 | 1.41 | 20.4     | 167        | 95  | 42 | 1.66 | 25.7     |
| $\geq 30$           | 27.0                | 143  | 34  | 24 | 17 | 1.16 | 14.1     | 109        | 71  | 35 | 1.44 | 21.2     |
| $\geq 60$           | 10.7                | 23   | 8   | 7  | 6  | 0.70 | 4.3      | 47         | 32  | 21 | 1.13 | 12.1     |

Notes: BA represents basal area in  $m^2$ , 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  $\log_{10}$ , and  $\alpha$  is Fisher's  $\alpha$ . Basal area includes all multiple stems for each individual. 9132 individuals were not identified to species or morphospecies. Data are from the first census.

Table 37.4. Sinharaja Rankings by Family

| Rank | Family           | Basal Area |      |         | Family           | No. of Trees |         | Family           | No. of Species |
|------|------------------|------------|------|---------|------------------|--------------|---------|------------------|----------------|
|      |                  | ( $m^2$ )  | % BA | % Trees |                  | Trees        | % Trees |                  |                |
| 1    | Guttiferae       | 304.9      | 26.7 | 15.5    | Guttiferae       | 31,825       | 15.5    | Euphorbiaceae    | 21             |
| 2    | Dipterocarpaceae | 246.4      | 21.6 | 14.1    | Euphorbiaceae    | 30,388       | 14.8    | Rubiaceae        | 18             |
| 3    | Bombacaceae      | 100.3      | 8.8  | 3.0     | Dipterocarpaceae | 28,984       | 14.1    | Melastomataceae  | 16             |
| 4    | Euphorbiaceae    | 67.6       | 5.9  | 14.8    | Leguminosae      | 22,537       | 11.0    | Myrtaceae        | 14             |
| 5    | Anacardiaceae    | 44.7       | 3.9  | 3.1     | Rubiaceae        | 16,169       | 7.9     | Dipterocarpaceae | 13             |
| 6    | Sapotaceae       | 44.6       | 3.9  | 4.2     | Sapotaceae       | 8,527        | 4.2     | Lauraceae        | 11             |
| 7    | Lauraceae        | 37.9       | 3.3  | 2.2     | Anacardiaceae    | 6,465        | 3.1     | Guttiferae       | 10             |
| 8    | Myristicaceae    | 37.0       | 3.2  | 1.3     | Bombacaceae      | 6,157        | 3.0     | Sapotaceae       | 9              |
| 9    | Myrtaceae        | 30.4       | 2.7  | 2.3     | Myrtaceae        | 4,744        | 2.3     | Anacardiaceae    | 8              |
| 10   | Meliaceae        | 22.7       | 2.0  | 0.6     | Lauraceae        | 4,606        | 2.2     | Ebenaceae        | 8              |

Notes: The top 10 families for trees  $\geq 1$  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.

decreases from 25.38 to 23.30, and the dominant canopy species change from *Shorea megistophylla* (Dipterocarpaceae), *Mesua ferrea* (Guttiferae), and *Shorea trapezifolia* (Dipterocarpaceae) to *Mesua nagassarium* (Guttiferae) and *Shorea disticha* (Dipterocarpaceae). See chapter 10 and tables 37.2–37.6.

Table 37.5. Sinharaja Rankings by Genus

| Rank | Genus                                  | Basal                     |         |            | Genus                                    | No. of<br>Trees | %                                | Genus                                 | No. of<br>Species |
|------|--|---------------------------|---------|------------|--|-----------------|----------------------------------|---------------------------------------|-------------------|
|      |  | Area<br>(m <sup>2</sup> ) | %<br>BA | %<br>Trees |  |                 |                                  |                                       |                   |
| 1    | <i>Mesua</i><br>(Guttiferae)           | 245.5                     | 21.9    | 10.6       | <i>Shorea</i><br>(Dipterocarpaceae)      | 27,824          | 14.2                             | <i>Memecylon</i><br>(Melastomataceae) | 13                |
| 2    | <i>Shorea</i><br>(Dipterocarpaceae)    | 233.0                     | 20.8    | 14.2       | <i>Agrostistachys</i><br>(Euphorbiaceae) | 25,343          | 12.9                             | <i>Syzygium</i><br>(Myrtaceae)        | 12                |
| 3    | <i>Cullenia*</i><br>(Bombacaceae)      | 99.8                      | 8.9     | 3.1        | <i>Humboldtia</i><br>(Leguminosae)       | 22,459          | 11.4                             | <i>Diospyros</i><br>(Ebenaceae)       | 8                 |
| 4    | <i>Garcinia</i><br>(Guttiferae)        | 51.8                      | 4.6     | 4.6        | <i>Mesua</i><br>(Guttiferae)             | 20,863          | 10.6                             | <i>Shorea</i><br>(Dipterocarpaceae)   | 8                 |
| 5    | <i>Palaquium</i><br>(Sapotaceae)       | 42.3                      | 3.8     | 4.1        | <i>Garcinia</i><br>(Guttiferae)          | 9,014           | 4.6                              | <i>Palaquium</i><br>(Sapotaceae)      | 6                 |
| 6    | <i>Myristica</i><br>(Myristicaceae)    | 35.6                      | 3.2     | 1.4        | <i>Psychotria</i><br>(Rubiaceae)         | 8,690           | 4.4                              | <i>Garcinia</i><br>(Guttiferae)       | 5                 |
| 7    | <i>Chaetocarpus</i><br>(Euphorbiaceae) | 31.0                      | 2.8     | 0.8        | <i>Palaquium</i><br>(Sapotaceae)         | 8,069           | 4.1                              | <i>Glochidion</i><br>(Euphorbiaceae)  | 5                 |
| 8    | <i>Syzygium</i><br>(Myrtaceae)         | 30.2                      | 2.7     | 2.3        | <i>Cullenia*</i><br>(Bombacaceae)        | 6,154           | 3.1                              | <i>Semecarpus</i><br>(Anacardiaceae)  | 5                 |
| 9    | <i>Litsea</i><br>(Lauraceae)           | 29.0                      | 2.6     | 0.9        | <i>Syzygium</i><br>(Myrtaceae)           | 4,593           | 2.3                              | <i>Symplocos</i><br>(Symplocaceae)    | 5                 |
| 10   | <i>Semecarpus</i><br>(Anacardiaceae)   | 22.8                      | 2.0     | 2.3        | <i>Semecarpus</i><br>(Anacardiaceae)     | 4,530           | 2.3                              | <i>Cinnamomum</i><br>(Lauraceae)      | 4                 |
| 11   |  |                           |         |            |  |                 | <i>Psychotria</i><br>(Rubiaceae) | 4                                     |                   |

\*Genus *Cullenia* has been changed to *Durio* according to Mabberley (1997), though *Durio* is not known to occur in Sri Lanka.

Notes: The top 10 tree genera for trees  $\geq 1$  cm dbh are ranked by basal area, number of individual trees, and number of species with the percentage of trees in the plot. Data are from the first census.

Each vertical stratum of the forest is dominated by one or two genera or species. In the canopy, 85% of the individuals are in the genera *Mesua* or *Shorea*, 49% of the understory trees are *Humboldtia laurifolia* (Leguminosae), and 41% of the treelets and shrubs are *Agrostistachys intramarginalis* (Euphorbiaceae) or *A. hookeri*.

Phenological studies on the *Shorea* species (Dipterocarpaceae) of section Doona present in Sinharaja have been monitored since 1984, in the selectively logged roadside areas of the forest where the tree crowns are easily visible. These *Shorea* spp. fall into two groups: the Thiniya-Dun and Beraliya. Members of the Thiniya-Dun group such as *Shorea trapezifolia*, *S. affinis*, and *S. congestiflora* have soft wood and very resinous small nonedible fruits. Species in this group bloom annually, and they flush almost all year long. In the Beraliya group, represented by *S. megistophylla*, *S. distica*, *S. worthingtonii* and *S. cordifolia*, trees possess medium hard wood and relatively less resinous, large edible fruits. They show sequential flowering with little overlap and synchronized fruiting. They flower supra-annually and flush during limited periods. All these *Shorea* species bloom at dawn, have fragrant flowers, and are pollinated by bees (Dayanandan

Table 37.6. Sinharaja Ranking by Species

| Rank | Species  | Number of Trees | % Trees | Species   | Basal Area (m <sup>2</sup> ) | % BA  | % Trees |
|------|--|-----------------|---------|---|------------------------------|-------|---------|
| 1    | <i>Humboldtia laurifolia</i><br>(Leguminosae)            | 22,459          | 10.9    | <i>Mesua nagassarium</i><br>(Guttiferae)          | 230.9                        | 20.24 | 7.3     |
| 2    | <i>Agrostistachys intramarginalis</i><br>(Euphorbiaceae) | 18,022          | 8.8     | <i>Cullenia ceylanica</i> *<br>(Bombacaceae)      | 86.6                         | 7.59  | 1.9     |
| 3    | <i>Mesua nagassarium</i><br>(Guttiferae)                 | 14,881          | 7.2     | <i>Shorea trapezifolia</i><br>(Dipterocarpaceae)  | 68.2                         | 5.98  | 1.3     |
| 4    | <i>Garcinia hermonii</i><br>(Guttiferae)                 | 8,133           | 4.0     | <i>Garcinia hermonii</i> *<br>(Guttiferae)        | 49.6                         | 4.34  | 4.0     |
| 5    | <i>Shorea disticha</i><br>(Dipterocarpaceae)             | 7,397           | 3.6     | <i>Shorea disticha</i><br>(Dipterocarpaceae)      | 42.8                         | 3.75  | 3.6     |
| 6    | <i>Agrostistachys hookeri</i><br>(Euphorbiaceae)         | 7,321           | 3.6     | <i>Myristica dactyloides</i><br>(Myristicaceae)   | 35.6                         | 3.12  | 1.3     |
| 7    | <i>Psychotria nigra</i><br>(Rubiaceae)                   | 6,087           | 3.0     | <i>Shorea stipularis</i><br>(Dipterocarpaceae)    | 30.8                         | 2.70  | 0.5     |
| 8    | <i>Mesua ferrea</i><br>(Guttiferae)                      | 5,982           | 2.9     | <i>Litsea gardneri</i><br>(Lauraceae)             | 27.9                         | 2.45  | 0.1     |
| 9    | <i>Shorea worthingtonii</i><br>(Dipterocarpaceae)        | 4,628           | 2.3     | <i>Shorea affinis</i><br>(Dipterocarpaceae)       | 22.3                         | 1.96  | 2.0     |
| 10   | <i>Shorea affinis</i><br>(Dipterocarpaceae)              | 4,193           | 2.0     | <i>Shorea megistophylla</i><br>(Dipterocarpaceae) | 21.5                         | 1.88  | 1.6     |

\*Genus *Cullenia* has been changed to *Durio* according to Mabberley (1997), though *Durio* is not known to occur in Sri Lanka.

Notes: The top 10 tree species for trees  $\geq 1$  cm dbh are ranked by number of trees and basal area. The percentage of the total population is also shown. Data are from the first census.

et al. 1990). Short-term studies on the phenology and reproductive biology have also been carried out on the palm *Caryota urens* (Palmae) (Ratnayake et al. 1991), the medicinal liana *Coscinium fenestratum* (Menispermaceae) (Senerath 1990), and the medicinal and spice herb *Elettaria cardamomum* (Zingiberaceae).

Sinharaja was included as one of 10 international sites for the Tropical Soil Biology and Fertility Programme (TSBF) of the International Union of Biological Sciences (IUBS) and UNESCO's Programme on Man and the Biosphere (MAB) under which comparative studies were carried out on the structure and functioning of natural and managed ecosystems (primary forest versus *Pinus* and *Hevea* plantations). A comprehensive site characterization study using standardized and calibrated methods selected and/or developed by TSBF was also carried out (Woomer and Swift 1994). During this study litter fall in the natural forest was found to be 832 g/m<sup>2</sup>/year. Leaf litter in some species, such as *Palaquium petiolare* (Sapotaceae), *Shorea affinis*, and *Shorea disticha* (Dipterocarpaceae), showed a single distinct peak during the relatively dry period of March to May. Multiple peaks in litter fall were observed in *Mesua nagassarium* (Guttiferae), *Palaquium thwaitesii* (Sapotaceae), and *Strombosia nana* (Olacaceae) (Myers et al. 1994).

## Fauna

Sinharaja has a rich faunal diversity. Of the island's vertebrate species, 36% (262 species, including 112 endemics) have been recorded at Sinharaja. Among the mammals at Sinharaja are the leopard (*Panthera pardus*), the endemic purple-faced leaf monkey (*Trachypithecus vetulus*), loris (*Loris tardigradus*), several species of shrews—many endemic—and squirrels such as the giant squirrel (*Ratufa macroura*), small flying squirrel (*Petinomys fuscocapillus*), and flame-striped jungle squirrel (*Funambulus layardi*). Sinharaja is home to 147 bird species, 18 of which are endemic. Among these endemics are the rare green-billed coucal (*Centropus chlororynchus*), colorful Sri Lanka blue magpie (*Urocissa ornata*), Sri Lanka grey hornbill (*Tockus gingalensis*), and the yellow-fronted barbet (*Megalaima flavifrons*). Twenty amphibian species, half of them endemic, and 65 species of butterflies, including the rare endemic Ceylon rose (*Atrophaneura japhon*), have also been recorded (de Zoysa and Raheem 1990; Ministry of Forestry and Environment 1999).

## Natural Disturbances

Some evidence exists that much of the forest may indeed be successional, implying occasional catastrophic disturbance presumably by wind (Ashton and Gunatilleke 1987). The mixed dipterocarp forests of southwestern Sri Lanka characteristically support a number of genera associated with forest succession elsewhere, notably *Dillenia* (Dilleniaceae) and *Vitex* (Labiatae), as well as the endemic *Schumacheria* (Dilleniaceae).

## Human Disturbance

Although all of the forest in the Sinharaja 25-ha plot is primary, 2000 ha of the Sinharaja reserve were selectively logged in 1972–77. Today, there is no selective timber harvesting within the reserve. In the past, local small-scale shifting agriculture was carried out, mostly near the perimeter of the current reserve. Extraction of nontimber forest products does not occur in the plot, but illicit extraction of nontimber forest products takes place near the reserve boundaries, which has led to the depletion of fruit and seed resources for germination, especially in species where the whole plant has been extracted from the wild, as in the rattans and the medicinal vine *Coscinium fenestratum* (Menispermaceae). In the case of the fish-tail palm *Caryota urens* (Palmae), the distal part of the immature inflorescence, long before the flowers even open, is cut and discarded, and the exudate emanating from the inflorescence stump is tapped and used for the production of sugar candy (jaggary), treacle, and an alcoholic beverage called toddy. Thus, as most of

the fruit is prevented from ripening in this species, the terminal inflorescence is never tapped, leaving enough fruit to maintain the population (Gunatilleke and Gunatilleke 1993; Ratnayake et al. 1991). Due to human disturbance, only about 75% of the Sinharaja reserve consists of mature forest, 4% is secondary forest, and 21% is nonforested and covered by fern lands and grasslands (Banyard and Fernando 1988).

### Plot Size and Location

Sinharaja is a 25-ha, 500 × 500 m plot. The plot is approximately located at 06°24'N and 80°24'E.

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### References

- Ashton, P. S., and C. V. S. Gunatilleke. 1987. New light on the plant geography of Ceylon I. Historical plant geography. *Journal of Biogeography* 14:249–85.
- Banyard, S. G., and D. Fernando. 1988. Sinharaja forest: Monitoring changes by using aerial photographs of two different dates. *Sri Lanka Forester* 18:101–08.
- Cooray, P. G. 1967. An introduction to the geology of Ceylon. *Spolia Zeylanica* 31:314.
- Dayanandan, S., D. N. C. Attygala, A. W. W. L. Abeygunasekara, I. A. U. N. Gunatilleke, and C. V. S. Gunatilleke. 1990. Phenology and floral morphology in relation to pollination of some Sri Lankan Dipterocarps. Pages 103–133 in K. S. Bawa and M. Hadley, editors. *Reproductive Ecology of Tropical Forest Plants*. Man and the Biosphere Series, Vol. 20. Parthenon Publishing Group, Pearl River, NY.
- de Zoysa, N., and R. Raheem. 1990. *Sinharaja: A Rain Forest in Sri Lanka*. Aitkin Spence & Co., Ltd., Colombo, Sri Lanka.
- Gunatilleke, C. V. S., and P. S. Ashton. 1987. New light on the plant geography of Ceylon II. The ecological biogeography of the lowland endemic tree flora. *Journal of Biogeography* 14:295–327.
- Gunatilleke, C. V. S., I. A. U. N. Gunatilleke, and P. M. S. Ashton. 1995. Rainforest research and conservation: The Sinharaja experience in Sri Lanka. *Sri Lanka Forester* 22:49–60.
- Gunatilleke, C. V. S., G. A. D. Perera, P. M. S. Ashton, P. S. Ashton, and I. A. U. N. Gunatilleke. 1996. Seedling growth of *Shorea* section *Doona* (Dipterocarpaceae) in soils from topographically different sites of Sinharaja rain forest, Sri Lanka. Pages 245–65 in M. D. Swaine, editor. *The Ecology of Tropical Forest Tree Seedlings*. Man and the Biosphere Series, Vol. 16. Parthenon Publishing Group, Carnforth, U.K.

- Gunatilleke, I. A. U. N., and C. V. S. Gunatilleke. 1993. Underutilized food plant resources of Sinharaja rain forest in Sri Lanka. Pages 183–98 in C. M. Hladik, A. Hladik, H. Pagzy, O. F. Linares, and M. Hadley, editors. *Food and Nutrition in the Tropical Rain Forest: Bicultural Interactions*. Man and the Biosphere Series, Vol. 15, UNESCO, Paris, and Parthenon Publishing, Carnforth, U.K.
- Gunatilleke, I. A. U. N., and J. Maheswaran. 1988. Nutrient change during litter decomposition in a lowland rain forest and a deforested area in Sri Lanka. Pages 291–305 in F. S. P. Ng, editor. *Trees and Mycorrhiza: Proceedings of the Asian Seminar, 13–17 April 1987*. Forest Research Institute Malaysia, Kepong, Malaysia.
- Hadley, M., and N. Ishwaran. 1997. Conservation, research and capacity building in the forest of the Lion King, Sri Lanka. Pages 89–102 in P. Gobel, editor. *Science and Technology in Asia and the Pacific. Co-operation for Development*. UNESCO, Paris.
- Hafeel, K. M. 1991. *Soil Physico-Chemical and Endomycorrhizal Studies in Natural and Modified Sites of Sinharaja Rain Forest, Sri Lanka*. Masters thesis, University of Peradeniya, Peradeniya, Sri Lanka.
- Mabberley, D. J. 1997. *The Plant-Book: A Portable Dictionary of the Vascular Plants*. Cambridge University Press, Cambridge, U.K.
- Ministry of Forestry and Environment. 1999. *Biodiversity Conservation in Sri Lanka: A Framework for Action*. Ministry of Forestry and Environment, Sri Lanka.
- Munidasa, B. K. H. C., C. V. S. Gunatilleke, and I. A. U. N. Gunatilleke. 2002. Climate of Sinharaja rain forest, Sri Lanka: An attempt to understand the El Niño and La Niña events. *Ceylon Journal of Science (Biological Sciences)* 30: 37–54.
- Myers, R. J. K., C. A. Palm, E. Cuevas, I. U. N. Gunatilleke, and M. Brossard. 1994. The synchronisation of nutrient mineralization and plant nutrient demand. Pages 81–116 in P. L. Woomer and M. J. Swift, editors. *The Biological Management of Tropical Soil Fertility*. Wiley, New York.
- Panabokke, C. R. 1996. *Soils and Agro-Ecological Environments of Sri Lanka*. Natural Resources, Energy and Science Authority, Sri Lanka.
- Ratnayake, P. D. K. C., C. V. S. Gunatilleke, and I. A. U. N. Gunatilleke. 1991. *Caryota urens* L. (Palmae): An indigenous multipurpose tree species in the wet lowlands of Sri Lanka. Pages 77–88 in D. A. Taylor and K. Macdicken, editors. *Research on Multipurpose Tree Species in Asia*. Winrock International F/FRED, Bangkok.
- Senerath, M. A. B. D. 1990. *Biological studies on Coscinium fenestratum Clobber (Menispermaceae)*. Masters thesis, University of Peradeniya, Peradeniya, Sri Lanka.
- Woomer, P. J., and M. J. Swift. 1994. *The Biological Management of Tropical Soil Fertility*. Wiley, New York.