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NOVEL LANDSCAPE DESIGN MODEL SYSTEM APPROACH: MONITORING, PREDICTING AND CALCULATING CARBON SEQUESTRATION RATE FOR TOURISM ACCOMMODATION PREMISES GREEN SPACES

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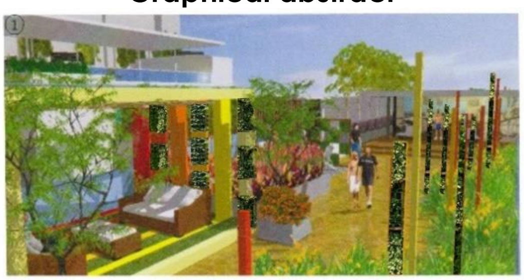
Graphical abstract



Abstract

Carbon emissions is expected to continue to increase unless major changes are made in the way carbon is managed. Managing hotel carbon emissions has emerged as a critical research matter and has become public and national interest since the last century. For instance daily appliances carbon emission from tourism accommodation premises is one of the major contributors for greenhouse effect especially in urban area and this could cause detrimental impact to the surrounding environment. One of the promising approach to reduce carbon emission to the atmosphere is by selecting an appropriate plant materials as well as optimization of spatial and space organization of green spaces. Besides character of the plant materials, criteria such as soil, plant material age, trunk diameter and trunk height are very much influenced the carbon sequestration rate. Therefore this study aimed to develop carbon sequestration model system through landscape design approach that can monitor, calculate and predict the amount of carbon that can be absorbed by proposed plant species at certain period of time. Two existing hotels were selected and the findings of this research showed that at both case studies, carbon sequestration rate by trees has the highest sequestration amount compared to other plant materials. This study also established that even with limited green space areas for tourism accommodation premises such as hotel, the carbon sequestration rate can be further increased with the right selection of plants, at the right place with the right spatial and space organization of green spaces. The significance outcomes of this study will be a novel landscape design approach to neutralize carbon emission which is cost effective and environmental friendly.

Keywords: Carbon Footprint, green space, Carbon sequestration rate, model system, landscape design, green technology

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1.0 INTRODUCTION

Since the late 19th century, carbon dioxide gas in the atmosphere has increased 25% [1]. While Hussain *et al*. [2] has highlighted that the carbon dioxide atmospheric concentration has risen to 35% from year 1870 to 2005 due to the dynamic development of industry sectors such as mining, energy, and manufacturing. In order to reduce carbon emission issue, Mangalassery *et al*. [3] highlighted that carbon sequestration has been suggested as a mean to help mitigate the increase in atmospheric carbon dioxide concentration. This technology can limit the carbon dioxide gas from entering the atmosphere and later on lower the concentration of carbon dioxide gas through period of time [3]. Towards the 20th century onwards, the human populations are also increasing over the world and Malaysia is not excluded. According to the Department of Statistics, Malaysia's population grew by a third since 1991 to reach 24.5 million inhabitants by the end of 2002 [4]. Referring to Sahabat Alam Malaysia [4], the Federal Territory contained over 6,000 city dwellers per km^2, Penang had 1,348 people per km^2, and Melaka has 408 people per km^2. In a 20-year period, the urban masses almost doubled from a 27% share to a 51% share of the population. Alternative ways that have been further studied to reduce these greenhouse effects in the atmosphere is through carbon sequestration technology [5].

Carbon sequestration is defined as a method or a process of moderating carbon dioxide in the atmosphere to stop it from being polluted [6]. Singh [6] further highlighted that as the name carbon sequestration suggested, carbon dioxide emitted from thermal power plants and carbon dioxide intensive industries is captured and stored in various reservoirs to lessen their polluting impact on the atmosphere. This method will contribute to mitigate global warming as it will capture and store carbon dioxide gas in a particular processes [7]. The processes includes capturing carbon dioxide that have been emitted, storing and absorbing it in a specific platform and then releasing the carbon dioxide gas with low concentration [8]. Terrestrial carbon sequestrations are methods which the carbon will be absorbed by the plant materials naturally [9]. In this case, plant materials are the platform for the carbon to be captured and absorbed, also known as biological sequestration. The largest net uptake for biological sequestration is due to the ongoing natural regrowth of forests that were harvested during the 19th and early 20th centuries [10]. It shows that plant materials play important roles to store the carbon that exist at the atmosphere.

Therefore this study aimed to develop carbon sequestration model system through landscape design approach that can monitor, calculate and predict the amount of carbon that can be absorbed by proposed plant species at certain period of time. The objectives of this study are to identify the built up area and green area of the selected tourism premises, to calculate the carbon sequestration rate occurred and to recommend strategies and approaches to achieve an optimum carbon sequestration rate to be implemented in a tourism accommodation premises. The case study for the research is differentiated between two characters of hotel which are horizontal and vertical hotel.

2.0 METHODOLOGY

2.1 Site Selection

Two sites with horizontal and vertical landscape design orientation will be selected. All the selected sites will be within tourism accommodation premises or to be exact hotel with vertical and horizontal building orientation. The preparation for data collection process in this section can be divided into two; observation and collecting data from authorities [11, 12].

2.2 Inventory and Analysis

In calculating the total built up areas and green areas of the selected site, the base map of each tourism premises are obtained from the authorities. The bill of quantities (BQ) were also collected to identify the exact quantity of the plant materials and to identify the specifications of vegetation including the overall height and breast height diameter of the existing vegetation to determine the age [14]. After collecting all the data needed at both sites, the Carbon Sequestration Rate (CSR) are calculated for every species of vegetation according to a specific formula [14]. The formulas are as detailed in Table 1.

In calculating the carbon sequestration rate of the selected hotel green spaces, there are a few matters needed to be considered as the rate for carbon sequestration vary greatly depending on a few factors such as tree species, age/stage of tree, composition/density of tree, location/condition of the tree and type of soil. With this information, the amount of CO_2 sequestered in a given tree/species can be roughly estimated by using only the tree age (weight, diameter and height). Thus, the yearly sequestration rate can be identified regardless the type of species, age, location or composition of the vegetation. The inventory list used are type of plant materials (tree, palm, shrub, ground cover), quantity, age, total area, height and diameter.

Table 1 CSR Formula for Trees, Shrubs, Turf, Creepers and Climbers

CSR formula for trees and shrubs	CSR formula for turf, creeper & climber
• **Total Green Weight (TGW)** TGW I: W = 0.25D2H (1.2)	• **Total Dry Weight (TDW)** TDW = 0.56 x area in meter squared
• **Total Dry Weight (TDW)** TDW I = TGW I x 0.725	• **Total Carbon Weight (TCW)** TCW = TDW x 0.427
• **Total Carbon Weight (TCW)** TCW I = TDW I x 0.5	• **Total CO_2 Weight (TCO_2W)** TCO_2W = TCW x 3.6663
• **Total CO2 Weight (TCO2W)** TCO2W I = TCW I x 3.6663	• **Carbon Rating System Point** tCO_2e = TCO_2W/1000
• **Total CO2 Weight (TCO2W/year)** TCO2W I/YEAR	
• **Carbon Rating System Point (tCO2e)** tCO2e I = TCO2W/2204.62	

3.0 CASE STUDY

A. Case Study 1 (Horizontal Hotel): Empayar Muzaffar Hotel, Ayer Keroh, Melaka

Referring to Table 2 below, it can be concluded that the built up area is 90% while the green area of this hotel are nearly 10% from the total area. This hotel also was classified as horizontal hotel because the total built up area is more than 30,000km^2 and it has only seven floors all together. The green area of the hotel are included the plants area at the parking lot, planter box and planter pot plants, planting area at water features, the garden fronting the lounge and VVIP room and the roof top garden. Empayar Muzaffar Hotel is perceived to have more development as compared to the green spaces. Thus, a ratio (X) of each hotel's green space per 10,000 km^2 must be made to know the percentage of green area for both hotels per 10,000 km^2. The ratios are calculated based on the in Table 3.

Figure 1 The Empayar Muzaffar Hotel Green Spaces Area

Table 2 Summary of Overall Areas

	AREA / Km²	***PERCENTAGE / %***
TOTAL BUILT UP AREA	31,861.40	90
TOTAL GREEN AREA	3,529.80	10
TOTAL AREA OF THE PREMISE	35,391.21	100

Table 3 Carbon Sequestration Rate Ratio Formula

$$\frac{X}{\text{Percentage of Green Area}} = \frac{1{,}000\ \text{km}^2}{\text{Total Built Up Area}}$$

Table 4 Vegetation Specs of Empayar Muzaffar Hotel, Melaka

TREE					
SPECIES	**OVERALL HEIGHT/feet**	**TOTAL DIAMETER /inch**	**AGE**	**QITY**	**CSR/ tCO_2e**
1.Baekea frutescen	6.56	11.81 - 27.56	28 year	11	5.95
2.Bucida molineti	6.56 – 9.84	11.81 -19.69	20 year	32	13.24
3. Dalbergiacochinchinensis	6.56 – 9.84	19.69 - 27.56	28 year	26	21.09
4. Plumeria alba	6.56	19.69 -27.56	28 year	5	2.70
PALM					
SPECIES	**OVERALL HEIGHT/feet**	**TOTAL DIAMETER /inch**	**AGE**	**QTY**	**CSR/ tCO_2e**
1. Cocosnucifera	9.84	3.94 – 7.87	8 year	18	1.98
2. Livistoniarotundifolia	9.84 - 13.12	3.94 – 5.91	6 year	11	0.68
3. Roystoneaoleracea	9.84 - 13.12	3.94 – 5.91	6 year	40	2.49
SHRUB					
SPECIES	**OVERALL HEIGHT/feet**	**TOTAL DIAMETER /inch**	**AGE**	**QTY**	**CSR/ tCO_2e**
1.Muraraya paniculata dwarf	0.66	0.59	1 year	2190	0.09
2.Phyllanthus myrtifolius	0.66	0.79	1.5 year	2320	0.17
3. Cyathealatebrosa	3.28	0.59	1 year	58	0.01
4. Jasminummultiflorum	1.31	0.39	1 year	650	0.02
5. Philodendron selloum	1.31	0.47	1 year	525	0.03
6. Thunbergia grandiflora alba	0.66	0.79	1.5 year	150	0.01
7. Wrightiaantidysenterica	1.31	0.79	1.5 year	750	0.09

Table 4 shows the vegetation details of Empayar Muzaffar Hotel plant materials. The carbon sequestration value for each species of the vegetation was identified. After calculate the sequestration value of each plant species and categories, a graph that combined the finding value for further evaluation has be made. Graph below indicate the relationship between plant categories and total carbon that can be sequestrate by them. Table 5 and graph is as follow:

Table 5 Distribution of Carbon Sequestration Rate by Types of Plants

TYPE	VALUE / tCO_2e
Trees	42.98
Palms	5.15
Shrubs	0.43

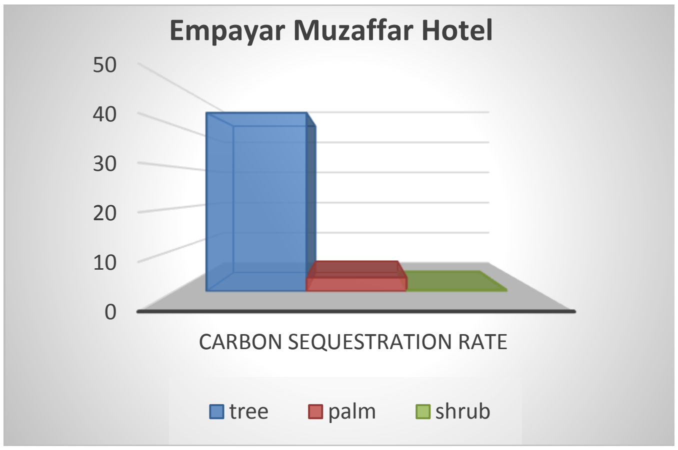

Figure 2 Carbon Sequestration Rate Based on Types of Plants

Figure 2 depicted that the highest value that can be sequestrated area from tree categories. Total carbon sequestration that occurs among tree species at this hotel is 42.98 tCO2e. The number is extremely high if compared to the palm and shrubs categories which are 5.15 tCO2e and 0.43tCO2e respectively. At this particular site, the reason trees is the dominant CSR agent is because the trees specification such as age, diameter and height proposed are very much influencing their CSR ability as they have a higher specification compared to other species.

B. Case Study 2 (Vertical Hotel): ION'D Element Hotel, Genting, Pahang

Figure 3 The I'ON D Element Hotel Area

Table 6 Summary of Overall Areas

	AREA / Km²	***PERCENTAGE / %***
TOTAL BUILT UP AREA	13,613.58	59
TOTAL GREEN AREA	9,646.42	41
TOTAL AREA OF THE PREMISE	23,260.00	100

According to Figure 3 and Table 6 above, it can be found that green area and built up area of Ion'D Element Hotel is 41% and 59% respectively. Since 10% is the standard allocated green space area reserved for any development, Ion'D Element Hotel illustrate that it has an advanced spaces for the green area. The green areas of the hotel are nearly equal to the built up area.

Below are the vegetation details of the plant materials at I'on D Element Hotel, Genting. The CSR of the premise is then calculated based on the criteria and details of the existing vegetation identified. The vegetation types and criteria were identified and their rates of carbon sequestration are tabulated.

Table 7 Vegetation Specs of I'OnD'Element

TREE					
SPECIES	**OVERALL HEIGHT/feet**	**TOTAL DIAMETER /inch**	**AGE**	**QTY**	**CSR/ tCO_2e**
1.*Baekea frutescen*	6.56	2.95	8 year	16	0.06
2.*Tabebuia argantaea*	6.56	2.95	8 year	2	0.01
3. *Browneaariza*	6.56	2.95	8 year	10	0.21
4. *Nageiarumphii*	6.56	2.95	8 year	6	0.06
5. *Cratoxyllumcochinensis*	6.56	2.95	8 year	9	0.09
6. *Pteleocarpalamponga*	9.84	2.95	8 year	5	0.08
7.*Eucalypthuscamaldulensis*	9.84	2.95	8 year	9	0.14
SHRUB/FERN					
SPECIES	**OVERALL HEIGHT/feet**	**TOTAL DIAMETER /inch**	**AGE**	**QTY**	**CSR/ tCO_2e**
1.*Canna hybrid*	1.97	15.00	1.5 year	75	0.67
2.*Habranthus sp.*	0.98	1.18	1.2 year	180	0.02
3. *Cyathealatebrosa*	1.48	3.94	1.2 year	375	9.16
4. *Loropetalumchinese*	1.48	1.18	1.2 year	125	0.05
5. *Philodendron selloum*	0.33	6.00	3 year	350	0.75
6. *Costusamazonicus*	0.33	0.78	0.8 year	250	0.01
7. *Penisettumrubrum*	0.98	1.10	1.2 year	130	0.28
8. *Lantana camara*	0.33	1.97	2 year	300	0.03
9. *Hippestrum amaryllis*	0.33	2.75	2.8 year	250	1.00
10 *Arundina sp.*	0.33	2.36	2.4 year	450	0.15
11. *Calathea Wilson princep*	0.33	5.12	2.5 year	950	1.49
12. *Angeloniabiflora*	0.33	1.97	2 year	250	0.06
13. *Sterlitziareginae*	0.33	13.00	1.3 year	200	2.02
GROUNDCOVER/CREEPER/CLIMBER					
SPECIES	**OVERALL HEIGHT/feet**	**TOTAL AREA/m^2**	**AGE**	**QTY**	**CSR/ tCO_2e**
1.*Axonapuscompresus*	0.16	1267.07	-	2850	0.17
2.*Zoysia matrella*	0.16	570.07	-	900	0.05
3. *Vernoniaelliptica*	-	206.68	-	3000	0.15
4. *Pogonantherumpaniceum*	0.16	96.85	-	475	0.03
5. *Vallarisglabra*	-	82.54	-	300	0.07

Table 8 Distribution of Carbon Sequestration Rate by Types of Plants

TYPE	**VALUE / tCO_2e**
Trees	2.17
Palms	0
Shrubs	15.00
Groundcover	1.69
Creeper	0.18
Climber	0.07
Ferns	0.40

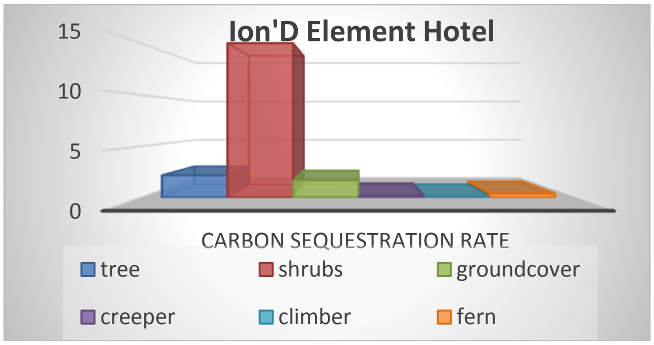

Figure 4 Carbon Sequestration Rate Based on Types of Plants

Figure 4 indicates the relationship between plant categories and total carbon that can be sequestrate by them.

From Figure 4, it can be depicted that the highest value that can be sequestrated is from the shrubs categories. Total carbon sequestration that occurs among shrubs species at this hotel is 15.00tCO2e. The number is extremely high if compared to the trees and groundcovers categories which are 2.17 tCO2e and 1.69 tCO2e respectively. At this particular area shrubs category is dominant CSR agent because the numbers of shrubs proposed are enormous compared to other plant types. Therefore the numbers of plant material proposed is also a major contributor to CSR percentage.

4.0 RESULTS AND DISCUSSION

A. Total of Green Spaces

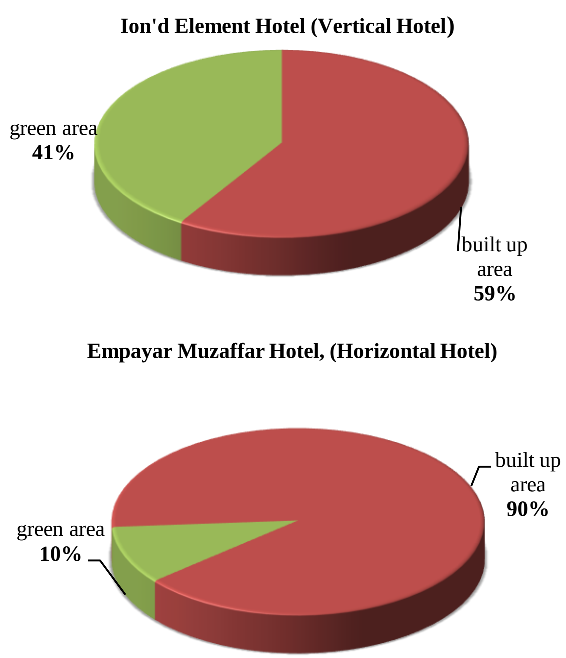

Figure 5 Percentage of Built Up and Green Areas

According to figure 5 above, it can be found that green area of Ion'D Element Hotel is higher than Empayar Muzaffar Hotel which are 42% and 10% respectively. Since 10% is the standard allocated green space area reserved for any development, Ion'D Element Hotel illustrate that it has an advanced spaces for the green area. The green areas of the hotel are nearly equal to the built up area. Whereas EmpayarMuzaffar Hotel are perceived to have more development as compared to the green spaces. Thus, a ratio (X) of each hotel's green space per 10,000 km2 must be made to know the percentage of green area for both hotels per 10,000 km2.

Based on the findings above, each types of vegetation are classified according to its grades based on the ability in sequestering carbon. This method somehow enables to identify the prime contributor in CSR of the hotel.

B. Plant Materials CSR Grad

As shown in Table 9 below, the species marked with (*) are the species existed in EmpayarMuzaffar Hotel and those without are in Ion'D Element Hotel. It is apparent the variety of plants used in the hotel which consist of mixture of grades in sequestering carbon. It can be depicted there is a difference in CSR for Baeckiafutescens whereby the tree species is in Grade 1 for EmpayarMuzaffar Hotel but considered as Grade 3 for Ion'D Element Hotel.

It can be suggested that the most potential species to sequestrate more carbon are from trees category which are Dalbergiacochinchinensis, Baekeafrutescens, and Bucidamolineti. It is because they are made of higher height and diameter which can improve the carbon sequestration rate if compared to other plant types and species.

This can be inferred due to the different property of the tree itself which differs in terms of height, diameter and the age of the tree even if the trees are of the same species. Thus it can be suggested that the CSR of a tree does not solely depend on the species itself but the properties of the tree. Whereas for groundcovers, creepers, climbers and ferns, the CSR are lesser compare to tree when counted as a unit.

Table 9 Grad Following the Potential of Carbon Sequestration Rate

TREE		
Grade 1 > 2.0 tCO_2e	**Grade 2 = 0.1-2.0 tCO_2e**	**Grade 3 < 0.1 tCO_2e**
*Dalbergiacochinchinensis**	*Browneaariza*	*Pteleocarpalamponga*
*Bucidamolineti**	*Juniperuschinensis*	*Agathisborneensis*
*Baeckiafutescens**	*Pinuscaribea*	*Casuarinanobilis*
*Plumeria alba**	*Spathodeacampanulata*	*Nageiarumphii*
	Eucalypthuscamaldulensis	*Cratoxyllumcochinensis*
		Baeckiafutescens
		Tabebuiaargantaea
PALM		
Grade 1 (1.8-2.6 tCO_2e)	**Grade 2 (0.9-1.7 tCO_2e)**	**Grade 3 (0-0.8 tCO_2e)**
*Roystoneaoleracea**	*Cocosnucifera**	*Livistoniarotundifolia**
SHRUB		
Grade 1 > 1.0 tCO_2e	**Grade 2 = 0.5-1.0 tCO_2e**	**Grade 3 < 0.5 tCO_2e**
Canna hybrid	*Philodendrumselloum **	*Habranthus sp.*
Calathea Wilson princep		*Loropetalumchinese*
Sterlitziareginae		*Penisettum sp.*
*Cyathealetebrosa **		*Lantana camara*
		Hippestrum amaryllis
		Arundina sp.
		Angeloniabiflora
		Philodendron
		*Murarayapaniculata dwarf**
		*Phyllanthusmyrtifolius**
		*Jasminummultiflorum**
		*Thunbergia grandiflora alba**
		*Wrightiaantidysenterica**
FERN		
Grade 1 >0.0005 tCO_2e	**Grade 2=0.0005 tCO_2e**	**Grade 3<0.0005 tCO_2e**
Nepenthes gracilis	*Neprolepsisbiserrata*	*Neprolepsisaculifolia*
GROUNDCOVER/CLIMBER/CREEPER		
Grade 1 >0.05 tCO_2e	**Grade 2 =0.05 tCO_2e**	**Grade 3 <0.05 tCO_2e**
Vernoniaelliptica	*Zoysiamatrella*	*Pogonantherumpaniceum*
Vallarisglabra		
Axonapuscompresus		

Table 10 Comparison of CSR for Both Premise Based on Plant Types

TYPE	Ion'D Element Hotel	EmpayarMuzaffar Hotel
Tree	2.17	42.98
Palm	0	5.15
Shrub	15.00	0.43
Groundcover	1.69	0
Creeper	0.18	0
Climber	0.07	0
Ferns	0.40	0
TOTAL CSR	**19.51**	**48.56**

C. Comparison of CSR in Horizontal and Vertical Premise

The findings suggest that, although Ion'D Element Hotel allocated more percentage of green areas in the hotel, the total CSR for the hotel is much lesser than that of Empayar Muzaffar Hotel's. Although Ion'D Element Hotel has much more variety of vegetation types, the CSR is still less to Empayar Muzaffar Hotel which has only three types of vegetation; trees, palms and shrubs. Interestingly, the most CSR in Ion'D Element Hotel is by shrubs but amounts only up to 15 tCO2e while Empayar Muzaffar Hotel's most CSR is done by trees which sequester approximately 43 tCO2e.

The difference between the ability of existing tree in both hotels to sequester carbon differs greatly although when referring back to Table 8 there are similarities in some of the tree species due to different grades the trees are. As the existing trees are older, the greater carbons are being absorbed by it and stored in the many of the tree trunks and branches. Similarly, if the application of shrub selection in Empayar Muzaffar Hotel is similar to Ion'D Element Hotel's, which by using the first grade shrubs in their hotel, the optimum rate of SCR could be achieved.

Factors influencing the total CSR of the hotels are most probably due to:

a) The specs of vegetation (tree height, diameter, and age)
b) The choice of plant materials in landscape design
c) The quantity of prominent vegetation type which sequester the most.
d) The percentage of allocated green area for the premise
e) The landscaping design of the premise

5.0 CONCLUSION AND RECOMMENDATION

In summary, the study first identifies the percentages of two types of coverage; built up area and green area. The different percentages of green area are identified in each block and ratios for every 1000km2 are made. Although some block has the same percentage of green area, the CSR of the blocks are different. This is due to the factors influencing the CSR is not according to the percentage of green area but the following factors are:

a) The total coverage of green area.
b) The selection of vegetation type.
c) The ability to sequester carbon differs according to the type of vegetation.
d) The variability of available type of vegetation.

Thus, it is important to note on the factors listed above in making sure the rate of carbon sequestration at the optimum rate for a development.

A. Design Approach and Guideline

The result revealed that both hotel tourism premises area need more plant materials and vegetation especially trees that is categorized as high potential to sequestrate carbon to increase the carbon sequestration rate at respective site [15]. Although both site contained green spaces which is approximately 3% to 30% compared to the total built up area, some workable approaches have been identified which can be implemented to maximally utilized towards the existing space of the green space in the hotel in order to receive high carbon sequestration rate. The approaches and guideline are as follows:

a) Use optimum height, diameter and age of the vegetation.
b) Choose plant materials species with high carbon sequestration rate.
c) Use optimum quantity of the plant materials compatible with the space.
d) Maximize the green area of the premises.
e) Maximize the landscape design at a premise according to its function.

B. Layout Design System Recommendations for Optimum Carbon Sequestration

Based on guideline and approaches that have been specified before, the design recommendation layouts have been produced as below:

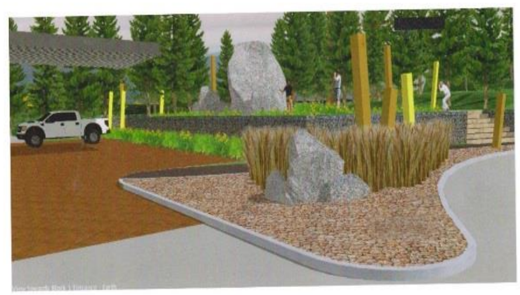

Figure 6 Before Recommendation

Figure 7 After Recommendation

Both images above describe the differences of pavement material used. Figure 6 shows that the pavement material which is interlocking pavement while Figure 7 shows the pavement material which is open grid pavement. The pavement is consist of loose hole at the center of each of the block that can be planted by some grass. This strategy could reduce the heat of the building effect and indirectly can help to increase the source of carbon sequestration run at this area [15].

Figure 8 Existing Rooftop Garden

Figure 9 Recommendation Rooftop Garden

Besides to provide the guest with a tangible connection to nature and to provide a downtown habitat can be seen in Figure 8 and Figure 9, rooftop garden also could help to mitigate the heat island effect that was present surround the hotel that caused by a lot of electrical appliances usage of the maintenance and management of the hotel itself. Other than that, maximizing the space of roof top garden could also reduce the amount of energy required to cool down the interior environment of the hotel that located underneath the rooftop garden and the important effect of maximizing the roof top garden are to increase the carbon storage by plant material at the area [16].

Figure 10 Before Recommendation

Figure 11 Recommendation Potted Plants

Referring to Figure 10 and 11, it show example of plotted plants and vines that can be planted at the entrance of a hotel and that can be recommended or implemented at any tourism premises.

Figure 12 Existing space of the Building

Figure 13 Recommended Vertical Garden

Vertical landscaping technology also could help to increase carbon sequestration alternatives by plant materials [16]. It is a freestanding or attached planting at existing walls and is available in great variety of sizes. Green walls or vertical garden are also seen as an increasingly popular approach among the developer [17.] Figure 12 visualize the existing outdoor spaces and elements while Figure 13 indicate the alternative to apply the vertical garden at the hardscape elements.

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