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ESTIMATION OF CARBON STORAGE AND SEQUESTRATION OF IPOH URBAN TREES FOR VOLUNTARY CARBON MARKET

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Abstract

Ipoh has strategies to sequester carbon by establishing a tree-planting program and increasing carbon storage in urban trees. The tree-planting program provides many environmental and social benefits. Hence, this research aims to quantify the mitigation of CO2 in the atmosphere by trees in the selected area which is Taman DR Seenivasagam for a pilot case study. The research objectives are to measure the carbon storage and sequestration of urban trees and to value the carbon credit for nature conservation. For the tree plant identification, carbon storage and sequestration were analysed using physical observation and a systematic literature review. A total of 220 trees were analysed and the total net carbon sequestration is estimated at 10,468.22 kg C/year, and the price for voluntary carbon credit in nature-based offset is estimated at USD 9.74 per year. This finding is an eye-opener to the community and policymakers: it signifies that every tree has a market value.

Keywords: Carbon Storage and Carbon Sequestration, Urban Tree, Carbon Credit, Nature Conservation Project, Voluntary Carbon Market

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INTRODUCTION

Carbon dioxide in the atmosphere is increasing yearly, especially in urban areas where primary industries and businesses are settled. Vegetation plays a vital role as it functions to 'absorb' carbon dioxide through photosynthesis and plays a part in the ecosystem's biodiversity. Vegetation has different functions, characters, and abilities for storing or sequestering carbon.

Carbon Storage, Carbon Sequestration, and Carbon Credit

According to Neufeld (2022), in the earth's ecosystem, carbons are stored in three ways: in the soil, atmosphere, plant and animal life. Among these, the soil component stored the highest carbon, followed by the atmosphere then the plant and animal life. One of the strategies to mitigate the carbon in the atmosphere is to store as much carbon in the plant life through tree planting programs and nature conservation. Carbon storage in plant life is the total amount of carbon in plant tissue or part of trees, such as in leaves, stems, fruits, and roots.

Carbon sequestration is the process of removing carbon from the atmosphere and storing it in another form that cannot immediately be released, like hardwood trees. It is the rate of uptake of carbon from the atmosphere. Half of the dry weight of trees contains carbon that was removed from the atmosphere. When a tree releases its stored carbon, whether by decomposing or tree burning, it produces CO_2. Converting the carbon in a tree to the equivalent amount of CO_2 makes it easier to compare with greenhouse gas mitigation strategies (Kosiba, 2021). Therefore, tree carbon is usually expressed as carbon dioxide equivalent (CO_2e).

According to Hassan Shah (2023), carbon credit is a certificate or permit that allows the owner to emit a certain amount of CO_2 or other GHG over a limited time. Carbon credits are represented in the unit of a tonne of CO_2 emission. Any company can purchase these credits to offset their carbon emissions, such as heavy factories that produce many carbon emissions. These credits represent emission reduction from projects that help to mitigate greenhouse gas emissions. In order to ensure the credits purchased are significant, they must genuinely result in a reduction in GHG emissions, and the exact credit cannot be used to offset emissions from more than one company. An example of purchase and sale is a fossil fuel producer, and car manufacturing industries that will purchase from companies that can provide quality carbon. In Malaysia, Shell (2023) is also involved in buying carbon credits in Voluntary Carbon Markets (VCM), which offers a platform for investors in carbon credits.

There are three types of carbon credit projects namely nature conservation, reforestation and carbon capture using technology (The Straits Times, 2022). Firstly, the nature conservation of carbon credit projects can be created by conserving existing forests. Secondly, reforestation of carbon credits is created based on the carbon captured by new trees planted like in the tree planting program. Thirdly, in carbon capture using technology, carbon dioxide is removed from the atmosphere and injected deep underground for storage, like Climeworks company, which established a carbon capture plant in Iceland (The Straits Times, 2022). According to Live Carbon Prices (2023), the first and second categories fall under nature-based carbon credit projects in the voluntary markets. Taman DR Seenivasagam in Ipoh City was selected for a case study for carbon storage and sequestration for voluntary carbon credit projects for nature conservation.

Ipoh towards Low Carbon Cities by 2030

The Low Carbon Cities also support two central Sustainable Development Goals: SDG11 of Sustainable Cities and Communities and SDG13 Climate Action. The government sets up many initiatives and strategies to mitigate carbon in the atmosphere to achieve low-carbon cities. One of the seven (7) key challenges that have been highlighted in the National Low Carbon Cities Masterplan (NLCCM) (2021 is that the data for greenhouse gas (GHG) inventory are weak in availability and access as well as accuracy, lack proper data, and have inconsistent methodology.

Malaysian Green Technology and Climate Change Corporation (MGTC) (2023) states that initiatives in developing low-carbon cities have five elements: energy, water, waste, mobility, and greenery. Under Greenery elements, the shift towards protecting existing greenery (conservation) and planting more trees are highlighted. For example, according to Setiausaha Kerajaan Negeri (SUK) Perak (2023), Perak state has also planted more trees and committed to planting 2.5 million trees in 2023. In Malaysia, there is no published information on the extent of carbon storage and sequestration by urban trees for the VCM. It was undeniable that the value of carbon is relatively low due to the life span of trees and ecosystems (Neufeld, 2022) compared with the tropical rainforest in Sabah, as reported by Cannon (2023). Thus, this research supports the government's agenda.

To investigate the strategies for urban governance employed by the local government in relation to LCC, the study also applied the case study method as mentioned in Abdullah (2022). It explained the importance of carbon to be investigated by the Shah Alam local authorities through a case study. In Perak, there are many efforts to mitigate the carbon dioxide in the atmosphere as initiated by the local government. In Ipoh City, to select the greenery conservation place, the researcher interviewed the director of the Landscape Department in Ipoh Local Authorities to suggest a place that has many trees in the city centre and also close to community engagement. Based on the feedback, Taman DR Seenivasagam is an active park where the trees are on a conservation track. The park has a variety of plant species, from heritage trees to different palms, exotic and non-exotic shrubs, and aquatic plants. It also offers a strategic location where the trees are accessible and under direct maintenance by local authorities and has an active community engagement, especially during weekends. Thus, Taman DR Seenivasagam was selected as the pilot case study for the Ipoh urban city under the management of Ipoh City Council and UiTM, which collect the data on carbon storage and sequestration of trees in designated parks in the urban areas. The research objectives are:

1. To measure the carbon storage and sequestration of urban trees in Taman DR Seenivasagam, and
2. To value the carbon credit for nature conservation.

MATERIALS AND METHOD

Two stages of data inventory are involved: physical observation and narrative literature review. The research was conducted in 2023.

Physical Observation for Tree Inventory

The Taman DR Seenivasagam has approximately 450 - 500 trees in approximately 195,477 m² or 48.3 acres. The inventory project has been divided into two phases, and for Phase 1, 220 trees with 39 tree species were collected in 2023. It was estimated that the tree inventory project would be completed in 2024.

Collaboration was made with the National Landscape Department and Ipoh City Council, to generate the tree inventory by a certified arborist who identifies and measure trees on the site. Several lists of data observed on the site was the name of tree species, tree count, and tree girth of diameter at breast height (DBH). The DBH are measured approximately 1.3 m from the ground level by using DBH tape. Based on the DBH tree measurements, the trees are categorised into four categories, namely girth 1 to 4 (Table 1). This category was referred to the National Parks Board (NPB) of Singapore for carbon storage and sequestration secondary data. The categorisation refers to the data value on carbon storage and sequestration to simplify the calculation in obtaining the estimation of carbon storage and sequestration, as stated in Tan (2009).

Table 1: Tree girth categories in Taman DR Seenivasagam.

No	Tree Girth Classification by the NPB	Girth
1	Girth at diameter of breast height (DBH) <50cm	Girth 1
2	Girth at a diameter of breast height (DBH) between 50cm - 100cm	Girth 2
3	Girth at a diameter of breast height (DBH) between 100cm -150cm	Girth 3
4	Girth at a diameter of breast height (DBH) more than 150cm	Girth 4

Source: Tan (2009).

Narrative Literature Review of Estimation Carbon Storage and Carbon Sequestration

According to George (2019), a narrative literature review is a general approach to an interesting topic. As shown in Figure 2, there are four steps to conduct narrative review; step 1: conduct a search, step 2: identify keywords, step 3: review abstracts and articles, and step 4: document results (George, 2019). This study was conducted to supply secondary data on carbon storage and sequestration of urban trees collected at Taman DR Seenivasagam. From 220 number of trees, 150 data (68.2%) were referred to from the book by Tan (2009) and 70 data (31.8%) were based on tree data from various journals published in Thailand, India and Nigeria such as Prasadan (2018), Anil Ragula (2021), Potadar (2016), Potadar (2017), Pinyarat (2021), and Olajide (2021),. Tan (2009) was referred to as a primary source of carbon storage and sequestration as they were recorded in Singapore, and the tropical data are more likely significant with Malaysia.

From these two stages of data inventory, the researcher measured the first objective of the carbon storage and sequestration of urban trees in Taman DR Seenivasagam by using the formula as stated in Figure 3 (Tan,2009) Figure 3. To obtain total carbon storage, the total of trees on the site needs to be multiplied by the value of carbon storage obtained through a narrative literature review. The same method was applied to find the value with carbon sequestration. The findings can be referred to in Table 2 in the results and discussion section.

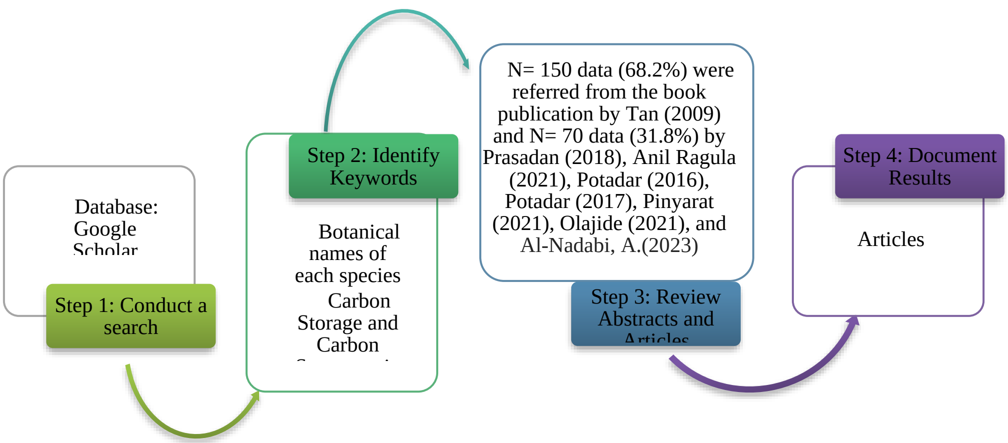

Figure 2: Secondary data on carbon storage and sequestration obtained from book and journal articles.
Source: Author

Total Carbon Storage (D) = Tree Count (A) x Per Tree Carbon Storage Rate (B)
Net Carbon Sequestration (E) = Tree Count (A) x Per Tree Carbon Sequestration Rate (C)

Figure 3: Formula in obtaining total carbon storage and net carbon sequestration.
Source: Tan (2009)

To answer the second objective of the value of the carbon credit for nature conservation, according to a recent update in Sabah forest regarding nature conservation, for the voluntary market, prices have ranged between USD1 and USD3 since early 2023, with nature-based credits currently going for $1.10 on the voluntary carbon market on November 1, 2023, (Cannon,2023). Thus, this statement was used to obtain the estimation value of carbon credit on this project, as it is closely related to the context of this project.

RESULTS AND DISCUSSION

The tree was tagged using a GPS handheld unit and presented in Figure 4. In phase 1 data collection, based on the physical observation and SLR, the researcher analysed that carbon storage of 220 trees is accumulated with a minimum of 166,349.42 kg C of carbon storage, and the total net carbon sequestration in a year is a minimum of 10,468.22 kg C / year as shown in Table 2. The largest size of tree girth and the highest value of carbon storage and sequestration is from *Ficus sp.,* which makes a total of 90,214 kg C of carbon storage and 7,525 kg C / year or 54.2% to 71.9% of the total contribution, respectively. The DBH of *Albizia saman* is reported as the largest girth at 386cm at tree tagged DR031, followed by *Pithecellobium dulce* at 304.4cm at tree tagged DR080.

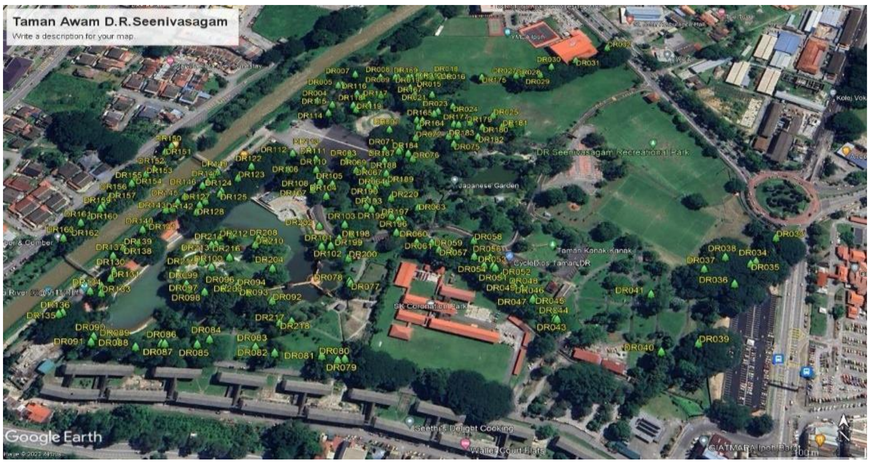

Figure 4: Inventory data collection of 220 tree tagging in Taman DR Seenivasagam
Source: Author

Table 2: Carbon storage and sequestration of 220 total tree count in Taman DR Seenivasagam.

No	Species	Tree tagging reference (DR)	Girth	Tree count (A)	Per Tree Carbon Storage Rate (kg C/tree) (B)	Per Tree Carbon Sequestration Rate (kg C year / tree) (C)	Total Carbon Storage (kg C) D=A x B	Net Carbon Sequestration (kg C/year) E=A x C
1	*Adenanthera pavonina*	2	G2	1	994.39	82.86	994.39	82.86
2	*Albizia saman*	122, 125, 126	G2	3	147	10	441	30
		1, 7, 39, 113, 124, 127, 128, 135, 150	G3	9	447	18	4023	162
		4, 5, 6, 29, 30, 31, 32, 33, 34, 36, 37, 38, 106, 123, 129, 136, 151	G4	17	1707	21	29019	357
3	*Andira inermis*	190, 194, 196, 213, 214, 215	G2	6	153	11	918	66
4	*Castanospermum australe*	77	G2	1	-	-	0	0
		78	G3	1	-	-	0	0
5	*Ceiba pentandra*	102, 200	G2	2	1137.66	94.8	2275.32	189.6
6	*Cinnamomum iners*	192, 193	G2	2	127	10	254	20
7	*Cyrtophyllum fragrans*	208	G1	1	24	4	24	4
		205, 206, 207, 209, 210	G2	5	102	9	510	45
8	*Delonix regia*	103, 181	G3	2	246	21	491.7	41
9	*Eucalyptus deglupta*	19, 21	G3	2	-	-	0	0
10	*Ficus benghalensis*	67	G4	1	2098	175	2098	175
11	*Ficus benjamina*	43, 44, 45, 47, 49, 50, 51, 54, 55, 57	G2	10	2098	175	20980	1750
		42, 48, 52, 53	G3	4	2098	175	8392	700
		46	G4	1	2098	175	2098	175
12	*Ficus callosa*	111, 112	G2	2	2098	175	4196	350

No	Species	Tree tagging reference (DR)	Girth	Tree count (A)	Per Tree Carbon Storage Rate (kg C/tree) (B)	Per Tree Carbon Sequestration Rate (kg C year / tree) (C)	Total Carbon Storage (kg C) D=A x B	Net Carbon Sequestration (kg C/year) E=A x C
		35, 61	G3	2	2098	175	4196	350
13	*Ficus elastica*	58	G4	1	2098	175	2098	175
14	*Ficus heteropleura*	110, 202	G2	2	2098	175	4196	350
		23	G3	1	2098	175	2098	175
15	*Ficus kurzii*	60, 72	G4	2	2098	175	4196	350
16	*Ficus microcarpa*	204	G3	1	2098	175	2098	175
		24, 76, 81, 116	G4	4	2098	175	8392	700
17	*Ficus religiosa*	68	G3	2	2098	175	4196	350
18	*Ficus rumphii*	131, 132	G2	2	2098	175	4196	350
		70, 71, 74, 75, 134	G3	4	2098	175	8392	700
		8, 25, 63, 114	G4	4	2098	175	8392	700
19	*Firmiana malayana*	185, 186, 201	G2	3	-	-	0	0
20	*Hura crepitans*	176, 177, 178, 182, 183	G2	5	750	62.5	3750	312.5
21	*Khaya senegalensis*	9-18, 28, 94-99, 137-149, 152-163, 168-175, 203	G2	49	143	10	7007	490
		16, 27, 92, 93, 97	G3	5	431	17	2155	85
22	*Lagerstroemia floribunda*	217	G2	1	124	9	124	9
23	*Lagerstroemia speciosa*	104	G2	1	124	9	124	9
		105	G3	1	373	16	373	16
24	*Mangifera cf pentandra*	187	G1	1	32	5	32	5
25	*Mangifera foetida*	100, 211, 212, 218	G2	4	150	10	600	40
26	*Mangifera indica*	199	G2	1	150	10	150	10
27	*Millettia pinnata*	73	G3	1	99	9	99	9
28	*Mimusops elengi*	64	G3	1	348	14	348	14

No	Species	Tree tagging reference (DR)	Girth	Tree count (A)	Per Tree Carbon Storage Rate (kg C/tree) (B)	Per Tree Carbon Sequestration Rate (kg C year / tree) (C)	Total Carbon Storage (kg C) D=A x B	Net Carbon Sequestration (kg C/year) E=A x C
29	*Morinda elliptica*	184	G2	1	-	-	0	0
30	*Nephelium lappaceum*	216	G2	1	-	-	0	0
31	*Peltophorum pterocarpum*	107, 108, 109, 133, 179, 180, 188, 197, 198	G2	9	139	10	1251	90
		90	G3	1	396	16	396	16
		26	G4	1	1135	30	1135	30
32	*Pithecellobium dulce*	79	G3	1	382.18	31.8	382.18	31.8
		80	G4	3	382.18	31.8	1146.54	95.4
33	*Polyalthia longifolia*	191, 195, 219, 220	G2	7	82.67	6.9	578.69	48.3
34	*Pterocarpus indicus*	**101, 130, 167**	G2	3	97	9	291	27
		20, 84, 85, 87, 89, 91	G3	6	390	17	2340	102
		22, 86, 88	G4	3	3233	38	9699	114
35	*Sterculia foetida*	3, 41, 69	G3	3	71	5.92	213	17.76
36	*Swietenia macrophylla*	40, 66, 189	G2	3	140	10	420	30
37	*Syzygium grande*	62	G2	1	144	10	144	10
		56	G3	1	389	16	389	16
38	*Tamarindus indica*	65	G2	1	153	10	153	10
		59	G3	1	392	17	392	17
39	*Tectona grandis*	115, 117, 118, 119, 120, 121	G2	6	582.1	48.5	3492.6	291
	Total			**220**			**166,349.42**	**10,468.22**

Source: Author

There are limitations in identifying the figure of carbon storage and sequestration based on the SLR due to limited data resources. Five species are not able to be identified for their carbon storage and carbon sequestration. The researcher put a Zero (0) value which indicates the minimum estimation value for *Castanospermum australe, Eucalyptus deglupta, Firmiana malayana, Morinda elliptica,* and *Nephelium lappaceum.* Due to the limited data resources, the researcher replicated the number of figure carbon storage and sequestration of *Ficus sp.* with 2,098 kg C / tree and 175 kg C year/tree to all girth categories in G1-G4, which put in the minimum estimation value. The highest frequency of species in the park is *Khaya senegalensis* with 54 tree counts, followed by *Albizia saman* at 29 and *Ficus benjamina* at 15.

The estimation value of carbon credit for nature conservation is based on the voluntary carbon market on November 14th, 2023, and was obtained in Live Carbon Prices (2023) at one metric ton of carbon dioxide valued at USD0.93. The price range, however, has been decreasing since the end of September 2023 (Figure 5). In Figure 6, the price was once as high as USD18.59 per metric ton on January 19th, 2022.

Figure 5: Voluntary Carbon Markets of Nature-Based Carbon Offset. 1 metric ton of carbon dioxide is valued at USD0.93 or MYR4.38.
Sources: Live Carbon Prices (2023) at November 14th, 2023

Figure 6: Voluntary Carbon Markets of Nature Based Carbon Offset trend from 2022 until 2023.
Sources: Live Carbon Prices (2023) at November 14th, 2023

In considering the Phase 1 data collection, the researcher put the minimum number of estimation values in carbon storage and carbon sequestration cited through SLR. Thus, the total net carbon sequestration of Taman DR Seenivasagam is 10,468.22 kg C/year, equal to 10.47 metric tons times USD0.93, equal to USD9.74 per year or RM45.90 in a year. Although the number is relatively low, the voluntary market of nature-based offset is among the highest compared with the aviation industry offset and technology-based offset in Figure 7, both at USD0.68.

CarbonCredits.com Live Carbon Prices	**Last**	**Change**	**YTD**
Compliance Markets			
European Union	€ 77.74	-0.44%	-2.83%
UK	£40.66	-9.04%	-44.49%
California	$29.45	-	+1.31%
Australia (AUD)	$31.00	-	-8.28%
New Zealand (NZD)	$70.10	-	-8.27%
South Korea	$7.49	-1.00%	-37.81%
China	$9.87	+1.25%	+24.62%
Voluntary Markets			
Aviation Industry Offset	$0.68	+21.43%	-82.29%
Nature Based Offset	**$0.93**	+8.14%	-79.78%
Tech Based Offset	$0.68	+33.33%	-40.35%

Figure 7: The comparison of carbon credit prices of voluntary markets.
Sources: Live Carbon Prices (2023) on November 14th, 2023

CONCLUSIONS AND FUTURE WORKS

In conclusion, the research aims to mitigate carbon emissions in the atmosphere through a nature conservation project by using carbon credit of voluntary markets. It is shown that there are fluctuations in the markets throughout the year. The outcome of this research paper can be used as an eye-opener to any nature-based project in Malaysia to obtain money from the voluntary markets by keeping the project sustained. According to the New Straits Times (2022), there is a lack of supply of carbon credits in Malaysia, even though they are in high demand.

Another nature-based project in Malaysia that has been committed to this project is found in Sabah, which has signed a nature conservation agreement with Hoch Standard from a Singaporean firm to sell credits for carbon and other natural capital for 4.9 million per acre of forest for the next 100 years (Cannon, 2023). However, to start the project, the ownership of the project must be clear for legal contributions. Taman DR Seenivasagam is one of the examples of a pilot study which involves calculating the carbon credit nature conservation project. In town planning for Low Carbon Cities, the tree planting program in a designated area of clear land ownership is an example of planning the small steps in change to obtain credit from a nature conservation project. The size and location of the project also affect the methods used in calculating the estimation of carbon storage and sequestration.

This research uses secondary data to estimate the pilot project for a small-scale nature conservation project due to time constraints. To improve the data collection, the primary data on carbon sequestration should be retrieved from the on-site measurement for significantly precise data collection. Depending on the land use classification, where the intensity of the tree is observed, and if the location is an urban site, the use of an instrument that can measure the photosynthesis rate for the carbon sequestration study is sufficient. However, if the location is in the forestry area and the accumulation of trees gathered can be obtained on average, the use of remote sensing technology and GIS can be conducted further.

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