EVALUATION OF CARBON DIOXIDE ABSORPTION CAPACITY AND BIOMASS ACCUMULATION OF SUB-URBAN PLANTS IN UNIVERSITI TUN HUSSEIN ONN MALAYSIA (UTHM)

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This thesis is dedicated to Allah and to my lovely mother Hajiya Ramatu, my wife and my beautiful children Summaya and Atika and to my late brother's children.

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ABSTRACT

Carbon dioxide (CO_2), is an important greenhouse gas which plays a vital role in the Earth's carbon cycle. Its continuous increase above the ambient concentration leads to global warming. The localized increase in CO_2 emission in UTHM is due to a large number of automobiles and other greenhouse gases released from building facilities and nearby industries. A study was carried out on the common species of trees, shrubs, palms, herbaceous and bamboos planted within the campus to estimate the amount of CO_2 sequestered. Estimation of carbon storage of studied species was obtained through assessments of standing biomass as well as measurement of their photosynthetic capacity. Data for A/Ci and AQ analysis was collected and the curve are fitted based on a nonrectangular hyperbola model. Results obtained indicates that tree species *Spathodea campanulata* recorded a high CO_2 absorption of 14.40 µmol m^{-2} s^{-1}. In shrub category, *Sanchezia speciosa* was found to have a high CO_2 absorption capacity of 15.37 µmol m^{-2} s^{-1}, while Palm *Roystonea regia* performed above others in their group, but *Musa* sp was found to absorb CO_2 better with 12.2 µmol m^{-2} s^{-1} in the herbaceous category. Whereas, *Bambusa vulgaris* absorbed CO_2 better with 5.38 µmol m^{-2} s^{-1} in its grouping. On biomass accumulation, *Alstonia scholaris* has the highest aboveground accumulation of 106.94 kg followed by *Samanea saman*. Shrub *Baphia nitida* sequestered 1.06 kg, while Palm *Elaesis guineensis* fairly accumulated 0.09 kg biomass, whereas herbaceous plants *Calathea lutea* and *Hymenocallis latifolia* had 0.04 kg biomass accumulation as the best in their category. While, Bamboo species *Phyllostachys aurea* accumulated 0.05 kg as the best in its group. Result from A/Ci and AQ curve indicate that at both elevated CO_2 and increase irradiance the rate of photosynthesis increase. The study identified the role of tree species in sequestering large amount of CO_2 within the UTHM community. The study recommended that 274,000 trees with higher photosynthesis potential and biomass accumulation as identified in the findings of this study should be considered for planting on campus for UTHM to attain sustainability (K) from KAMI as a low carbon campus.

ABSTRAK

Karbon dioksida (CO_2) adalah gas rumah hijau penting dalam proses kitaran karbon bumi. Peningkatan gas CO_2 yang berterusan melebihi kepekatan normal menyebabkan pemanasan global. Kadar pembebasan CO_2 di UTHM semakin meningkat disebabkan oleh gas rumah hijau dari kenderaan, bangunan dan industri berdekatan. Satu kajian telah dilakukan terhadap spesies pokok, shrub, palma serta buluh yang ditanam di kawasan kampus bagi menganggar jumlah CO_2 yang disekuester. Anggaran simpanan karbon setiap spesies diperoleh melalui penilaian biojisim atas tanah serta ukuran kapasiti fotosintetik. Data bagi analisis A/Ci dan AQ diperoleh dan lengkung tersebut dimuatkan berdasarkan model hiperbola bukan segiempat tepat. Hasil kajian menunjukkan spesies pokok *Spathodea campanulata* mempunyai kadar penyerapan CO_2 yang tinggi sebanyak 14.40 µmol m^{-2} s^{-1}. Bagi kategori shrub, *Sanchezia speciosa* menunjukkan kapasiti penyerapan CO_2 yang tinggi sebanyak 15.37 µmol m^{-2} s^{-1}, manakala palma *Royastonea regia* adalah antara yang terbaik bagi kumpulan palma. Selain itu, *Musa* sp. menyerap CO_2 dengan baik bagi tumbuhan herba sebanyak 12.2 µmol m^{-2} s^{-1}. Manakala, *Bambusa vulgaris* menyerap CO_2 dengan baik dalam kumpulannya dengan kadar 5.38 µmol m^{-2} s^{-1}. Bagi penumpukan biojisim, *Alstonia scholaris* mempunyai penumpukan atas tanah tertinggi sebanyak 106.94 kg, diikuti *Samanea saman*. Shrub *Baphia nitida* sekuester 1.06 kg manakala palma *Elaesis guineensis* menumpukan sebanyak 0.09 kg biojisim, manakala bagi herba, *Calathea lutea* dan *Hymenocallis latifolia* menumpukan 0.04 kg biojisim, terbaik dalam kelasnya. Bagi buluh, *Phyllostachys aurea* menumpukan 0.05 kg biojisim, terbaik dalam kelasnya. Hasil lengkungan A/Ci dan AQ menunjukkan peningkatan CO_2 dan sinaran akan meningkatkan kadar fotosintesis. Kajian ini mengenal pasti peranan pokok dalam proses pensekeusteran karbon dalam jumlah yang banyak. di UTHM. Kajian ini menyarankan pihak UTHM mempertimbangan penanaman 274,000 batang pokok yang mempunyai potensi fotosintesis dan punumpukan biojisim yang tinggi seperti dapatan kajian. Hal ini membolehkan UTHM mencapai salah satu matlamat mapan (K) dari KAMI sebagai kampus rendah karbon.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATION

AGB	-	Above ground biomass
ANOVA	-	Analysis of variance
CAM	-	Crassulacean acid metabolism
CFCs	-	Chlorofluorocarbons
CH_4	-	Methane
DBH	-	Diameter at breast height
EP	-	Eucalyptus plantation
GDP	-	Gross domestic product
HCFCs	-	Hydrochlorofluorocarbon
IPCC	-	Intergovernmental Panel on Climate Change
IUCN	-	International Union for Conservation of Nature
LAI	-	Leaf area index
LCC	-	Leaf carbon content
MP	-	Mix plantation
NO_2	-	Nitrous oxide
NOAA	-	National Oceanic and Atmospheric Administration
S/F	-	Species factor
STC	-	Stomatal count
TSB	-	Total Standing Biomass
UNFCCC	-	United Nations Framework Convention on Climate Change
UNEP	-	United Nations Environment Programme
Kg	-	Kilogram
MOC	-	Mean organic carbon
PSI	-	Photosynthesis 1
PS11	-	Photosynthesis 11
NPP	-	Net primary production
NADPH	-	Dihydronicotinamide-adenine dinucleotide phosphate

RUBP	-	Ribulose bisphosphate
ATP	-	Adenosine triphosphate
NADP	-	Nicotinamide adenine diphosphate
PGA	-	Phosphoglycerate
OM	-	Organic matter
EX	-	Extinction
EW	-	Extinct in the wild
CR	-	Critically endangered
EN	-	Endangered
VU	-	Vulnerable
NT	-	Not threatened
LC	-	Least concern
DD	-	Data deficient
WCMC	-	World Conservation Monitoring Centre

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the study

The current influx of greenhouse gases into the environment is now higher than ever. This is largely contributed by human anthropogenic activities through exponential economic growth (Archer & Rahmstorf, 2010). These activities has led to unprecedented levels of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), and other green house gases in the atmosphere since the last 18,000 years (IPCC, 2014). As a result, these anthropogenic drivers are likely the major cause of climate change and global warming since the mid 20th century (Kundzewicz, 2014).

The Intergovernmental Panel on Climate Change (IPCC) under United Nations Environment Programme (UNEP) reported that each of the last three decades has been successively warmer than any preceding decade since 1850 (IPCC, 2013). While upholding this report, Vivien (2015) and NOAA (2018) added that the Northern hemisphere had marked its warmest temperature between 1983–2018. This is a dramatic change in the 33-year period considering what was obtainable 1400 years ago. Through multiple independently produced data sets, the global average of land and ocean surface temperature data showed a warming of 0.85 °C between the year 1880 to 2015 (Kundzewicz, 2014; Vivien, 2015).

Consequently, a recent report pigeonholed that January 2018 was characterized as warmer-than-average conditions across much of the world's land and ocean surfaces. The basis for this report was the record of warmth environment scattered across the globe (NOAA, 2018). Carbon dioxide is the most abundant element, which constitutes about 0.004% of the greenhouse gases. Other gases present in the atmosphere include nitrous oxide, ozone and methane (Vaughan, 2015). Virtually most of these gases protect earth from the rapid loss of heat in the hours of the night. However, excess concentration of these gases results in warming globally (Kundzewicz, 2014). Industrial development has led to an increase in CO_2 concentration from 280 ppm in 1850 to 394 ppm by 2012 (Ahmedin *et al.*, 2013).

Sundarapandian *et al.* (2014) reported a 43% increase in atmospheric CO_2 concentration between the preindustrial age (1760-1850) and the modern industrial age. Burning of fossils fuel, deforestation, urbanisation and changes in agriculture or forestry accelerate greenhouse gases emission, resulting in high concentration of greenhouse gases in the atmosphere (Kundzewicz, 2014; IPCC, 2001). These increase in the concentration of CO_2 and other trace gases such as CH_4, NO_2, CFCs and HCFCs have the potential to bring about a profound change in climate, which could pave the way to a continues increase in land surface temperature as has been observed for about 25 years (IPCC, 2001).

One of the natural ways of mitigating CO_2 emission from the environment is through carbon fixation in plants by photosynthesis. A high concentration of CO_2 in the atmosphere also increases the rate of photosynthetic carbon fixation by leaves. In a range of experiments on a variety of plant species at an elevated CO_2 concentration of 475–600 ppm, leaf photosynthetic rate increased was recorded by an average of 40% (Ainsworth and Rogers, 2007).

Historically, UTHM has developed in must ramification since its establishment on September 16, 1993. Central to this research is the strong relationship between physical infrastructural development, economic development and escalation in tons of CO_2 emitted over time (Abdullah, 2017).

Adequately equipped buildings are required for optimal performance of occupants but usually at the detriment of carbon footprint. It is pertinent to note that physical development may also encourage deforestation. This will further expose the environment to contend with the emission of CO_2.

There exists a nexus between the built environment and energy generation and consumption, since there are large number of electrical appliances that consume energy, even though the sum of individual consumption may be negligible, the sum of power consume by the appliances will be higher (Abdallah, 2017 and El-Shennawy, 2013). Therefore, the more the consumption of energy by the appliances the more the emission of CO_2 from electricity generation through the combustion of fossil fuels to generate heat at the source of the power generation (Abdallah, 2017 and El-Shennawy, 2013). The appliance that consume the electricity includes air conditioning system, computers, electrical bulbs and other electrical energy powered appliances on the campus. Take the instance of the laboratory equipment as a source of CO_2 emission that is linked to the energy consumed in the campus. Shah *et al.* (2015) reported that laboratory equipment and air condition system emit more CO_2 to the environment.

The CO_2 emission chain gets stronger with increase in number of automobile on campus. This is as a result of growth in population. Emission from cars was estimated to be 1,998.37 metric tons per month (Abdullah, 2017). It is 60% higher than emission from the motorcycles. In addition to CO_2, emission from automobiles also produce other gases like methane (CH_4), nitrous oxide (N_2O) and hydrofluorocarbon from leaking air conditions (Montzka *et aI.*, 2011).

The strategic location of UTHM campus is commendable in the aspect of deriving optimal benefits for corroboration with industries in Batu Pahat. The benefits and challenges are like two sides of a coin. The CO_2 emission from industries within the province also aggravates the tones and causes local warming on the campus (Fong *et al.,* 2008), in the study carried out on establishment of city level carbon dioxide emission baseline database. Batu Pahat had 0.83 total million ton of CO_2 emissions from 1990 to 2005.

The author further established that increasing volumes of emissions are apparently taking place in Batu Pahat city. Although the increase rates of CO_2 emission of the rural-based Batu Pahat city seem to be negligible when compared with Iskandar city CO_2 emission. However, the role played by the vegetation in Batu Pahat as a large carbon sink will be gradually decreasing due to an internal increase of CO_2 emissions (Fong *et al.*, 2008). He therefore concluded that city level of CO_2 emission has a positive correlation with population size and GDP value. Thus, this implies that the discharge of CO_2 from the nearby industry into UTHM can increase local warming (Fong *et al*., 2008).

1.2 Carbon dioxide emission in Malaysia

Malaysia is a country that is growing rapidly in development when compared with other developing countries of the world. The country has recorded a fast development in many sectors of its economy (Koen *et al*., 2017). This includes a well-developed political, economic, physical, educational (low level of illiteracy), and low level of poverty. The giant success comes from dominance in its tertiary and quaternary sectors of industry. Unfortunately, the existence of functional industries leads to an increase in higher emission of CO_2 and other greenhouse gases in the country (Islam and Ismail, 2010). The problem of massive emissions of CO_2 from the burning of fossil fuels and their climatic impact has become a major scientific and political issues (Safaai *et al*., 2011). Electricity generation, transportation, industrial and residential are the main sectors identified to contribute to the emission of CO_2 in Malaysia (Safaai *et al*., 2011). It was projected that without any mitigation measures being taken up by the country, 285.73 million tons of CO_2 would be released in 2020, which is a 68.86% increase compared to the amount of CO_2 emitted in the year 2000 (Safaai *et al*., 2011).

Gas and coal are major electricity sources in Malaysia, and more than 87% of electricity has been generated using these sources (NEB, 2013) and that cause lots of harmful gasses (Safaai *et al*., 2011). CO_2 emission from electricity generation has been increased significantly in the 21st century in Malaysia. The authors have forecasted that the CO_2 emission from electricity production may reach to about 125 million tons by 2020 (Safaai *et al*., 2011). The previous record to present (1982-2017) showed a progressive increase from 131.28 M to 255.78 M metric tons of CO_2 (Full record refer to Appendix).

The source of CO_2 emission is immaterial. Its impacts on human health may be hazardous. Laura (2008) conducted a study at Stanford University California (USA) and reported that from each 1^{o}C increase in temperature due to CO_2 emission, the effect of air pollution caused could lead to more than 20,000 deaths a year worldwide and many more cases of respiratory illness. In addition to local warming on the campus, research conducted by Permentier *et al*. (2017) linked CO_2 emissions to increase in death. The effect may be gradual, but it is inevitable. Therefore, an option and a sustainable solution is to sequester the emission using a green approach (Nogia *et al*., 2016; Othman *et al*., 2016).

Generally, Urbanization influences economic growth, human health and urban vegetation. Moreover, urbanization also reduces green spaces, due to encroachment for infrastructural development (Choi *et al*., 2012). The projection made by Ho *et al*. (2013) on the increase in population in Asia and particularly Malaysia was due to the continuous growth of urban dwellers. This increase may double the current population in urban areas between 2000 and 2030 as projected. The implication of this rapid urbanization is a direct reduction in afforestation and green reserved area in exchange for infrastructural development activities. This may result to an increase in Green House Gases (GHG) which can be detrimental to human health.

A study by Kellett *et al*. (2013) explain the scenario about the value of carbon dioxide emission and uptake in urban area, indicating the accumulates of gas in the atmosphere with reference to CO_2. This will trap most of the heat and radiation from the land rather than pass through the atmospheric layer (O'Gorman, 2018). Increase of heat in the atmosphere increases global temperature and finally create global warming.

In order to find a solution to the effects caused by these gases in the atmosphere naturally, greener environment needs to be increased and maintained. Urban greenery refers to a number of different green practices such as urban tree planting and the creation of lawn, parks and gardens. It is on this view that urban forestry becomes very important both in urban areas and university campus where much of green environment is of paramount importance. Urban forests play a crucial role in temperature reduction, better health, cooling effect, carbon sequestration, carbon stock, habitat for animal and aesthetic value. Urban forests refer to group of trees and other vegetation located in the metropolitan area (Nowak, 2004).

1.3 Aim and objectives of the study

This research focuses on measuring the amount of CO_2 absorbed and biomass accumulated by sub-urban plants in UTHM main campus. The objectives of this study are:

i. To identify, record and categorise the diversity of plants in UTHM main campus.
ii. To measure the CO_2 absorption capacity (photosynthetic capacity) and biomass accumulation of plants in UTHM.
iii. To recommend exotic/indigenous plants that have higher CO_2 absorption potential to be planted in UTHM main campus.
iv. To strategically project the population of plants and period (years) required to achieve a green sustainable mitigation of CO_2 by the recommended species of plants.

1.4 Problem statement

Environmental challenges are numerous. The continuous change in climatic condition has become so paramount that the global society raises a serious concern. Emerging issues are directed at the rate at which the world atmospheric condition is polluted with anthropogenic activities of human populace and the industrial discharge of gases leading to global warming. This paves way to CO_2 and other greenhouse gases to exponentially escalate above normal percentages in the atmosphere from approximately 315 ppm to 394 ppm (Van *et al*., 2009; Hansen *et al.*, 2013). The current trend will continue to rise to as much as 500 ppm to 1000 ppm by the year 2100 (IPCC, 2007; Taub, 2010).

The increase of CO_2 emission in UTHM can lead to a rise in environmental temperatures (Crowley, 2000; Abdullah, 2017). If this persists, it may cause a reduction in the CO_2 sinking ability of the suburban plants (Bazzaz, 1990; Newton, 1991and Drake *et al.*, 1997). Increase in CO_2 emission is directly proportional to the increase in the number of infrastructural development due to campus expansion (Fong *et al*., 2008). This is because the expansion leads to the increase of on-campus building and facilities as a result of the increase in the number of students, staff and additional vehicles. Data obtained from the university shows that there are about 11,403 registered cars within the campus. Logically, an increase in the number of vehicles implies an increase of CO_2 emission and other gases in the UTHM environment (Abdullah, 2017). Therefore, this partly forms the basis on which this research was carried out to find a way of minimising the emission through natural way.

As a fast-growing institution, UTHM always plans a better life and with the provision of modern equipment and infrastructure on the campus area to create an excellent environment of learning. The university has different vegetation types that include trees, shrubs, herbaceous plants, palms, some bamboos, and very few grasses covers. The vegetations and green areas play a role in balancing the CO_2 emission in their capacity, yet less attention is given to the greener aspect of the campus when compared to the level of CO_2 emission in the environment. This is a clear observation by the researcher during the pilot study of the research work (see figure 3.4 to 3.5). This scores the green campus sustainability program to be slower when compared to other institution of higher learning in Malaysia, with a track record of higher green campus.

It is strongly believed that for control measures to be taken by the institution, the rate of emission should be measured and quantified. The scanty nature of information on the absorption and accumulation capacity of the plants in UTHM has left a gap to be filled by the research of these nature. In the same vein, the rate of absorption and accumulation of CO_2 by plants species on campus should be handy to damping the effect of CO_2 quantified.

In addition to CO_2 sequestration by the vegetation and to reach a carbon balance, the university management has commenced a program on sustainability in the campus (Reduce, reused and recycle). However, it is interesting to know that this research work is the pioneering work to measure the CO_2 absorption capacity and to estimate the amount of biomass accumulated by the existing species of plant in the study area, which is the novelty of the study.

The findings will serve as a baseline data for future research work and would be useful in supporting the university management to address their commitment on sustainable campus. Even though this study is carried out in UTHM, its applicability will be relevant to the world, since many university campuses may likely have the same conditions. And finally to recommend the preservation and maintenance of the existing species.

1.5 Justification of the study

Considering the extent to which global warming is increasing, it is imperative that the emission of CO_2 in UTHM is giving much attention. Therefore, the research work was carried out to assess the capacity of CO_2 absorption by different species of plants in UTHM and to look at the possibility of reducing the CO_2 concentration on campus. This will be done by identifying and suggesting/recommending species of plants with optimum photosynthetic potential and high capacity of sequestering and storing excess CO_2 from the atmosphere.

This study would provide information on the potential status of the vegetation in CO_2 absorption and sequestration within the university environment and give recommendations on target plant species for the future tree, shrubs, palms, herbaceous

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