FLORISTIC COMPOSITION AND BIOMASS CARBON SEQUESTRATION OF BORELLA CEMETERY IN COLOMBO DISTRICT, SRI LANKA

K. A. J. M. Kuruppuarachchi
Department of Botany, The Open University of Sri Lanka
P.O. Box 21, Nawala, Nugegoda
10250, Sri Lanka
Email:kajmkuruppu@gmail.com

B. D. Madurapperuma
Department of Environmental Science and Management
Humboldt State University
Arcata, CA 95521, USA
Email:bdm280@humboldt.edu

ABSTRACT

Enhancement of green cover of highly congested cities with limited land areas will provide both environmental and social benefits. The Borella Cemetery in Colombo was established in the colonial era, which was more than 170 years old. A part of it is recognized as the biggest one of the six common wealth war cemeteries in Sri Lanka. Scientific record on floristic composition is merely available in this site and therefore we examine site-specific green cover in Borella Cemetery with spatial, species composition, crown cover, and growth performance. The tree cover of the area was determined by digitizing over a 2015 Google Earth image, and it was compared with estimated crown cover using in-situ data. The vegetation parameters such as, DBH, height, and crown radius were measured in each individual species. The aerial extent of the cemetery is 17.75 ha and the estimated green cover using GIS is 7.75 ha (44%). However, the ground estimated crown cover for the Borella Cemetery is 5.45 ha (31%). A total of 748 individuals belonging to 58 species, 50 genera and 25 families were recorded in the Borella Cemetery. The largest contribution for the green space is given by Peltophorum pterocarpum (19.6%), Terminalia arjuna (8.8%), Filicium decipiens (7.9%), Delonix regia (6.9%) and Ficus benjamina (5.5%). The total basal area of the species is 104 m^2/ha, and P. pterocarpum (12 m^2/ha) and F. benjamina (10 m^2/ha) contributed the highest. The DBH class distribution showed that the Salix tetrasperma is dominant at the middle DBH class between 100-149 cm and 150-199 cm, and the largest DBH classes (i.e. 300-499 cm and > 500 cm) are dominated by T. arjuna and Ficus religiosa respectively. The study recognized that total aboveground and belowground biomass stocks of Borella Cemetery are 1895 kg and 455 kg respectively. Hence, aboveground and belowground carbon amounts per hectare were recognized as 107 Kg C /ha, 22 Kg C/ha respectively. We observed trend of natural invasion of parasitic species "Ficus" into the cemetery flora and misguided management of trees: burning logs at the living trees for proving space for new buriers, dropping off thrash into tree holes, removing and burning leaf litter. We recommend training staff on legality and protection of trees, introducing indigenous trees with deep and less spreading root systems for the gaps.

Key words: Green space, Floristics, Crown cover, Crematory

Introduction

Green space in urban cities is vital since it reduces heat built up through natural air conditioning, makes aesthetic beauty, and increases carbon sequestration (Senanayake, 2013). Therefore, urban development plans generally associate with street tree planting and creation of city parks to provide valuable ecological and recreational services. In addition, it is useful to evaluate green space in urban cities recommended by the World Health Organization (WHO). For example, WHO standards suggested that the minimum amount of green space required per capita for healthy living is 9.5 m^2/person (Kuchelmeister, 1998). Although the UN (1991) figures indicate that in 1990 only 37% of the total population of developing countries was urbanized, it is predicted that by the year 2025 the proportion will be 61%. Rapid and uncontrolled urbanization in many developing countries are already having fundamental social and environmental consequences. The role of urban trees in ameliorating this situation might appear to be small at first thought. Yet urban forestry may provide third world town and city dwellers with significant environmental and material benefits.

Urban green space can be maintained by care and management of tree populations in urban settings for the purpose of improving the urban environment. Urban green space advocates the role of trees as a critical part of the urban infrastructure. Especially in congested cities of developing countries such as "Colombo", people illegally make slumps without proper planning and create critical social, cultural, health and environmental problems. Hence, city planners need to provide a huge emphasis on increasing green spaces that are parallel with concrete developments. The suitable ground to achieve these endeavors are to cover roadsides, parks, public places as well as buried grounds with trees without damaging physical constructions or urban people.

The Borella Cemetery is the largest buried ground in Colombo City that provides considerable green space with different tree species. The aerial view of the Colombo City shows that the Borella Cemetery harbors enormous green space. However, historic records on silvicultural practices and floristics information, such as tree-plated dates, species maintained etc. is lacking. Therefore, scientific investigations of urban green space in liaison with spatial and floristic scenario are useful to provide strategies for better and sustainable management of the cemetery green space for betterment of the urban environment. This study examines site-specific green cover in Borella Cemetery, Colombo, Sri Lanka in association with spatial, species composition, crown cover, and growth performance and accumulated biomass carbon stocks.

Sampling site

Borella Cemetery is the largest general cemetery located in the Western Province of Sri Lanka. It has a length of 1.67 kilometers. The GPS coordinates of Borella Cemetery is 6.909N and 79.88E (Fig. 1). The Borella Cemetery came into existence in 1866 and the first dead human being that was interred there was a widow of 55 years. Since then, thousands of dead persons from different social backgrounds, such as governors, politicians, government officials, artistes, literary personalities, military top brass etc., have buried or incinerated there. The total extent of the Borella Cemetery is about 48 acres, which has over 50,000 tombstones marking permanent graves. In addition to tombstones a large number of cenotaphs, which are monuments erected for people, were buried or cremated elsewhere. The funeral vaults are another type of monument that one comes across at the Borella Cemetery. The cemetery contains a Commonwealth War Graves Plot and a number of additional war graves dispersed around the site. Graves shown in the cemetery register to be in Plots 6B and 6C are within the War Graves enclosure, while all others are dispersed (www.fco.gov.uk; December, 2015).

The cemetery, at Borella, belongs to the Municipality of Colombo. The main area of the grounds is ripe with Christian symbols but people of others faiths have been buried here as well. The Borella Cemetery has three different sectors. One sector serves the funeral requisites of Buddhists, Hindus and Christians. This sector is run by the Colombo municipal council. The second sector is set apart for the dead of the Anglicans and is run by the Anglican Church. The third sector is set apart for the Roman Catholics, which is maintained by the Roman Catholic Church. There is another eye-catching section in the Borella Cemetery known as the Commonwealth War Cemetery. This part of the graveyard contains the remains of those who fought in the Second World War (1939-1945) and made the supreme sacrifice. Several monuments for top brass of the three services in several countries, who died in the war, were interred here. Trees are settled besides main roads, cross road as well as spaces between graves.

Figure 1. Goodle Earth image showing the green cover of Borella Cemetery

Materials and methods

This study surveyed green cover in Borella Cemetery Sri Lanka, which adapted two field approaches as top down and bottom up approaches. A GIS application was adopted for estimating green cover spatially as a top-down approach, whereas a filed survey was carried out for floristic studies as a bottom up approach. The tree cover of the area was determined by digitizing over a Google Earth image and it compared with estimating crown cover using in-situ data. The vegetation parameters such as, DBH, height and crown radius were measured in each individual plant. The crown radius was used to calculate crown cover assuming the tree crown is circular in shape. GPS coordinates for each block of the park were taken to create a boundary and to assess the site-specific green cover. We documented tree health such as, abnormal growths, dead trees, diseased trees, parasitic invasion and plant-animal interactions.

Aboveground and belowground biomass and C stocks

The field inventory survey was conducted from June to December 2015. Given a lack of standard approach and available allometric equations to estimate carbon stock in Sri Lanka, pan-tropical allometric equations for tropical natural forests were used (Mattsson et al., 2013; Kuruppuarachchi et al., 2015).

Aboveground biomass was calculated from Diameter at Breast Height (DBH) using standard biomass equations (Anderson and Ingram, 1998; Brown et al., 1989). Using area specific correlation factors, belowground biomass and above/belowground C stock were calculated. Two internationally accepted biomass regression equations (Anderson and Ingram, 1998; Brown et al., 1989) were applied to calculate aboveground biomass stock. Brown et al. (1989) has developed different biomass regression equations based on annual rainfall. Mean annual rainfall of Colombo City is ca. 2,525 mm could be regarded as tropical monsoon climate (Kuruppuarachchi et al., 2013). Thus the biomass regression equation developed for tropical moist forests with annual rainfall between 1500 - 4000 mm, B = exp (-2.134 + 2.53 x In D); R^2 = 0.97 (Anderson and Ingram, 1998) was adapted to determine of above-ground biomass stocks of trees of Borella Cemetery, where B and D are biomass and DBH, respectively. According to IPCC guidelines for national greenhouse gas inventories (IPCC, 2006), aboveground C stock of tropical forests is calculated as Biomass x 0.49 (Hughes et al., 2000).

Aboveground to belowground biomass ratio, and its C ratio for tropical rain forests (annual rainfall > 2000 mm) and moist deciduous forests (annual rainfall between 1000–2000 mm) were found to be 0.2 (Fittkau and Klinge, 1973; Mokany et al., 2006).

Therefore, belowground biomass or C equals aboveground biomass or C x 0.2

Results and discussion

The results of the study presented under two sections namely: floristic composition, and above/below ground carbon stocks of the study area.

Floristic composition

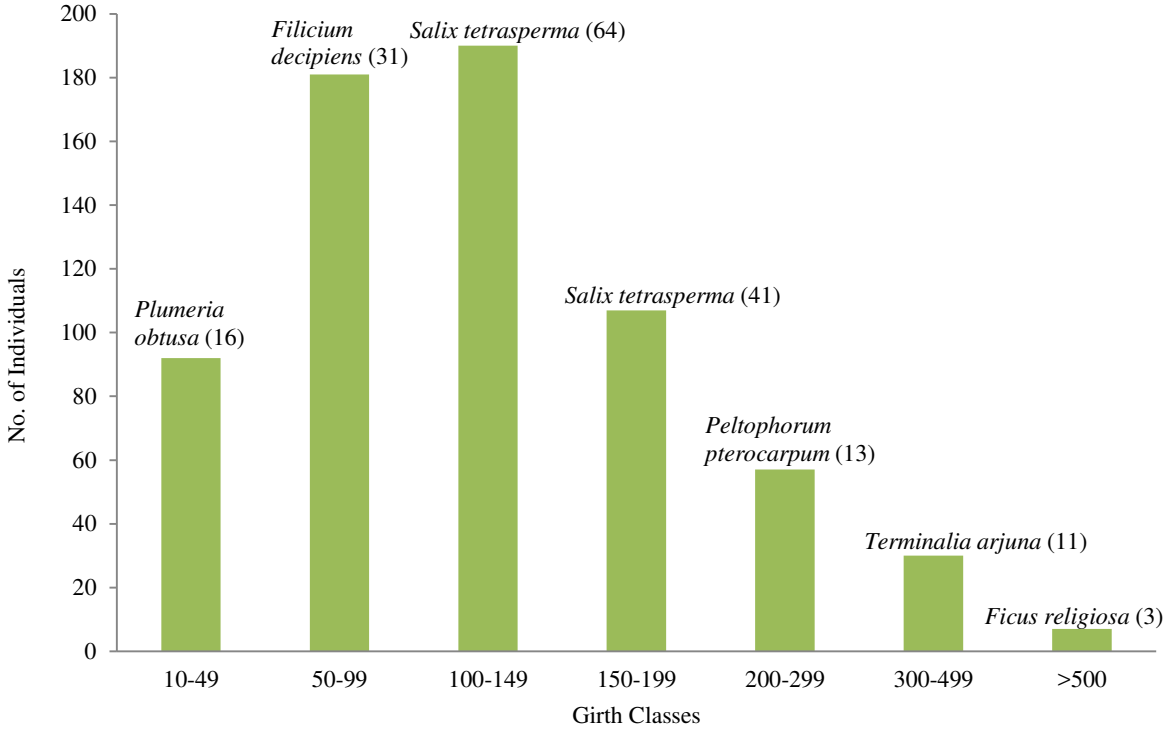
The study encountered 748 individuals belonging to 58 species, 50 genera and 25 families in the Borella Cemetery. The leading family was recognized as Fabaceae, which counted 151 individuals belonging to 11 species. The most dominant species in Fabaceae was *Peltophorum pterocarpum* (Table 1).

The total basal area of the species is 104 m^2/ha, and *Peltophorum pterocarpum* (12 m^2/ha) and *Ficus benjamina* (10 m^2/ha) contributed the highest. The floristic study of Viharamahadevi Park in Colombo conducted by Madurapperuma and Kuruppuarachchi (2015), recorded that the species with the highest basal area was *Ficus* species (89.2 m^2) followed by *Pterocarpus marsupium* (28.5 m^2), *Tabebuia rosea* (26.5 m^2), *Cassia fistula* (16.9 m^2), and *Mangifera indica* (15.1 m^2). It is showed that *Pterocarpus* and *Ficus* species are dominant in the cemetery. The DBH class distribution showed that the *Salix tetrasperma* dominate at the middle DBH class between 100-149 cm and 150-199 cm and the largest DBH classes (i.e. 300-499 cm and > 500 cm) were dominated by *Terminalia arjuna* and *Ficus religiosa* respectively (Fig.1).

Table 1. The first ten leading families with species richness and dominance at Borella Cemetery, Colombo

Family	Species Richness	No. of Individuals	Dominant Species with individuals
Fabaceae	11	151	*Peltophorum pterocarpum* (86), *Delonix regia* (25)
Moraceae	5	50	*Artocarpus heterophyllus* (37)
Arecaceae	4	58	*Cocos nucifera* (27), *Wodyetia bifurcata* (20)
Anacardiaceae	3	63	*Mangifera indica* (17)
Combretaceae	3	36	*Terminalia arjuna* (17), *Terminalia catappa* (17)
Meliaceae	3	25	*Azadirachta indica* (17)
Myrtaceae	3	21	*Syzygium cumini* (5)
Sapindaceae	3	7	*Filicium decipiens* (61)
Apocynaceae	2	36	*Plumeria obtusa* (33)
Tiliaceae	2	7	*Berrya cordifolia* (5)

Figure 1. Girth class distribution of trees in the Borella Cemetery. The species with the highest number of individuals in each girth class is shown above the bar graph



Aboveground and belowground carbon stocks

Trees in urban areas provide a valuable ecosystem service of reducing the effect of greenhouse gases. Trees store carbon in their structure and sequester additional carbon in the process of growth and act as a sink for carbon dioxide. Urban forests are useful not only for storing and sequestering large amounts of carbon but also for providing other environmental benefits such as, storm water runoff mitigation, energy saving through shading and air pollution reduction, and urban aesthetic enhancement.

Tropical trees contribute to high efficiency of biomass and carbon sequestration. It is very important to adapt proper silvicultural practices and plant selection in urban setup to accumulate efficient biomass carbon storage to mitigate the impacts of climatic change. Hence, this study provides special attention to explore biomass carbon amounts in the study area. The total aboveground biomass stock of Borella Cemetery is 1894.9 kg and the belowground biomass stock is 454.78 kg. The aboveground carbon amount per hectare was recognized as 106.76 (t kg/ha) and belowground carbon stock per hectare is 22.4 (t kg/ha.). When compared to aboveground and belowground biomass in a similar study at the Open University premises (50 (t kg/ha) and 10 (t kg/ha) respectively), Borella Cemetery showed a comparatively high amount of biomass accumulation (Wijerathne et al., 2013). Most contributed tree species for carbon accumulation were *Peltophorum pterocarpum*, *Ficus benjamina*, *Salix tetrasperma*, *Ficus religiosa*, *Filicium decipiens*, *Terminalia arjuna*, *Tectona grandis*, *Albizia saman* and *Delonix regia* (Table 2).

Green cover

For this task, top down approaches were adapted. Urban green spaces were extracted from Satellite view of Google Earth in 2015 using screen-digitizing techniques. The aerial extent of the cemetery is 17.75 ha and the estimated green cover using GIS is 7.75 ha (44%). However, ground estimated crown cover for the Borella Cemetery is 5.45 ha (31%). This difference may be due to ground-truthing errors and aerial digitizing errors. Similar to the study of Viharamahadevi Park, Colombo recognized that Ca. 59% of the park was covered by the tree crown cover (Madurapperuma and Kuruppuarachchi, 2015). A proper management of tree flora of Borella Cemetery can be upgraded to green cover. According to the present study, the largest contribution for the green space is given by *Peltophorum pterocarpum* (19.6%), *Terminalia arjuna* (8.8%), *Filicium decipiens* (7.9%), *Delonix regia* (6.9%) and *Ficus benjamina* (5.5%). When comparing the species contribution for high green cover in Viharamahadevi Park, which is in proximity to Borella Cemetery Colombo (Madurapperuma and kuruppuarachchi, 2015) the species composition is different. For example, the large green spaces are given by *Tabebuia rosea* (2.4%), *Terminalia catappa* (2.2%), *Cassia fistula* (2.1%), *Mangifera indica* (2.0%) and *Terminalia arjuna* (2.0%). The comparison clearly shows that contributions for the green space by two major land use patterns in urban setup of Colombo are different.

We observed the trend of the natural invasion of parasitic species "*Ficus*" into the cemetery flora. The similar trend was observed for Viharamahdevi Park, Colombo (Madurapperuma and Kuruppuarachchi, 2015). According to Ranwala (2012) studies, the above semi-parasitic species was invaded in streets of Colombo City especially at very old exotic tress such as *Peltophorum pterocarpum* and *Samanea saman*. As stated by Jim and Zhang (2013), *Ficus* species were highly invaded into urban flora

especially in tropical land uses. It can be concluded that the invasion of parasitic tress such as *Ficus* would change the urban floristic natures of tropical cities like Colombo in the near future.

Table 2. The most contributed species for biomass carbon sequestration at the Borella Cemetery, Sri Lanka in 2015

Tree species	Aboveground Biomass	Aboveground C stock	Belowground C stocks
Peltophorum pterocarpum	169.6302	83.1188	19.9485
Ficus benjamina	135.4483	66.3697	15.9287
Salix tetrasperma	116.5165	57.0931	13.7023
Ficus religiosa	110.3245	54.0590	12.9742
Filicium decipiens	85.0941	41.6961	10.0071
Terminalia arjuna	84.1231	41.2203	9.8929
Tectona grandis	28.8673	14.1450	3.3948
Albizia saman	23.7053	11.6156	2.7877
Delonix regia	22.3038	10.9289	2.6229
Tabebuia rosea	19.1049	9.3614	2.2467
Artocarpus heterophyllus	13.1257	6.4316	1.5436
Terminalia catappa	12.8760	6.3093	1.5142
Mesua ferrea	9.4427	4.6269	1.1105
Leucaena leucocephala	7.8085	3.8261	0.9183
Cocos nucifera	7.1010	3.4795	0.8351
Swietenia mahagoni	6.5718	3.2202	0.7728
Mangifera indica	5.4589	2.6749	0.6420
Alstonia scholaris	4.7444	2.3247	0.5579
Pericopsis mooniana	3.6636	1.7951	0.4308
Acacia melanoxylon	2.8522	1.3976	0.3354
Chukrasia tabularis	2.6163	1.2820	0.3077
Pinus caribaea	2.4270	1.1892	0.2854
Caryota urens	2.3694	1.1610	0.2786
Plumeria obtusa	2.3267	1.1401	0.2736
Terminalia chebula	2.2480	1.1015	0.2644
Azadirachta indica	2.0583	1.0086	0.2421

Management and plant selection

We interviewed cemetery staff members and observed the silvicultural practices for caring for trees in the cemetery. The Borella Cemetery has three different sectors. One sector serves the funeral requisites of Buddhists, Hindus and Christians. This sector is run by the Colombo Municipal Council. The second sector is set apart for the dead of the Anglicans and is run by the Anglican Church. The third sector is set apart for the Roman Catholics, which is maintained by the Roman Catholic Church. There is another section in the Borella Cemetery, known as the Commonwealth War Cemetery. This part is managed under Royal Botanical Garden of Sri Lanka and managed significantly for maintaining recreational value as well as promoting. We observed that different parts of the cemetery are managed by different authorities without much concern on tree cover. Some field laborers are working in the cemetery removing trees from the cemetery to get facilities for expansion of buried ground area for new dead bodies. The misguided management of trees, such as, burning logs around the living trees for providing space for new buriers, dropping off thrash into tree holes, and removing and burning leaf litter, were observed. We recommend training staff on the legality and protection of trees, introducing indigenous trees with deep and less spreading root systems for the gaps (Figure 2). Selecting suitable plants for appropriate locations is one key aspect on landscaping specially in urban areas, which most landscape designers of Sri Lanka fail to tackle. Placing plants in the most suitable locations allow them to facilitate optimum biological and ecological functioning (Silva et al., 2012). We recommend the following best management practices for trees in the cemetery premises: putup naming boards for plants on common and scientific name, origin and habitat preference, soil condition, growth forms and growth rate, whether evergreen or deciduous, tree architectures such as height, branching pattern, stem type and nature, root depth and distribution, canopy shapes and size, bark shape and roughness, recreational value, flowers and nature of fruits, uses, nature of interactions with animals. To select suitable plants for a certain location is a complex task

because it needs to consider multiple factors simultaneously and the decision maker needs to have sufficient multidisciplinary knowledge. For such cemetery landscapes, we believe that the introduction of plants with recreational, effective wild habits will be useful. In addition to that, more attention should be paid on root morphology and spreading nature.

Figure 2. Mismanagement and poor silvicultural practices (i.e. burning) in the Borella Cemetery, Colombo

Conclusion

This floristic survey found that only 37.5% of the area is occupied by trees. We highly recommend planting native species with high carbon sequestration potential. In addition, recreational, shade-providing plants with bird attraction will be recommended. More attention should be paid on root morphology and spreading nature to protect existing tombstones marking permanent graves. Cemetery management should place plants in the most suitable locations to allow them to facilitate optimum biological and ecological functioning and sustainable care for trees. We observed a misguided management of trees and cemetery flora by burning logs around the living trees for providing space for new buriers, dropping off thrash into tree holes, and removing and burning leaf litter. The cemetery field management staffs are not much aware of plant species and sustainable silvicultural practices, and therefore formal training for the staff would be beneficial for proper maintenance of tree flora in the cemetery.

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References

Anderson, J.M. & Ingram, J.S.I. (1998). *Tropical Soil Biology and Fertility: A Handbook of Methods*, 2nd ed., CABI international, UK.

Brown, S.A., Gillespie, J.R. & Lugo, A.E. (1989). Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science, 35, 881-902.

Fittkau, E.J. & Klinge, N.H. (1973). On biomass and tropic structure of the central Amazonian rainforest ecosystem. Biotropica, 5, 2-14.

Hughers, R.F., Kauffman, J.B. & Jaramillo-Luque, V.J. (2000). Ecosystem-scale impacts of deforestration and land use in a humic tropical region of Mexico. *Ecological Applications*, 10, 515-527.

IPCC (2006). IPCC Guidelines for National Greenhouse Gas Inventories. In H.S. Eggleston, L. Buendia, K. Miwa, T. Ngara & K. Tanabe (Eds.), IPCC National Greenhouse Gas Inventories Programme Institute for Global Environmental Strategies, Japan.

Jim, C.Y. & Zhang, H. (2013). Species diversity and spatial differentiation of old-valuable trees in urban Hong Kong. Urban Forestry & Urban Greening, 12, 171-182.

Madurapperuma, B.D. & Kuruppuarachchi, K.A.J.M. (2015). Crown/tree cover of Viharamahadevi Park, Colombo, The Institute of Biology Sri Lanka, Proceedings of 35th Annual Sessions, 25th September, 2015, Colombo, ISSN: 2012-8924: 18.

Mattsson, E., Ostwald, M., Nissanka, S.P. & Marambe, B. (2013). Homegardens as a multi-functional land-use strategy in Sri Lanka with focus on carbon sequestration. Ambio, 42, 892-902.

Mokany, K., Raison, J.R. & Prokushkin, A.S. (2006). Critical analysis of root: shoot ratios in terrestrial biomes. Global Change Biology, 12, 84-96.

Kuchelmeister, G. (1998). Urban forestry: present situation and prospects in the Asia and Pacific region, FAO Asia-Pasificforestry sector outlook study. Food and Agriculture Organization of the United Nations, Forestry Policy and Planning Division, Rome.

Kuruppuarachchi, K.A.J.M., Seneviratne G. & Madurapperuma, B.D. (2015) Forest carbon sequestration and its control: A comparison between a dry zone tropical forest and an arboretum. International Journal of Agriculture, Forestry and Plantation, 1 (35-44).

Kuruppuarachchi, K.A.J.M. & Seneviratne, G. (2013) Carbon sequestration controlled by climatic, plant and soil parameters: Their dynamics and control of selected Sri Lankan forests. Scholar's Press.

Ranwala, S.M.W. (2012). Figs (Ficus spp.) dispel the splendor of Colombo streets: A case study. Proceedings of the 32nd Annual Symposium, Institute of Biology, Sri Lanka, 6th July, 2012.

Silva, D.A.M.S.,Yakandawala. K., Jayathilaka, H.A.C.K. & Perera, K.D.K.A. (2012). Plant selection database for landscape designers, SAITM Research Symposium on Engineering Advancements, Sri Lanka: 93-96.

Senanayake, I.P., Welivitiya, W.D.D.P. & Nadeeka, P.M. (2013). Urban green spaces analysis for development planning in Colombo, Sri Lanka, utilizing THEOS satellite imagery – A remote sensing and GIS approach. Urban Forest & Urban Greening,12, 307-314.

Wijerathna, D., Nimanthika W.J., Kuruppuarachchi, K.A.J.M. & Madurapperuma, B.D. (2013). Floristic diversity of OUSL premises, Proceedings of 33nd Annual Sessions of the Institute of Biology of Sri Lanka, 27th September, 2014 Sri Lanka ISSN 2012-8924, P 20.