ESTIMATION OF CARBON SEQUESTRATION RATE OF URBAN PARK WITH LINEAR AND CURVILINEAR DESIGN LANDSCAPE SETTING

OTHMAN, R.[1*] – SUID, S.[1] – MOHD NOOR, N. F.[1] – BAHARUDDIN, Z. M.[1] – HASHIM, K. S. H. Y.[2] – LUKMAN HAKIM MAHAMOD, L. H.[3]

[1]*International Institute for Halal Research and Training (INHART)*
Department of Landscape Architecture, Kulliyyah of Architecture and Environmental Design (KAED), International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia

[2]*Department of Urban & Regional Planning, Kulliyyah of Architecture and Environmental Design (KAED), International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia*

[3]*Department of Quantity Surveying, Kulliyyah of Architecture and Environmental Design (KAED), International Islamic University Malaysia, 53100 Kuala Lumpur, Malaysia*

[*]*Corresponding author*
e-mail: rashidi@iium.edu.my; phone: +60-126-644-772; fax: +60-361-964-864

(Received 24th Jan 2019; accepted 3rd May 2019)

Abstract. The need for urban parks became greater as cities expanded and the urban population rapidly grew. Therefore, having an urban park can facilitate a reduction in GHG emissions by alleviating some of the impacts of this dense development. Trees in the urban parks are an important factors reducing the amount of carbon dioxide accumulated in the urban area. The carbon sequestration rate was calculated with biomass equations, using field data collection, measurements and survey data analysis. This study aimed to calculate, predict and compare carbon sequestration rate of plant materials with linear and curvilinear design landscape setting. The decisive outcome of this study are the optimization of carbon sequestration rate by selecting the right plant material specifications with suitable landscape design setting. The findings revealed that the curvilinear design landscape setting sequesters more carbon per m^2 than linear design landscape setting. Plants with bigger girth and larger quantities contribute to sequestering greater carbon compared to smaller girth and fewer trees. These findings will become a green practice approached towards building a sustainable environment with better design solutions.
Keywords: *carbon stock, air pollution, green technology, phytosequestration, urban landscape design*

Introduction

Urban parks have been viewed as an important component of the urban fabric that benefits for community development by providing space for recreation and leisure. From a social perspective, green spaces provide health and a range of recreational and psychological benefits, create environmental awareness and encourage positive actions toward climate change (Pataki et al., 2011; Demuzere et al., 2014). A study conducted in Helsinki, Finland, indicated that nearly all (97%) city residents participate in some outdoor recreation during the year (Sadeghian and Vardanyan, 2013). Thus, the need for urban parks become greater as cities expanded and the urban population rapidly grew. According to Department of Statistics Malaysia (2011), in tandem with Malaysia's rapid development, the proportion of urban population increased to 71.0 percent in 2010 and this growth is expected to continue as total population increased over the years. One of the state in Malaysia with a high level of urbanization was Selangor with 91.4 percent.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

A significant increase in the urban population in a short span of time creates various problems, especially environmental problems. Therefore, under the Paris Agreement, in accordance with decisions of the United Nations Framework Convention on Climate Change (UNFCCC) (Biennial Update Report to the UNFCCC, 2015), Malaysia has committed to reducing its greenhouse gas (GHG) emissions intensity of GDP by 45% by 2030 relative to the emissions intensity of GDP in 2005. Alternative ways that have been further studied to reduce these greenhouse effects in the atmosphere is through carbon sequestration technology (Wiedman et al., 2007). Carbon sequestration is the process through which CO_2 from the atmosphere is absorbed naturally through photosynthesis by the plants (Pandya et al., 2013). Trees in urban parks play an important role in the urban environment by sequestering a substantial amount of carbon dioxide from the atmosphere. Urban trees in air pollution reduction, mentioning their effects in terms of intercepting atmospheric particles and absorbing various gaseous pollutants (Yin et al., 2011). In both neighborhoods, the trees with the highest carbon stocks and sequestration rates are generally located along the main roads and in public parks (Velasco et al., 2016). Although the impacts of urban trees thus have been studied rather extensively, at least through urban quality models, there is a suggestion that research specifically on urban parks has been limited so far (Pataki et al., 2011; Yin et al., 2011). Hence, this study aimed to estimate, predict and compare carbon sequestration rate produced by plant materials through linear and curvilinear design landscape setting at two selected urban parks in Selangor. The chosen case studies for this research is differentiated between two urban parks with different landscape settings, which are linear and curvilinear design landscape setting.

Materials and Method

The first method of this study used field data collection through site inventory and analysis to estimate total carbon sequestration rate Two selected urban parks in Selangor with different landscape design settings were chosen as site studies which are Putra Heights Linear Park (3°01'13.1"N 101°34'31.7"E, linear design landscape setting) and Subang Jaya Urban Forest Park (3°03'19.0"N 101°34'15.0"E, curvilinear design landscape setting) (*Fig. 1*).

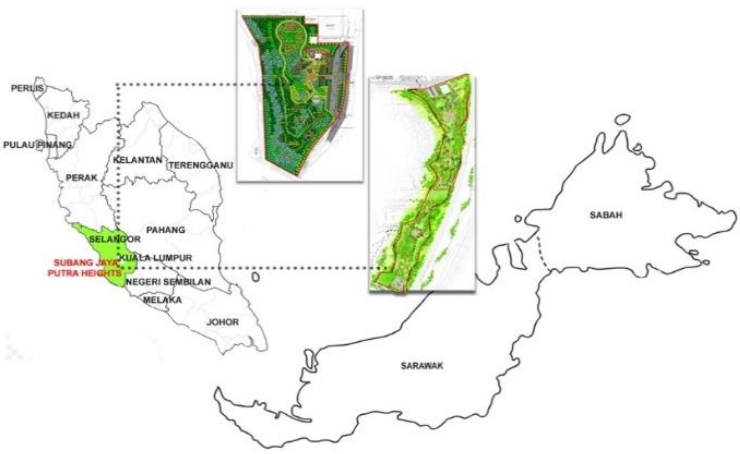

Figure 1. *Base map showing Subang Jaya Urban Forest Park with curvilinear design (left) and Putra Heights Linear Park (right), Selangor, Malaysia*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

Both sites were selected for inventory and analysis process in acquiring data needed. Besides, for calculating the total green area and built up area of the selected site studies, the site plan for both urban parks was obtained from the authorities. Whereas, for calculating the exact numbers of trees and detailed plants specifications on site, bill of quantities is also collected from the authorities. The data needed in this study including plants specifications such as overall plant's heights, trunk diameter, plant's age, plant's quantity and area of the plants (for climbers and turfing). Next, the current carbon sequestration rate (CSR) on every planting species was calculated using the carbon calculator formula stated in *Table 1*.

Table 1. *The formula to calculate carbon sequestration rate (CSR)*

CSR formula for tree and shrub	CSR formula for turf, climber and groundcover
Total Green Weight (TGW): $0.25D^2H$ (1.2)	Total Dry Weight (TDW): 0.56 x area (m^2)
Total Dry Weight (TDW): TGW x 0.725	Total Carbon Weight (TCW): TDW x 0.427
Total Carbon Weight (TCW): TDW x 0.5	Total CO_2 Weight (TCO_2W): TCW x 3.6663
Total CO_2 Weight (TCO_2W): TCW x 3.6663	D = Diameter of the trunk; H = Height of the tree

Results and Discussions

Carbon sequestration rate at Putra Heights Linear Park (linear design landscape setting)

Fig. 2 showed the planting plan at Putra Heights Linear Park which depicted linear design landscape planting. *Tables 2-4* portrayed the amount of CO_2 that sequestered by different types of plant species categorized under tree, shrub and turfgrass at Putra Heights Linear Park.

Figure 2. *Planting Plan of Putra Heights Linear Park located in Selangor, Malaysia*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

Table 2. *Carbon sequestration rate produced by trees at Linear Park, Putra Heights*

NO	SPECIES	OVERALL HEIGHT (feet)	TRUNK DIAMETER (Inch)	QUANTITY (Nos)	AGE	tCO_2e /unit	TOTAL CO_2e (kg)
1.	*Agathis borneensis*	9.84	1.57	110	1.6	0.0027	301.57
2.	*Cratoxylum cochinchinense*	13.12	1.97	55	2	0.0046	253.23
3.	*Eucalyptus deglupta*	9.84	1.97	55	2	0.0035	189.93
4.	*Eugenia grandis*	9.84	1.57	25	1.6	0.0027	68.54
5.	*Fagraea fragrans*	9.84	1.57	16	1.6	0.0027	43.86
6.	*Filicium decipiens*	9.84	1.77	50	1.8	0.0031	154.87
7.	*Gardenia carinata*	9.84	1.57	165	1.6	0.0027	452.36
8.	*Hopea odorata*	13.12	1.77	325	1.8	0.0041	1342.19
9.	*Lagerstroemia langkawiensis*	9.84	1.57	50	1.6	0.0027	137.08
10.	*Melaleuca leucadendron*	13.12	1.97	60	2	0.0046	276.26
11.	*Michelia champaca*	11.48	1.57	65	1.6	0.0032	207.90
12.	*Pongamia pinnata*	9.84	1.57	30	1.6	0.0027	82.25
13.	*Samanea saman*	22.97	4	131	4	0.0166	2176.79
14.	*Tristaniopsis whiteana*	9.84	1.57	46	1.6	0.0027	126.11
15.	*Xanthostemon chrysanthus*	9.84	1.57	25	1.6	0.0027	68.54
16.	*Cynometra cauliflora*	9.84	1.57	28	1.6	0.0027	76.76
17.	*Garcinia mangostana*	9.84	1.57	21	1.6	0.0027	57.57
18.	*Mangifera indica*	9.84	1.57	43	1.6	0.0027	117.89
19.	*Nephelium lappaceum*	9.84	1.57	37	1.6	0.0027	101.44
20.	*Phyllanthus acidus*	9.84	1.57	32	1.6	0.0027	87.73
21.	*Azadirachta exelsa*	9.84	1.57	38	1.6	0.0027	104.18
22.	*Cinnamomum iners*	9.84	1.57	35	1.6	0.0027	95.95
23.	*Cratoxylum formosum*	9.84	1.57	38	1.6	0.0027	104.18
24.	*Mesua ferrea*	9.84	1.57	53	1.6	0.0027	145.30
25.	*Acacia auriculiformis*	32.81	10	20	10	0.0356	712.05
26.	*Dyera costulata*	32.81	10	13	10	0.0356	462.83
27.	*Hevea brasiliensis*	32.81	10	42	10	0.0356	1495.31
28.	*Koompassia excelsa*	32.81	10	7	10	0.0356	249.22
							9691.89

Table 3. *Carbon sequestration rate produced by shrubs at Linear Park, Putra Heights*

NO	SPECIES	OVERALL HEIGHT (feet)	TRUNK DIAMETER (Inch)	QUANTITY (Nos)	AGE	tCOe /unit	TOTAL COe (kg)
1	*Eugenia oleana*	3.28	1	600	1	0.0006	355.92
2	*Murraya paniculata*	1.48	0.5	5000	1	0.0001	334.58
							690.49

Table 4. *Carbon sequestration rate produced by turfgrass at Linear Park, Putra Heights*

NO.	SPECIES	AREA (M^2)	QUANTITY	TOTAL COe (kg)
1	*Axonopus compresus*	96300	96300	84430.00
2	*Zoysia matrella*	18000	18000	15780.00
				100,210.00

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

The highest amount of CO_2 sequestered by *Axonopus compressus* at 100,205.17 kgCO_2e. This amount is substantially high as compared to the other planting categories which are from tree and shrub category, sequestered at 9691.89 kgCO_2e and 690.49 kgCO_2e, respectively. The main reason for this turfgrass becomes a dominant CSR agent because of the large coverage area planted with turfing at this particular site. Thus, it can be concluded that larger turfing area contributes to the greater amount of CO_2 that can be sequestered at one time. The tree species that sequestered the highest total amount of carbon at this site is *Samanea saman* (2176.79 kgCO_2e). The high CSR value of this species compared to the other tree species is due to higher plants specification used such as taller in height, bigger in trunk diameter, planted in larger quantity and had an older age (*Table 2*). According to Othman et al. (2016), the effect of carbon sequestration varies from the plant species, for instance, parks with trees and shrubs have the most efficient carbon sequestration effect. Meanwhile, *Eugenia oleana* ranked as the highest sequester agent for a shrub with the amount of 355.92 kgCO_2e. This value is slightly higher from the other one shrub species which is *Murraya paniculata* with the sequestered amount of 334.58 kgCO_2e. From *Table 3*, it can be clearly seen that even though the quantity of shrub for *Murraya paniculata* has a greater number planted on site (5000 nos), the total CSR value for this plant is still lower than *Eugenia oleana* which was only planted at 600 nos on site. Therefore, this finding revealed that plants specifications such as overall height and trunk diameter have very much influenced the total CSR percentage.

Fig. 3 indicates the relationship between planting categories and the total amount of carbon sequestration rate from each category. It can be depicted that the highest CSR value is from turfing category, followed by trees and shrubs category.

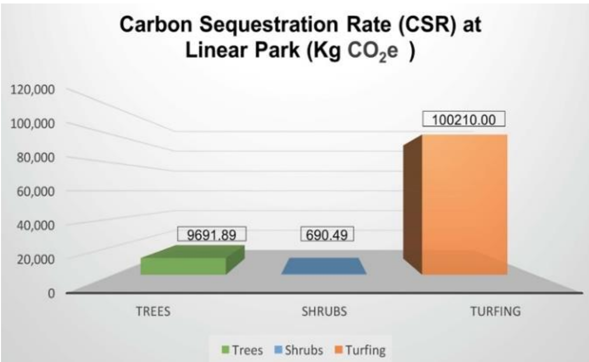

Figure 3. *Carbon sequestration rate based on planting categories at Putra Heights Linear Park (linear design landscape setting)*

Table 5 tabulated in detail distribution of plant's category, plant's quantity and CSR value obtained from each category. With the total numbers of 1615 nos of trees, 5600 nos of shrubs and 114,300 m^2 of planted turfing, the overall total of CO_2 sequestered by all plants in this site is 110,592.38 kgCO_2e.

Carbon sequestration rate at Subang Jaya urban forest park (curvilinear design landscape setting)

Fig. 4 illustrates the planting plan at Subang Jaya urban forest park which represents curvilinear design landscape setting. *Tables 6-11* showed the current carbon

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

sequestration rate obtained at Subang Jaya urban forest park (curvilinear design landscape setting) based on plants categories and the total amount of CO_2 sequestered by each plant. It can be concluded that the highest value represented as an effective CSR agent to sequester carbon is from turfgrass category, which named *Axonopus compressus* and *Zoysia matrella* with the sequestered amount of 24,190 $kgCO_2e$ and 350 $kgCO_2e$, respectively.

Table 5. *Distribution of plant's quantity and carbon sequestration rate by plant's category*

Plant's Category	Plant's Quantity	CSR Value/ ($kgCO_2e$)
Trees	1615 nos	9,691.89
Shrubs	5600 nos	690.49
Turfing	114300 m^2	100,210.00
Total CSR ($kgCO_2e$)		**110,592.38**

Figure 4. *Planting plan of Subang Jaya urban forest park, Selangor*

At this particular plant's category, *Axonopus compressus* has become a dominant CSR agent because of the quantity planted is tremendously high compared to *Zoysia matrella*. Thus, this finding proved that quantities of the plant have very much influence on the CSR value. The total amount of carbon sequestration rate produced by turfgrass at this site is 24,540 $kgCO_2e$. The amount is tremendously high as compared to the other planting categories such as trees (2781.28 $kgCO_2e$), palm (170.84 kg CO_2e) and

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

tall shrubs (518.59 kgCO_2e) categories. Besides, for the shrubs and climbers categories have the same CSR value which is 310 kgCO_2e each. The tree species that sequestered the highest amount of CO_2 is known as *Hopea odorata* (274.06 kgCO_2e) whereas for the palm species is *Livistonia rotundifolia* (170.84 kgCO_2e). Apart from that, as for the tall shrubs category, *Murraya paniculata* has the highest amount of CO_2 sequestered. *Labisia pumila* (90 kgCO_2e) and *Tristellateia australasiae* (100 kgCO_2e) have ranked the highest contributor of carbon sequestration for shrubs and climbers categories.

Table 6. *Carbon sequestration rate produced by trees at Subang Jaya Urban Forest Park*

NO	Species	Overall Height (Feet)	Trunk Diameter (Inch)	Quantity (Nos)	Age	tCO_2e/unit	Total CO_2e (kg)
1.	*Cinnamomum inners*	9.84	2	20	2	0.0036	71.18
2.	*Dillenia indica*	9.84	2	15	2	0.0036	53.39
3.	*Evatamia divaricata*	6.56	2	15	2	0.0024	35.59
4.	*Fragraea fragrans*	11.48	2	35	2	0.0042	145.33
5.	*Gardenia carinata*	9.84	2	30	2	0.0036	106.78
6.	*Mechelia champaka*	9.84	2	20	2	0.0036	71.18
7.	*Melia indica*	8.2	2	15	2	0.0030	44.49
8.	*Mimosup elengi*	8.2	2	20	2	0.0030	59.32
9.	*Casia fistula*	9.84	1.97	15	1.6	0.0043	64.75
10.	*Jacaranda obtusifolia*	9.84	1.97	20	1.97	0.0035	70.12
11.	*Langerstomia speciosa*	9.84	1.97	20	1.97	0.0035	70.12
12.	*Plumeriarubra*	8.2	2	15	2	0.0030	44.49
13.	*Tabeibuia rosea*	8.2	2	30	2	0.0030	88.98
14.	*Xanthostemon chrysanthus*	8.2	1.8	30	1.8	0.0027	80.08
15.	*Andira enermis*	9.84	1.97	30	1.97	0.0035	105.17
16.	*Cratoxylum cochichinensis*	11.48	3	42	3	0.0062	261.60
17.	*Dipterocarpuschartaceus*	8.2	2	25	2	0.0030	74.15
18.	*Dyeracostulata*	9.84	2	16	2	0.0036	56.95
19.	*Eucalyptus deglupta*	11.48	3	40	3	0.0062	249.14
20.	*Neobalanocarpusheimii*	9.84	2	15	2	0.0036	53.39
21.	*Hopea odorata*	11.48	2	66	2	0.0042	274.06
22.	*Melaleuca cajuputi*	9.84	1.97	25	1.97	0.0035	87.64
23.	*Mesua ferrea*	9.84	2	30	2	0.0036	106.78
24.	*Pentaspadon motley*	8.2	1.6	20	1.6	0.0024	47.46
25.	*Pometia pinnata*	9.84	1.97	20	1.97	0.0035	70.12
26.	*Shorea leprosula*	9.84	1.97	35	1.97	0.0035	122.70
27.	*Stercula foetida*	8.2	1.6	16	1.6	0.0024	37.96
28.	*Tectona grandis*	8.2	1.6	30	1.6	0.0024	71.18
29.	*Tristaniopsis whiteana*	9.84	2	40	2	0.0036	142.37
30.	*Eurycoma longifolia*	3.28	1	25	1	0.0006	14.83
							2781.28

Table 7. *Carbon sequestration rate produced by palm at Subang Jaya Urban Forest Park*

NO	Species	Overall Height (Feet)	Trunk Diameter (Inch)	Quantity (Nos)	Age	tCO_2e /unit	Total CO_2e (kg)
1.	*Livistonia rotundifolia*	13.12	4	18	4	0.0095	170.84
							170.84

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

Table 8. *Carbon sequestration rate produced by tall shrubs at Subang Jaya Urban Forest Park*

NO	Species	Overall Height (Feet)	Trunk Diameter (Inch)	Quantity (Nos)	Age	tCO2e /unit	Total CO2e (kg)
1.	*Gardenia jasminoides*	1.64	1	300	1	0.00030	88.98
2.	*Jasminium sambac*	1.31	1	350	1	0.00024	82.92
3.	*Murraya paniculata*	1.64	1	350	1	0.00030	103.81
4.	*Acalypha siamensis*	1.31	1	400	1	0.00024	94.77
5.	*Bougainvillea spectabilis*	1.31	1	100	1	0.00024	23.69
6.	*Durantha erecta Gold*	1.31	1	400	1	0.00024	94.77
7.	*Leucophyllum frutescens*	1.64	1	100	1	0.00030	29.66
							518.59

Table 9. *Carbon sequestration rate produced by shrubs at Subang Jaya Urban Forest Park*

NO.	Species	Area (m²)	Quantity	Total CO_2e (kg)
1.	*Pandanus anaryllifolius*	33.33	100	30.00
2.	*Costus woodsonii*	33.33	100	30.00
3.	*Clinacanthu snutans*	50	300	40.00
4.	*Cosmos caudafusi*	50	300	40.00
5.	*Gynura procumbens*	50	300	40.00
6.	*Labisia pumila*	100	300	90.00
7.	*Orthosiphon aristatus*	50	300	40.00
				310.00

Table 10. *Carbon sequestration rate produced by climbers at Subang Jaya Urban Forest Park*

NO.	Species	Area (m²)	Quantity	Total CO_2e (kg)
1.	*Vallaris glabra*	66.67	400	60.00
2.	*Portulaca grandifolia*	21.67	130	20.00
3.	*Thunbergia grandifolia*	50	300	40.00
4.	*Tristellateia australasiae*	110	660	100.00
5.	*Quisqualis indica*	50	300	40.00
6.	*Ophiopogon jaburan*	53.33	320	50.00
				310.00

Table 11. *Carbon sequestration rate produced by turfgrass at Subang Jaya Urban Forest Park*

NO.	Species	Area (m²)	Quantity	Total CO_2e (kg)
1.	*Axonopus compressus*	27591	27591	24190.00
2.	*Zoysia matrella*	400	400	350.00
				24540.00

Fig. 5 showed the relationship between planting categories and the total amount of carbon sequestration rate from each category at Subang Jaya urban forest park. It can be depicted that the highest CSR value is from turfing category, followed by trees, tall shrubs, shrubs, climbers and palm category. At this particular period of time, turfing has become the dominant CSR agent due to the large coverage area for turfing. *Table 12*

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

tabulated distribution of plant's category, quantities and the CSR value that sequestered from each planting category. With the total number of 775 nos trees, 18 nos palm, 2000 nos tall shrubs, 366.66 m^2 of shrubs, 351.67 m^2 of climbers and 27,991 m^2 of turfing, total carbon sequestration rate for this particular site is 28,630.71 $kgCO_2e$.

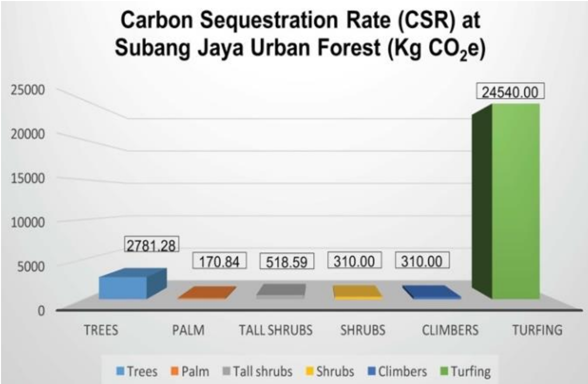

***Figure 5.** Carbon sequestration rate based on planting categories at Subang Jaya urban forest park (curvilinear design landscape setting)*

***Table 12.** Distribution of plant's category, plant's quantity, andcarbon sequestration rate value*

Plant's Category	Plant's Quantity	CSR Value/ $KgCO_2e$
Trees	775 nos	2781.28
Palms	18 nos	170.84
Tall Shrubs	2000 nos	518.59
Shrubs	366.66 m^2	310.00
Climbers	351.67 m^2	310.00
Turfgrass	27991 m^2	24,540.00
Total CSR ($kgCO_2e$)		**28,630.71**

Total Park Area, Green Area and Built Up Area

Fig. 6 illustrated the total park area, green area and built up area for both selected site studies. It has been found that the green area for Putra Heights linear park (114300 m^2) is enormously larger than Subang Jaya urban forest park (25,446.63 m^2). From the results, it can be concluded that a larger green area contributes to the greater value of carbon sequestration rate.

Fig. 7 showed the comparison of carbon sequestration rate obtained at Putra Heights linear park (linear design landscape setting) and Subang Jaya urban forest park (curvilinear design landscape setting). From the bar graph shown, it can be clearly seen that the Putra Heights linear park (110592.38 $kgCO_2e$) had sequestered more carbon compared to Subang Jaya urban forest park (28630.71 $kgCO_2e$). There are many factors contribute to this difference which will be explained on the next page.

Comparison of Carbon Sequestration Rate for Linear and Curvilinear Design Landscape Setting

Table 13 portrayed comparison between Putra Heights linear park character and Subang Jaya urban forest park character. There are four categories considered in doing

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

this assessment, which are a green area, landscape design setting, plant's category and quantity and also means trees specification. From the tabulated results, it is shown that Putra Heights linear park possessed higher amount in terms of green area, plant's category, and quantity and also mean trees specifications. Therefore, these factors have very much influenced the total CSR rate.

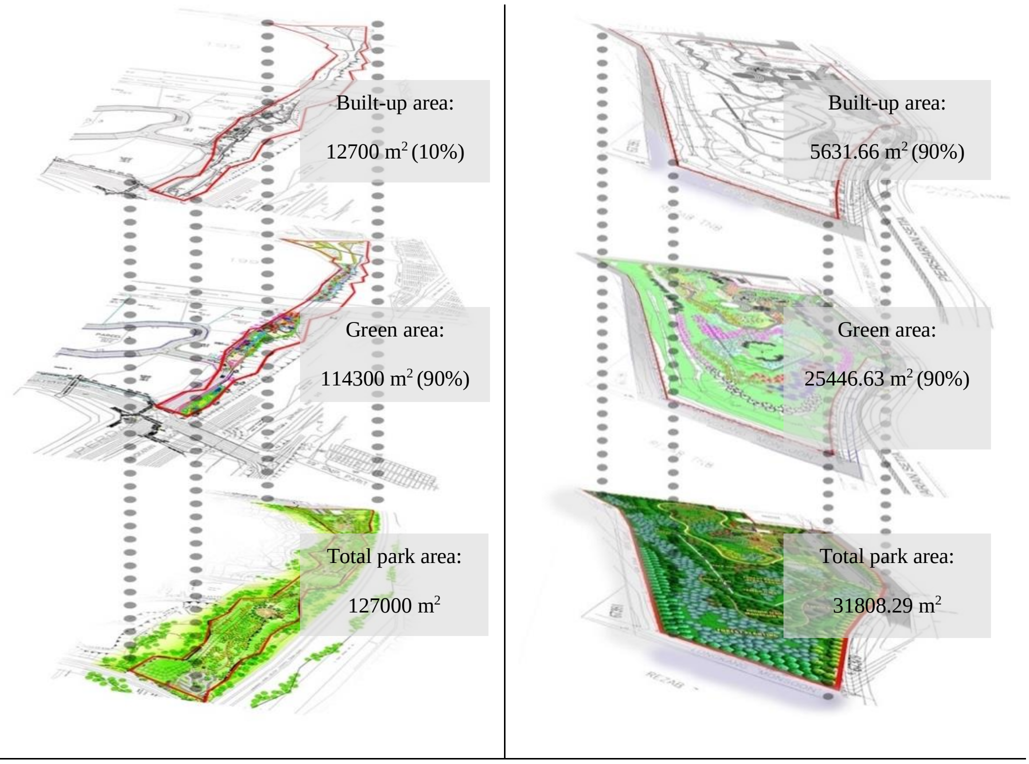

Figure 6. *Distribution of total park area, green area and built up area for both urban parks*

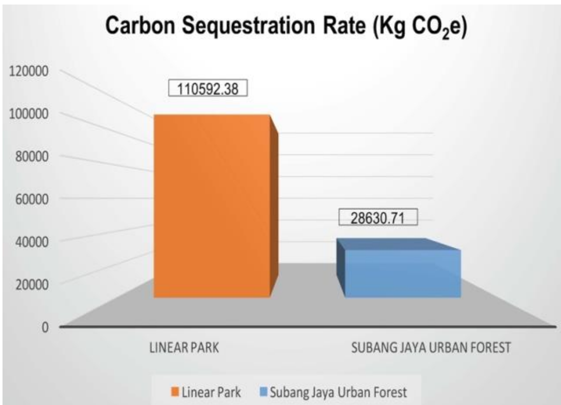

Figure 7. *Carbon sequestration rate based on planting categories at Subang Jaya Urban Forest Park (curvilinear design landscape setting)*

Optimizing the Carbon Sequestration Rate

According to Safaai et al. (2011), Malaysia's carbon emission is predicted at around 285.73 million tonnes by the year 2020. With the total land area of 330,803 km^2, every

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

1 m^2 of Malaysia should sequester minimum of 0.863 $kgCO_2e$ emissions. Next, the amount will be multiplied by the total area of the site. *Table 14* showed the distribution of total CSR and CO_2 sequestered per m^2 for both urban parks according to planting categories. Surprisingly, Subang Jaya curvilinear urban forest park sequestered 0.9 kgCOe/m^2, which is higher than Putra Heights linear park. Therefore, this finding revealed that curvilinear design landscape setting contributes to the greater amount of CO_2 sequestered per m^2. Both urban parks sequestered more than the amount of CO_2 that it should sequester. Apart from that, the amount of CO_2 sequestered per m^2 for trees category of Subang Jaya curvilinear urban forest park (0.09 $kgCO_2e$) is higher even though the total quantity of trees is lower compared to Putra Heights linear park (0.08 $kgCO_2e$). There are a few factors affected such as planting distance and spatial design organization. The total amount of CO_2 sequestered per m^2 for turfing category is nearly equal for both parks.

Table 13. *Comparison between Putra Heights linear park and Subang Jaya urban forest park landscape design setting*

	Putra Heights Linear Park	**Subang Jaya Urban Forest Park**
Green area (m^2)	114,300.00 m^2	25,446.63 m^2
Landscape design setting	Linear design	Curvilinear design
Plant's category & quantity	Trees – 1615 nos Shrubs – 5600 nos Turfing – 114,300 m^2	Trees – 775 nos Palm – 18 nos Tall shrubs – 2000 nos Shrubs – 366.66 m^2 Climbers – 351.67 m^2 Turfing – 24,540m^2
Trees specification	Overall height – 14 ft Trunk diameter – 2.92 inch Age – 2.9 years	Overall height – 9.24ft Trunk diameter – 1.98 inch Age – 2 years

Table 14. *Distribution of total CSR and CO_2 Sequestered per m^2 for both site studies area*

	Total CSR ($kgCO_2e$)	**CO_2 Sequestered per m^2 ($kgCO_2e$)**
Putra Heights Linear Park		
Total Park Area = 127,000 m^2		
Trees (1615 nos)	**110,592.38**	**0.871**
Shrubs (5600 nos)	9,691.89	0.076
Turfing (114,300 m^2)	690.49	0.005
	100,210.00	0.789
Subang Jaya Urban Forest Park		
Total Park Area = 31,808.29 m^2		
Trees (775 nos)	**28,630.71**	**0.900**
Palm (18 nos)	2781.28	0.087
Tall Shrubs (2000 nos)	170.84	0.003
Shrubs (366.66 m^2)	518.59	0.016
Climbers (351.67 m^2)	310.00	0.010
Turfing (27,991 m^2)	310.00	0.010
	24,540.00	

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

Conclusions

Plants in urban parks are important agents that sequester the CO_2 emission of the earth atmosphere. Thus, the sequestration of carbon by urban trees and other vegetation plays an important role in mitigating climate change and have a high potential in reducing urban air pollution. Carbon sequestration rates differ based on the species of tree, planting quantity and specifications, type of plant materials group, percentage of green area and built up area as well as landscape design setting or spatial design organization. Therefore, by selecting the appropriate planting materials with suitable landscape design setting will contribute to sequestering greater value or carbon sequestration rate. It can be concluded that curvilinear design landscape setting sequester more CO_2 per m^2 compared to the linear design landscape setting. Thus, the selection of landscape design settings also plays an important role in contributing to the higher CSR value. Moreover, a higher percentage of the green area has much influenced in contributing to the greater CSR value. By selecting the right plant materials with higher specifications and larger quantities will also contribute to the optimum value of carbon sequestration rate in urban parks. Therefore, having an urban park with an optimum value of carbon sequestration rates will help to strengthen the ecosystem services, as a result, alleviating urban heat island and global warming. These findings will become a green practice approached towards building a sustainable environment with better design solutions. Thus, for future research, the environmental factors such as locality, type of soil and seasonal climatic variation may have influenced the carbon sequestration rate. Clearly, a further study utilizing plant material grown under different environmental conditions is required to confirm this hypothesis.

Acknowledgements. The research was supported by the Ministry of Higher Education Malaysia (MOHE) and International Islamic University Malaysia (IIUM) under research grant MOHE18-001-0001.

REFERENCES

[1] Biennial Update Report to the UNFCCC (2015): Framework Convention On Climate Change In December 2015. – Ministry Of Natural Resources and Environment Malaysia, 1-174.

[2] Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A. G., Mittal, N., Feliu, E., Faehnle, M. (2014): Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. – Journal of environmental management 146C: 107-115.

[3] Department of Statistics, Malaysia. (2011): Population Distribution and Basic Demographic Characteristic Report.

[4] Othman, R., Abu Kassim, S. Z. (2016): Assessment of plant materials carbon sequestration rate for horizontal and vertical landscape design. – International Journal of Environmental Science and Development 7(6): 410-414.

[5] Pandya Ishan, Y., Salvi, H., Chahar, O., Vaghela, N. (2013): Quantitative Analysis on Carbon Storage of 25 Valuable Tree Species of Gujrat, Incredible India. – Indian J. Sci. Res. 4(1): 137-141.

[6] Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., Pouyat, R., Whitlow, T., Zipperer, W. (2011): Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. – Frontiers in Ecology and the Environment 9(1): 27-36.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101

[7] Sadeghian, M. M., Vardanyan, Z. (2013): The Benefits of Urban Parks, a Review of Urban Research. – Journal of Novel Applied Sciences: 231-237.
[8] Safaai, N. S. M., Noor, Z. Z., Hashim, H., Ujang, Z., Talib, J. (2011): Projection of CO_2 emissions in Malaysia. – Environmental Progress and Sustainable Energy 30(4): 658-665.
[9] Velasco, E., Roth, M., Norford, L., Molina, L. T. (2016): Landscape and Urban Planning Does urban vegetation enhance carbon sequestration? – Landscape and Urban Planning 148: 99-107.
[10] Wiedman, T., Minx, J. (2007): The Carbon Trust Helps UK Businesses Reduce their Environmental Effect. – Ecological Economic Research Trend, Library of Congress Cataloging-In-Publication Data, Nova Science Publisher, pp.1-11.
[11] Yin, S., Shen, Z., Zhou, P., Zou, X., Che, S., Wang, W. (2011): Quantifying air pollution attenuation within urban parks: An experimental approach in Shanghai, China. – Environmental Pollution 159(8-9): 2155-2163.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/1704_80898101