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ECOLOGICAL ASSESSMENT OF THE KANNELIYA DEDIYAGALA-NAKIYADENIYA (KDN) FOREST COMPLEX

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Abstract

A plant-ecological survey of the complex was carried out in November 1993 to January 1994. It is concluded that the Kanneliya reserve should be made a totally protected area, with buffer zones included within the present boundaries, and the other two reserves put under sustained management for multiple uses. In terms of endemism, number of species, hydrological importance, etc, Kanneliya is found to be second on Sri Lanka only to Sinharaja in its conservation interest.

Introduction

The Kanneliya Forest Reserve (6024.5 ha) and the Nakiyadeniya Proposed Reserve (2235.5 ha) in Galle District, and the Dediyagala Forest Reserve (3790 ha) in Matara District form a continuous block of 12,050 ha of natural forest in the southwest lowland hills, commonly referred to as the KDN forest complex.

The complex was logged by the Ceylon Plywood Corporation from 1968 until logging was suspended in 1988. The present survey showed that logging had extended throughout the whole area, including ridge tops and slopes of more than 30°. Different phases of the forest growth cycle – gaps, building, and mature forest – can be observed in various parts of the reserves. A characteristic tree colonizing heavily exploited and degraded areas is the naturalized exotic *Alstonia macrophylla* (hawari nuga). It is one of the pioneers (light demanders) which establishes itself in the large gaps in the wet-zone forests that are created by heavy logging. Advance growth of the canopy species is also found in most of the moderately-logged areas of the forest reserve.

The forest inventory that was carried out between 1982 and 1985, with the assistance of FAO, for the preparation of the Forestry Master Plan, identified 119,000 ha of closed tropical forest in the lowland wet zone as being suitable for sustainable management for timber production. These forests have high genetic, species, and habitat or ecosystem diversity and contain most of the endemic flora and fauna of the island. The proposal to exploit timber from these reserves was criticized by scientists and conservationists. As a result, the Sri Lanka government requested the International Union for Conservation of Nature (IUCN) to assess the impact of the proposed forestry operations and to develop a

conservation strategy for the forest reserves, as well as a monitoring system for assessing changes in biodiversity (Gunatilleke & Gunatilleke, 1990).

Under the Accelerated Conservation Review conducted in 1991, the biological and hydrological value of 31 forest reserves in Kalutara, Ratnapura, Galle and Matara Districts was evaluated, and 13 of them were identified as conservation forests. The National Conservation Review, which started in 1992, will evaluate all forest reserves in the island.

The main objective of the ecological assessment of the KDN forests reported here was to identify for conservation the ecologically critical areas, and core areas within these critical areas, taking note of biodiversity, endemism, and hydrological importance. A conservation management plan will be prepared for the parts of the complex that are designated as totally protected areas (TPAs).

Site and methodology

Site

The KDN complex forms a compact unit in the south-western corner of the wet zone between 60°09' and 60°18' N, and 80°19' and 80°27' E. The mean elevation is about 185 m, varying from 60 to 425 m. The Kanneliya Forest Reserve consists of several parallel ridges and valleys aligned northwest- southeast. The ridges in Nakiyadeniya and Dediyagala are lower and often broken into isolated rounded hills, all rising to about 230 m (Nisbet, 1961).

The Kanneliya Forest Reserve receives more rainfall (about 4445 mm annually) than Dediyagala or Nakiyadeniya (3750 mm). This difference is mainly due to aspect and relief. The south-west corner of Dediyagala forest receives only about 3125 mm (Nisbet 1961).

De Rosayro (1942) showed that there are four plant communities in the KDN forests. The complex was exploited, although not very intensively, at the beginning of this century. In the 1920s it was enumerated with a view to the proper management of the forest reserves. From 1950, there was controlled exploitation, by coupes managed under the selection system. However, administrative and other difficulties led to "high grading" and illegal felling (Nisbet, 1961). Even before 1961, therefore, there were large areas of advanced secondary forests in the complex.

Methodology

A review was made of the floristic and faunal (biodiversity), soil-conservation and hydrology assessment of the KDN forests by the NCR (NCR, 1992). According to the NCR data, the whole of the complex can be considered as a biologically and hydrologically critical area.

A new hydrological assessment was made by the present survey, according to the method developed by the NCR (NCR Report 1992, Part B).

The assessment of biological diversity (in this case species diversity) of KDN forests by the NCR was made by the enumeration of only four transects. The data were collected by the Environmental Management Division of the Forest Department. A more detailed enumeration was carried out for the present study, to find core areas with high endemism and species richness in the complex. The sampling of vegetation aimed at being representative of forest stands in the valleys, on mid-slopes, on ridge-tops, and on other sites. The base map used was the 1:25,000 map prepared by the Forest Department from aerial photographs taken in 1983, which demarcated various stand types. The cover types within a stand were identified by a visual reconnaissance survey and sample plots were laid out in each type.

The fixed-area method was used for sampling because it yields data such as a species list, and estimates of stem density, frequency, diameter-class distribution, basal area, and abundance (Wenger, 1984). Several sizes of plots were laid out at each sampling location:

For trees: 500 m^2 (0.05 ha, horizontal radius 12.6 m)
For saplings: 25 m^2 (0.0025 ha, horizontal radius 2.82 m)
For seedlings: 1 m^2 (0.0001 ha, horizontal radius 56.4 cm)

The following definitions of different habits were used:

Tree: A woody plant with a dbh greater than 10 cm.
Sapling: A woody plant of either a shrub or tree species with a dbh less than 10 cm, more than 1 m tall.
Seedling: A woody plant of either a shrub or tree species, less than 1 m tall.

The following parameters were recorded:

For trees: species and dbh
For saplings: species and number of stems
For seedlings: species and number of individuals

Herbarium specimens were prepared from each tree newly encountered in the samples and also along the way to the plots. General collections were also made in the surrounding area of the plots and on some transects through the reserves. In addition to the terrestrial flowering plants, epiphytes, parasites, lianes, ferns, bryophytes and lichens were collected. Most of the plants were identified by comparing them with the specimens at the National Herbarium, Royal Botanic Gardens, Peradeniya and by using the keys and information given in Dassanayake & Fosberg (1980-1991), Mabberley (1989), Jaye-weera (1981-1982); Abeyawickrama (1978); Sri Lanka Forester (1874), Fonseka & Vinasithamby (1971), Abeyawickrama (1959), Worthington (1959), and Senaratne (1956).

The data on species, family, local name, dbh, height, serial numers of herbarium specimens, endemicity, ecological status, economic importance, altitude, etc. were recorded in a dBase program. Programs were written for the calculation of stand variables, diversity indices, and IVI values, for species, genera, and families. An annotated checklist has also been prepared.

Maps were prepared to show the catchment boundaries within the KDN forests, stand or cover types, plant communities, topography, infrastructure, and designated conservation zones.

Stand tables were prepared showing the distribution of diameter classes for stems greater than 10 cm dbh. These reveal the extent of past logging.

The reserves have been assessed for soil conservation and hydrology by the methods developed by the NCR (IUCN/EMI Report No. 14).

Ecological indices were calculated for each plot by the following formulae:

Diversity: $H' = -Sp_i \times \log(p_i)$, where p_i is the proportional abundance

Evenness: $J' = H'/H'max$, where $H'max = \log s$, s being the number of species present

Dominance: $1 - J'$

The importance value index (IVI) is an expression of the dominance of particular species (Curtis & McIntosh, 1950) in different habitats. In incorporates three measures: the relative density (RD), relative frequency (RF), and relative basal area (RBA) – or relative dominance – into one index. This index attaches more importance to those species that tend toward large size and ubiquitous distribution than to those that do not. It is therefore a more accurate measure of the degree of influence that a species has on the community than any one of the measures it incorporates.

Relative density = species density/stand density

(where species density is the number of individuals of a species per unit area; i.e. the total number of individuals of a species divided by the area of the stand, and stand density is the number of individuals per unit area, i.e. the total number of individuals divided by the area of the stand; relative density is therefore also given by the number of individuals of a species divided by the total number of individuals of all species; it is also the same as the proportional abundance of a species).

Basal area is the cross-sectional area of the trees at 1.3 m height above ground ("breast height"). The total basal area is an important parameter which indicates the amount of biomass in the stand.

Basal area: $g = \pi d^2/4$, where d is the dbh

Relative basal area: Total basal area of a species/total basal area of all species

Frequency: The number of plots in which a species is represented by at least one individual

Relative frequency: Frequency of one species/sum of frequencies of all species

Importance value index = relative density + relative basal area + relative frequency

Results

There were 89 plots: 47 (total area 2.35 ha) in Kanneliya, 29 (1.45 ha) in Dediyagala, and 13 (0.65 ha) in Nakiyadeniya. Altogether, 3303 trees of more than 10 cm dbh were enumerated. More than 600 specimens were collected. The plants of all kinds belonged to 426 species, of which 319 have been identified, and 107 have not. The 319 identified belong to 194 genera and 75 families; 301 were found in Kanneliya, 280 in Dediyagala, and 295 in Nakiyadeniya. Of the 107 unidentified, 35 were identified only to family level, and 13 more to genus level, leaving 59 completely unknown. There were 159 identified endemics (i.e. out of 319 species). Of the 18 endemic genera in Sri Lanka (Bandaranaike & Sultanbawa, 1991; Mabberley, 1989), 9 were found, and one, *Stemonoporus*, was represented by two species (Table 1). Several species were unique to Kanneliya or Nakiyadeniya (Tables 2 and 3).

Table 1: Endemic genera

Genus	Number of species in Sri Lanka	Number of species found in KDN complex
Hortonia	2	1
Leucocodon	1	1
Loxococcus	1	1
Nargedia	1	1
Phoenicanthus	2	1
Schumacheria	3	1
Scyphostachys	2	1
Stenoporus	15(26)	2
Schizostigma	1	1

Table 2 : Species unique to Kanneliya forest reserve (not recorded from the other two reserves in the course of present survey)

Species	Family	END	THR	RDB
Agrostistachys hookeri	Euphorbiaceae	✓		V
Burmannia pusilla	Burmanniaceae			
Cotylelobium scabriusculum	Dipterocarpaceae	✓	✓	E
Elastoma linoleatum	Urticaceae			
Eugenia insignis	Myrtaceae	✓		
Hopea jucunda ssp. *jucunda*	Dipterocarpaceae	✓		R
Microtropis wallichiana	Celastraceae			
Sonerila zeylanica	Melastomataceae	✓		
Stemonoporus kanneliyansis	Dipterocarpaceae	✓		
Vatica affinis	Dipterocarpaceae	✓		E

END – endemic; THR – threatened; RDB: Red Data Book category

Table 3 : Species unique to Nakiyadeniya forest reserve (not recorded from the other two reserves in the course of present survey)

Species	Family	END	THR	RDB
Ficus exasperata	Moraceae			
Pterospermum canescens	Sterculiaceae			
Symplocos coronata	Symplocaceae			
Vanilla moonii	Orchidaceae	✓		

END – endemic; THR – threatened; RDB: Red Data Book category

Table 4 gives the number of endemic species, number of endemic individuals and their basal area. Table 5 summarizes these data, and ranks the three reserves according to the importance of the contribution of their endemic species, taking into account the number of species, number of individuals, and basal area.

Table 4: Sampling data (trees of more than 10 cm dbh)

	Kanneliya	Dediyagala	Nakiyadeniya
Plots	47	29	13
Species identified	144	107	98
Endemic species	75	59	50
Endemic species as % of identified species	52	55	51
Total individuals	1773	1067	463
Endemic individuals	1126	370	278
Endemic individuals as % of total enumerated	63.5	34.7	60.0
Total basal area (m^2)	77.0	49.1	26.8
Basal area of endemics (m^2)	50.1	33.6	17.0
Basal area of endemics as % of total	65.0	68.3	63.5

Table 5: Ranking of reserves according to the contribution made by endemic tree species of more than 10 cm dbh (see text)

	Species	Endemic species	Individuals	Endemic individuals	Basal area	Endemic basal area	Rank
Kanneliya	144	75	1173	1126	77.0	50.1	**1**
Dediyagala	107	59	1067	370	49.1	33.6	**2**
Nakiyadeniya	98	50	463	278	26.8	17.0	**3**

According to IUCN (1993) there are more than 30 species of threatened plants (24 of them endemic) among those enumerated in these reserves. This number is an underestimate because some species will not have been collected during the two months of field work, and also because some of the collected specimens have not been identified because of the absence of material for comparison in the National Herbarium.

Plant rarity

There were 144, 107, and 98 species of trees of more than 10 cm dbh identified in the Kanneliya, Dediyagala and Nakiyadeniya reserves, respectively. None of these species was represented in all of the sample. On the other hand, there were 49, 29 and 43 species that were recorded only once, taking each reserve separately. In Kanneliya, for example, nearly a third of the species were found only once. It can be considered that these species are rare.

Biological diversity

The diversity indices show that all three forest reserves have more or less similar high species diversity, except for a few plots with low diversity. The average diversity does not show any significant difference between the three reserves (Table 6).

Table 6 : Analysis of variance

Source	DF	SS	MS	F	P
Factor	2	0.0691	0.0345	2.09	0.130
Error	86	1.4211	0.0165		
Total	88	1.4902			

Level	N	Mean	STDEV
Kanneliya	47	1.1172	0.1235
Dediyagala	29	1.0597	0.1330
Nakiyadeniya	13	1.1249	0.1368

Evenness (or equitability) is also very high in the three forest reserves, because of the more or less equal distribution of different taxa. In diverse communities, most species are relatively rare. The lowland forest shows the least dominance, when compared with the other forest formations. Consoci-ations have therefore less chance of occurring in lowland forest formations.

Importance value indices (IVI)

Tables 7 shows the ranking by IVI indices of the 15 most dominant families in each of the three reserves. The Clusiaceae and Dipterocarpaceae are generally the first and second most dominant in undisturbed lowland forests, e.g. in the Sinharaja World Heritage site (Gunatilleke & Gunatilleke, 1985). Table 7 shows that in Kanneliya, these two families are the first and third most dominant.

Table 7 :Ranking of 15 families in each reserve by IVI

	Kanneliya	Dediyagala	Nakiyadeniya
Clusiaceae	1	8	6
Anacardiaceae	2	2	4
Dipterocarpaceae	3	7	3
Euphorbiaceae	3	3	1
Sapotaceae	5	5	9
Dilleniaceae	6	1	2
Anisophyllaceae	7	4	12
Bombacaceae	8	14	11
Annonaceae	9	6	5
Thymelaeaceae	10	9	-
Rubiaceae	11	10	8
Myrtaceae	12	12	-
Myristicaceae	13	11	14
Melastomataceae	14	-	15
Flacourtiaceae	15	13	7
Lauraceae	-	15	-
Ebenaceae	-	-	10
Moraceae	-	-	13

Table 8 compares the five most dominant families in each of the three reserves with those of Singharaja, and ranks the reserves by comparison with undisturbed forest (i.e. Singharaja).

Table 8 : Dominance of families: reserves ranked by comparison with Singharaja

Kanneliya	Clusiaceae	Anacardiaceae	Dipterocarpaceae	Euphorbiaceae	Sapotaceae	Rank 1
Dediyagala	Dilleniaceae	Anacardiaceae	Euphorbiaceae	Anisophylleaceae	Sapotaceae	Rank 3
Nakiyadeniya	Euphorbiaceae	Dilleniaceae	Dipterocarpaceae	Anacardiaceae	Annonaceae	Rank 2
Singharaja	Clusiaceae	Dipterocarpaceae	Sapotaceae	Bombacaceae	Myrtaceae	

Tables 9 shows the ranking by IVI indices of the 15 most dominant genera in each of the three reserves.

Table 9 : Ranking of 15 genera in each reserve by IVI

	Kanneliya	Dediyagala	Nakiyadeniya
Shorea	1	5	3
Semecarpus	2	3	2
Palaquium	3	6	9
Dillenia	4	1	1
Anisophyllea	5	2	13
Cullenia	6		7
Gyrinops	7b	8	
Garcinia	8		12
Chaetocarpus	9	4	10
Syzygium	10	14	
Calophyllum	11		14
Xylopia	12	7	4
Diospyros	13		6
Myristica	14	13	15
Mesua	15		
Campnosperma		9	
Mangifera		11	11
Gaertnera		12	
Hydnocarpus			5
Mallotus			8

Tables 10 shows the ranking by IVI indices of the 15 most dominant species in each of the three reserves.

Table 10 – Ranking of 15 species in each reserve by IVI

	Kanneliya	Dediyagala	Nakiyadeniya
Anisophyllea cinnamomoides	1	1	11
Cullenia rosayroana	2		5
Gyrinops walla	3	5	
Dillenia retusa	4	2	1
Xylopia champonii	5	4	2
Semecarpus walkeri	6	6	12
Palaquium canaliculatum	7	12	
Semecarpus parvifolia	8		8
Chaetocarpus castanocarpus	9	3	10
Myristica dactyloides	10	11	13
Garcinia echinocarpa	11		
Dillenia triquetra	12	9	
Campnosperma zeylanica	13	7	
Shorea congestiflora	14	14	
Shorea megistophylla	15		
Mangifera zeylanica		8	6
Gaertnera vaginance		10	

Aporusa cardiosperma	13	
Hydnocarpus octandra	15	3
Diospyros sp.		4
Mallotus sp.		9
Cyathocalyx		15
Palaquium petiolare		7
Shorea worthingtonii		14

Diameter distribution

Table 11 shows the number of stems enumerated in the plots by three diameter classes (10-30, 30-60, and >60 cm) in each reserve. These data are also converted to stems per hectare. Note in particular that the numer of stems/ha of more than 60 cm at Kanneliya, Dediyagala and Nakiyadeniya was only 8, 10, and 15. This gives an indication of the severity of logging. In the areas set apart for sustainable timber management there must first be a long resting period.

Table 11 : Diameter-class distribution

	Plots	Total stems			Stems/ha		
		10-30 cm	30-60 cm	> 60 cm	10-30 cm	30-60 cm	> 60 cm
Kanneliya	17	1499	255	19	637	108	8
Dediyagala	29	871	181	18	600	125	10
Nakiyadeniya	13	392	61	10	603	94	15

Plant communities

The IVI index was calculated for the 10 most dominant species in each plot. Note that the relative frequency, as defined above, is the same for all species, as it depends only on occurrence in the plot. It will be recalled also that "dominant" here does not refer to status in the canopy. The following is a list of the species that occur as the most dominant species in particular plots, as determined by their IVI value:

Dipterocarpaceae
- *Shorea pallescens*
- *S. worthingtonii*
- *S. megistophylla*
- *S. congestiflora*
- *S. disticha*
- *Vateria copallifera*
- *Vatica affinis*

Clusiaceae
- *Mesua nagassarium*
- *M. ferrea*
- *Garcinia echinocarpa*

Sapotaceae
- *Palaquium canaliculatum*
- *Madhuca fulva*

Bombacaceae
- *Cullenia rosayroana*

Myrtaceae
Syzygium makul
S. firmum
Anisophylleaceae
Anisophyllea cinnamomoides
Anacardiaceae
Campnosperma zeylanica
Semecarpus walkeri
Euphorbiaceae
Chaetocarpus castanocarpus
Agrostistachys hookeri
Aporusa cardiosperma
Apocynaceae
Alstonia macrophylla
Melastomataceae
Axinandra zeylanica
Dilleniaceae
Dillenia retusa
Cornaceae
Mastixia tetrandra
Celastraceae
Bhesa zeylanica
Annonaceae
Cythocalyx zeylanica
Verbenaceae
Vitex altissitna
Moraceae
Ficus spp.

Several plant communities can be distinguished. De Rosayro's first two communities *(Dipterocarpus* and *Mesua-Shorea)* are present in some parts of the reserves, mixed with some secondary species. Ashton & Gunatilicke (1987) correctly identified these as successional composite communities. The *Dipterocarpus* community is found close to the Dediyagala Arnaya. It is not recorded from Kanneliya or Nakiyadeniya. The *Mesua-Shorea* community is recorded from different parts of Kanneliya – mainly ridge tops. Most of the *Shorea* species are dominant in the valleys and on the mid-slopes in Kanneliyaa, but *Mesua* is not well represented. This community is more dominant in successional areas in the Kanneliya forest than it is in the other two reserves.

Alstonia macrophylla is dominant in heavily logged areas in all the reserves as a secondary (pioneer) tree species. A *Dillenia-Anisophyllea-Axinandra-Chaetocarpus-Aporusa-Campnosperma* community is found in parts of Dediyagala (plots 61-72) and Nakiyadeniya (plots 73-79) as a successional community. It is possible to identify the seedlings, saplings, and pole-size trees of primary (climax) species in the successional communities. It is concluded that the species composition of the community described by de Rosayro has been disturbed.

Forest structure

Emergent trees are not found in any of the reserves. The main canopy contains species such as *Shorea pallescens, S. worthingtonii, S. megistophylla, S. congestiflora, S. disticha, Vateria copallifera, Vatica affinis, Hopea* spp., *Calophyllum* spp., *Mesua* spp., *Myristica dactyloides, Hydnocarpus octandra, Cullenia rosayroana, Palaquium canaliculatum, Bhesa* spp., *Syzygium* spp., and *Dipterocarpus* spp.

The sub-canopy consists of *Calophyllum* spp., *Garcinia echinocarpa, G. hermonii, Xylopia championii, Axinandra zeylanica, Semecarpus* spp. *Dillenia retusa, D. triquetra, Aporusa* spp., *Chaetocarpus* spp., *Cyathocalyx* spp., and *Enicosanthum* spp.

The understorey contains *Cryptocarya wightiana, Memecylon* spp., *Mallotus* spp., *Hedyotis* spp., *Gyrinops walla, Timonius jambosella, Diospyros* spp., *Stemonoporus kanneliyensis,* and *S. bullatus,* along with seedlings and saplings of canopy and sub-canopy species.

Discussion

Present status of the KDN forest complex

The investigations described above have shown that most areas of the reserves have been degraded by various degrees of disturbance, i.e. by authorized logging or illicit felling. The enumerations found an average of only ten trees per ha of more than 60 cm dbh, which means that there must have been heavy logging in most of the accessible parts of the complex. The Plywood Corporation was unable to supply data on removals.

However, the forest contains more than 20,000 saplings (dbh >10 cm, height >1 m) and more than 600 trees of 10-30 cm dbh per hectare. The disturbed forest is regenerating fast. Most of the heavily logged and degraded areas are being colonized by *Alstonia macrophylla*, which is an exotic pioneer (light demander or secondary species) now naturalized in the wet zone of Sri Lanka. There are more or less pure stands of this species in some parts of the reserves. Seedlings, saplings and pole-size trees of climax species (shade bearers or primary species) are also established under the *Alstonia macrophylla*. Most pioneer tree species have a relatively short life span compared to that of climax species. All pioneer trees need full sunlight for seed germination and therefore it can be assumed that once the existing *Alstonia macrophylla* die off the growing space will be occupied by saplings and pole-size trees of primary species. In time these species will form a climax forest.

There are also moderately logged areas which are in difkrent phases of the forest growth cycle (gap, building, and mature phases). These areas show a mixture of the plant species that are found in both undisturbed and secondary forests. The species recorded in de Rosayro's *Dipterocarpus* and *Shorea-Mesua* communities are found, along with those found in the other two communities of lowland rain forest, which shows that these areas are in different stages of secondary succession.

The skidding trails and logging roads are partly covered with kekilla fern *(Dicranopteris linearis)* and grasses, or by shrub species such as *Schizostigma hirsuta*. This cover helps to reduce soil erosion. The developing crowns of adjacent trees are causing these species to die out, but regeneration of tree species is poor because of soil compaction and the absence of litter.

There are encroachments for tea growing and human settlement along the boundaries of all the reserves. Illicit felling continues unabated, especially in Dediyagala and Nakiyadeniya. More than twenty pit saws were seen in the detached part of the Nakiyadeniya reserve.

People from the surrounding villages collect various non-wood products (dummala, kokun bark, weniwel, wewel, etc.) Some kokun trees *(Kokoona zeylanica)* have been killed by excessive removal of bark. Dorana trees *(Dipterocarpus glandulosa)* have also been damaged or killed by people extracting dorana oil.

Plant diversity

The diversity indices showed no significant differences between the reserves. However, these indices only show that in numerical terms each reserve is equally diverse. They do not take account of habitat differences between the reserves. Also, they refer only to woody plants of more than 10 cm dbh. These limitations should be kept in mind when areas are selected for conservation. There may also be differences in hydrological importance.

The total numbers of species, endemic species, individuals, and basal areas were all greatest in Kanneliya, which contains 23 species of Dipterocarpaceae. The present survey found 10 species only in Kanneliya and 4 in Dediyagala, but most of them are recorded also in forests other than those in this survey.

The NCR covered a total of 52 forests, including the KDN complex, in and around the Southern Province. It used Gradset sampling, i.e. it took samples along the steepest environmental gradients. Table 12 sets out its results for the three KDN reserves:

Table 12 – Diversity of woody plants according to National Conservation Review

	Families	Genera	Species	Unique	Endemic	Threatened	
						Nationally	Globally
Kanneliyab	147	149	233	2	140	26	16
Dediyagala	126	126	189	1	112	18	10
Nakiyadeniy a	161	164	237	5	117	24	11

According to the NCR data, Nakiyadeniya and Kanneliya are the most diverse forests for woody plants after Sinharaja World Heritage Site (which has 277 woody species and 150 endemic woody species). The second highest number of endemic plants has been recorded from Kanneliya. The Kanneliya reserve is also notable for having the highest numbers of threatened woody plants nationally (26) and globally (16).

For both woody plants and animals the NCR data show that the larger the size of a forest, up to a certain limit, the greater the number of species it contains. The NCR also shows that many forests contain one or more rare species that are uniquely restricted to that particular site. There is no clear relationship between the number of species unique to a particular forest and its size in the case of either plants or animals. Seventy-five "unique woody plant species" were recorded from 39 forest reserves in the wet zone during the NCR survey in 1992. However, almost all of these species have been recorded from other wet zone forests since that date. Also, the finding of a species unique to a particular forest depends on the sampling intensity. More intensive sampling of the flora in one forest may reduce the numbers of "unique species" recorded for another reserve.

A ranking of forest complexes based on their contribution of unique species or unique endemic species to the network has been made by the NCR (1992). Ranking of forest reserves on the basis of species uniqueness is not a good method for selecting conservation areas in the wet zone, but in addition, the NCR does also take account of the forests' importance for soil conservation and hydrology.

Table 13 lists the species recorded by the NCR as unique to one forest of the KDN complex, and gives the other localities for which there are records.

Table 13 : NCR's "unique" species, and other recorded localities

KDN Forest	NCR (1992)	Other localities	Recorded in
Kanneliya	Gardenia latifolia	Colombo & Kalutara Districts	Revised Flora Vol. IV
	Hiptage benghalensis	7 Districts	Revised Flora Vol. VII
Dediyagala	Madhuca moonii	Kanneliya	Present survey
Nakiyadeniya	Ficus asperrima	Kandy District	Revised Flora Vol. III
	Ixora thwaitesii	Maliboda	Peak Wilderness Survey
	Rhynchotoechum permolle	3 Districts	Revised Flora Vol. III
	Sygygium turbinatum	Maskeliya	Peak Wilderness Survey
	Wrightia angustifolia	8 Districts	Revised Flora Vol. IV

Importance value indices

The IVI values for plant families in Kanneliya show that the families dominant in undisturbed forests found in the other two reserves are well represented. This finding indicates that the floristic compo-sition of Kanneliya is still that of an undisturbed forest of the low-country wet zone. It is important therefore to designate this reserve as a

Totally Protected Area (TPA). The natural recovery of the species composition after logging is greater in Kanneliya than in the other two reserves. It will be an area of high species diversity and endemism second only to Sinharaja.

Tropical forest ecologists believe that in Southeast Asia, those forests which have had a first cut of selective logging have not lost many plant species, so that species diversity may be the same before and after logging, while many species may be lost if a second cut takes place. However, this outcome will depend on when the second cut takes place and on what basis (Whitmore & Sayer, 1992).

Plant rarity

Of the total number of plant species recorded from plots in each reserve, 49 species in Kanneliya were recorded only once. The corresponding numbers in Dediyagala and Nakiyadeniya were 29 and 43. The plants represented by these numbers are obviously not distributed throughout the reserves, and for this reason it is necessary to designate large protected areas to conserve plant species which have low population densities. The animal species that pollinate and disperse the fruits and seeds of these plant species may also show a patchy distribution.

The present ecological assessment does not allow an assessment to be made of the size of the populations of particular plant species. The number of individuals of a plant species may have been reduced as a result of logging. The population sizes of most tropical plant species are unknown. Many exist as small populations of 500, 100, or even fewer individuals, either from natural causes or as a result of habitat loss and other threats. If these populations are below a minimum viable size, they may be subject to inbreeding, and the continued loss of genetic variation by random genetic drift, rather than natural selection. Inbred populations may lose vigour, in terms of reproductive fitness and resistance to disease. The genetic erosion of species is therefore likely to become an increasing problem (Whitmore & Sayer, 1992). Furthermore, demographic and ecological problems are particularly acute in very small populations.

Ecologically sensitive areas

The Kanneliya reserve contains areas of greater ecological sensitivity than Dediyagala and Nakiyadeniya, because of its topography (large number of valleys and ridges) and its high stream density. It is important to conserve the Kanneliya reserve in order to protect these ecologically sensitive areas.

Some sites are so sensitive to disturbance that careful consideration is needed as to whether timber should be removed from them. Where there are steep slopes, wet soils, shallow soils, stream banks, and other fragile features, conventional harvesting can cause severe damage. Sometimes the damage is virtually irreparable, and can degrade an ecosystem's productivity for decades or even centuries (Hunter, 1992).

It is especially sensible to ensure that any relatively undisturbed forests in the riparian zones are protected. Riparian forests are key components in maintaining the biological diversity of the forests. They may be the single most important type of wildlife habitat and by excluding them from harvesting their intrinsic value can easily be maintained. Moreover, they can provide a system of corridors linking all the old-growth stands in a reserve into a network that will mitigate the effects of forest fragmentation (Hunter, 1992).

Prescribed areas for conservation

The results of the present ecological survey, along with other available data, identify the whole KDN forest complex as a biologically and hydrologically critical area. The Kanneliya reserve can be identified as the core area of the complex on account of its high biodiversity and hydrological importance; it is proposed therefore that it should be made a Totally Protected Area (TPA), with a buffer zone which can be demarcated within the existing boundaries. The southwest and northwest parts of Kanneliya contain major streams (Udugama Dola, Nannikita Ela, Kanneli Ela) which are very important constituents of the catchment of the Gin Ganga. This is the area that is most important for total protection.

An attempt was made to demarcate zones within the complex based on the diversity indices of clusters of plots. However, the index of one cluster of plots (e.g. plots 1-4, 13, 14, and 21, or plots 30, 34, 36-39, etc.) is not significantly different from another. It is not possible to identify a core area of high diversity representing all three reserves.

The diversity index does not evaluate the habitat diversity or ecosystem diversity. Therefore, it is necessary to rely on other parameters, such as soil conservation and hydrological importance, the total number of plant and animal species in an area, the number of threatened species, the contribution made by endemic species to floristic richness and density (Table 4) and the importance value indices of species, genera and plant families (Tables 13-16), to evaluate a given area for conservation. A comparison of these parameters among the three reserves shows that the Kanneliya reserve is the core area.

It would have been difficult, when conducting field work for a short period (such as two months in the case of the present survey) to carry out detailed sampling of flora, fauna and habitats so as to identify smaller units which have exceptionally high species diversity, habitat diversity, and endemism within the KDN complex. Even if such areas exist it is necessary to protect larger areas in order to conserve ecosystem diversity. Therefore, it is recommended that the whole Kanneliya reserve should be conserved. It is the largest forest reserve (5845 ha) in the complex. Dediyagala (3607 ha) and Nakiyadeniya (1694 ha) are accorded lower priority for designation as conservation forests. These two reserves can be managed on a sustainable basis for multiple uses. However, there are a few ridge tops in both Dediyagala and Nakiyadeniya which could be demarcated as protected or conservation areas.

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