International Journal of Sustainable Built Environment (2016) xxx, xxx–xxx

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Gulf Organisation for Research and Development

International Journal of Sustainable Built Environment

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Original Article/Research

Rehabilitating a landfill site of lowland tropical landscape into an urban green space: A case study from the Open University of Sri Lanka

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Received 8 January 2016; accepted 13 September 2016

Abstract

This study examines vegetation, carbon sequestration, and spatial and temporal changes of green space at the premises of the Open University of Sri Lanka (OUSL). The primary objective of this study is to examine floral diversity of the OUSL premises that was rehabilitated from a landfill site and to determine suitable trees for landfill sites based on growth performance and biomass carbon stocks. The girth and height of plants $\geqslant 5$ cm dbh were measured to estimate biomass carbon stocks of each individual tree. GPS coordinates of each individual tree were taken for spatial mapping. Urban green spaces were extracted from Satellite view of Google Earth for a decade using screen digitizing techniques. A total of 722 individuals, comprising 95 plant species belonging to 75 genera and 33 families, were recorded. Of the total species 45% were native species. The above-ground and below-ground biomass were estimated to be 50 (t C/ha) and 10 (t C/ha) respectively. These results are comparable with above-ground biomass and below-ground biomass in the dry zone forest (60 and 17 (t C/ha) respectively). The study recognized that *Terminalia catappa*, *Filicium decipiens*, *Mangifera indica*, *Cassia bacillaris* and *Tabebuia rosea* species grow well in such landfill with effective carbon accumulation, and the species list presented in this paper will provide useful information that will help city planners to maximize biomass carbon sequestration by choosing optimal plants for landscaping in landfill sites.

Keywords: Landfill; Green space; Carbon stock; Tree planting

1. Introduction

Urban cities are becoming more vibrant, due to centralization of social and economic endeavors. Consequently, natural habitats, such as wetlands, are utilized for infrastructure development by creating landfills in suburban areas. Although this transformation is inevitable, urban forests and green infrastructures make cities cleaner and healthier, raise the standard of the environment and improve esthetic beauty. Green spaces provide ecological services, such as ambient water quality improvement, by filtering urban water runoff, building energy conservation, and air pollution and greenhouse gas reduction (Nowak and Greenfield, 2012). It is predicted that more than 80% of the world's urban population will be gathered in developing countries by 2030 (Beardsley et al., 2009). In

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Peer review under responsibility of The Gulf Organisation for Research and Development.

http://dx.doi.org/10.1016/j.ijsbe.2016.09.001
2212-6090/

fact, a small island in the south Asian region, namely Sri Lanka, harbored 20.3 million people in 2012 within a land area of 65,610 km^2 (UNDP, 2012). The population density in large cities in Sri Lanka is comparatively higher than in rural areas. The population density in the Colombo District was 3438 persons/km^2 in 2012, while it was 771 persons/km^2 in the Kalutara District, and both districts were located within the Western Province of Sri Lanka (Department of Census and Statistics in Sri Lanka, 2012a). A tremendous increase in population was observed in Colombo City, especially in the 20th Century. This population growth is mainly due to human migration to the capital from rural areas (RMIT University, 2014). In addition, a large number of people who reside outside the city travel from their residences to Colombo on a daily basis for work and to access services such as health, education, etc. It has been estimated that the daytime population in Colombo is more than twice the number of permanent residents (RMIT University, 2014).

Colombo, the lowland coastal capital city of Sri Lanka has been recognized as the most polluted city in Sri Lanka (Liyanage, 2003; Senanayake et al., 2013). The urban sprawl in Colombo City has led to an increase in landfills in the lowland marsh areas, resulting in seasonal flooding. Changes in water level have caused retention of pollutants in the marsh resulting in invasion of exotic aquatic plants such as, *Annona glabra* and *Eichchornia crassipes*. Consequently, marshes were considered as wastelands due to abundance of aquatic invasive plants, which resulted in reclamation of marsh through landfill in the urban cities. This transformation has caused dumping of industrial and domestic wastes (e.g. paper, plastics, rags, organic materials and sewage) into swamps, as landfilling materials in Colombo and its suburbs. This practice causes environmental consequences, such as ground water pollution due to toxic substances, such as, mercury, arsenic, cadmium, PVC, solvents, acids and lead (CEA, 1994; McLean and Bledsoe, 1992). In addition, emission of potent greenhouse gases (e.g. methane and nitrous oxide) is higher in newly filled marsh areas.

The urban planning of Colombo City is now being integrated with sustainable green space planning resulting in the beautification project of Colombo City after 30 years of civil conflict. This project aims to improve environmental quality of the city, while making better quality and living standards of urban dwellers. According to the findings of Senanayake et al. (2013), green space accounted for 24% of the Colombo Municipal Council area. The green urban space in Colombo City is comparatively higher than the green urban space in European Cities (Baycan-Levent et al., 2009). Nevertheless, a gradual declining trend of green cover in Colombo City was highlighted as 35.7%, 32.2%, 31.5% and 22.2% in 1956, 1982, 2001 and 2010 respectively (Wickramasinghe et al., 2013). A top down approach adopted by Madurapperuma & Kuruppuarachchi (2015a) to estimate the green cover in Colombo City in 2015 was 29% green space, which resulted in an increment of green space estimated by Senanayake et al. (2013) and Wickramasinghe et al. (2013) (i.e. 24% and 22% respectively).

It is questionable whether Sri Lankan urban landscape expertise would have practiced any scientific criteria to select trees for planting urban systems. Even we could not find any type of tree planting history records or data management systems available in responsible authorities such as, Urban Planning Authority of Sri Lanka. Placing plants in most suitable locations allow them to establish better, and facilitates optimum biological and ecological functioning. When introducing plants for urban development, it primarily concerns the growth rate of species with less priority for important factors, such as habitat, climatic zone in which the plant originated, preferred soil conditions, light preference, plant height, branching pattern, stem type, trunk shape, bark roughness, canopy size and shapes, nature of thorns, root distribution and depth, flower type, fruiting, leaf size, deciduous /evergreen nature, and economic and ecological uses (Silva et al., 2012). Therefore, it needs to consider multiple factors simultaneously and decision makers need to have sufficient multidisciplinary knowledge. Selecting suitable plants for appropriate locations is one key aspect in landscaping projects, where most landscape designers fail to tackle (Silva et al., 2012).

Our study site is located in the central campus of the Open University of Sri Lanka (OUSL), which is in proximity to the southeast boundary of Colombo City. OUSL was built in 1980 from a landfill marsh site (nearly 38 ha), which was characterized by a low-lying polluted water runoff site that was inundated with a high flood water from "Diyawanna Oya" (Kotte Canal or Kirulapane Canal), a man-made water canal made during the colonial era. The canal system, which is in and around Colombo-Sri Jayewardenepura area, is currently in such an environmentally deteriorated condition, due to rapid development and urbanization of the area. The quality of water and habitat in most of the areas are influenced by industrial and public effluent discharge to the canal system (Perera et al., 2012). In rainy seasons, this area is subject to the inundation with canal water, due to high water level of the canal. During short dry spells more, the study site [(i.e. February to early April)] is subjected to sudden dry offs. The study site is recognized as bog and half bog soils, which are characterized by high soil pH, low soil organic carbon and high moisture content in soil resulting in the fluctuation of water retention capacity. In addition, some of the gaseous and metallic constituents in the soil inhibit plant growth.

Landscape management was conducted by tree-planting programs at the OUSL premises during 1984, 1990, 2000 and 2008. In the beginning, a selection of tree species for rehabilitation of the landfill site was carried out without adequate scientific basis. However, in the latter stage, suitable tree species for the OUSL premises were recommended by the Department of Botany at OUSL. When selecting tree species for the OUSL landfill site, two main

Please cite this article in press as: Madurapperuma, B.D., Kuruppuarachchi, K.A.J.M. Rehabilitating a landfill site of lowland tropical landscape into an urban green space: A case study from the Open University of Sri Lanka. International Journal of Sustainable Built Environment (2016), http://dx.doi.org/10.1016/j.ijsbe.2016.09.001