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REGENERATION DYNAMICS OF SILVICULTURALLY ASSISTED DRY ZONE SCRUB VEGETATION AT DAMBULLA ARBORETUM

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ABSTRACT

Regeneration dynamics of silviculturally assisted scrub vegetation is described for a three year period between 1993 and 1995 in Dambulla Arboretum. The tree flora based on an enumeration of all trees above 3.1 cm girth at breast height (1 cm dbh) in a plot of 1352 m^2 were tabulated and analyzed. The diversity recorded in 1995 was 45 species, 42 genera and 19 families. The most diverse families were Euphorbiaceae (Relative Diversity [RD] = 8.9) and Sapindaceae (RD = 8.9) in 1993: and Euphorbiaceae (RD = 13.3), Rubiaceae (RD = 13.3) and Rutaceae (RD = 11.1) in 1995. The most abundant families in all size classes were Euphorbiaceae (Relative Frequency [RF] = 12.9) and Mimosaceae (RF = 13.9) in 1993, whilst these in 1995 were 10.6 and 6.5 respectively. The most abundant species, *Phyllanthus polyphyllus* (Euphorbiaceae) accounted for 57.4% of the total number of trees in 1993, and 37.6% in 1995. The common species of canopy and emergent trees in the Dry Zone primary forest are not common at this stage. Six emergents (2 from root suckers), six pioneers, eight main canopy species and 25 understorey species were recorded in 1995. On this floristic evidence, it is too early to predict which species will prevail in future on the study plot in the regeneration process. Long-term studies should provide further information.

INTRODUCTION

Of Sri Lanka's total land area of 6.5 million hectares, 3.9 million hectares belong to the dry zone (Panabokke, 1988). The dry zone of the Island comprises 80% of the total dense forest cover of the Island. Most of these forests have been replaced by scrub jungles as a result of slash and burn agriculture, illegal felling, fire, irrigation schemes, and agricultural expansion resulting from a growing population.

Over the past few years, natural regeneration has received increased attention due to a failure to establish exotic tree plantations in the dry zone (Popham and Neil 1994; Brown and Miller 1994; Perera 1994). Thus, attention is now being paid to the systematic management of chena scrubland and disturbed forests by silviculturally

assisted natural regeneration processes. There will have to be a considerable amount of research both to identify and improve silvicultural methods.

During September 1993, a silviculturally treated 1352 m^2 plot was established in scrubland of the Dambulla Arboretum to monitor the changes of the vegetation over time. It is thought that information derived from this plot will help in the management of areas with a comparable history, to conserve forest diversity and to promote the sustainable use of forest resources.

The goals of this study are to:

- document plant diversity of silviculturally treated dry zone scrub vegetation
- provide long-term data on the growth, mortality, regeneration and dynamics of tree species
- prepare an information base for dry zone forest management

This paper summarizes the structure, composition and dynamics of the study plot over the last three years.

THE STUDY SITE

The Dambulla Arboretum is located at latitude 7°51'34" North and longitude 80°40'28" West and is about 140 km North East of Colombo and 180 m above sea level. The total area of 14.57 hectares comprises 3.64 ha of Arboretum and 10.93 ha of woodland. The Arboretum lies in the dry zone a few kilometres from its northern boundary with the intermediate zone. The mean annual rainfall in the NE monsoonal period (October to December) is 343.1 mm. In the twelve years from 1978 to 1984, droughts have averaged 219 days which is 60% of the year (Popham and Neil 1994). The average day temperature is between 28.1°C and 29.6°C while that in the north-east monsoonal period is 25.1°C to 25.9°C. According to the USDA soil taxonomy of 1975, the soil in the area is classified as an Alfisol (sub-order : Ustatls). Cramer (1993), has identified three main vegetation types in the Arboretum viz., tropical dry (mixed) evergreen forest, moist tropical semi-evergreen forest and scrub jungle. The dry (mixed) evergreen forest consists of evergreen and deciduous species and it is dominated by *Manilkara hexandra, Chloroxylon swietenia, Vitex altissima, Syzygium cumini* and *Chukrasia tabularis*. In the moist tropical semi-evergreen type the dominant species are *Dialium ovoideum, Schleichera oleosa, Manilkara hexandra* and associated species such as *Chloroxylon swietenia, Drypetes sepiaria, Grewia damine*. Generally, scrub vegetation comprises relatively smaller trees (1.5 to 8 m high) such as *Bauhinia racemosa, Pterospermum suberifolium, Cassia roxburghii, Dichrostachys cinerea, Mischodon zeylanicus* and shrubs, particularly of the Euphorbiaceae, such as *Croton aromaticus, Securinega leucopyrus* and *Phyllanthus polyphyllus*.

METHOD

Ecological studies for taxonomic purpose were initiated at Dambulla Arboretum in 1991 (Cramer 1993). Seedling recruitment and mortality (Popham 1995) and tree parameter relationships of selected species have been studied (Samarasinghe 1995).

The study plot, silviculturally assisted using the Popham Method (Appendix - 1) in 1991, was chosen as the location of the study as it was considered to be relatively high in diversity and it was close to the control block (No treatment) for comparison purposes. The plot was divided into seventeen 5 m sub-plots using a central base line drawn across the middle of the longest largest axis of the plot. In all of the 17 segmented sub-plots, trees above 1 m in height were measured for height; individuals less than 1 m were measured for girth at breast height (gbh); the number of shrubs per sub-plot was obtained; and all individuals enumerated in 1993 and 1994 were listed. In 1995, all individuals were numbered using aluminium tags and trees above 3 cm gbh were measured for girth. Girth measurements at breast height of coppicing trees (>= 3 sprouts) with two larger sprouts were measured and their mean was calculated. Heights were measured for the trees below 3 cm in gbh. The species recorded on the plot were grouped for canopy, sub-canopy and shrubs (Dittus 1997).

RESULTS

The 1352 m^2 plot sample for trees in 1993 included 25 species in 23 genera from 13 families, which increased to 45 species in 42 genera and 19 families by 1995 (Table 1).

Table 1. Changes in the number of families, genera and species between 1993 and 1995 in the study plot at Dambulla Arboretum.

	1993	1994	1995
Families	13	18	19
Genera	23	34	42
Species	25	36	45

Ten dominant families and their relative diversities (RD = Number of species in one family / total number of species x 100) are given in Table 2. The most diverse families in 1993 were Sapindaceae (RD = 8.88) and Euphorbiaceae (RD = 8.88) while in 1995 they were Euphorbiaceae (RD = 13.32) and Rubiaceae (RD = 13.32). The family Rutaceae showed an increase in RD from 4.44 to 11.11 within the study period.

Table 2. **Relative diversity of ten dominant families in the study plot at Dambulla Arboretum.**

Family Name	Relative Diversity		
	1993	1994	1995
Caesalpiniaceae	4.4	4.4	4.4
Ebenaceae	4.4	4.4	4.4
Euphorbiaceae	8.9	11.1	13.3
Myrtaceae	2.2	4.4	4.4
Mimosaceae	2.2	2.2	2.2
Rutaceae	4.4	6.7	11.1
Rubiaceae	---	11.1	13.3
Sapindaceae	8.9	8.9	8.9
Tiliaceae	4.4	4.4	4.4
Verbenaceae	4.4	4.4	4.4

The ten most common species and their relative density (RD = number of individuals of a species / total number of individuals of all species x 100) and relative frequency (RF = number of plots in which a species is found (frequency) / sum of all frequencies) were calculated (Table 3).

Table 3. **Relative density (RD) and relative frequency (RF) of the 10 commonest species for 1993, 1994 and 1995 in the study plot at Dambulla Arboretum.**

Species Name	Year					
	1993		1994		1995	
	RD	RF	RD	RF	RD	RF
Chloroxylon swietenia	3.9	8.6	3.4	5.5	3.4	5.8
Dichrostachys cinerea	14.0	13.9	12.5	6.8	10.6	5.8
Phyllanthus ploiphyllus	57.4	12.9	40.5	9.6	37.8	6.5
Bauhinia racemosa	0.5	3.2	0.7	2.0	0.8	1.8
Allophyllus serratus	3.0	6.5	6.0	3.4	6.4	3.5
Diospyros ferrea	---	---	4.7	8.2	0.1	6.4
Grewia damine	2.8	7.5	2.9	5.5	0.1	7.6
Memecylon umbellatum	4.5	10.8	4.8	8.2	4.0	5.3
Pterospermum subertifolium	1.0	4.3	0.8	2.7	0.5	3.5
Sapindus emarginata	0.3	5.4	1.4	5.5	0.8	4.7

P. polyphyllus and *D. cinerea* showed higher densities during the study period but they declined from 14.07 to 10.58 and 57.44 to 37.75 respectively. As a result of new recruits of other species, relative densities of *P. polyphyllus* and *D. cinerea*

declined from 57.44 to 37.75, and 14.07 to 10.58 respectively. Because of the recruitment of seedlings, *S. cumini* showed increment on each occasion. Among selected timber species *C. swietenia* showed the highest relative density (Table 4).

Table 4. Relative density of selected timber species in the study plot.

Species Name	Family	Relative density		
		1993	1994	1995
Drypetes sepiaria	Euphorbiaceae	---	0.1	0.1
Manilkara hexandra	Sapotaceae	---	---	0.1
Chloroxylon swietenia	Rutaceae	3.9	3.4	3.4
Cassia roxburghii	Caesalpiniaceae	1.0	1.0	0.9
Diospyros ebenum	Ebenaceae	0.5	0.5	0.5
Vitex altissima	Verbenaceae	0.3	0.3	0.4
Syzygium cumini	Myrtaceae	0.3	0.4	0.5

The Shannon Diversity Index and Species Evenness (Magurran 1998) were calculated for each year (Table 5). Considering the overall diversity, species richness increases from 1993 to 1995. Comparisons of the diversity among layers of the vegetation showed that the scrub was high in diversity.

Table 5 Shannon Diversity Indices and Evenness of Canopy (C), Sub-Canopy and Understorey (U) species during the study period.

	1993			1994			1995		
	C	SC	SH	C	SC	SH	C	SC	SH
Number of Species (S)	3	10	12	6	14	15	10	16	19
Number of individuals (N)	29	74	651	43	141	57	69	169	642
Shannon Diversity Index (H)	.477	1.68	1.42	1.28	2.17	1.63	1.74	2.14	1.71
Evenness Ratio (E)	.43	.81	.68	.72	.82	.60	.75	.77	.56
Variance of Shannon Index (Var H')	.02	.008	.001	.022	.005	.002	.014	.005	.003

C - Canopy SC - Sub-Canopy SH - Shrub

The sources of regeneration of selected canopy and sub-canopy species are given in Table 6. *C. swietenia* and *S. cumini* showed the highest number of germinants for canopy species and *G. damine* for the sub-canopy. *Lepisanthes tetraphylla* showed the highest coppicing ability within the study plot.

Table 6. Source of regeneration of selected canopy (C) and sub- canopy (SC) species in the study plot.

Source of Regeneration	Seedling	Coppice	Root
Canopy			
Chloroxylon swietenia	18	9	3
Diopyros ebenum	--	-	3
Syzygium cumini	18	1	-
Manilkara hexandra	2	-	-
Sub-Canopy			
Cassia roxburghii	6	1	-
Lepisanthes tetraphylla	11	10	-
Grewia damine	19	7	-
Bridelia retusa	4	2	-

DISCUSSION

Natural regeneration arises after natural or man-made disturbance. No species adapts to all kinds of disturbance and therefore it is necessary to know which species appears after which type of disturbance. Woodland areas of the Arboretum are dominated by different understorey species such as *P. polyphyllus, M. umbellatum, D. cinerea* and *R. dumentorum*. The study plot was treated by the Popham Method in 1991 and enumeration was started in 1993. Seven pioneer species viz; *P. polyphyllus, C. roxburghii, M. umbellatum, G. damine, Pityranthe verucosa*, and *Trema orientalis* were recorded in 1993 which increased to eight after *Premna tomentosa* was recorded in 1994. Of these, *P. pollyphyllus* recorded the highest relative density of more than 35% over the study period. Two main canopy species, namely *D. ebenum* and *S. cumini*, regenerating from root stock, were recorded in 1993. Recruitment of main canopy species was started in 1994 after recording *Drypetes sepiaria* while *Manilkara hexandra* was recorded in 1995.

Closer inspection, however, reveals a number of clear changes in the dynamic process. Recruitment of species accelerated during the study period. There was a clear fluctuation in species richness between 1993 and 1994 (44%) and 1994 and 1995 (25%) respectively (Calculated from Table 1). This is also evident in the number of families and genera between 1993 and 1994. The number of families increased by 1 from 1994 to 1995.

In the study plot, *P. polyphyllus* provides a canopy for seedling growth. Stools of coppiced *C. swietenia, Pteropermum suberifolium* etc. in the plot frequently have the central stem removed during shifting cultivation. This suggests that the coppicing of these species promotes the regeneration process by ameliorating the hash dry zone climate and creating a microclimate for seedlings to germinate at different successional phases in the study plot.

From the increase in the Diversity Index of canopy species, it is evident that the germination of canopy seedlings has been encouraged by existing site conditions as a result of the Popham Method and early canopy cover from coppiced species. The number of species recorded from the sub-canopy and shrub layers also shows an increase. Families such as Euophorbiaceae, Rubiaceae and Rutaceae showed greater diversity in the plot in 1995. The Euphorbiaceae was represented by 3 canopy and 3 understorey species while the latter two each were represented by one canopy, one sub-canopy and two understorey species. Of the dominant families in dry mixed evergreen forest (Dittus 1997), Meliaceae and Moraceae were not recorded.

Observation indicate that the source of regeneration within species is from seedlings and that this is the main source of regeneration in the study plot. Profuse seed producing trees of *C. roxburghii, S. cumini* and *C. swietenia* are found close to the plot, but other seedlings are probably produced from seeds dispersed by wind and birds. Early seed production by *C. swietenia* and *S. cumini* regenerated from coppiced trees within the study plot, has increased the number of seedlings of these species.

Litter accumulation, decomposition rates and microbial activity are factors which are also important in the dynamics of all vegetation successions - as well as the dry zone vegetation itself. Colonization of herbaceous legumes on the degraded areas is important for fixing nitrogen and to improve the soil. Except for tree legume species, no herbaceous species was recorded from the study plot.

The main issue here is to describe the changes in scrub vegetation as a result of the Popham Method and to introduce it for the restoration of the degraded dry zone. It is quite clear that the changes in the study plot are a consequence of the Popham Method. Further studies of the changes in growth rate, mortality and recruitment for the species groups are needed - this should help to describe follow-up changes.

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APPENDIX - 1
THE POPHAM METHOD

The traditional cultivation practise adopted in the dry zone has resulted in ecologically undesirable and economically low productive chena scrub lands. The competition by grasses and creepers and physical threats such as prolonged droughts and fire influence the forest regeneration on these lands.

Mr F.H. Popham has developed a silvicultural method that assists natural regeneration on abandoned chena lands. It promotes indigenous and endemic species to recolonize the dry zone landscape and improve the biological diversity; it provides a habitat for native fauna, enhances the soil water retention properties, and also decreases the fire hazard in the dry zone.

The method releases young trees from undesirable competition and protects them from fire. The *modus operandi* controls grasses *(Imperata cylindrica, Pennisetum sp.)*, and excludes creepers *(Carissa spinarum, Thodalia asiatica)* and thorny shrubs such as *(Randia dumentorum, Gmelina asiatica)*. This enables young trees to grow at a faster rate than would otherwise have been possible, reducing the problem of competition from repressive species.

After a new area is opened, the ground sanitation programme continues for several rounds per year until the new canopies form a dense, closed forest which takes over its own ground control. But the young trees are still susceptible to damage by creepers and careful control is needed. Exposure of the treated scrub to direct sunlight stimulates new recruits. These seedings are protected by stakes to avoid damage from subsequent ground sanitation and their progress is monitored. The new recruits in each season are marked by different identification pegs.

Protecting the land from fire is also a priority. Fire paths are maintained inside the woodlands and these divide the land into small blocks. The tree sanitation program is done during the dry season for protection of existing trees from fire and cyclones and removal of epiphytes harmful to the trees.