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Assessment of Urban Park Landscape Setting Design Towards Carbon Sequestration Rate

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Abstact: Urban parks varies in size ranging from 400-30 000 ha all over the world and one thing in common they possessed is that urban trees play an important role in mitigating the impacts of climate change by sequestering atmospheric carbon dioxide (CO_2). Calculation of carbon (C) stored and sequestered by urban trees is the actual and critical assessment of the real potential role of an urban park in reducing atmospheric CO_2. This study provides a case study of the quantification of C storage and sequestration by two urban parks with two different landscape setting design in Subang Jaya and Damansara, a rapidly urbanized and populated city in West coast of Malaysia. The C storage or sequestration rate was estimated by biomass equations, using field inventory and analysis survey data. The calculation of biomass provides reasonably accurate estimation of the amount of carbon that was sequestered from trees over the years. The findings revealed that different landscape setting design contribute to marked differences in carbon stored. Curvilinear landscape setting design was found to sequester more carbon compared to informal landscape setting even though total green and built up areas for both sites are similar. These findings provide insights and better understanding of the role of urban park as carbon sink.

Key words: Carbon sequestration rate, urban parks, landscape setting design, curvilinear design, concentric design

INTRODUCTION

In recent years there have been more concerns that the high rate of CO_2 emission in the earth's atmosphere will lead to negative changes especially in global climate change. Cities are blamed for climate change (Dodman, 2009). Urban lifestyle issues have gained more concern in research as cities search for effective plans to reduce their 80% share of the global carbon emissions (Heinonen and Junnila, 2011). Planting trees in urban green space, will not only give opportunity to sequester carbon from air and soil but it will also reduce the energy consumption as well as creating ambient microclimate by providing cooler surface and shade for buildings. The highest four emitting countries which resulted almost two thirds (61%) of the total global CO_2 emissions are China (30%), the United States (15%), the European Union (EU-28) (10%) and India (6.5%). In Malaysia context, urban population is growing rapidly. The concept of low carbon city is now gaining much attention among the designers and city dwellers due to the issue of current global climate changes. Formation of low carbon cities comprises establishment of low carbon society by encouraging low carbon emission (Fong *et al*., 2008).

The major contributor of carbon emissions in Malaysia came from electricity power plant, transportation, industrial and residential (Safaai *et al*., 2011). However, transportation activities were found to contribute approximately 97% CO_2 emissions into the atmosphere (Yahya *et al*., 2013). Hence, this research aimed to assess two types of urban park landscape setting design namely curvilinear and concentric design that possess high carbon sequestration rate. Therefore, urban trees can be significant agent as carbon sink for sequestering carbon dioxide for better living and environment.

MATERIALS AND METHODS

Methods in optimizing the Carbon Sequestration Rate (CSR) at urban parks: First method or step in optimizing CSR is through inventory and analysis of the sites. Two

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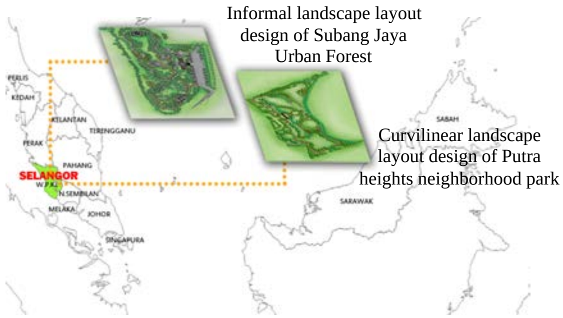

Fig. 1: Selected urban parks as case studies in Selangor, Malaysia

Table 1: Formula to calculate the carbon sequestration rate using plants (Othman and Kasim, 2016)

CSR formula for trees and shrubs	CSR formula for Turf, Creeper and Climber
Total Green Weight (TGW) for diameter less than 11 inch TGW I: W = 0.25D2H (1.2)	Total Dry Weight (TDW) TDW = 0.56 x area in m^2
Total Green Weight (TGW) for diameter more than 11 inch TGW I: W = 0.15D2H (1.2)	Total Carbon Weight (TCW) TCW = TDW×0.427
Total Dry Weight (TDW) TDW I = TGW I x 0.725	Total CO_2 Weight (TCO_2W) TCO2W = TCW x 3.6663
Total Carbon Weight (TCW) TCW I = TDW I x 0.5	Carbon rating system point $tCO_2e = TCO_2W/1000$
Total CO_2 Weight (TCO_2W) TCO_2W I = TCW I x 3.6663	
Total CO_2 Weight (TCO_2W/year) TCO_2W I/Year	
Carbon Rating System Point (tCO_2e) tCO_2e I = TCO_2W/2204.62	

sites of different landscape setting design of urban parks were chosen as case studies which are Subang Jaya urban forest (concentric/informal landscape setting design) and Putra heights neighborhood park (curvilinear landscape setting design) (Fig. 1). All sites were selected for inventory and analysis process in obtaining data needed. Apart from that, for calculating the exact numbers of trees and detailed specifications of the plants at the site, bill of quantity is also collected from authorities. The data needed include plants specifications such as its height, diameter, year, quantity and area of the plants (for groundcovers species). Whereas, base map from authorities was obtained in order to calculate the total built up area and green area of the site

Next, the current carbon sequestration rate on every species at the site was calculated using formula stated on Table 1.

RESULTS AND DISCUSSION

Carbon sequestration rate at Subang Jaya urban forest (informal landscape setting design): Table 2-5 and Fig. 2. portrayed the amount of CO_2 that sequestered by different types of plants species at Subang Jaya urban forest (informal landscape setting design). The highest amount of carbon sequestration rate is from the groundcovers species which named *Axonopus compressus* and *Zoysia matrella*. The total amount of CO_2 sequestered by these groundcovers is 4951.5 kg CO_2e, compared to other plants species such as trees (2091.5 kg CO_2e), palms (248.6 kg CO_2e) and shrubs (895.8 kg CO_2e). The tree species which sequestered highest total amount of carbon at the site is called *Hopea odorata* (150.4 kg CO_2e). Meanwhile, *Livistonia grandifolia* ranked as the highest sequester agent for palm with the amount of 248.63 kg CO_2e. Lastly, there were three species of shrubs at the site that sequestered the highest carbon, known as *Jasminium sambac*, *Durantha eracta* gold and *Acalypha siamensis* that contributed to 94.04 kg CO_2e for each of the species. From the result, the overall total of CO_2 sequestered by all plants at this site is 8187.4 kg CO_2e.

Carbon sequestration rate at Putra heights neighborhood park (curvilinear landscape setting design: Table 6-9 and Fig. 3-5 showed the current carbon sequestration rate at Putra heights neighborhood park (curvilinear landscape setting design) based on plants categories and total carbon that sequestered by them. It can be concluded that the highest value represented as an effective agent to sequester carbon is from groundcovers categories. The total amount of carbon sequestration rate produced by groundcover at this site is 5898.17 kg CO_2e. The amount is tremendously high compared to other plants species such as trees (1550.7 kg CO_2e), palms (1096.5 kg CO_2e) and shrubs (1845.8 kg CO_2e). The groundcovers are namely *Axonopus compressus* and *Quisqualis indica*. The tree species that sequestered highest carbon is known as *Samanea saman* (151.26 kg CO_2e) whereas for the palm species is *Wodyetia bifurcata* (207.15 kg CO_2e). Whereas, *Eugenia oleana* (506.38 kg CO_2e) is the highest contributor of carbon sequestration rate compared to other shrub species. The overall total of CO_2 sequestered by all plants at this site is 10391.1 kg CO_2.

According to Fig. 6, it has been found that the green area of Subang Jaya urban forest (informal landscape setting design) is nearly equaled to green area of neighborhood park Putra heights (curvilinear landscape setting design) which resulted 80% (26537.07 m^2) and 81% (27420.73 m^2), respectively. From the result, it can be concluded that both sites consisted enormous green areas which potentially to be as parks that sequester high amount of carbon. Meanwhile, for total built up area of both sites, it differed only 1% which represented around 20% (6824.54 m^2) for Subang Jaya urban forest (informal

Table 2: Plants at Subang Jaya urban forest

Species	Height (feet)	Diameter (inch)	Year	No.	tCO_2e/unit	Total CO_2e (kg)
Evatamia divaricata	6.70	2.00	2.0	20	0.00242	48.46
Fragraea fragrans	6.70	2.00	2.0	60	0.00242	245.40
Gardenia carinata	6.70	2.00	2.0	30	0.00242	72.70
Mimosup elengi	6.70	1.60	1.6	30	0.00194	58.16
Mechelia champaka	6.70	2.00	2.0	25	0.00242	60.58
Dillenia indica	6.70	2.00	2.0	20	0.00242	48.46
Cinnamomum inners	6.70	2.00	2.0	25	0.00242	60.58
Melia indica	6.70	2.00	2.0	28	0.00242	67.85
Cassia fistula	8.20	0.98	1.0	20	0.00142	28.48
Jacaranda obtusifolia	8.20	1.57	1.6	40	0.00228	91.38
Lagerstomias peciosa	8.20	1.57	1.6	35	0.00228	79.96
Plumeria rubra	8.20	1.96	2.0	17	0.00285	48.42
Xanthostemon chrysanthus	8.20	1.77	1.8	57	0.00258	147.12
Tabeibuia rosea	8.20	1.96	2.0	43	0.00285	122.48
Pometia pinnata	8.20	1.37	1.4	24	0.00199	47.71
Eucalpytus deglupta	6.56	1.37	1.4	40	0.00159	63.62
Cratoxylum cochichinensis	6.56	1.57	1.6	42	0.00183	76.76
Hopea odorata	6.56	1.96	2.0	66	0.00228	150.40
Melaleuca cajuputi	6.56	1.57	1.6	25	0.00183	45.69
Shorea leprosula	6.56	1.57	1.6	45	0.00183	82.24
Tristaniopsis whiteana	6.56	1.96	2.0	41	0.00228	93.43
Heobalano carpusheimii	13.12	3.93	4.0	15	0.00550	82.45
Dipterocarpus chartaceus	6.56	1.57	1.6	30	0.00183	54.83
Stercula foetida	6.56	1.57	1.6	26	0.00183	47.52
Pentaspadon motley	6.56	1.57	1.6	30	0.00183	54.83
Andira enermis	6.56	1.57	1.6	30	0.00183	54.83
Dyera costulata	6.56	1.57	1.6	16	0.00183	29.24
Mesua ferrea	6.56	1.57	1.6	30	0.00183	54.83
Tectona grandis	6.56	1.57	1.6	40	0.00183	73.10

2191.5 kg CO_2e

Table 3: Carbon sequestration rate produced by trees at Subang Jaya urban forest

Species	Height (feet)	Diameter (inch)	Year	No.	tCO_2e/Unit	Total CO_2e (kg)
Livistonia grandifolia	9.84-13.12	3.94-5.91	6	18	0.01381	248.63

Fig. 2: Plants at Subang Jaya urban forest

landscape setting design) and 19% (6571.78 m^2) from of neighborhood park Putra heights (curvilinear landscape setting design).

Optimizing the carbon sequestration rate: This formula is created in order to identify minimum amount of carbon sequestration rate required in every 1 m^2:

$$\frac{\text{Max. total of predicted amount of } CO_2 \text{ emissions}}{\text{Country size}} = \frac{x}{1 km^2}$$

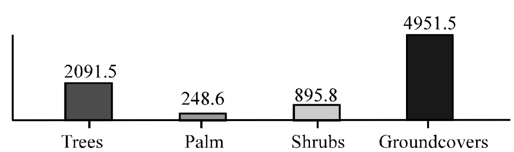

Fig. 3: Current sequestration rate based on plants species at Subang Jaya urban forest; informal landscape setting design (kg CO_2e)

Fig. 4: Plants at Putra heights neighborhood park

Example: Malaysia's carbon emission is predicted around 285.73 million tonnes by year 2020 (Safaai *et al.*, 2011):

Table 4: Carbon sequestration rate produced by palm at Subang Jaya urban forest

Species	Height (feet)	Diameter (inch)	Year	No.	tCO_2e/Unit	Total CO_2e (kg)
Gardenia jasminaides	1.60	1.00	1.0	300	0.00029	86.80
Jasminium sambac	1.30	1.00	1.0	400	0.00024	94.04
Murraya paniculata	1.30	1.00	1.0	100	0.00024	23.51
Pandanus anarylifolius	1.60	1.00	1.0	100	0.00029	28.93
Costus woodsonii	1.64	1.00	1.0	100	0.00030	29.65
Bougainvillea spectabilis	1.30	1.00	1.0	100	0.00024	23.51
Leucophyllum frutescens	1.30	1.00	1.0	100	0.00024	23.51
Duranthaerecta gold	1.30	1.00	1.0	400	0.00024	94.04
Acalypha siamensis	1.30	1.00	1.0	400	0.00024	94.04
Vallaris glabra	0.82	1.00	0.5	400	0.00012	48.00
Thunbergia grandifolia	0.67	0.02	0.5	400	0.00004	15.51
Tristella australasiae	0.67	0.40	0.5	660	0.00004	11.63
Portulaca grandifolia	0.67	0.40	0.5	130	0.00004	5.04
Ophiopogon jaburan	0.67	0.40	0.5	320	0.00006	19.39
Clinacanthus nutans	0.98	0.50	1.0	300	0.00018	53.17
Cosmos caudafusi	0.98	1.00	1.0	300	0.00018	53.17
Eurycoma longifolia	3.20	1.00	1.0	25	0.00058	14.46
Gynura procumbens	0.98	1.00	1.0	300	0.00018	53.17
Labisia ponila	1.31	1.00	1.0	300	0.00024	71.07
Orthosiphon aristatus	0.98	1.00	1.0	300	0.00018	53.17

Table 5: Carbon sequestration rate produced by shrubs at Subang Jaya urban forest

Species	Height (feet)	Diameter (inch)	Year	No.	Total CO_2e (kg)
Axonopus compressus	-	5574	-	30000	4886.64
Zoysia matrella	-	74.32	-	400	65.15

4951.5 kg CO_2e

Table 6: Carbon sequestration rate produced by trees at Putra heights neighborhood park

Species	Height (feet)	Diameter (inch)	Year	No.	Total CO_2e (kg)
Axonopus compressus	-	6683.226	-	35970	5859.08
Quisqualis indica	-	44.592	-	40	39.09

5898.17 kg CO_2e

Table 7: Carbon sequestration rate produced by palms at Putra heights neighborhood park

Species	Height (feet)	Diameter (inch)	Year	No.	tCO_2e/Unit	Total CO_2e (kg)
Agathis borneensis	8.2	1.38	1.4	33	0.0020	66.57
Azadirachta excelsa	8.2	1.38	1.4	40	0.0020	80.69
Bucida molineti	8.2	2.00	2.0	36	0.0030	106.77
Caesalpinia ferrea	8.2	1.60	1.6	14	0.0024	33.21
Cinnamomum inners	8.2	1.60	1.6	35	0.0024	83.04
Cratoxylum formosum	8.2	2.00	1.6	25	0.0037	92.68
Dalbergia latifolia	8.2	1.19	1.6	35	0.0013	45.93
Eugenia grandis	8.2	2.00	2.0	50	0.0030	148.29
Fagraea fragrans	8.2	1.60	1.6	27	0.0024	64.00
Hopea odorata	8.2	1.60	1.6	35	0.0024	83.04
Mesua ferrea	8.2	1.60	1.6	11	0.0024	26.10
Pongamia pinnata	8.2	1.60	1.6	47	0.0024	111.52
Samanea saman	8.2	3.00	3.0	34	0.0044	151.26
Saraca cauliflora	8.2	1.60	1.6	10	0.0024	23.72
Schizolobium parahyba	8.2	1.60	1.6	20	0.0024	47.45
Spathodeacam panulata	8.2	2.00	2.0	34	0.0030	100.84
Tristoniopsis whiteana	8.2	1.60	1.6	28	0.0024	66.43
Xanthostemonchrysanthus	8.2	1.60	1.6	38	0.0024	90.16
Garcinia mangostana	6.7	1.19	1.2	21	0.0014	30.02
Muntingia calabura	6.7	1.60	1.6	10	0.0019	19.38
Mangifera indica	6.7	1.19	1.2	18	0.0014	25.73
Nephelium lappaceum	6.7	1.19	1.2	24	0.0014	34.31
Phyllanthus acidus	6.7	1.00	1.0	16	0.0012	19.38

1550.7 kg CO_2e

$$\frac{285.73 \text{ million tonnes}}{330{,}803 \text{ km}^2} = \frac{x}{1\text{km}^2}$$

$$1 \text{ km}^2 \times 285730000 \text{ tonnes km}^2 = x\ (330{,}803 \text{ km}^2)$$

$$x = 285730000 \text{ tonnes km}^2/330803 \text{ km}^2$$

$$x = 863.746 \text{ tonnes per km}^2/1000000$$

$$1 \text{ m}^2 = 0.000863 \text{ tonnes}/0.863 \text{ kg } CO_2$$

From the calculation above, every 1 m^2 of Malaysia should sequester minimum 0.863 kg CO_2 emissions. Next,

Table 8: Carbon sequestration rate produced by groundcovers at Putra heights neighborhood park

Species	Height (feet)	Diameter (inch)	Year	No.	tCO_2e/Unit	Total CO_2e (kg)
Eugenia oleana	4.00	1	1	700	0.00072	506.38
Rhapis multifida	3.30	1	1	105	0.00059	62.66
Alocasia macrorhiza	2.00	1	1	39	0.00081	31.59
Baphiantida gold	1.60	1	1	240	0.00065	155.56
Bougainvillea Apple Blossom	1.60	1	1	150	0.00065	97.22
Bougainvillea Mr. Eva Variegated	1.60	1	1	150	0.00065	97.22
Codieum variegatum	1.30	1	1	180	0.00053	94.79
Draceana marginata bicolor	1.60	1	1	80	0.00065	51.85
Durantha erecta Gold	0.82	1	1	475	0.00033	157.78
Hibiscus rosa sinensis	1.60	1	1	264	0.00065	171.11
Ixora cultivar	1.60	1	1	160	0.00065	103.70
Ixora super queen	1.30	1	1	160	0.00053	84.26
Osmoxy lumlineare	1.30	1	1	280	0.00053	147.45
Schefflera arboricola cultivar	1.30	1	1	160	0.00053	84.26

1845.83 kg CO_2e

Table 9: Carbon sequestration rate produced by shrubs at Putra heights neighborhood park

Species	Height (feet)	Diameter (inch)	Year	No.	tCO_2e/Unit	Total CO_2e (kg)
Livistonia rotundifolia	13.12	3.94-5.91	6	10	0.01381	138.10
Neodypsis leptocheilos	13.12	3.94-5.91	6	30	0.01381	414.30
Ptychosperma macarthurii	13.12	3.94-5.91	6	14	0.01381	199.33
Wodyetia bifurcata	13.12	3.94-5.91	6	15	0.01381	207.15
Cocos nucifera dwaft	9.84	3.94-7.87	8	10	0.01377	137.70

1096.58kg CO_2e

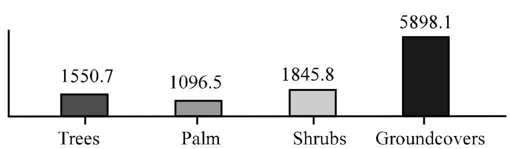

Fig. 5: Carbon sequestration rate produced by all plants species at Putra heights neighborhood park curvilinear landscape setting design (kg CO_2e)

the amount will be multiplied by the total area of the site. Hence, both urban parks sequestered fewer than amount of CO_2 than it should sequester. For Subang Jaya urban forest (informal landscape setting design) sequestered 0.24 kg CO_2 every 1 m^2. Besides, neighborhood park Putra heights (curvilinear landscape setting design) can be identified that curvilinear landscape setting design is more effective in sequestering CO_2 than informal landscape setting design.

From the result, urban parks with curvilinear landscape setting design sequestered more CO_2 than informal landscape setting design. Both sites sequester different rate of CO_2 emissions because of each of the park consisted different ecosystem or network. It can be concluded that, there are key factors that influenced the CSR. The key factors are as follows:

- Landscape layout design
- Planting quantity and specifications
- Percentage of Built up area and green area

In addition, trees played as an important role in contributing towards the environmental change and many studies aware about the role of trees in urban environments. The rate of carbon that stored by the plants are influenced by number of that species and plants' size (Fischer *et al*., 2007). Trees in urban areas stored around 700 million tonnes of carbon emission and 22.8 million of carbon sequestration rates per year (Nowak and Crane, 2002). Carbon storage of urban trees can lead to thorough understanding of the ability of urban trees in global carbon that relating to greenhouse emissions (Myeong *et al*., 2006). Thus, optimizing CSR will be achieved if the factors that influenced the CSR are considered.

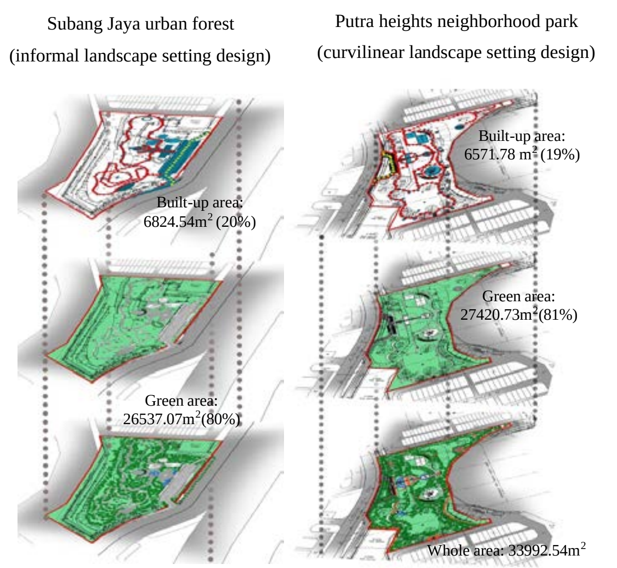

Fig. 6: The components of both urban parks

CONCLUSION

This study aimed to explore the best urban park landscape setting design that can optimize high carbon sequestration rate. From the analysis, it proved that curvilinear landscape layout sequester more carbon than informal landscape setting design. Apart from that, plants in urban parks are important agents that sequester the CO_2 emission of the earth atmosphere. Plants specification should be identified and calculated using the CSR formula before the CSR can be optimized. Plus, the formula for optimizing CSR will really come in handy to other researchers and designers in considering the rate of carbon sequestration before starting any developments.

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