TREE SPECIES FOR URBAN PARKS AND ROADSIDE BASED ON CARBON STORAGE, SEQUESTRATION AND MAINTENANCE IN ISKANDAR MALAYSIA

ROHAYU BINTI ABDULLAH

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DEDICATION

This thesis is dedicated to

My parents

Mr. Abdullah & *Mrs. Fatimah*

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ABSTRACT

Urbanisation triggers high carbon emission and exacerbates global warming. Trees play a significant role to tackle these problems as they provide vital ecosystem services including carbon storage and sequestration. However, trees vary in their ability to provide these services and there is little information on how actual carbon storage and sequestration by trees could be estimated particularly in the tropical region. Furthermore, trees with low endurance rate and unhealthy ones can be harmful to properties and human lives as well as overhanging branches can obscure streetlights, signs and traffic signals and affect road users' vision in the vicinity. These situations contribute to the cumulative maintenance burden to the local authority. This research aims to select types of urban tree species suitable for urban parks and roadsides based on their capacity to store and sequester carbon, and ease of maintenance in Iskandar Malaysia. Field data of 2,245 urban trees were collected from two local authorities, namely Johor Bahru City Council and Pasir Gudang Municipal Council. Allometric equations were used to estimate carbon storage and sequestration. The findings showed that *Pterocarpus indicus*, *Alstonia angustifolia*, *Syzygium grande*, *Pongamia pinnata* and *Hopea odorata* stored (2,019, 1,531, 615, 321 and 244 kg tree^{-1}, respectively) and sequestered (78, 61, 30, 17 and 13 kg tree^{-1} year^{-1}, respectively) the highest carbon in comparison to other species. In addition, a questionnaire survey was also conducted to gain detailed information about tree maintenance from professionals including urban planners, landscape architects and certified arborists. Results showed that *Pongamia pinnata* had the highest score of 94, followed by *Syzygium grande* (91), *Alstonia angustifolia* (90), *Hopea odorata* (90) and *Pterocarpus indicus* (83). Hence, these are the most suitable tree species to be planted at urban parks and roadsides because of their high capacity to store and sequester carbon and their low maintenance as shown by the local authorities. This study has shown ways to assess the actual role of urban trees in reducing carbon and mitigate climate change as well as reduce the burden of maintenance for local authorities and decision makers. The implication would be better management plans for urban forestry in Malaysia for the future.

ABSTRAK

Perbandaran mencetuskan pelepasan karbon yang tinggi dan memburukkan lagi pemanasan global. Pokok-pokok memainkan peranan penting dalam menangani masalah ini kerana pokok-pokok menyediakan perkhidmatan ekosistem yang penting termasuk penyimpanan dan penyerapan karbon. Walau bagaimanapun, kemampuan untuk menyediakan perkhidmatan ini adalah berbeza-beza mengikut pokok dan maklumat mengenai bagaimana penyimpanan dan penyerapan karbon boleh dianggarkan terutamanya di rantau tropika adalah kurang. Selain itu, pokok-pokok dengan daya ketahanan yang rendah dan tidak sihat boleh memberi kemudaratan kepada harta benda dan nyawa manusia, serta dahan pokok yang tergantung boleh menghalang lampu jalan, tanda dan isyarat lalu lintas dan menjejaskan penglihatan pengguna jalan raya di sekitarnya. Keadaan ini menyumbang kepada beban penyelenggaraan secara kumulatif kepada pihak berkuasa tempatan. Kajian ini bertujuan untuk memilih spesies pokok bandar yang sesuai untuk ditanam di taman bandar dan tepi jalan berdasarkan kapasiti mereka untuk menyimpan dan menyerap karbon, dan memudahkan penyelenggaraan di Iskandar Malaysia. Sebanyak 2,245 data pokok bandar telah dikumpulkan daripada dua pihak berkuasa tempatan iaitu Majlis Bandaraya Johor Bahru dan Majlis Perbandaran Pasir Gudang. Persamaan allometrik telah digunakan untuk menganggarkan jumlah penyimpanan dan penyerapan karbon. Dapatan kajian menunjukkan *Pterocarpus indicus*, *Alstonia angustifolia*, *Syzygium grande*, *Pongamia pinnata* dan *Hopea odorata* menyimpan (masing-masing 2,019, 1,531, 615, 321 and 244 kg pokok^{-1}) dan menyerap (masing-masing 78, 61, 30, 17 and 13 kg pokok^{-1} tahun^{-1}) karbon paling tinggi berbanding spesies yang lain. Di samping itu, kajian soal selidik juga dijalankan untuk mendapatkan maklumat terperinci tentang penyelenggaraan pokok daripada golongan profesional termasuk perancang bandar, arkitek landskap dan arboris yang diperakui. Hasil kajian menunjukkan bahawa *Pongamia pinnata* memperoleh skor tertinggi iaitu 94, diikuti oleh *Syzygium grande* (91), *Alstonia angustifolia* (90), *Hopea odorata* (90) dan *Pterocarpus indicus* (83). Oleh itu, spesies ini merupakan spesies pokok yang paling sesuai untuk ditanam di taman bandar dan tepi jalan kerana mempunyai kapasiti yang tinggi dalam menyimpan dan menyerap karbon dan memerlukan penyelenggaraan yang sedikit seperti yang ditunjukkan oleh pihak berkuasa tempatan. Kajian ini telah menunjukkan cara untuk menilai peranan sebenar pokok-pokok bandar dalam mengurangkan karbon dan mengurangkan kesan perubahan iklim serta mengurangkan beban penyelenggaraan kepada pihak berkuasa tempatan dan pembuat keputusan. Implikasinya adalah menyumbang kepada rancangan pengurusan yang lebih baik untuk perhutanan bandar di Malaysia pada masa yang akan datang.

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LIST OF ABBREVIATIONS

AGB	-	Above ground biomass
BaU	-	Business as Usual
BOVC	-	Biogenic volatile organic compound
CTCC	-	CUFR Tree Carbon Calculator
CUFR	-	Center for Urban Forest Research's
DBH	-	Diameter at breast height
EC		Eddy covariance
GHG	-	Greenhouse gases
JB	-	Johor Bahru
LB	-	Leaf biomass
MBJB	-	Johor Bahru City Council
MPPG	-	Pasir Gudang Municipal Council
NPO	-	Non-profit organisation
PG	-	Pasir Gudang
RB	-	Root biomass
SD	-	Standard deviation
SOC	-	Soil organic carbon
USDA	-	United States Department of Agriculture

LIST OF SYMBOLS

cm	-	centimetre
CO_2	-	carbon dioxide
g/cm^3	-	gram per cubic centimetre
H_2O	-	water
Ha	-	hectare
O_2	-	oxygen
ρ	-	wood density
m	-	meter
m^2	-	square meter
kg $tree^{-1}$	-	kilogram per tree
km	-	kilometer
^oC	-	Celsius
PgC	-	Petagram of Carbon
PgC/yr	-	Petagram of Carbon per year
tC/ha		tonne Carbon per hectare
tC/yr	-	tonne Carbon per year
kg $tree^{-1}$ $year^{-1}$	-	kilogram per tree per year
$MtCO_2eq$	-	Million tonne carbon dioxide equivalent
NOx	-	Nitrogen Oxides

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CHAPTER 1

INTRODUCTION

1.1 Background of Research

Many countries including Malaysia government recognise climate change and its consequences. At the United Nations Climate Change Conference 2009 in Copenhagen (COP15), our former Prime Minister aspired to reduce 40 percent of carbon emissions intensity by the year 2020 compared to 2005 levels. In 2014, 33 percent of carbon emission intensity is successfully reduced. The target has been revised up to 45 percent reduction in emission intensity by 2030 at COP21 in Paris in 2015. Since cities around the world are responsible for consuming two-thirds of the world's energy (The World Bank, 2010) and 70 percent of national carbon emission are responsible by urban developments (Ho et al., 2010), thus it is necessary for authority of urban areas in Malaysia to support the government effort by regulating and minimising its carbon emissions.

Iskandar Malaysia also makes an effort to minimise its carbon emission. Covering an area of 2,217 square kilometres, Iskandar Malaysia is a visionary economic region in Southern Peninsular that was established in 2005 as one of the catalyst development corridors to spur the growth of the Malaysia economy as well as an integrated global node that synergises with the growth of the global City-state of Singapore and Indonesia. The population is expected to increase by more than double from 1.35 million people in 2005 to 3 million by 2025. This is supported by a stable seven (7) to eight (8) percent annual GDP (Johor Bahru Low Carbon Society Action Plan 2025). Five (5) flagship zones have been earmarked as key growth poles for the development in Iskandar Malaysia in order to strengthen the existing economic and

diversifying growth (refer to Figure 1.1). Every flagship is identified by its key economic activities including industries and manufacturing, services and commercial.

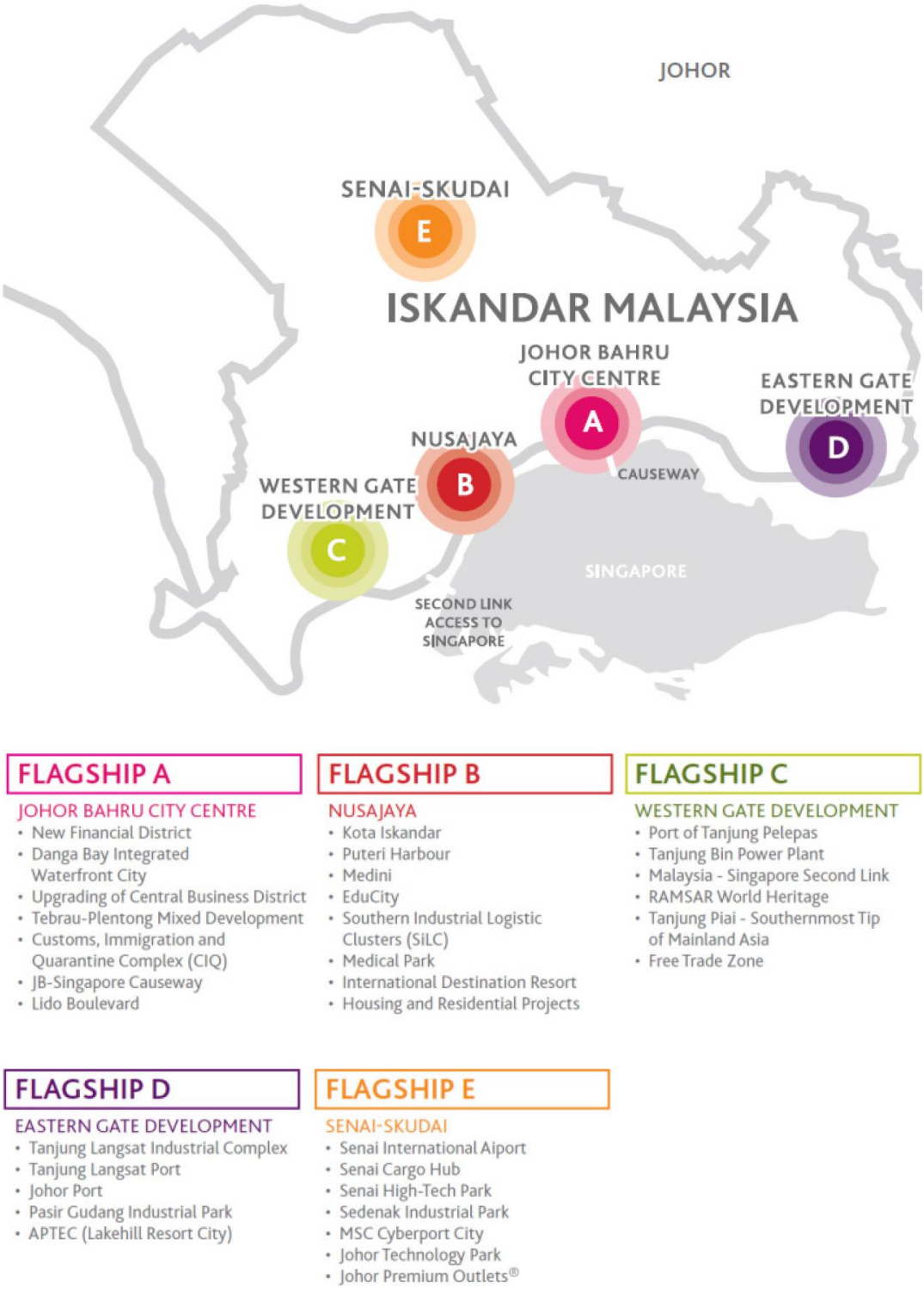

Figure 1. 1 Five flagship zones in Iskandar Malaysia (Johor Bahru Low Carbon Society Action Plan 2025)

Economic activities and carbon dioxide emissions are interrelated. Most economic activities involve the use of fossil fuels which led to an increase in carbon emission. In line with Iskandar Malaysia's vision to be "a strong sustainable metropolis of international standing" and Malaysia's voluntary commitment to reduce carbon emission, it is important for Iskandar Malaysia consider its carbon generation at the same time seeking robust economic growth. This principle is known as decoupling of carbon emission against economic growth. In the year 2013, Iskandar Malaysia with the cooperation of Universiti Teknologi Malaysia (UTM) and several other universities, produced the "Low Carbon Society Blueprint for Iskandar Malaysia 2025", sponsored by the Japan International Cooperation Agency (JICA) and Japan Science and Technology Agency (JST).

The blueprint is to guide the development in Iskandar Malaysia towards climate resilient urban development. It nurtures low carbon living society and develop a total urban –regional environment that enables rapid economic growth but at the same time, reducing the carbon emission. The Low Carbon Society Blueprint for Iskandar Malaysia 2025 proposed 12 Actions Plan and one of them is "Green and Blue Infrastructure and Rural Resources". Green and blue infrastructure includes the natural environmental components as well as green and blue spaces within or adjoining an urban area. Hence, in relation to creating low carbon society for Iskandar Malaysia, it is important to know how this green and blue infrastructure works.

1.2 Problem Statement

World's urbanisation rate has increased from under 30 percent to over 50 percent in the year between 1950 and 2010 (United Nations, 2012). Urbanisation leads to the growth of cities and population as a result of industrialisation and economic development. Consequences of urbanisation contribute to both positive and negative implications. Positive implications of urbanisation include the growth of commercial activities, improvement in the economy, employment opportunities and efficient services. Moreover, it can offer better basic services and other specialist facilities including transportation, water, educational and health care. However, in many

instances, rapid urbanisation may result also in uncoordinated and uncontrolled development.

The rapid increase of urbanisation triggers environmental degradation and exacerbated global warming. To accommodate population increase, land is developed into buildings comprises of housing, commercial and other uses which indirectly cause more artificial and impervious surfaces. The transportation sector is also involved. Motorised vehicles lead to combustion of fossil fuel. Rising vehicle-dependence lifestyle attributed by urbanisation caused further increase in consumption of fossil fuel and overdependence on vehicle, thus worsening the situation. Cities with poor public transport system are often linked to overdependence of private vehicles which also cause traffic congestion. These kinds of activities indirectly emitted many greenhouse gases (GHG) primarily carbon dioxide (CO_2) to the atmosphere. Despite causing serious human health problems and inhibit plant growth, these GHG gases can create smog and acid rain (B.Bhatta, 2010). The most alarming effect of GHG gases is rising atmospheric temperature, also known as global warming. According to Nowak and Crane (2002), since the late 1800s, average air temperature on the earth's surface has increased from 0.3 ^{o}C to 0.6 ^{o}C. The floating ice over the Arctic Ocean is also thinning from an average thickness of 10 feet in 1950 to 6 feet in the late 1990s due to global warming (BBC News, 2000).

Iskandar Malaysia is also experiencing rapid urbanisation. It is evident that the urban area has grown by 78 percent in 2014 compared to 2000. On the other hand, green and blue infrastructure including forest, mangrove and rubber have experienced degradation (Kanniah et al. 2015). GHG emission in Iskandar Malaysia is predicted to increase to 31.3MtCO_2eq in 2025 based on Business as Usual (Low Carbon Society Blueprint for Iskandar Malaysia, 2013). Iskandar Malaysia therefore initiate its' own climate change action plan named 'Low Carbon Society Blueprint for Iskandar Malaysia 2025'. It is also in line with Malaysia's voluntary commitment to reduce 45 percent reduction in emission intensity by 2030.

The Low Carbon Society Blueprint for Iskandar Malaysia 2025 is a written document that presents a comprehensive climate change mitigation policy and 12

detail action plans and strategies to guide the development of Iskandar Malaysia towards a strong and sustainable metropolis of international standing in the year 2025. One of them is "Action 10: Green and Blue Infrastructure and Rural Resources" (refer to Table 1.1). Green infrastructure refers to any vegetated lands within or adjoining an urban area such as urban forests (trees in parks, roadsides and incidental pocket parks), golf course, grassland, agriculture land, community garden and sports fields and other open lands within the built-up area. Meanwhile, blue infrastructure is linked to water bodies and courses, wetlands and woodlands such as rivers, lakes, fountains, pools, ponds and any water features (water fountains and water walls). Both green and blue infrastructure are key elements of sustainable development and critical as other action plans. They can help to store and sequestrate excessive carbon, moderate environment temperature, moderate storm water runoff, reduce urban noise and provide shading. Thus, all of these must be protected and managed wisely.

However, among all benefits that trees can offer, their capabilities to store and sequestrate excessive carbon is critical for developing cities including Iskandar Malaysia. Known as a sink for CO_2, trees play a significant role to tackle the increasing levels of atmospheric carbon which resulted from anthropogenic sources and also to improve urban sustainability (Rahman and Ennos n.d.). In order to evaluate the actual and potential role of urban forests in reducing atmospheric CO_2, research regarding carbon storage and sequestration by the urban trees is vital (Nowak and Crane, 2002). One of the research areas is through the identification of urban tree species that can store and sequester more carbon. Urban tree species vary in their ability to provide these benefits due to their features such as genus, wood density, diameter at breast height (DBH) and others. Suggestions on suitable urban tree species that can store and sequester more carbon can be made in order to effectively reduce carbon emission as well as guide future urban development towards climate resilient and low carbon.

At present, there is very little published information on the extent of carbon storage and sequestration by urban trees in Iskandar Malaysia or even in Malaysia. In other countries such as the United Kingdom (UK), United States (US) and China, carbon storage and sequestration have been widely researched. In addition, there is limited information on how carbon storage and sequestration by urban trees could be

estimated particularly in the tropical region. Therefore, this research is expected to initiate the determination of carbon storage and sequestration by urban trees in Iskandar Malaysia.

Table 1. 1 12 Actions in Low Carbon Society Blueprint for Iskandar Malaysia 2025

Actions
Green Economy
Action 1: Integrated Green Transportation
Action 2: Green Industry
Action 3: Low Carbon Urban Governance
Action 4: Green Building and Construction
Action 5: Green Energy System and Renewable Energy
Green Community
Action 6: Low Carbon Lifestyle
Action 7: Community Engagement and Consensus Building
Green Environment
Action 8: Walkable, Safe and Livable City Design
Action 9: Smart Urban Growth
Action 10: Green and Blue Infrastructure and Rural Resources
Action 11: Sustainable Waste Management
Action 12: Clean Air Environment

Source: Low Carbon Society Blueprint for Iskandar Malaysia 2025

Trees, however, can also be harmful to both human lives and properties. Trees which are unhealthy or have a low endurance rate planted at roadsides increase the risk of falling trees which are hazardous to motorists and pedestrians and may cause damage to properties (ISA, 2011). Although there is no report of an accident caused by roadside tree in Iskandar Malaysia, it does happen in other cities like Kuala Lumpur (refer to Figure 1.2). Overhanging branches can also obscure streetlights, signs and traffic signals and affect road users' vision in the vicinity. These situations contribute to the maintenance cost to the local authority, shorter-survival of trees as well as the production of secondary air pollutants (Churkina et al., 2015). Besides, selection of site or location to plant trees should also be appropriate according to tree species (City

of London Urban Forestry Strategy, 2014). This helps to assure trees become healthy, safe, resilient, can survive for long-term and reduce maintenance burden to the local authority. Therefore, it is imperative to consider tree maintenance and suitable location for urban trees planting when making the selection for tree planting, apart from the ability to store and sequester carbon.

Figure 1. 2 Fallen trees in Kuala Lumpur – Bentong highway (Utusan Malaysia, 2015)

At the end of this study, urban trees that can help to minimise more concentration of CO_2 through carbon storage and sequestration and need least necessary maintenance will be listed and suggested to be planted at urban parks and roadsides in Iskandar Malaysia. This helps to provide new insights to the local authorities in Iskandar Malaysia or related professionals such as town planners and landscape architects to improve management plans for urban forestry in Malaysia in the future. Local authorities have always focused on the beautification of places (Sreetheran et al. 2006), thus, most trees were planted due to their appearance. Unfortunately, these trees are reported to be dying rapidly because they get infected by an unknown disease. Subsequently, local authorities make changes in tree planting by including tree maintenance. This is reported in many landscape policies or plans including *Garis Panduan Landskap Negara* (2008) by the National Landscape Department, Ministry of Federal Territories. However, not all tree species are included. Up until now, the tree feature or form as well as tree maintenance are the

only parameters that local authorities considered when planting trees. It is therefore timely for cities that experiencing rapid urbanisation and increasing of GHG emission including Iskandar Malaysia to consider trees capability to store and sequester more carbon for future planting.

1.3 Research Aim

This research aims to;

"Select types of urban trees species that are suitable for urban parks and roadsides based on their capacity to store and sequester carbon and have low maintenance in Iskandar Malaysia"

1.4 Research Objectives

Four research objectives have been outlined as follow;

(a) To identify urban trees species that can store and sequester more carbon in Iskandar Malaysia.
(b) To find out the maintenance level of urban tree species in Iskandar Malaysia.
(c) To identify suitable locations for tree planting in Iskandar Malaysia.
(d) To determine urban tree species that are suitable to be planted in urban parks and roadsides in Iskandar Malaysia based on carbon storage and sequestration and maintenance level.

1.5 Research Questions

The research questions that have been raised in this research are;

(a) Which urban tree species store and sequester more carbon in Iskandar Malaysia?
(b) Which urban tree species require least maintenance level in Iskandar Malaysia?

(c) Where are suitable locations for tree planting in Iskandar Malaysia?

(d) What appropriate urban tree species should be planted for urban parks and roadsides in Iskandar Malaysia based on carbon storage and sequestration and maintenance level?

1.6 Scope of Research

The scope of the research includes the following aspects;

(a) The study area covers two (2) local authorities; Johor Bahru City Council and Pasir Gudang Municipal Council. This project limits the study area based on the available data of urban trees.

(b) Only data of urban trees that have been planted and supervised by both local authorities will be taken into account.

(c) Apart from urban trees field data collection, a questionnaire survey also will be conducted to gain detailed information about trees maintenance and location for tree planting. Meanwhile, allometric equations will be applied to estimate the carbon storage and sequestration of trees, simple scoring method and frequency analysis will be used to predict the maintenance level and location for tree planting in this research.

(d) In order to respond to the issues raised in the research, this study proposes a list of urban trees that is suitable for urban parks and roadsides in Iskandar Malaysia that concern on carbon storage and sequestration and tree maintenance. It can be as an alternative way to select urban trees for future planting.

1.7 Expected Findings

This research is expected to produce a list of trees species that are suitable for urban parks and roadsides in Iskandar Malaysia by taking carbon storage and sequestration, tree maintenance and location for planting into consideration. Such trees can help reduce GHG emission caused by urbanisation in Iskandar Malaysia. At the same time, it can reduce the maintenance burden to the local authority. Suitable

locations for tree planting will also be identified (either urban parks or roadsides or both) based on the suggestion from expertise such as arborist and landscape architect from the local authority and other institutions.

1.8 Research Significance

The list of urban trees species is important to guide and inform the local authorities particularly landscape architect and urban planners to decide the most suitable trees species to be planted at the urban parks and by the roadsides in the future. This list is initiated by considering both carbon storage and sequestration, and maintenance of trees which can help reduce GHG emission and mitigate climate change without compromising the need for least tree maintenance to reduce burden to the local authority in Iskandar Malaysia. The study of carbon storage and sequestration alone is still new in Malaysia and knowledge on maintenance of each of trees species is still presently lacking. Hence, this research is significant to solve the problems and at the same time, helps cities or regions particularly Iskandar Malaysia to develop toward low carbon society and achieve the vision to be "a strong sustainable metropolis of international standing".

1.9 Structure of Thesis

The discussion in this research is organised into five (5) chapters as follows;

Chapter 1: Introduction

The introduction establishes the context and significance of this research being conducted. It starts by summarising the current understanding and background about the selection of trees species for urban parks and roadside in Iskandar Malaysia. It is followed by research objectives, research questions, scope of the research, expected contribution, significance of research and organisation of chapters.

Chapter 2: Literature Review

Chapter 2 discusses previous studies or research related to selection of tree species for urban parks and roadsides in Iskandar Malaysia. It is pivoted on related literature to produce a theoretical basis and context of the research.

Chapter 3: Research Methodology

Chapter 3 describes the research methods used to evaluate carbon storage and sequestration and maintenance of trees. It starts with an elaboration of the background of the study area, followed by research framework, data collection method, sampling methods and data analysis.

Chapter 4: Data Analysis and Findings

Upon methodology in Chapter 3 been applied, the findings of carbon storage and sequestration, tree maintenance and location for tree planting analysis are gathered and reported. The findings are arranged in a logical sequence to avoid biasness or misinterpretation.

Chapter 5: Discussion and Conclusion

Chapter 5 presents the summary of finding and its significance to the research. It also includes a recommendation on a list of trees species suitable for urban parks and roadside in Iskandar Malaysia. It will also discuss the study limitation and offer suggestion on future research.

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