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Distribution, Estimation of Carbon Storage and Sequestration of *Pelthoporum pterocarpum* Species: A Case Study of Universiti Teknologi MARA, Seri Iskandar Green Campus

Norasikin Hassan[1*], Haslina Hashim[1], Izrahayu Che Hashim[1], Suzanah Abdullah[1], Wan Noor Anira Wan Ali @ Yaacob

[1] Department of Built Environment Studies and Technology, College of Built Environment, Universiti Teknologi MARA (UiTM), 32610, Perak Branch, Perak, Malaysia

*Corresponding Author: sikinhassan@uitm.edu.my

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Abstract: *Trees in Malaysia serve various purposes, including their aesthetic appeal due to lush foliage and vibrant flowers. However, they hold additional significance by offering numerous environmental advantages, particularly concerning carbon storage and sequestration and their function to absorb excess carbon that affects global warming. Despite their importance, estimating carbon storage for most tropical trees in open space, roadside planting, and urban trees has been challenging due to limited research and unclear methodologies. Addressing this gap, this preliminary study aims to focus on mapping and developing a basic carbon sequestration estimation method for the Pelthoporum pterocarpum species, a heritage tree that was among the mostly planted trees within the UiTM Perak Green Campus open space and one of the best tropical trees that has a high percentage of carbon storage and sequestration. The study calculated the carbon sequestration rate using biomass equations and data from field mapping, inventories, measurements, plan analysis, and surveys. To facilitate efficient data management, the researchers leveraged Geographic Information System (GIS) technology, an influential urban forest data organization tool. The study's significant finding was accurately representing tree distribution and positions on the 2D trail map. These outcomes hold immense value for decision-makers as they provide a systematic inventory database and a 2D map, supporting future planning, estimating carbon storage, and efficiently managing tropical trees in open space, roadside planting, and trees in urban parks.*

Keywords: carbon storage, carbon sequestration, global warming, urban trees, sustainable environment, green campus

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1. Introduction

According to Michael and Louise Judd (2018), "Trees are the earth's lungs." In the context of the Garden City of Malaysia, the tree-lined roads have become the "backbone" of the city's extensive development. However, urban pollution caused by motor vehicles and industrial activities releasing carbon dioxide into the atmosphere has become a serious global issue. Therefore, tree planting has emerged as a vital approach to addressing urban pollution.

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Trees offer many environmental and ecological benefits, including mitigating the urban heat island (UHI) phenomenon in Malaysia. According to the Singapore Centre of Urban Greenery and Ecology (CUGE, 2009), trees and greenery play significant roles in air purification, stormwater regulation, and carbon storage, which is crucial for biodiversity conservation within urban areas and reducing the impact of UHI. This contributes to various positive outcomes, such as reduced energy consumption in buildings, decreased formation of ground-level ozone, improved outdoor thermal comfort, reduced heat-stress-related events, and enhanced outdoor experiences in sunny and warm conditions.

In light of climate change and global warming, the role of trees as natural carbon sinks has gained significant international attention. Research shows that forests store approximately 40% of the world's terrestrial carbon stock, making tree planting in urban settings a vital measure to offset carbon emissions and energy consumption (CUGE, 2009). The focus on climate change and urban heat islands has become a prominent research topic to support Sustainable Development Goal (SDG 13- climate action) in Malaysia. Sustainable design and solutions have been widely incorporated into planning and development across various sectors, including government, private sectors, and educational institutions such as campuses (Mohd Shobri, Yaacob, Mt Akhir & Md Sakip, 2017). UiTM Perak, for instance, has taken steps towards human-influenced climate change and environmental sustainability by establishing a Green Campus initiative.

2. Literature Review

Green Campus

The United Nations has designated 2005–2014 as the ‘Decade of Education for Sustainable Development,’ with its overall goal ‘to integrate the principles, values, and practices of sustainable development into all aspects of education and learning... [and to] encourage changes in economic behaviour that will create a more sustainable future in terms of environmental integrity, economic vitality, and a just society for present and future generations’ (Abraham, 2007). To this end, students and faculty at several colleges and universities have undertaken efforts to make their institutions more sustainable and educate others on the importance of resource use and sustainable development. According to history, at this point, universities and colleges were the best and in a unique position to address these issues. The university is an institution of research, and education plays a vital role in educating prospective future leaders to emphasize the issue of sustainability to ensure the sustainability of the communities in the future (Ryan et al., 2010). They are the educators of future generations of professionals and possess the intellectual capacity and resources to effectively integrate educational initiatives into their mission and programs.

Today, Wiedmann & Minx (2008) stated that the reductions of carbon emissions and global warming are at the top of the environmental policy agenda. Green campus programmes provide the stability of human well-being by incorporating economic feasibility, environmental conservation and preservation, and social equality through development, operation design, maintenance, and waste management (Yiing et al., 2013). Universiti Teknologi MARA has established the Institute Sustainable Initiatives UiTM, which consists of 10 faculties and 39 excellence entities to initiate Greenation @ UiTM. This institute was undertaken to stimulate and encourage students and visitors on sustainability, experience, and interaction toward a healthy lifestyle. UiTM has made some positive impacts from some of the initiatives, such as practices in recycling and waste management activities., deploys energy efficient practices and

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proper water management, induced CO2 emissions reduction practices, eco-friendly transport policies, increases campus community awareness and deploys campus environmental management initiatives.

These practices have been carried out in a few UiTM campuses throughout peninsular Malaysia, namely UiTM Selangor, UiTM Seri Iskandar and UiTM Pahang (Anthony & Bokolo, 2021), which have helped in achieving the mission of reducing carbon dioxide emission in campus concerning the global climate issues and challenges faced. The most common challenge Malaysian universities face in increasing forest and plant vegetation areas on campus is a need for more finance. This is due to the high cost of implementing this initiative and the limited availability of funds provided by the university. Ultimately, the budget allocated is just for maintaining the current campus landscape, forest, and plant vegetation area. Thus, universities decided to preserve and sustain the well-being of the existing campus green areas (Mohd et al., Md Sakip & Janah Singh, 2022). In line with the aim of the study, it is hope, a proper selection of tree species will be taken into consideration in future physical planning of UiTM Green campus.

The Morphology of Pelthoporum pterocarpum (Yellow flame)

Results reported from a study done by the Singapore Centre of Urban Greenery and Ecology (CUGE, 2009) on carbon storage and sequestration on urban typical and common trees like Samanea saman (rain tree), Khaya senegalensis (African mahogany) and Pelthoporum pterocarpum (yellow flame) trees shown high percentage of carbon storage and sequestration in tonnes as compared to others roadside and urban trees. Peltophorum pterocarpum (copper pod, golden flamboyant, yellow flamboyant, yellow flame tree, yellowing Bengali) is a species of Peltophorum, native to tropical southeastern Asia and a popularly ornamental tree grown around the world (World Agro Forestry Centre, 2023). Peltophorum pterocarpum is a deciduous tree growing to 15–25 m (rarely up to 50 m) tall, with a trunk diameter of up to 1 m belonging to Family Leguminosae and sub-family Caesalpiniaceaea. The leaves are bipinnate, 30–60 cm long, with 16-20 pinnae, each pinna with 20-40 oval leaflets 8–25 mm long and 4–10 mm broad. The flowers are yellow, 2.5–4 cm in diameter, produced in large compound racemes up to 20 cm long. The fruit is a pod 5–10 cm long and 2.5 cm broad, red at first, ripening black, and containing one to four seeds. Trees begin to flower after about four years.
The tree is widely grown in tropical regions as an ornamental tree, particularly in Malaysia, India, Nigeria, Pakistan, Florida and Hawaii in the United States. In Malaysia (Figure 1), Peltophorum pterocarpum is a renowned tree which has high vegetation density and its capability to the reduction of air temperature by promoting more evapotranspiration and effectively improving the ambience and outdoor thermal comfort in tropical urban open spaces (Yaacob, Hassan & Mohd Sarip, 2012). The trees are a fast-growing famous street tree with luxuriant spreading, and one of the charms of these lovely trees is the carpet of golden blooms which accumulates on the ground underneath (Gardner & Pindar, 2011).

Figure 1: Specimen Selected for Field Measurement of Yellow Flame (Peltophorum pterocarpum)
Source: Researcher (2023)

GIS Approach for Tree Distribution Mapping and Carbon Estimation Calculation

Today, the expected carbon sequestration rate in urban parks is calculated by biomass equations using field data inventory, measurements, plan analysis and survey data analysis (Othman et al., 2019). Based on the literature study, little research was carried out on urban trees in the case of carbon estimation despite the significant interest in this area (CUGE, 2009). Due to the needing for published information on the extent of carbon storage and sequestration, this preliminary research aimed to fill the gap. The study uses GIS tools to develop a Pelthoporum pterocarpum single species inventory database and visualize this information in a two-dimensional map showing the tree trail alongside the UiTM Perak branch. GIS was once recognized as a potent technology for effectively managing data about urban forests (Adam et al., 2017). Information systems have thus been employed extensively for challenges relating to environmental management, and this dissemination offers several benefits to researchers and administrators. Field and secondary data are combined to create an understandable map for users of various skill levels. Due to that, GIS can assist users and decision-makers in cities to efficiently manage urban park projects and lower management costs. GIS combines various data types for intelligent planning for future conservation of natural features in the urban park area (Hashim et al., 2022).

As technology advanced, GIS technology created sophisticated digital maps (Hashim et al., 2022). With its high-quality cartographic output, GIS can help users with no cartographic skills advance from traditional descriptive mapping to prescriptive mapping (Maizatullah et al., 2022). It dramatically simplifies the administration of information. Geographic Information Systems (GIS) systems have found widespread use in urban planning, real estate management, administration, infrastructure management, and many other spheres of life because of the extremely rapid rise of information technology (Mierzejowska & Zogala, 2018). Moreover, GIS can combine different data types for intelligent planning (Tasoulas et al., 2013).

Due to the rapid development of information technology, GIS systems are now widely used in urban planning, real estate management, administration, infrastructure management, and many other areas of life (Mierzejowska & Zogala, 2018). GIS, hardware, software, and data may be integrated for analysis, expression, and management. The terms ‘data’ and ‘information’ should be distinguished when discussing data management (Maritz, 2003). GIS allows for producing data or information in additional formats, such as tables and maps (San et al., 2018). Given the amount of data that needs to be processed, a visual representation can help users comprehend ideas more easily (Hashim et al., 2022). Furthermore, GIS mapping enabled more straightforward information to obtain and comprehend by the customer or end-user (Akif, 2001). Therefore, GIS as a mapping tool enables users to develop more user-friendly and intelligible information.

3. Methodology

This research study uses the GIS approach to identify Peltophorum Pterocarpum tree allometries and their distribution in UiTM Perak areas. Tree parameters such as tree location will be collected using specific geospatial apps. ArcGIS software will process and develop the tree inventory database and its two-dimensional trail map. The tabular data from the tree information will be analysed to show the distribution of each tree that contributes to providing better living and aesthetic value to the community in the area.

Materials

For this research, the primary data collection, the tree location (X, Y coordinate), was collected using geospatial mobile tools, SM Maps. In contrast, tree girth and diameter were collected using the specific technique from a landscape perspective.

Samples

For this study, samples were divided into two categories. The first primary data was the tree information, including the tree species, botanical name, Diameter Breast Height (DBH) and tree girth. The second category was the tree location (X, Y coordinate), and the picture was collected using geospatial mobile tools, SM Map. Table 1 below shows an example of the tabular data for this research study.

Table 1: The representative heritage tree species (part of the data)

Tree ID	Name of Tree	Girth size (m)
1	pelthoporum pterocarpum	0.99
2	pelthoporum pterocarpum	1.01
3	pelthoporum pterocarpum	0.79
4	pelthoporum pterocarpum	0.91
5	pelthoporum pterocarpum	0.94
6	pelthoporum pterocarpum	0.77
7	pelthoporum pterocarpum	1.02
8	pelthoporum pterocarpum	1.2
9	pelthoporum pterocarpum	0.83
10	pelthoporum pterocarpum	0.82
11	pelthoporum pterocarpum	1.14
12	pelthoporum pterocarpum	0.59
13	pelthoporum pterocarpum	1.07
14	pelthoporum pterocarpum	1.06
15	pelthoporum pterocarpum	1.04
16	pelthoporum pterocarpum	1
17	pelthoporum pterocarpum	0.76
18	pelthoporum pterocarpum	0.82
19	pelthoporum pterocarpum	0.61
20	pelthoporum pterocarpum	0.64
21	pelthoporum pterocarpum	0.95
22	pelthoporum pterocarpum	0.63
23	pelthoporum pterocarpum	0.65
24	pelthoporum pterocarpum	1.04
25	pelthoporum pterocarpum	0.6
26	pelthoporum pterocarpum	0.84
27	pelthoporum pterocarpum	0.39
28	pelthoporum pterocarpum	0.63
29	pelthoporum pterocarpum	0.96
30	pelthoporum pterocarpum	0.63

The Site

This study area of this research covered the whole area of the UiTM Perak branch, as can be referred to in Figure 2. The main factor of this research is done in this area because of the distribution of Peltophorum Pterocarpum trees.

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Figure 2: Image of study area in UiTM Perak Branch
Source: Google Earth

Procedures

The research flowchart in Figure 3 provides an overview of the methods used for this research study. This study involves three (3) phases: data collection, data processing and analysis and result preparation.

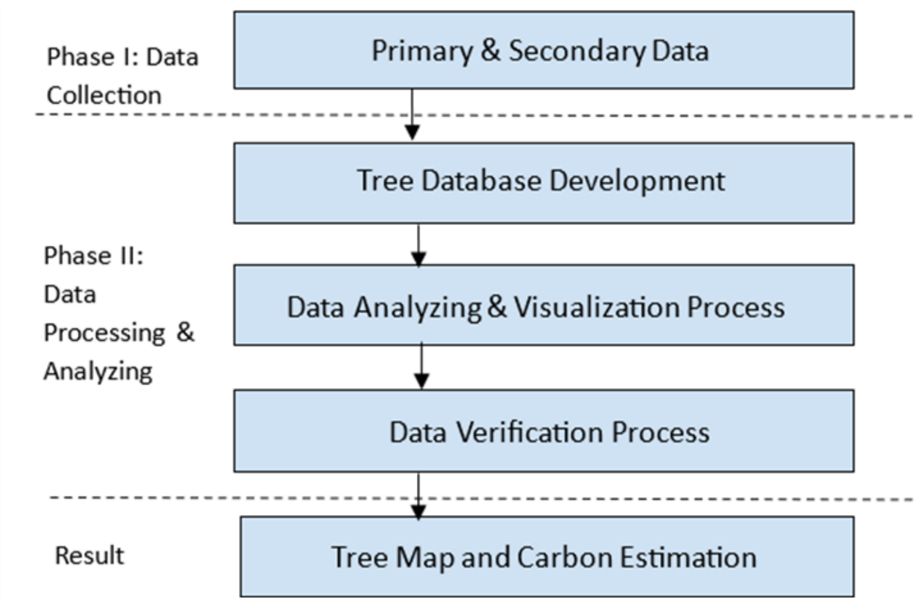

Figure 3: The methodology flow chart of Tree Database and 2D Mapping

Data Collection

Data observation for all the trees was collected using specific tools such as SW Map Field Data Collector. The tree location (X, Y coordinate) was collected using geospatial mobile tools. The tree distribution data was exported to Google Earth to verify the field ata. Then, the observer verified all the tree locations per the approved requirements. All collected data will be processed, analysed, and visualized using specific software and presented in two-dimensional maps and tabular data.

Data Processing and Analysing

The data processing and analysing phase involves the development of the tree inventory database in ArcGIS software. This database contains the tree inventory data and their exact location (X, Y coordinate). Analysis related to the inventory data can be performed using the developed database and calculation of carbon storage and sequestration based on the Centre for Urban Greenery and Ecology (CUGE) to create the two-dimension (2D) map. For the verification process, the tree distribution data was exported to Google Earth to verify the tree's location. Approximately 72 representative trees were identified for the database development, and the allometries detail for each species was recorded in an attribute table linked to the GIS application.

Estimation for carbon storage and sequestration for each tree was calculated by referring to CUGE, where the calculation was based on tree species and its girth size. Table 1 shows detailed information regarding the carbon estimation value. Table 2 shows part of the tree allometries data.

Table 1: Amount of carbon storage and sequestration per tree according to the girth range (CUGE)

Species	**Unit Rate Carbon Storage (kg C/tree)**				**Unit Rate Net Carbon Sequestration (Kg C year /tree)**			
Girth Range	G1	G2	G3	G4	G1	G2	G3	G4
Peltophorum pterocarpum	31	139	396	1135	5	10	16	30

Table 2: Tree inventory data

Distribution of Batai Laut (Features: 72, Selected: 0)

ID No	Botanical Name	Girth Value (m)	Carbon Storage (Kg/C)	Net Carbon Sequestration (KgC/year)	Diameter (meters)
16	pelthoporum pterocarpum	0.99	139	10	0.27
17	pelthoporum pterocarpum	0.76	139	10	0.21
18	pelthoporum pterocarpum	0.82	139	10	0.24
19	pelthoporum pterocarpum	0.61	139	10	0.18
20	pelthoporum pterocarpum	0.64	139	10	0.19
21	pelthoporum pterocarpum	0.95	139	10	0.40
22	pelthoporum pterocarpum	0.63	139	10	0.19
23	pelthoporum pterocarpum	0.65	139	10	0.22
24	pelthoporum pterocarpum	1.04	396	16	0.24
25	pelthoporum pterocarpum	0.60	139	10	0.17
26	pelthoporum pterocarpum	0.84	139	10	0.25
27	pelthoporum pterocarpum	0.39	31	5	0.12
28	pelthoporum pterocarpum	0.63	139	10	0.19
29	pelthoporum pterocarpum	0.96	139	10	0.23
30	pelthoporum pterocarpum	0.63	139	10	0.17

Result Preparation

Result preparation involves the creation of a 2D map showing the distribution of Peltophorum pterocarpum in UiTM Perak, a map for carbon storage and sequestration and a map showing the distribution of the tree with the girth range. On the other hand, tabular information displaying tree allometries and carbon estimation are also included in the outcome.

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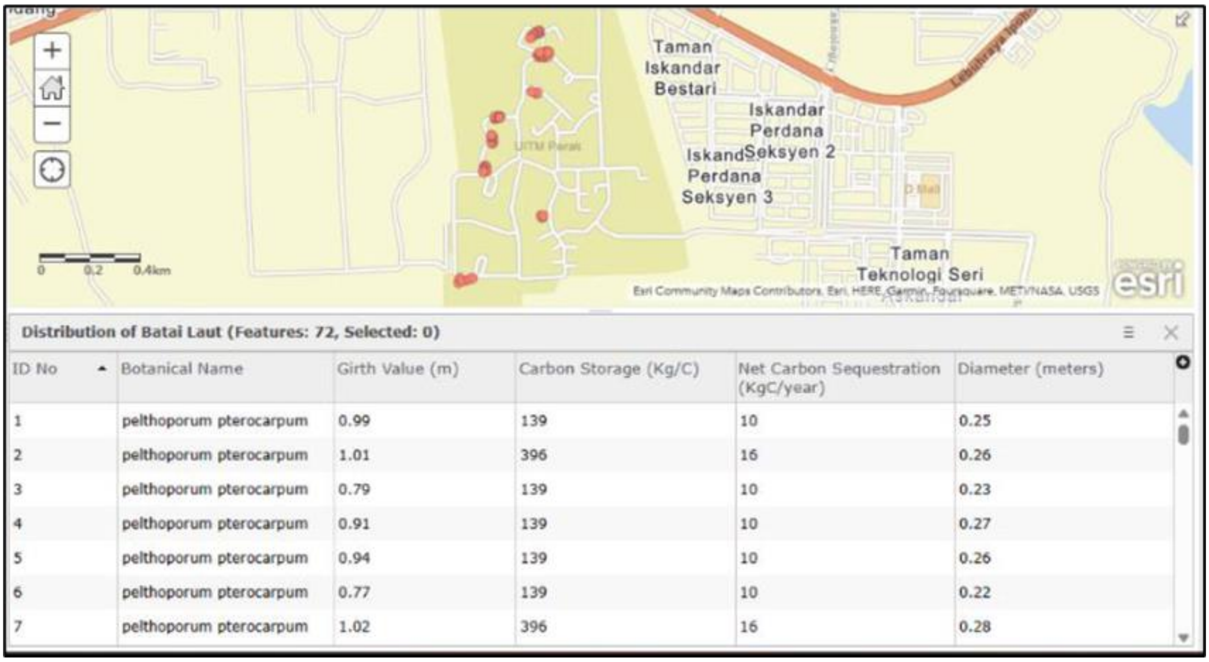
4. Result and Analysis

Tree Inventory database

Tree inventory databases can be created and developed using ArcGIS software, as shown in Figure 4. Once we have accurate and up-to-date information on the trees, the tabular data created in Microsoft Excel will be imported into the ArcGIS software for processing. The tree inventory database was successfully created by manipulating and analysing tabular data. This database will present systematic attribute tables with precise tree data. The two-dimensional tree trail map will then be made using this table.



ID No	Botanical Name	Girth Value (m)	Carbon Storage (Kg/C)	Net Carbon Sequestration (KgC/year)	Diameter (meters)
1	pelthoporum pterocarpum	0.99	139	10	0.25
2	pelthoporum pterocarpum	1.01	396	16	0.26
3	pelthoporum pterocarpum	0.79	139	10	0.23
4	pelthoporum pterocarpum	0.91	139	10	0.27
5	pelthoporum pterocarpum	0.94	139	10	0.26
6	pelthoporum pterocarpum	0.77	139	10	0.22
7	pelthoporum pterocarpum	1.02	396	16	0.28

Figure 4: Trees inventory database with GIS

Map for distribution of Peltophorum pterocarpum

Figure 5, the research study shows the two-dimensional tree trail map planted along the roadside at UiTM Perak. This trail map shows the exact location of each tree in its X and Y coordinates detected using geospatial tools, SW Map Field Collector.

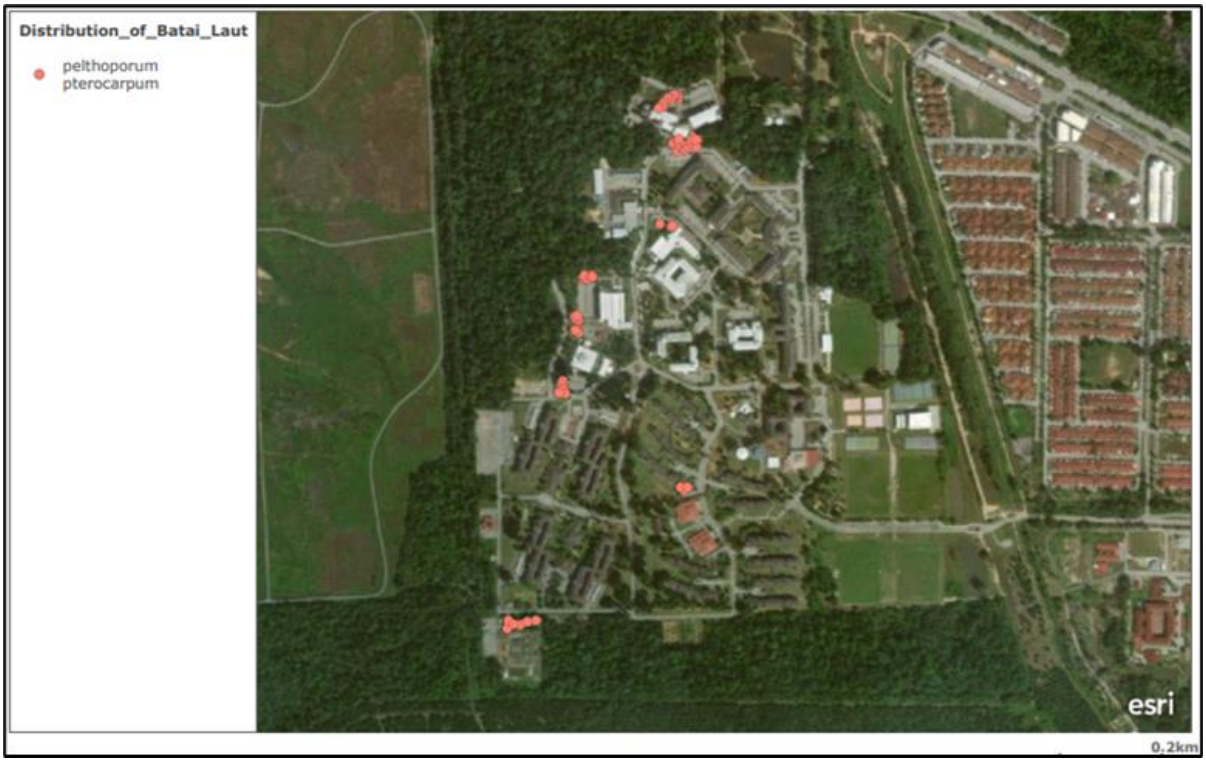


Figure 5: Two-dimensional tree trail map planted along the roadside at UiTM Perak

Figure 6: Map for distribution of Peltophorum pterocarpum

Map for Estimation of Carbon Storage and sequestration for Peltophorum pterocarpum

The map in Figure 6 shows the distribution of Peltophorum pterocarpum in UiTM Perak. In comparison, the estimation of carbon storage by each tree in the study area is shown in Figure 7. The calculation for both carbon storage and sequestration is based on the CUGE. Figure 7

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also shows the estimation of the carbon storage map for Peltophorum pterocarpum, the range for carbon estimation is from 31 to 1135 kg C, while Figure 8 shows the estimation of carbon sequestration for each tree from the range of 5 to 30 Kg C/year.

Figure 7: Estimation of carbon storage for Peltophorum pterocarpum

Figure 8: Estimation of carbon sequestration for Peltophorum pterocarpum

5. Discussion

Based on the findings, Peltophorum pterocarpum mapping has accurately represented tree distribution and positions on the 2D trail map and provided a systematic inventory database for future landscape maintenance. The calculation for both carbon storage and sequestration, which is based on the CUGE, can be done for any of the relevant tropical species depending on the tree species of the site study in situations where the tree inventory is known (CUGE, 2009).

The results of a preliminary study on 72 representative trees of Peltophorum pterocarpum have shown that this species manages to store carbon in the range of 31 to 1135 kg C, while the estimation of carbon sequestration for each tree is in the range of 5 to 30 Kg C/year. The result of this study is similar to Singapore Parks and Trees CUGE method of calculation. GIS was once recognized as a potent technology for effectively managing data about urban forests and environmental management (Adam et al., 2017). Therefore, using GIS tools in current practice and approach is relevant in landscape planning and management for a successful green university. The quantity of carbon storage and sequestration is normally determined by the number of trees in the species and the species characteristics (CUGE, 2009). Therefore, the species that has been selected in this study is Peltophorum pterocarpum, the second most selected species found within the campus. UiTM Perak Green Campus has taken a proper step in campus landscape and design planning through campus environmental management (Anthony & Bokolo, 2021), such as creating a sustainable environment on campus.

Apart from the tree inventory data gathered, this preliminary study on estimation of carbon storage and carbon sequestration can be applied to other species such as Swietenia macrophylla, Khaya senegalensis, Cinnamomum iners, and Mimosops elengi found on the campus and among the top species recommended by the National Parks of Singapore for open space and roadside planting. Based on a study done by Mongkoldhumrongkul, K., and Sukkanta, P. (2022), one of the many ways the green campus concept can be developed is by providing more space for greenery and promoting tree-planting activities in the vicinity of buildings on campus. Selecting a proper species can have an impact by taking into consideration tree selection that can help store more carbon, which helps mitigate environmental impacts such as global warming and green house effects, besides supporting the local agenda of SDG goals.

6. Conclusion

In conclusion, obtaining spatially detailed information about trees in park and open areas is crucial but necessary for sustainable urban park management. In this study, geospatial tools were used to create a manageable tree inventory system and a two-dimensional trail map that allows users to explore and analyse the tree information. Geospatial technology has grown to the point where numerous helpful information may be accessible graphically and quickly using GIS. As a result, it will be possible to manage vast volumes of tree information better. The result shows the tree distribution and correct position in the two-dimensional (2D) trail map. Moreover, carbon storage and sequestration estimation are shown in the map with specific symbology. This research output can assist the decision-makers by providing a systematic inventory database and a 2D map for future planning on efficiently managing these trees in the park areas. This findings and assessment of the trees will provide data to develop a future guidelines on tree selections best for op roadside and species suitable for carbon sinks and offset the carbon emmision in UiTM Perak Green Campus. Therefore, to comply with the green campus aim, carbon storage and sequestration estimates can help reduce urban heat challenges. This method also can be tested to calculate carbon storage and sequestration on other tree species found in UiTM Perak in future.

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