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STRUCTURE AND COMPOSITION OF SCRUBLAND VEGETATION IN THE LOWER WALAWE BASIN IRRIGATION EXTENSION AREA IN SRI LANKA

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ABSTRACT

A large scale irrigation development project has been initated in the lower Walawe basin in the Hambantota district by the Mahaweli Authority of Sri Lanka. An attempt was made to examine the salient community ecological features of the scrubland vegetation before the large scale clearing of the remaining natural vegetation for this development project. A systematic study on the vegetation of the scrublands in this area was carried out by selecting representative sampling sites along the climatic gradient that spanned over part of the dry zone towards the arid zone through an ecotone. Fifteen transects, each 5 m × 50 m, were established representatively. Eighty plant species belonging to 63 genera and 29 families were identified during the study. Thirty three of them are medicinally important, two have timber value one is of medicinal value. Among these were trees (11 spp.), shrubs (30 spp.), herbaceous plants (37 spp.) and climbers (2 spp.). In the scrub vegetation in different climatic zones, the range of stem density was 524-600 individuals/ha and the total basal area was 2.0-3.8 m^2/ha. Overall, the dominant plant species in different size classes of the vegetation were *Flueggea leucopyrus* and *Dichrostachys cinerea.*

A detrended correspondence analysis, using the abundance of species separated the ecotone transects from those in the dry and arid zones. In a cluster analysis some of the arid and dry zone transects separated out into two major groups, while the remaining transects grouped with those in the ecotone.

The plant communities recognized in this study across the climatic gradient will provide a preliminary scientific basis for delineating conservation areas and for monitoring the vegetational changes in them with time.

Key Words

Species composition, Structure, Species richness, Scrubland vegetation, Walawe basin, Cluster analysis

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INTRODUCTION

Sri Lanka has experienced a boost in large-scale irrigation development especially, over the past two decades (Manchanayake and Madduma Bandara, 1999). Since the agricultural sector plays a vital role in Sri Lanka's economy, irrigation has received a high priority in development initiatives. The Walawe basin is a major water resource on which large scale irrigation development projects have been based since ancient times. The tank cascade system then used exemplifies the efficacy of this ancient irrigation system. Based on this knowledge, the Udawalawe Left Bank Irrigation Project (under the Mahaweli Authority of Sri Lanka) proposes to construct an irrigation channel that will provide water to Hambanthota via the south eastern dry zone.

While major irrigation development projects have contributed to an increase in the agricultural productivity of the country and enhanced the livelihood of rural communities, the island has lost vast areas of natural ecosystems, which in turn has led to a depletion of the floral and faunal diversity (Anon., 1995). At present the extent of land available for biodiversity conservation is limited. Therefore, it is important that water resources be allocated in a manner that will provide sustainable livelihoods, while protecting an adequate representation of the country's natural ecosystems.

Documenting the present status as well as the previous history of the natural vegetation in this area marked for development, will enable policy makers to pay attention to areas of high biodiversity while making decisions on land allocations. A study carried out in 1960 focused especially on the Walawe basin, which includes parts of the dry, wet and intermediate zones, emphasized that there are four natural vegetation types, *viz.*, grasslands, woodlands, swamps and marshes in the area (Anon., 1960). When this study was done, 49.1% of the land was under woodland. However, a reconnaissance survey of the natural vegetation in the Walawe basin in 2001 indicated that dry thorny scrubland was the major vegetation type covering 58% of the study area. In this survey remnant degraded forest patches and rocky out crop forests were also identified (Dilhan *et al.*, 2001) as additional natural vegetation types in this area. Samarasinghe (1995) suggested that the thorny scrub has replaced dry zone forests as a result of shifting cultivation.

Cramer (1977) suggested that the vegetation in the dry zone is relatively poor in diversity and structure compared to that of the wet zone forests. The classification and /or floristic composition of the vegetation has been described by different biologists. De Rosayro (1956) and Koelmeyer (1957) classified the forests of Sri Lanka on the basis of geographic, climatic and floristic criteria. They reported that the lowland semi-evergreen thorn forest was dominated by *Salvadora persica*, *Cassia* spp., *Euphorbia* spp., *Randia dumetorum*, *Carissa spinarum* and *Ziziphus* spp. However, according to Gaussen *et al.*, (1964), the vegetation of these southern thorn forests are dominated by *Manilkara hexandra* and *Chloroxylon swietenia*, where as Greller *et al.* (1980) report that they are dominated by a Manilkara-*Randia-Dichrostachys* association.

The main aims of the present study were to find out what vegetation type/s exist in the lower Walawe basin area. Also, to describe these vegetation types in terms of their structure and floristic composition and to understand the spatial distribution patterns of their component species across the climatic gradient from dry to arid zones through the ecotone.

MATERIALS AND METHODS

Study Site

The study was undertaken in the Walawe basin in the south-eastern part of Sri Lanka (6^0 07'- 6^0 19' N and 81^0- 81^0 06' E). The entire extent of the study area is 15,000 ha. A photographic survey (Anon., 1960) depicted that it had two irrigation extension areas *viz.*, the south west and south eastern parts. The left bank main canal of the Walawe basin and its branch canals are due to be constructed to provide water resources to the south-eastern extension. Therefore, in the present study representative sampling sites were selected from the areas earmarked for development as well as from the undisturbed areas along the 'Adiseeya para' meaning 100 feet wide road from Suriyawewa to Mirijjawila.

The lower Walawe basin irrigation extension area falls within the DL1 (Reddish Brown Earth Region) and DL2 (very dry semi arid) agroecological regions demarcated in terms of their rainfall probability regime, soils and elevation (Panabokke, 1996). Consequently, the study sites were placed randomly, in the DL1 and DL2 regions such that each region had at least 5 transects. Another set of 5 transects was laid at an equal distance from the border between the two agro ecological zones to observe the transition in the vegetation between these two regions.

The study area falls within three administrative districts, Moneragala, Embilipitiya and Hambanthota, located in the dry and arid zones of Sri Lanka (Fig.1a). Ancient tank cascade systems were also present within each climatic zone. Some of them are used for agricultural purposes and others are now in ruin.

The climate of the lower Walawe basin irrigation extension study area as classified by Mueller-Dombois (1968) represents a humid winter and summer drought climate. For this study, the climatic data were gathered from Angunakolapelessa meteorological station, the closest station to the study area. The mean annual temperature and the mean annual rainfall for the area as given by the Angunakolapelassa weather station are 27.6^{0}C and 1101 mm respectively. A considerable amount of precipitation to the area is received during the northeast monsoon in October-December (100 mm-210 mm), while the driest period is in July-August (40 mm-50 mm).

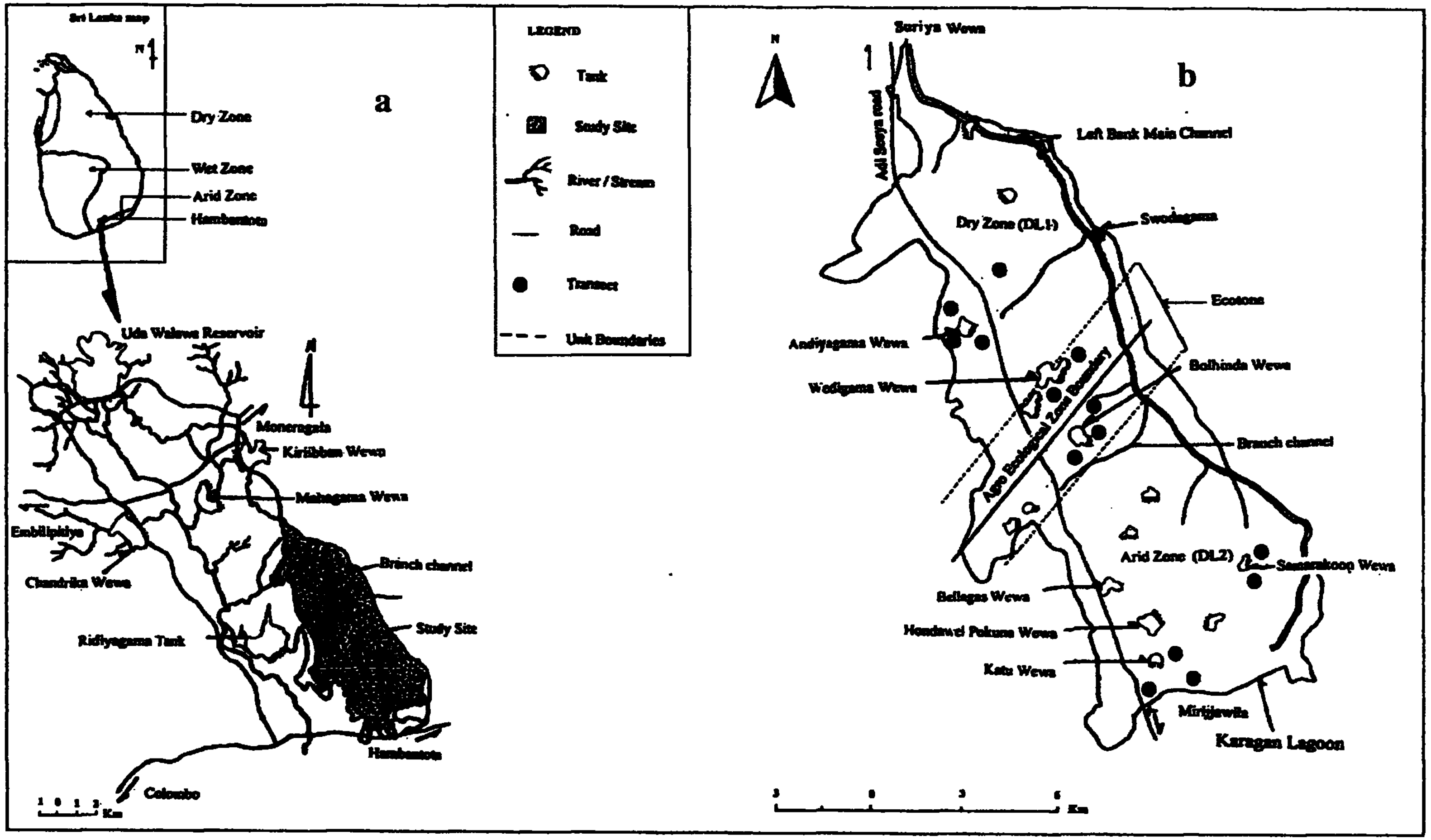

Figure 1 a. Hydrological Map of Walawe Ganga Basin in Sri Lanka (Wewa = small reservoirs or tanks).
b. Detail map of the study area showing the locations, agroecological zone boundary and the tank cascade system.

Sampling

The transect method was used for sampling in this study, since it is a rapid method. Fifteen transects, each 50 m × 5 m were demarcated within 15 different sites (Fig. 1b) representing the dry zone (DL1), arid zone (DL2) and the ecotone in the study area. Five transects per zone were selected and each transect was divided into 10 m × 5 m sub plots to facilitate sampling. Three of these subplots located at the two ends and the center of each transect were enumerated per transect as shown in Fig. 2.

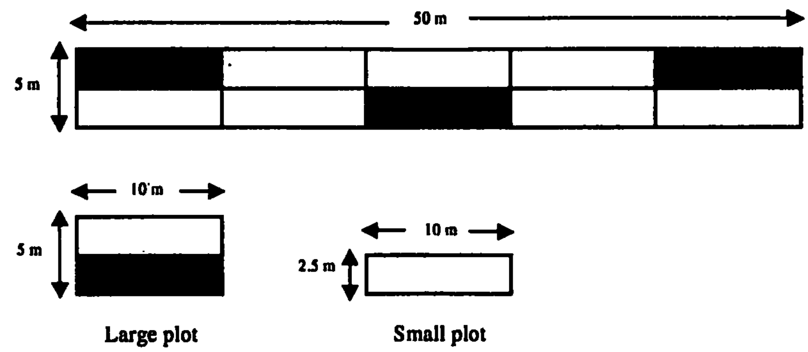

Figure 2. Sketch diagram of the transect and plot sizes used for vegetation sampling in the lower Walawe basin study area. Plots of size 10 m x 5 m and 10 m x 2.5 m were used to sample the vegetation >10 cm gbh and < 10 cm gbh and >1 m in height respectively. Plants <1 m height were recorded at 30 regular points along the 50 m length of the transect.

Individual trees over 10 cm girth at breast height (1.3 m above the ground) in these sub plots were enumerated and they were marked with numbered aluminum tags. The sampling method used was similar to that adopted by Gunawardena and Gunatilleke (1996) but with a few modifications. Sub plots of size 10 m × 2.5 m were demarcated within the main plot (Fig. 2) to enumerate individuals below 10 cm gbh and above 1 m in height. Individuals less than 1 m in height were enumerated by point quadrat sampling, where the vegetation at ten points were studied along the center line of each transect in a systematic way and a total of 150 points were studied for all transects.

A number of characteristics of the vegetation, *viz.*, frequency, density and gbh of all woody species were recorded. The Importance Value Indices (IVI) of all the species were calculated using relative basal area, relative density and relative frequency for individuals over 10 cm girth, whereas relative stem density and relative frequency were used for the species in the size class below 10 cm gbh and above 1 m in height. On the other hand, relative cover and relative frequency were used for individuals less than 1 m in height.

Herbarium specimens were prepared from the plant material collected in the field. Each individual sampled was identified to its species as far as possible with help from the National Herbarium, Peradeniya, use of the Hand Book to the

Flora of Ceylon Dassanayake and Fosberg (1990-1991), Dassanayake *et al.* (1994-1995) and Dassanayake and Clayton (1996-2000).

An ordination and classification of the vegetation gradients in the dataset that could be compared against their spatial distribution on the ground and in relation to climatic gradients, was carried out using multivariate analysis with the help of $PCORD_4$ software.

RESULTS

Structure of the scrubland vegetation

Density

The density of trees >10 cm gbh in the scrubland are shown in Table 1. Comparing the climatic zones, the ecotone recorded the highest density of individuals, where as the arid zone recorded the lowest density. The density of the species common to the dry and ecotone areas were high in the ecotone area with two exceptions. However, the species that were restricted to the dry zone were mostly tree species (Appendix 1), but those restricted to the ecotone were shrubs. Among all the species in this size class, *Prosopis juliflora* recorded the highest density and it was the only species present in the arid zone.

Table 1

List of species represented in the vegetation size class above 10 cm gbh with their density in the different climatic zones (dry, ecotone, arid and all three areas together). (T = Tree, S = Shrub).

Species	Life form	Density/ha			
		Dry	Ecotone	Arid	Whole Area

Basal area

The total basal area contributed by the scrubland studied was 2.5 m^2/ha. In the dry, ecotone and arid zones, the basal areas were 3.8, 2.0 and 2.5 m^2 per hectare respectively (Table 2). The highest contribution of basal area by a single species in the dry, ecotone and arid zones was 2.3, 0.67 and 2.2 respectively and each of them was restricted to the particular zone itself, except for that in the ecotone.

Table 2

List of species represented in the vegetation size class above 10 cm gbh with their basal areas, in the different climatic zones, *viz.*, dry, ecotone and arid as well as in all three areas together. (T = Tree, S = Shrub).

Species	Life form	Basal Area (m2/ha)			
		Dry	Ecotone	Arid	Whole
Limonia acidissima	T	0.38 ± 0.07	0.67 ± 0.12	0.01 ± 0.002	0.35 ± 0.05
Flueggea leucopyrus	S	0.12 ± .02	0.19 ± 0.02	0.07 ± 0.01	0.13 ± 0.01
Dichrostachys cinerea	S	0.02± 0.004	0.39 ± 0.03	0.16 ± 0.03	0.19 ± 0.02
Phyllanthus polyphyllus	S	0.12 ± 0.02	0.02 ± 0.004	-	0.05 ± 0.01
Catunaregam spinosa	S	0.07 ± 0.01	0.04 ± 0.01	-	0.04 ± 0.01
Randia malabarica	S	0.01 ± 0.002	0.09 ± 0.01	-	0.03 ± 0.004
Strychnos potatorum	T	2.28 ± 0.31	-	-	0.76 ± 0.11
Bauhinia racemosa	T	0.61± 0.1	-	-	0.02 ± 0.04
Ziziphus mauritiana	S	0.05 ± 0.01	-	-	0.02 ± 0.003
Chloroxylon swietenia	T	0.04 ± 0.01	-	-	0.01 ± 0.003
Cassia fistula	T	0.03 ± 0.01	-	-	0.01 ± 0.002
Crateva adansonii	T	0.01 ± 0.002	-	-	-
Capparis sepiaria	S	-	0.012 ± 0.002	-	-
Carissa carandas	S	-	0.012 ± 0.002	-	-
Cassia auriculata	S	-	0.486 ± 0.08	-	0.16 ± 0.03
Cassipourea ceylanica	S	-	0.34 ± 0.01	-	0.01 ± 0.002
Grewia carpinifolia	S	-	0.026 ± 0.005	-	0.01 ± 0.01
Parkinsonia aculeata	T	-	0.011 ± 0.002	-	-
Prosopis juliflora	T	-	-	2.24 ± .042	0.75 ± 0.14
Total		**3.8 ± 0.31**	**2.0 ± 0.22**	**2.5 ± .041**	**2.5 ± 0.18**

Girth

On the basis of girth size distribution, five classes (Fig. 3) of individuals were recognized. The girth class 10-20 cm had a high proportion (about 80%) of individuals of shrub and tree species in each of the zones. However, the number of species in this girth class in the dry and ecotone areas were more or less similar whereas that in the arid zone was much lower (only 4) but had the highest proportion of individuals. Individuals in the dry zone were distributed in all five girth classes showing a wide variation in size, while the number of girth size classes and the maximum size of individuals was lower in the ecotone and the arid zone, where almost all the individuals were less than 40 cm gbh.

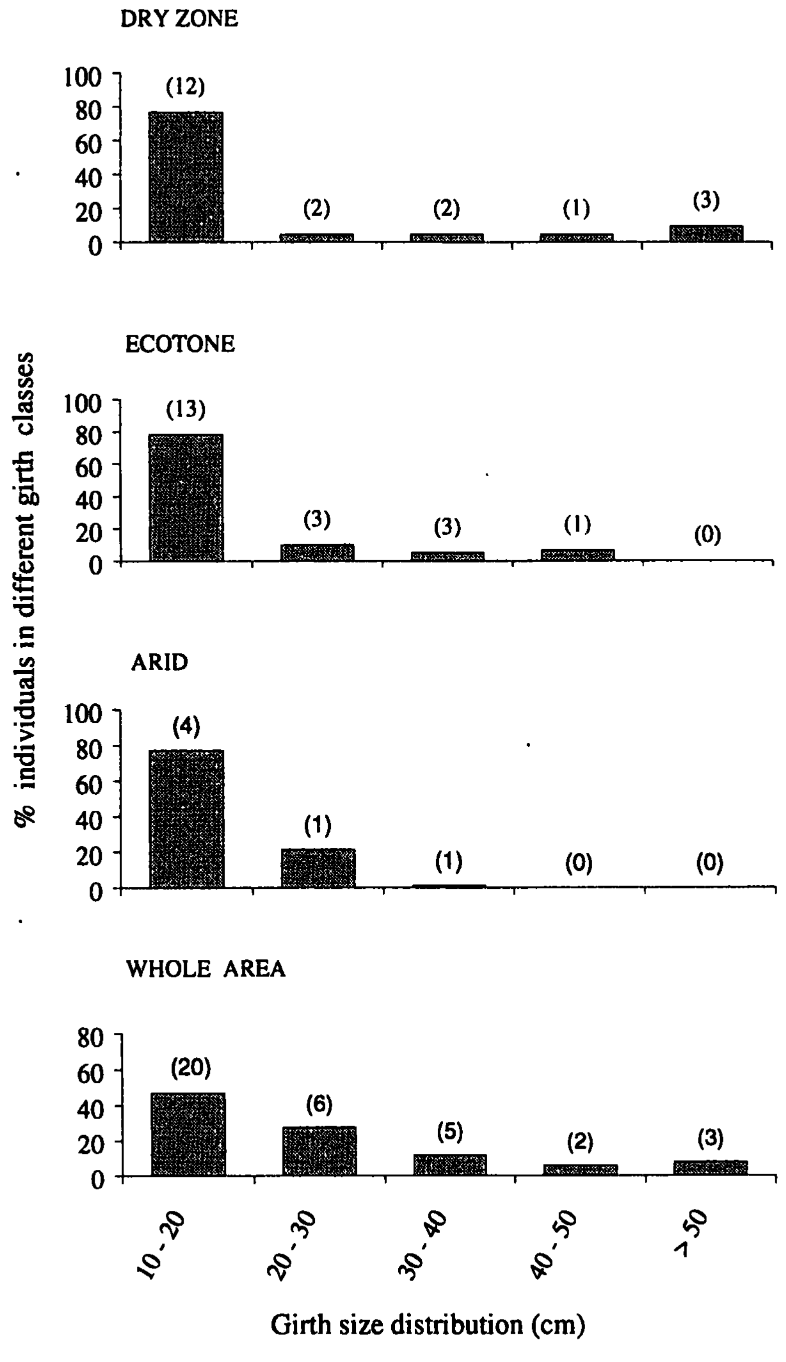

Figure 3. Girth class distribution of individuals greater than 10 cm gbh (trees and shrubs) in the scrub vegetation of the study area of the lower Walawe basin. The number of species that were present in each size class is given in parentheses.

A Kolmogorov-Smirnov test (Sokal, 1995) on cumulative frequency of species against girth was used for each pair-wise test on each zone. The statistical analysis showed that these girth size distributions among climatic zones were not significantly different ($\alpha = 0.01$).

Floristic composition of the scrubland vegetation

Floristic richness

The floristic richness and life form distribution (Table 3) of the vegetation sampled showed that the dry zone comprised 50 species belonging to 39 genera and 18 families. The plots sampled in the ecotone had 48 species in 39 genera and 20 families. The arid area sampled had 42 species in 39 genera and 17 families. Total individuals enumerated belonged to 86 species (including 6 unknown species) in 63 genera and 29 families. Of the 80 species identified, 33 (41.2%) were medicinally important (Jayaweera 1982) (Appendix 1) and two species *Chloroxylon swietenia* and *Cassia fistula* (2.3%) had timber value. However, *Cassia fistula* was the only species (1.2%) that had both medicinal and timber value.

Table 3

Floristic richness and life form distribution of all vegetation classes in the scrub vegetation sampled in the lower Walawe basin, Sri Lanka.

Taxa and Life Form Groups	Dry	Ecotone	Arid	Whole
Families	18	20	17	29
Genera	39	39	39	63
Species	50	48	42	86
Trees spp.	8	2	2	11
Shrub spp.	20	21	20	30
Herbs spp.	20	20	19	37
Climber spp.	1	1	0	2
unknown	1	4	1	6

Species and family dominance in the dry, ecotone and arid zones

On the basis of IVI values, the leading dominant in the vegetation size class >10 cm gbh in the dry zone was *Strychnos potatorum* (Fig. 4), whereas in the ecotone and arid zones it was *Dichrostachys cinerea* and *Prosopis juliflora* respectively. *Limonia acidissima* and *Flueggea leucopyrus* were common to all three zones, but *L. acidissima* was more abundant in the ecotone (IVI-40), whereas *F. leucopyrus* was more abundant in the arid zone (IVI-33). There were only two species *viz.*, *S. potatorum* and *Bauhinia racemosa* that were restricted to the dry zone. In contrast, *C. auriculata* and *P.juliflora* were restricted to the ecotone and arid zone respectively.

In the middle size class (Fig. 4) the most dominant species in the dry zone was *Phyllanthus polyphyllus*. Even though the species was found in all areas, it was not predominant in the ecotone and arid zone. *Flueggea leucopyrus* clearly dominated this size class of the vegetation in the ecotone. This species was codominant with *Capparis sepiaria* in the arid zone, as well. *Phyllanthus pinnatus* and *Opuntiá dillenii* were common to ecotone and arid zones.

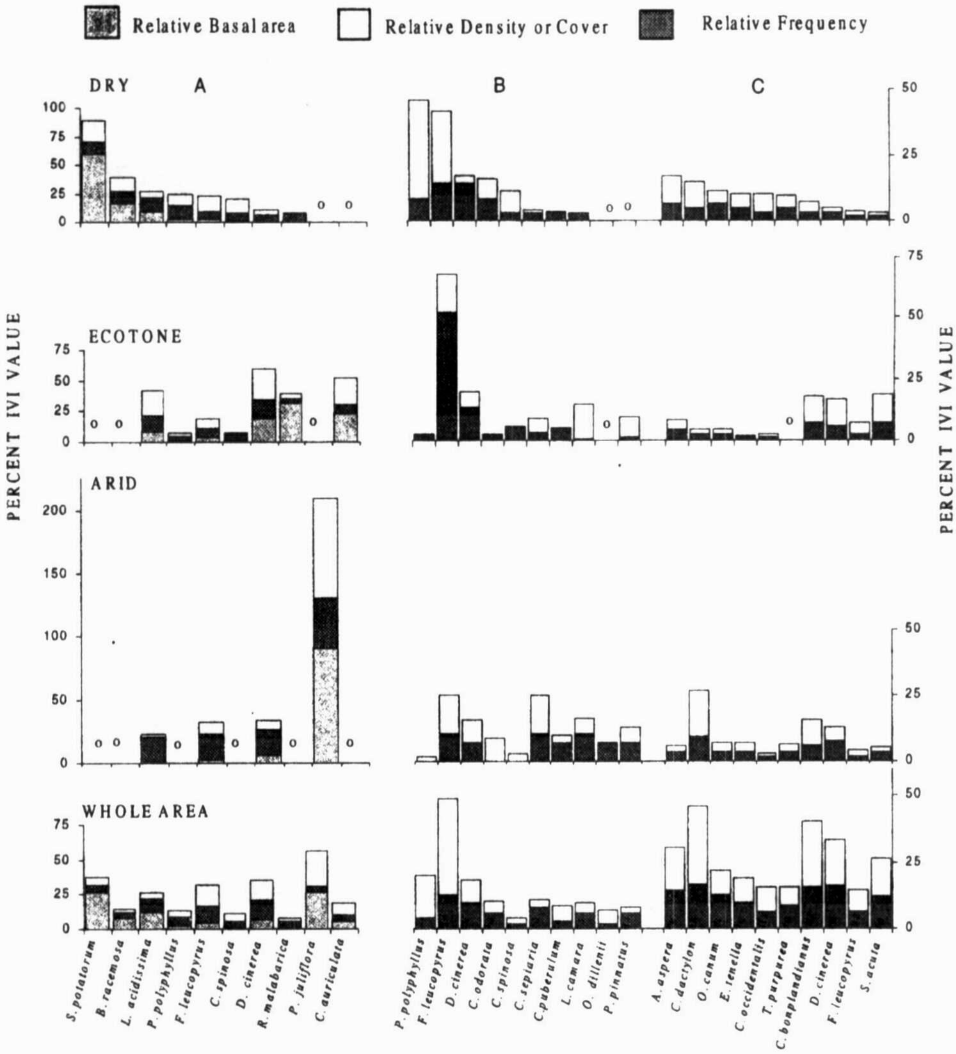

Figure 4. Variation in IVI values of the first ten leading species in each zone in the size classes >10 cm gbh (A), <10 cm gbh and >1 m (B) and <1 m in height (C) in the lower Walawe basin study area.
***IVI values for C were calculated using relative frequency and instead of relative density relative cover.**

In the vegetation below 1 m height, both *Cynodon dactylon* and *Achyranthus aspera* were common in all the areas, but the most dominant species in the arid zone was *C. dactylon* and in the dry zone *A. aspera.*

Based on IVI values, the family Fabaceae clearly dominated both the ecotone and arid zone in the vegetation size class over 10 cm girth. Loganiaceae was the most dominant family in the dry zone. Euphorbiaceae ranked second dominant in all three areas, the dry, ecotone and arid zones.

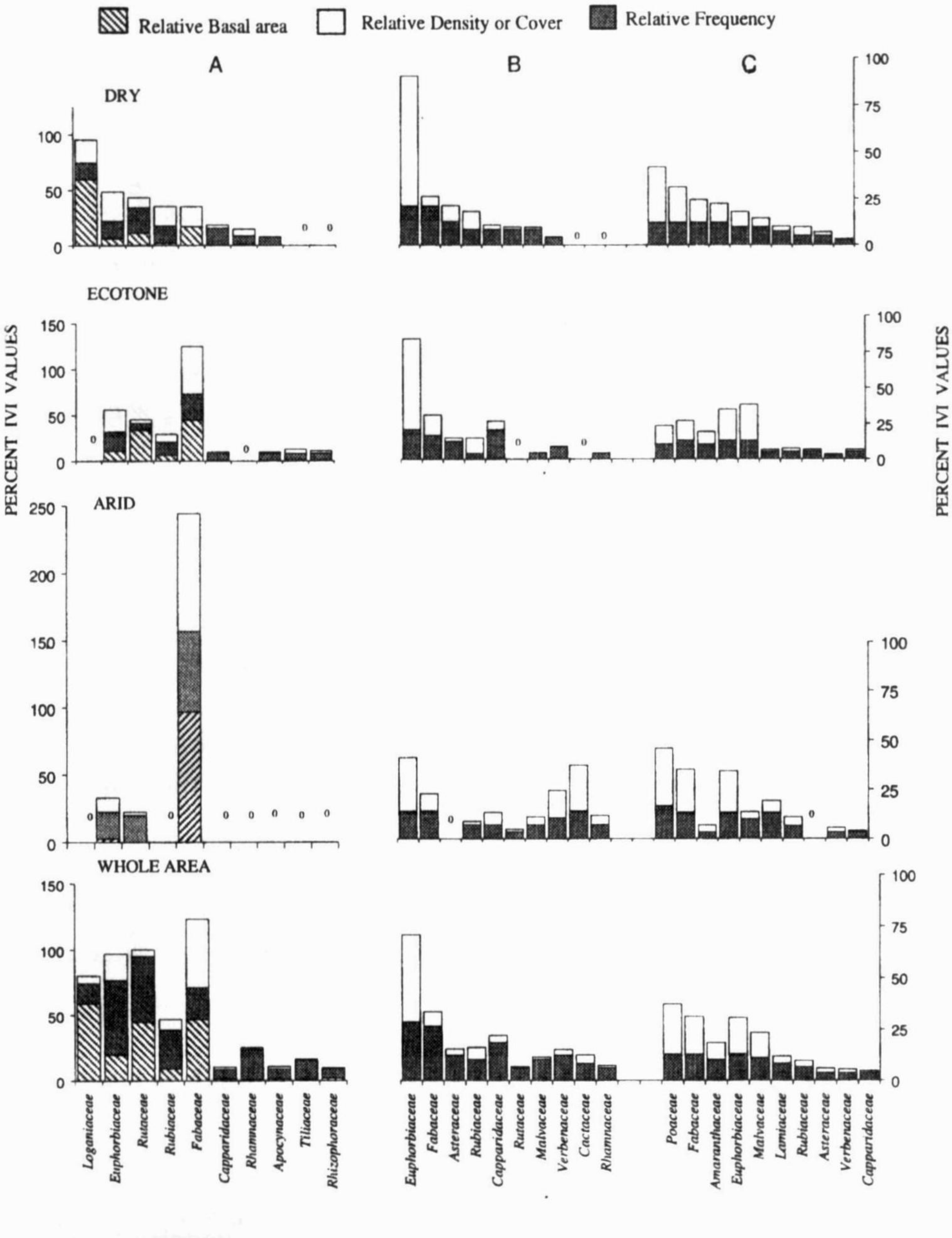

Figure 5. Variation in IVI values of the first ten leading families in each zone in the size classes >10 cm gbh (A), <10 cm gbh and >1 m (B) and <1 m in height (C) in the lower Walawe basin study area.
***IVI values for C were calculated using relative frequency and instead of relative density relative cover.**

There were only two families that were restricted to the dry zone area; Loganiaceae and Rhamnaceae. The ecotone area had Tiliaceae and Rhizophoraceae (Fig. 5). The families recorded in the arid zone were common to the other zones as well.

In the middle size class, Euphorbiaceae was the most dominant in all areas, with Fabaceae ranking second, except in the arid zone. Asteraceae was restricted to the dry and ecotone areas, Rutaceae to the arid and dry zone areas, and Rhamnaceae to the ecotone and arid zone. Cactaceae was restricted to the arid zone.

Species and family dominance in the entire vegetation

The three most dominant species in the entire study area based on IVI values, was *Prosopis juliflora, Strychnos potatorum* and *Dichrostachys cinerea* (IVI-56.7, 37.4, 34.8 respectively) in the vegetation size class above 10 cm gbh (Fig. 4) and *Flueggea leucopyrus*, *Phyllanthus polyphyllus* and *Dichrostachys cinerea* (IVI-49.2, 20.3, 18.2 respectively) in the vegetation less than 10 cm girth and above 1m in height. The ground cover (vegetaion below 1 m height) on the other hand, was dominated by *Cynodon dactylon*, *Croton bonplandianus* and *D. cinerea* (IVI-45.9, 40.3, 33.5 respectively). In addition, though *F. leucopyrus* and *D. cinerea* were common to all size classes, *F. leucopyrus was* the most dominant in the middle size class while *D. cinerea was* the most dominant in the vegetation above 10 cm gbh.

The families recorded in the study sites, in the size class above 10 cm gbh were Fabaceae, Rutaceae and Euphorbiaceae (IVI-123.2, 100.2, 97 respectively), in the middle size class Euphorbiaceae, Fabaceae and Capparidaceae (IVI-71, 33.5, 22 respectively) and in the size class less than 1 m in height Poaceae, Fabaceae and Euphorbiaceae (IVI-37.1, 31.2, 30.5 respectively) were the three leading families. Fabaceae, Rutaceae, Euphorbiaceae and Capparidaceae were common in the different size classes, even though they ranked differently in them.

Endemicity

Of the 80 plant species identified from the study areas, none were endemic to Sri Lanka (Senaratna, 2001).

Population size

In the ecotone 8 species and in the dry zone 4 species were represented by one individual each in the vegetation size class above 10 cm gbh. In the dry zone, a relatively higher number of species had less than 10 individuals each in the middle size class. Among the species with large populations all but one were represented in the middle size class of the vegetation (Fig. 6).

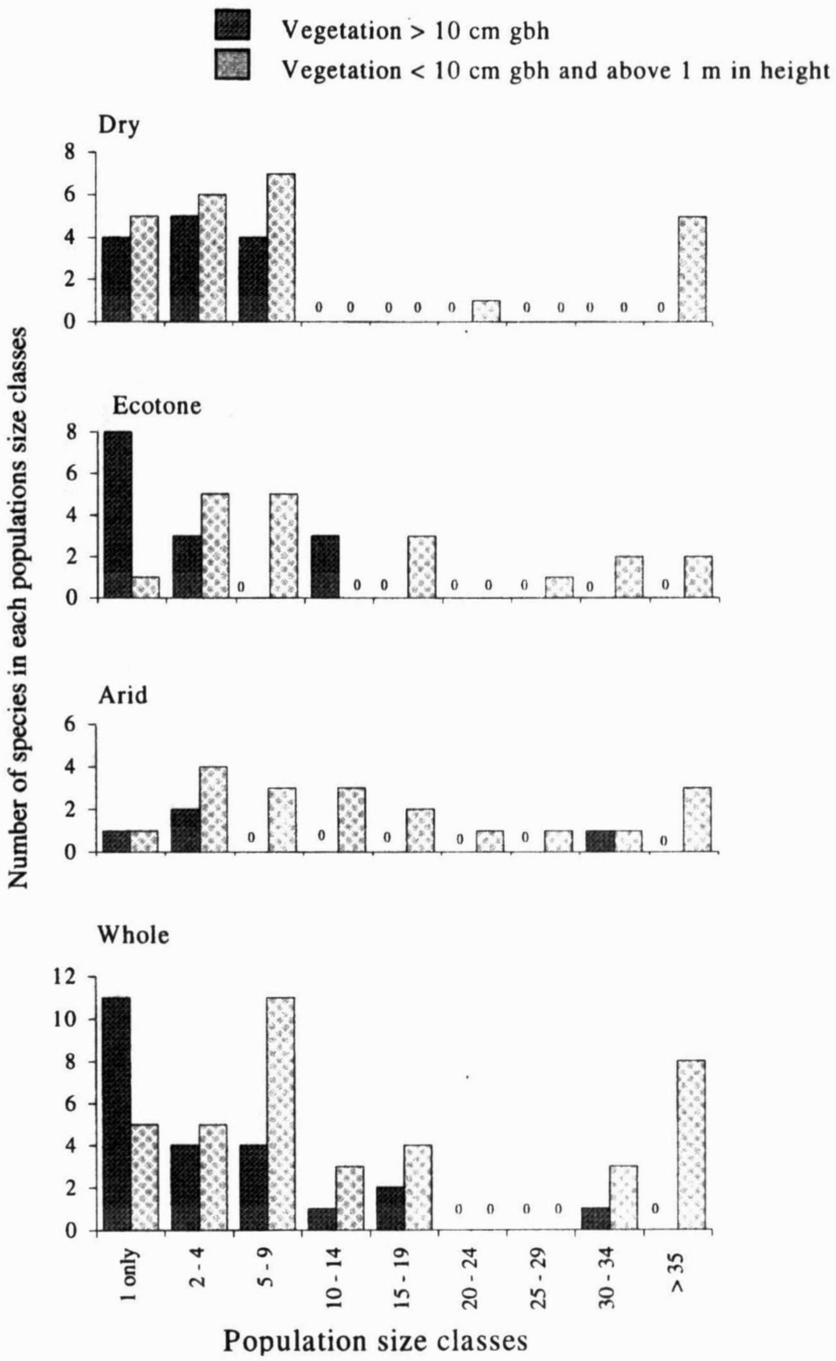

Figure 6. Number of species in each of the population size classes in the vegetaion of the lower Walawe basin irrigation extension area. Results given represent data in 0.08 ha in each zone.

Trends and relationships

The data were analyzed using DECORANA (Detrended Correspondence Analysis) and cluster analysis using the $PCORD_4$ package. Figure 7.1 gives the stand ordination map of the scrubland. Axis 1 appears to correspond to the climatic gradient where the arid zone (A) plots are distributed mostly on the right of the axis, and three of the dry zone (D) plots on the left with the ecotone (E) plots and the two remaining dry zone plots in the middle.

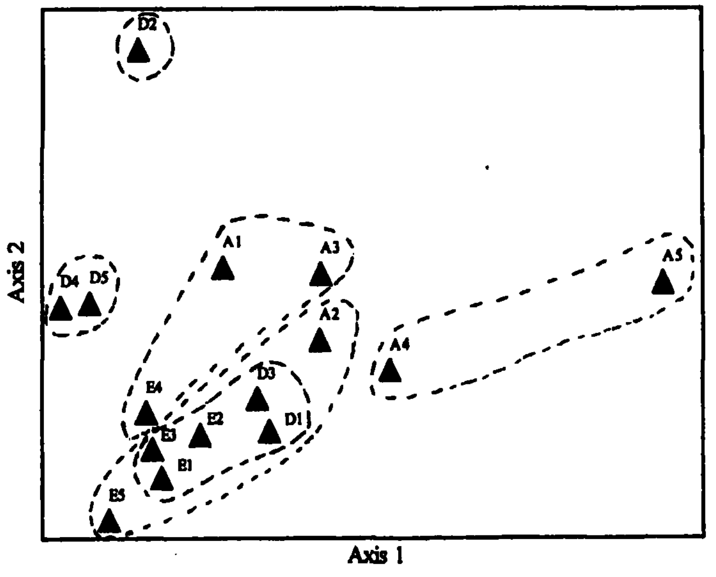

Figure 7.1 Map of site ordination showing the distribution of plots sampled in the lower Walawe basin irrigation extension area, A-Arid Zone plots, D-Dry Zone plots and E - ecotone plots.

Figure 7.2 gives the resultant dendrogram of stand association. Transects D2, D4 and D5 cluster separately from other transects. Similarly, A4 and A5 form another cluster. The remaining plots appear as a major cluster, within which three smaller groups can be identified *viz.*, clusters D1, D3, E1, E2, E3; A2, E5, and A1, A3, E4.

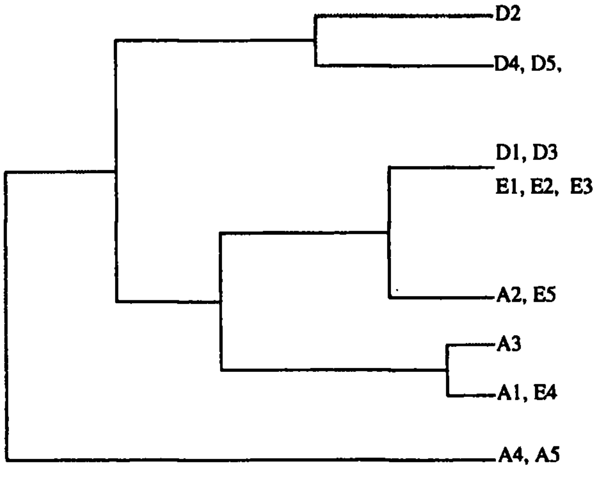

Figure 7.2 Dendrogram of the classification of 15 plots sampled in the lower Walawe basin irrigation extension area, using $PCORD_4$ cluster analysis.

DISCUSSION

Vegetation structure and composition provide important information to understand the vegetation in different climatic regions. In this study, the total density and the density of individual species above 10 cm gbh were different among the climatic zones. The dry zone recorded the highest number of tree species and the highest basal area (3.8 m^2/ha) as expected, followed by a decline from the ecotone to the arid zone. These results indicate that the dry zone study sites, though disturbed, still support a higher tree species richness compared to that of the ecotone and arid zone. The dry, harsh environment with prolonged droughts in the arid zone may contribute to this difference.

The relatively higher number of individuals represented in the smallest girth size class considered in this study may be the nature of secondary scrub forest, where the removal of larger individuals may have encouraged recruitment into the smaller size classes. However, statistical evidence on girth class distribution among the zones was not significantly different. The dominant vegetation in the area are the shrubs, which have a limited growth in girth. This too, would contribute to the reverse 'J' shaped curve for girth classes in each climatic region.

The higher and exclusive occurance of *Prosopis juliflora* in the arid zone, which is near the coast, indicates that it can tolerate high salinity levels (Chandrasekara *et al.*, 2001). This species has been identified as an alien invasive species, the seeds of which are reported to be spread by monkeys and cattle (Seneviratne and Algama, 2001; Bambaradeniya, 2001). In the present study, we observed the dominance of large trees of *P. juliflora* but relatively fewer seedlings and saplings. Another well-known alien invasive species, *Opuntia dillenii,* was also restricted to the arid zone plots of this study. We also observed an abundance of *P. juliflora* in the overstory vegetation and *O. dillenii* in the understory vegetation around Karagan lagoon. However, according to our results and field observations both these species have still not invaded the dry zone through the ecotone.

Liyanage (1998) reported that *Dichrostachys cinerea* is the dominant shrub in open areas at Kahalla forest reserve in Anuradhapura district. In the present study, we recorded *D. cinerea* as the leading dominant in the ecotone in all size classes and it was also present in the dry zone plots but in smaller numbers. This suggests its widespread distribution in the Dry Zone.

The dry zone area was dominated by the tree species *Strychnos potatorum* and *Bauhinia racemosa*. This is probably because the area was not much affected by shifting cultivation. But their absence in the ecotone and arid zone reflects the removal of large trees for chena cultivation.

In the vegetation above 10 cm gbh, *Flueggea leucopyrus* was the second leading dominant species in the arid zone, but in the ecotone it dominated the vegetation below 10 cm gbh. This suggests that this species regenerates well in the ecotone compared to its performance in the dry and arid zones.

All the species recorded in the middle size class were shrubs (Fig. 4) and most of them have the ability to coppice. Among them, *Flueggea leucopyrus* as well as *Dichrostachys cinerea* ranked high indicating that they can adapt to the harsh environmental conditions.

The two most dominant families were Fabaceae and Euphorbiaceae. Plants in these families are adapted to grow under dry and stressed environmental conditions. Some members of the Euphorbaceae have latex, thorns, cladodes and/or relatively small leaves to conserve water and escape herbivory. Some members of Fabaceae can fix nitrogen and therefore, they can perform well in these degraded lands. These factors may have contributed to their dominance in the study areas.

The only quality timber species in our study was *Chloroxylon swietenia* (Appendix 1). On the other hand, 41% of the speices including *Crateva adansonii*, *Cassia* spp., *Sida* spp. etc. recorded were of medicinal value. The harsh conditions prevailing in this region may favour the production of secondary metabolites, some of which may be of medicinal significance.

Peeris (1975) in her studies in reported that 9 tree species, 13 shrub spp. and 12 herb spp. found in the dry zone were endemic to Sri Lanka. None of these species were present in the area sampled in this study. This may be due to anthropogenic disturbances which may have adversely affected the survival of endemic species if any did exist in the past.

The results of ordination and classification indicated 3 major groupings of plots. It clearly showed three dry zone plots (D2, D4 and D5) forming one major cluster and two arid zone plots forming a second cluster. The remaining plots in both these zones formed a third major cluster together with the Ecotone plots. In the ordination, the ecotone plots were seen to be more closely clustered than those of the dry and arid zone clusters. This suggest a greater similarity in species composition among the ecotone plots. These groupings corroborate the view that the transition of vegetation from dry to arid zone through an ecotone.

The results of this study also provide base line information that would be useful in the future, especially to understand the effects of climate change on the boundaries of the arid, ecotone and dry zones in the study area. Furthermore, this baseline information would be useful to examine the changes in vegetation resulting from the implementation of the irrigation scheme being developed for the left bank canal of the lower Walawe basin and for comparison of any future work.

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REFERENCES

Anon. (1960). *A report on a reconnaissance survey of the resources of the Walawe ganga basin, Ceylon.* The photographic survey corporation of Toronto, Canada in a Canada - Ceylon Colombo Plan project. Government Press, Colombo, Pp. 92-146.

Anon. (1995). *Sri Lanka Forestry Sector Master Plan.* Forestry Planning Unit, Ministry of Agriculture, Lands and Forestry, Sri Lanka. 511 pp.

Ashton, M., Gunatilleke, S., De Soyza, N., Dassanayake, M.D., Gunatilleke, N., Wijesundara, S. (1997). *A field guide to the common trees and shrubs of Sri Lanka.* WHT Publications (Pvt.) Ltd. Pp. 51-390.

Bambaradeniya, C.N.B. (2001). *A Field Guide to Bundala National Park.* The World Conservation Union. Pp. 5 - 25.

Chandrasekara, C.M.C.P., Perera, G.A.D., Senevirathne, G. (2001). Effect of soil nutrient status on the invasion of *Prosopis juliflora* and *Opuntia dillenii* at Bundala National Park. *Proceedings of the 57th Annual Sessions of the Sri Lanka Association for the Advancement of Science.* Abstract, P. 166.

Cramer, L.H. (1977). The significance of the indigenous flora in the area of the Mahaweli complex, *The Sri Lanka Forester* **13**(1 & 2): 9-18.

Dassanayake, M.D. and Fosberg, F.R. (1980-1991). *A Reversed Hand Book to the Flora of Ceylon.* Amerind Publishing Co. Ltd., New Delhi. **I-VII**.

Dassanayake, M.D., Fosberg, F.R. and Clayton, W.D. (1994 -1995). *A Revised Hand Book to the Flora of Ceylon.* Amerind Publishing Co. Ltd., New Delhi. **VIII-IX** .

Dassanayake, M.D., and Clayton, W.D. (1996-2000). *A Revised Hand book to the Flora of Ceylon.* Amerind Publishing Co. Ltd., New Delhi. **X-II**.

De Rosayro, R.A. (1956). Tropical ecological studies in Ceylon. *The Ceylon Forester* **2**(4): 168-175.

Dilhan, M.A.A.B, Bambaradeniya, C.N.B., Gunatilleke, C.V.S., Yakandawala, D. and Amarasinghe, F.P. (2001). The structure and composition of natural vegetation types in lower Walawe basin irrigation extension area. *Proceedings of the Annual Forestry Symposium. Dept. of Forestry and Environment Science, University of Sri Jayawardenepura, Sri Lanka.*Abstract. P. 12.

Gaussen, H., Legris, P., Viart, M. and Labrouse L. (1964). *International map of the vegetation: Ceylon (1:1,000,000).* French Institute of Pondicherry, India.

Greller, A.M. and Balasubramaniam, S. (1980). A preliminary floristic - climatic classification of the forests of Sri Lanka. *The Sri Lanka Forester* **14**(3 & 4): 163-169.

Gunawardena, N.P.T. and Gunatilleke, C.V.S. (1996). The understorey vegetation at Samanalawewa in Sri Lanka. *Phyta* **4**(1): 18-33.

Jayaweera, D.M.A. (1982). *Medicinal plants (indigenous and exotic) used in Sri Lanka (1st edition).* The National Science Council, Sri Lanka. **1-4**.

Koelmeyer, K.O. (1957). Climatic classification and distribution of vegetation in Ceylon. The *Ceylon Forester* **3**(2): 144-163.

Liyanage, S. (1998). *Floristic structure and aspects of regeneration of tree species in the Kahalla forest reserve.* M. Phil. Thesis, University of Peradeniya, Sri Lanka.

Manchanayake, P. and Madduma Bandara, C.M. (1999). Water Resources of Sri Lanka. National Science Foundation, Sri Lanka. Pp. 43-54.

Mueller Dombois, D. (1968). Ecographic analysis of a climate map of Ceylon with particular reference to vegetation. *Ceylon forester,* **8**(3 & 4): 1-20.

Panabokke, C.R. (1996). *Soils and agro-ecological environments of Sri Lanka.* Natural Resources, energy and science authority of Sri Lanka. Pp. 121-138.

Peeris, C.V.S. (1975). *The ecology of the endemic tree species of Sri Lanka in relation to their conservation.* Ph.D. Thesis, University of Aberdeen, U.K.

Samarasinghe, J. (1995). Regeneration dynamics of silviculturally assisted dry zone scrub vegetation at Dambulla arboretum. *Proceedings of the Annual Forestry Symposium. Dept. of Forestry and Environment Science, University of Sri Jayawardenepura, Sri Lanka.* Pp. 291-299.

Senaratna, L. K. (2001). *A check list of the flowering plants of Sri Lanka.* National Science Foundation, Sri Lanka. Pp. 451.

Seneviratne, G. I. and Algama, A. L. M. N. S. (2001). Invasive species *Prosopis juliflora* in the coastal region of Hambantota district. Sri Lanka Biodiversity Review **1**: 79-83.

Sokal, R.R. and Rohlf, F.J. (1995). *Biometry (3rd ed.).* W.H. Freeman and Company, USA. Pp. 434-439.

Wijesinghe, Y. (1994). *Checklist of woody perennial plants of Sri Lanka*. National Science Foundation – Published by the Sri Lanka Forest Department. Pp. 1-201.

Appendix 1

Species list of the scrub vegetation in the lower Walawe basin irrigation extension area. (T = Tree, S = Shrub, H = Herb, C= Climber).

Taxa / Life form	Life form	Medicine (M) Timber (T)	Sinhala name
Acanthaceae			
Ecbolium ligustrinum	[H]		
Justicia procumbens	[H]	M	Mayani
Amaranthaceae			
Achyranthes aspera	[H]	M	Gas-karal-heba
Aerva lanata	[H]	M	Pol-pala
Alternanthera pungens	[H]		
Alternanthera paronychioides	[H]		
Alternanthera sessilis	[H]	M	Mukunu-wenna
Apocynaceae			
Carissa carandas	[S]		Maha-karamba
Carissa spinarum	[T]	M	Heen-karamba
Asclepiadaceae			
Calotropis gigantea	[S]	M	Ela-wara
Asteraceae			
Chromolaena odorata	[S]		Podisinghomaran
Vernonia cineria	[H]	M	Monara-kudumbiya
Xanthium indicum	[H]	M	Uru-kossa
Boraginaceae			
Cordia oblongifolia	[S]		
Cactaceae			
Opuntia dillenii	[S]		Katu-patok
Capparidaceae			
Capparis sepiaria	[S]		
Capparis zeylanica	[S]	M	Welangiriya
Crateva adansonii	[T]	M	
Convolvulaceae			
Evolvulus alsinoides	[H]	M	Visnu-kranthi
Cyperaceae			
Fimbristylis argentea	[H]		
Euphorbiaceae			
Croton sp.	[H]		
Croton bonplandianus	[H]		
Flueggea leucopyrus	[S]	M	Heen-katu-pila
Jatropha gossypiifolia	[S]		
Phyllanthus pinnatus	[S]		
Phyllanthus polyphyllus	[S]		Ambitilla
Fabaceae			
Bauhinia racemosa	[T]	M	Mayila
Cassia auriculata	[S]	M	Rana-wara
Cassia fistula	[T]	M/ T	Ehela
Cassia occidentalis	[H]	M	Peni-tora
Cassia tora	[H]	M	Peti-tora

Appendix 1 contd.

Taxa / Life form	Life form	Medicine (M) Timber (T)	Sinhala name
Crotalaria verrucosa	[H]		
Dichrostachys cinerea	[S]	M	Andara
Leucaena leucocephala	[T]		Ipil-ipil
Mimosa pudica	[H]	M	Nidi-kumba
Parkinsonia aculeata	[T]		
Prosopis juliflora	[T]		
Tephrosia purpurea	[H]	M	Pila
Lamiaceae			
Leucas zeylanica	[H]		Geta-tumba
Ocimum canum	[H]		Heen-tala
Ocimum gratissimum	[S]	M	Gas-tala
Orthosiphon thymiflorus	[H]		
Loganiaceae			
Strychnos potatorum	[T]	M	Ingini
Malvaceae			
Hibiscus micranthus	[S]		Bavila
Hibiscus vitifolius	[S]		Maha-epala
Sida acuta	[S]	M	Gas-bevila
Sida cordifolia	[S]	M	Heen-anoda
Periplocaceae			
Hemidesmus indicus	[C]	M	Heen-iramusu
Poaceae			
Aristida setacea	[H]		Tuttiri
Brachiaria sp.	[H]		
Brachiaria distachya	[H]		
Brachiaria reptans	[H]		
Brachiaria setigera	[H]		
Chloris montana	[H]		
Cynodon dactylon	[H]		Ruha
Dactyloctenium aegyptium	[H]		Putu-tana
Dimeria sp.	[H]		
Eragrostis tenella	[H]		
Eragrostis gangetica	[H]		
Paspalum conjugatum	[H]		
Polygalaceae			
Polygala javana	[H]		Tilo-guru
Pontederiaceae			
*Eichhornia crassipes**	[H]		Japan-jabara
Rhamnaceae			
Scutia myrtina	[S]		
Ziziphus mauritiana	[S]	M	Debara
Ziziphus oenoplia	[S]	M	Heen-eraminiya
Rhizophoraceae			
Cassipourea ceylanica	[S]		Pana
Rubiaceae			
Borreria hispida	[H]		Galkura
Canthium puberulum	[S]		
Catunaregam spinosa	[S]	M	Kukurman
Mitracarpus villosus	[H]		
Randia malabarica	[S]	M	Pudan

Appendix 1 contd.

Taxa / Life form	Life form	Medicine (M) Timber (T)	Sinhala name
Rutaceae			
Atalantia ceylanica	[S]	M	Yakinaran
Chloroxylon swietenia	[T]	T	Buruta
Citrus crenatifolia	[T]		
Limonia acidissima	[T]	M	Divul
Salvadoraceae			
Azima tetracantha	[S]		
Sapindaceae			
Cardiospermum halicacabum	[C]		Penela-wel
Solanaceae			
Solanum surattense	[S]	M	Ela-batu
Tiliaceae			
Grewia carpinifolia	[S]		
Verbenaceae			
Lantana camara	[S]	M	Hinguru

**Aquatic plants recorded because the sampling site was located near a seasonal tank.*
(Source: Jayaweera (1982), Wijesinghe (1994), Ashton *et al.* (1997), Senaratna (2001).